Disruptions in Ecosystems

Ecosystem Interactions, Energy, & Dynamics

Middle School Unit Aligned with the Next Generation Science Standards

American Museum of Natural History

The Lawrence Hall of Science
University of California, Berkeley

Teacher's Guide

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Moving Next Generation Science Standards Into Practice:
A Middle School Ecology Unit and Teacher Professional Development Model

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CHAPTER

1 Wolves in Yellowstone

Activity 1.1
Engage

How do living things interact with living and non-living parts of the environment?

Students begin the unit by discussing a familiar local environment. They share their ideas about the living and non-living parts of the environment and any interactions that they may have observed or be aware of. Through a short video and reading, students are introduced to the issue of wolf reintroduction to Yellowstone National Park. They discuss the effects that the reintroduction might have had on the environment and people.

Activity 1.2
Explore

What effect did the reintroduction of wolves have on the food web in Yellowstone National Park?

Students explore feeding relationships and develop a food web of organisms in Yellowstone National Park. They speculate as to the influence of humans on food webs and how the reintroduction of wolves in Yellowstone might impact the food web.

Activity 1.3
Explain

How do organisms interact with each other?

Students are formally introduced to patterns of ecological interactions, including predator-prey, competition, and symbiosis. They look at examples of these interactions both within and outside of Yellowstone. Students are able to further develop their ideas about patterns of interactions between organisms within an ecosystem.

Activity 1.4
Explain

What effects do living and non-living factors have on populations?

Students interpret graphs as they examine changes in populations of organisms over time. They try to determine cause and effect relationships related to the changes. In doing so, they learn that populations of organisms are dependent on their environmental interactions both with living and with non-living factors.

Activity 1.5
Elaborate

How do biotic and abiotic factors affect patterns of interaction among organisms?

Students interpret data from graphs and match them to ecological scenarios describing patterns of interaction that affect population size. This allows them to deepen their understanding of the concepts of ecological interactions, biotic and abiotic factors, cause and effect relationships, and graphing. Scientific explanations are formally introduced as students use an Explanation Tool to construct a scientific explanation about the pattern of interaction described in one of the scenarios.

Activity 1.6
Evaluate

Should wolves be reintroduced into the northeastern United States?

Students revisit the concept of reintroducing a predator into an ecosystem. This time the context is the northeastern United States and their specific impact on deer. They begin by constructing a scientific explanation about the deer's impact on the ecosystem. They apply concepts that they have learned from the chapter as they debate the possible reintroduction of wolves to the Adirondacks.

Chapter 1 Overview

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Engage **1.1 People and Animals Interacting** **Guiding Question:** How do living things interact with living and non-living parts of the environment? Students share their prior knowledge about the living and non-living aspects of a local outdoor environment. They watch a video segment and read about the re-introduction of wolves into the Yellowstone National Park environment. The teacher begins a KWL chart on the environments discussed in the activity.	MS LS2.A.4 (prior knowledge) Connections to Engineering, Technology, and Applications of Science Connections to the Nature of Science	Constructing explanations (preliminary) Engaging in Argument from Evidence (preliminary)	disruption	2
Explore **1.2 Ecological Interactions** **Guiding Question:** What effect did the reintroduction of wolves have on the food web in Yellowstone National Park? Students use a set of organism cards to explore feeding relationships and develop a food web of organisms in Yellowstone. The cards provide students with an opportunity to develop, discuss, and revise their ideas. Students explore the influence of humans on food webs and how the reintroduction of wolves in Yellowstone might impact the food web. The role of decomposers is introduced.	MS LS2.A.4 Patterns Cause & Effect Connections to Engineering, Technology, and Applications of Science	Developing and Using Models (food webs) Constructing Explanations (food webs)	food chain food web	1-2
Explain **1.3 Patterns of Interaction Among Organisms** **Guiding Question:** How do organisms interact with each other? Students view video segments of ecological interactions, including predator-prey, competition, and symbiosis. Groups work together to develop definitions for these patterns of interaction. They read a text passage that provides more explanation of these interactions and revise their definitions. They apply the definitions to organisms in the Yellowstone ecosystem.	MS LS2.A.4 MS ESS3.C.2 Patterns Cause & Effect Connections to Engineering, Technology, and Applications of Science	Obtaining, Evaluating, and Communicating Information Constructing Explanations (preliminary)	competition predator-prey ecosystem symbiosis commensalism mutualism parasitism (host)	1-2

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Explain **1.4 Living and Non-Living Factors in Ecosystems** **Guiding Question:** What effects do living and non-living factors have on populations? Students begin by predicting the pattern of predator-prey interactions. They interpret and discuss a graph showing the interaction of wolves and moose (both living factors). They then interpret and discuss a data set showing the interaction of antelope (living factor) and rainfall (non-living factor).	MS LS2.A.4 Patterns Cause & Effect (predictions) Connections to Engineering, Technology, and Applications of Science	Analyzing & Interpreting Data Constructing Explanations (preliminary)		1-2
Elaborate **1.5 Analyzing Patterns in Ecosystems** **Guiding Question:** How do biotic and abiotic factors affect patterns of interaction among organisms? Students examine a variety of graphs and match them to a range of written scenarios. Each scenario describes the effect of a biotic or abiotic factor over time on a population of organisms. Students are then introduced to the Explanation Tool which they use to construct a scientific explanation about the pattern of interaction described in one of the scenarios.	MS LS2.A.4 Patterns Cause & Effect Connections to Engineering, Technology, and Applications of Science	Analyzing & Interpreting Data Constructing Explanations	abiotic factors biotic factors claim evidence competition predator-prey symbiosis commensalism mutualism parasitism (host)	2
Evaluate **1.6 Disrupting Ecosystems with Wolves** **Guiding Question:** Should wolves be reintroduced into the northeastern United States? Students read about the deer populations in the northeastern United States and their effect on ecosystems. They use information from the reading to construct a scientific explanation about the deer's impact on the ecosystem. They draw upon their explanations about the deer's impact and other concepts from the chapter as they debate about the possible reintroduction of wolves to the Adirondacks.	MS LS2.A.4 MS ESS3.C.2 Patterns Cause & Effect	Constructing Explanations Engaging in Argument from Evidence (preliminary)	claim evidence	2

Assessment Overview

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explore	Activity 4 Explain	Activity 5 Elaborate	Activity 6 Evaluate
Disciplinary Core Ideas						
MS LS2.A.4*	Analysis 2	Steps 4-15 Analysis 2, 4	Steps 2-6 Analysis 2, 3	Analysis 1, 2	Steps 4, 8 Analysis 1	
MS ESS3.C.2**			Analysis 4			
Science and Engineering Practices						
Constructing Explanations and Designing Solutions*		Steps 4-15		Analysis 3	Step 8	
Engaging in Argument from Evidence**	Analysis 3					
Crosscutting Concepts						
Patterns*		Steps 4-15 Analysis 2, 4	Steps 2, 5, 6 Analysis 2	Step 2 Analysis 1, 2	Steps 2-4, 8	
Cause and Effect**		Step 16		Steps 1, 4, 7, 8 Analysis 1, 2	Steps 5, 8	
Connections to Engineering, Technology and Applications of Science**	Step 3	Step 16	Analysis 4	Analysis 3	Analysis 2	
Connections to the Nature of Science**	Analysis 3					
Performance Expectations						
MS-LS2-2*						Step 2
MS-ESS3-4**						Analysis 1
CCSS ELA						
RST.6-8.1			Analysis 4			Steps 2, 3
WHST.6-8.2					Step 8	Step 2
WHST.6-8.9						Steps 2, 3
(SL.8.1)	Steps 1, 3	Steps 7, 10, 13-15	Steps 1, 2, 3, 5	Steps 1, 4, 7	Steps 2, 3, 5, 7 Analysis 2	Step 4 Analysis 1

* Primary PE and supporting elements **Secondary PE and supporting elements ***Not associated with PE

DCI	**MS LS2.A.4** Predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.
	MS ESS3.C.2 Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
SEP	**CEDS:** Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.
	EAE: Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
CCC	**P:** Patterns can be used to identify cause and effect relationships.
	C&E: Cause and effect relationships may be used to predict phenomena in natural or designed systems.
	(CET&S): All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.
	(CNoS): Science knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.
PE	**MS-LS2-2** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
	MS-ESS3-4 Construct an argument supported by evidence for how increases in human population ~~and per-capita consumption of natural resources~~ impact Earth's systems.
CC ELA	**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts.
	WHST.6-8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
	WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.
	(SL.8.1) Engage effectively in a range of collaborative discussions (e.g., one-on-one, in groups, teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

1–2 class sessions

People and Animals Interacting

How do living things interact with living and non-living parts of the environment?

Students begin the unit by discussing a familiar local environment. They share their ideas about the living and non-living parts of the environment and any interactions that they may have observed or be aware of. Through a short video and reading, students are introduced to the issue of wolf reintroduction to Yellowstone National Park. They discuss the effects that the reintroduction might have had on the environment and people.

Rationale and NGSS Integration

This Engage activity is intended to elicit students' prior ideas about patterns of interactions in ecosystems, including human interactions. The prior knowledge expected at this grade level includes a basic understanding of food webs as models of feeding interactions in ecosystems, the interactions of subsystems (organisms and ecosystems), and the cycling of matter between biotic and abiotic components of the ecosystem included in the Grade 5 NGSS (DCI 5-LS2A and B). The activity also provides an opportunity to determine the extent to which students apply the lens of patterns as they begin to engage in practices such as asking questions and developing explanations about ecosystems. The activity provides an opportunity to elicit and review this knowledge, and provides a common experience for those students who might need additional support. The activity also engages students in the story of a specific ecosystem in and near Yellowstone National Park. This ecosystem provides an example of an environmental disruption—the elimination and then reintroduction of wolves in Yellowstone National Park—that students will focus on in this chapter.

The scientific practices stressed in this chapter are constructing explanations and engaging in argument from evidence, with a secondary emphasis on analyzing and interpreting data. Students will engage in these practices when they analyze data and apply the crosscutting concepts of patterns and cause and effect to develop their own explanations and arguments about interactions between organisms and changes in the Yellowstone ecosystem.

Review the chapter overview and assessment chart for an overview of the NGSS taught and assessed in this activity and how the standards are woven together throughout the chapter. Decide in advance which assessments you plan to emphasize.

Activity Overview

In Part One of the activity, students share their prior knowledge about the living and non-living aspects of a local outdoor environment. In Part Two, they watch a video segment and read about the re-introduction of wolves into the Yellowstone National Park environment. The teacher begins a KWL chart on the environments discussed in the activity.

Key Vocabulary

disruption

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  Preview the video clip on wolves in Yellowstone available at the link below. You can stop the video segment at 9 minutes (note that the entire segment is over 16 minutes and goes further into the role of humans in the Yellowstone area). The link to the segment follows.
  http://www.pbslearningmedia.org/resource/7b6479f4-31ce-4883-91e0-0db661e99e73/a-river-runs-through-it-lynn-and-devonna-owens/
- ☐ 1 large computer monitor or projector

For each student

- ☐ 1 Handout 1.1-1, “Video Guide: Wolves in Yellowstone”

Teaching Summary

Getting Started

1. Students share their ideas about a local outdoor environment.

Doing the Activity

2. The class watches a short video segment on Yellowstone.

3. (Assessment) Students read and discuss the story of wolves in Yellowstone.

Follow-up

4. Begin a KWL chart on patterns of interaction in ecosystems, and review the Analysis questions.

5. Revisit the Guiding Question and introduce Crosscutting Concepts.

6. Preview the chapter.

References

- PBS Learning Media. (2008) NOW Classroom: A River Runs Through It: Lynn and Devonna Owens (video segment). PBS and WGBH.

- Yellowstone National Park. (February 10, 2010) Interactive Map: Where Yellowstone Wolves Roam (website). PBS Nature. Retrieved May 2015 from http://www.pbs.org/wnet/nature/in-the-valley-of-the-wolves-interactive-map-where-yellowstone-wolves-roam/228/

Teaching Suggestions

Getting Started

1. **Students share their ideas about a local outdoor environment.** (10 minutes)

   a. Begin by reading the Guiding Question aloud.

      Refer students to the Guiding Question and explain that the purpose of this activity is to get students thinking about what they know about interactions between living and non-living things in their own environment. Then they will be introduced to another environment found in the western U.S., Yellowstone National Park. The reintroduction of wolves to Yellowstone national Park is the anchoring event used to introduce the set of phenomena students will investigate. These phenomena all relate to the ways humans or natural disasters can disrupt ecosystems.

The Elicit, Probe, and Challenge Questions strategy is effective for revealing students' initial understanding of a science concept and how that understanding changes over the course of an activity, chapter, or unit. Elicit Questions are especially useful during an Engage activity, where the goal is to reveal students' preconceptions and ideas. See Section 2 of Teaching Strategies in the Teacher Support Materials for more information.

b. Have students work in groups of four to complete Part One of the Procedure and to briefly share their ideas with the class.

This is an Engage activity, so the goal is to uncover students' ideas and engage their interest. It isn't expected that students' ideas will correspond to scientific ideas about ecosystems, and it is important to keep the group and class discussions open-ended. Elicit students' prior knowledge and ideas about interactions in a local outdoor environment. If necessary, explain that things that interact each have an effect (or act) on the other. You may also need to have the class discuss possible local environments that could be the focus of the group discussion.

Effective group work is essential as students engage in scientific and engineering practices. For more suggestions on group work, see Communication Skills and Group Work in Section 2 of Teaching Strategies. You may wish to use Procedure Steps 1 and 3 as opportunities to assess students' abilities relative to collaborative discussion.

Student responses to the discussion questions will vary. If students are having difficulty getting started, you may need to prompt them with additional questions to better elicit their prior knowledge. For that reason, possible student responses to the discussions questions in Procedure Step 1 follow.

- A park or similar environment may include living things such as: squirrels, pigeons, crows, rats, raccoons, feral cats, ducks, fish, turtles, ants, beetles, crickets, grass, nuts, flowers, leaves, and trees.
- These organisms may interact with each other by eating or being eaten by other living organisms, or by competing for resources such as food or space.
- Non-living things may include air, water, land, rocks, sunlight, wind, rain, snow, buildings, or roads.

- The living things need the non-living things to survive, and can be affected by changes in the availability of the non-living things, such as during a drought where there is a water shortage.
- Depending on the location, the area may have been more natural or more developed in the past. Disruptions may have been a result of human activity (such as the construction of new building or the development of the park) or natural events (such as flooding or high winds).
- Introducing a new living thing could change the interactions among other living organisms. For example, the introduction of another predator could result in competition with an existing predator population. It could also result in a decline in an existing prey population. A new living thing could also effect interactions between living and non-living things. For example, the addition of a new population could reduce the amount of water in a pond that provides habitat for many living creatures.

Doing the Activity

2. **The class watches a short video segment on Yellowstone.** (10 minutes)

   a. Have students read the introduction to the activity.

   Depending on your class, have students read the introduction to the activity or read it aloud. Explain how the map shows the location of Yellowstone National Park. Students may need support to see that the map represents a section of the United States shown in the inset to the map.

   b. Show students the video segment on the reintroduction of wolves into Yellowstone National Park.

   Provide students with Handout 1.1-1, "Video Guide: Wolves in Yellowstone," to help guide their viewing. Note that all of the statements are true, with the exception of statement #3.

   Depending on your student population, you may want to show the video segment more than once. Note that the language used in the segment may be challenging for some learners, and it may be helpful to introduce some of these terms prior to viewing the segment. For example, ranchers in the video refer to their animals as livestock, cattle, heifer, and calf. In addition, some animals are shown during the segment but are not identified, including sheep (killed by wolves), elk, and bison. In several instances, wolves are referred to as predators, a term that will be formally introduced and defined in Activity 1.3.

See Section 1 of Teaching Strategies for suggestions on how to support English Learners with key vocabulary and other terms, such as interaction, frequently used in this chapter. Discussing the roots of some of these words may help students to understand and remember these terms and may also help them recognize other words they may encounter. Some of these roots are the same as or similar to the equivalents in Spanish, which may be especially helpful for students whose native language is Spanish.

You might have students keep a Personal Vocabulary Log, described in Section 1 of Teaching Strategies. Students use this log to record definitions they create in their own words and/or in images.

3. **Students read and discuss the story of wolves in Yellowstone.** (15 minutes)

> **Assessment – CCC - Connections to Engineering, Technology, and Applications of Science**
> Procedure Step 3 provides an opportunity for an early check of student understanding of the idea that human activity has consequences for the health of other organisms and the environment.

The text in the Student Book provides additional context about the wolf re-introduction. Procedure Step 3 provides an opportunity for students to discuss the types of interactions that are occurring within Yellowstone, both between different organisms and between wild animals and people. Note that Figure 2 refers to the range of the different wolf packs. You may need to explain that a range is the area in which the animals can be found.

Follow-Up

4. **Begin a KWL chart on patterns of interaction in ecosystems, and review the Analysis questions.** (10 minutes)

   a. Review the Analysis questions.

   The Analysis questions in this activity begin to develop the idea of ecosystem boundaries and the broader implications of ecosystem restoration. Help students interpret the map in Analysis question 1. The three dimensions of the NGSS are integrated as students begin to use the SEPs of constructing preliminary explanations (Procedure Step and Analysis 1), asking questions (Analysis 2), and developing preliminary arguments (Analysis 3) about patterns of interactions between living and non-living subsystems of the ecosystem (LS2.A). Support for developing the KWL in Analysis item 2 is provided in the next section. Encourage students to make claims and explain their thinking for Analysis question 3. Use these questions to introduce the idea that science can explain what might happen if people take actions such as hunting wolves or protecting areas, but that societal decisions about these actions aren't necessarily determined only by science. Students will be introduced to scientific explanation and argumentation at the end of this chapter as well as later in the unit.

b. Use Analysis Question 2 to construct a KWL chart.

Decide in advance which Analysis questions will be used for group or class discussion and which you will ask students to respond to in writing. Analysis questions suggested for assessment are marked (Assessment).

Students are likely to have more questions than answers at this point in the chapter. Use Analysis Question 2 to construct a KWL chart, focusing in particular on the interaction of organisms, such as wolves and people, within an ecosystem. You will be using this chart throughout this chapter, so be sure to create it in such a way that it can be revisited (e.g. create an electronic file to project, put it on poster paper on the wall, etc.).

Ask students for answers for the first column, What We Know, about the two different environments discussed in this activity: a local environment and Yellowstone National Park. Note that throughout this unit, different ecosystems will be introduced, and more information about the Yellowstone ecosystem will be provided. Plan for helping students keep track of the organisms associated with different ecosystems by constructing the KWL chart in a way that distinguishes information for different environments. This can be done by creating rows within the KWL chart or by using a different chart for different environments. One goal of NGSS is for students to see similar patterns of interaction in different ecosystems.

Move to the second column, What We Want to Know, and have students suggest questions about what they want to know about these two environments. Guide students to questions that may relate to patterns of interaction (such as feeding behaviors or competition for resources) and disruptions to ecosystems (such as natural disasters or large-scale influences by humans), which are the focus of the unit. Explain to students that, over the course of the unit, some of their questions will be answered and this information can be added to the third column, What We Learned. Some questions may remain unanswered and can either be researched independently or provide opportunities for future study.

For additional information on the use of KWL charts see Teaching Strategies.

If this activity cannot be completed in one period, consider stopping at the KWL chart and resuming with it the next day as a form of review.

5. **Revisit the Guiding Question and introduce Crosscutting Concepts.** (10 minutes)

   a. Revisit the Guiding Question for the activity.

   Revisit the Guiding Question for the activity. "How do living things interact with living and non-living parts of the environment?" Use this opportunity to begin using the language of the crosscutting concepts for this chapter: patterns and cause and effect. You might ask: Did you see any patterns in the ways organisms interact? What were they? As organisms interact, how might a change in the number or actions of one type of organisms cause a change (effect) on other types of organisms? Include humans in the discussion of interactions between organisms.

   b. Introduce Crosscutting Concepts.

   Explain that the patterns and cause and effect are two examples of Crosscutting Concepts. Point out that Crosscutting Concepts are concepts that are found across all disciplines of science and engineering. Explain that they can be a lens or touchstone through which students make sense of phenomena and deepen their understanding of disciplinary core ideas.

   c. Discuss examples of the Crosscutting Concept of Patterns.

   Ask students to describe patterns they may have noticed related to Earth Science. If necessary, prompt students to think about patterns such as the predictable pattern of the seasons or patterns in rock layers. Broaden the discussion to include Physical and Life Science. Students might suggest that physical scientists could study patterns in the behavior of chemicals and life scientists might study patterns in the kinds of trees in different climates. Explain that observing, questioning, and trying to explain patterns are things all scientists do. This is why patterns are considered a Crosscutting Concept.

   d. Start a Crosscutting Concepts poster.

   Begin a Crosscutting Concepts poster by writing the words "Patterns" along the top of a large piece of paper on the wall. Tell students that they will add examples of patterns when they encounter them during the unit. Explain that posters for other Crosscutting Concepts, such as cause and effect, will be developed throughout the unit.

   e. Start a Word Wall.

   Start a Word Wall and explain to the class that key words will be added to the Word Wall as they progress through the unit. Add the word "disruption" to the Word Wall and discuss what it means. Point out the title of the unit is "Disruptions in Ecosystems" and ask what type of disruption was introduced in this activity. Guide students to understanding that re-introducing wolves to Yellowstone National Park was the disruption. For additional information on Word Walls, see Section 1 of Teaching Strategies. For a list of academic language introduced and used throughout the unit on a chapter by chapter basis, see Section 1 of Teaching Strategies.

6. **Preview the chapter.** (10 minutes)

   Use the Chapter Overview to guide you as you preview the rest of the chapter with the class. Tell students the guiding question for the chapter, "What happens when a predator comes back into an environment?" and briefly preview the content they will be learning, including the disciplinary core ideas, and the crosscutting concepts and science and engineering practices they will use to build conceptual understanding.

   Write the chapter guiding question on chart paper, a board, or some other place where it can be seen by students as the class works through the rest of the chapter. Be sure to refer back to the question at appropriate points in subsequent activities.

   Explain to students that they have two main learning goals for this chapter: 1) to analyze and interpret data about interactions in the environment, and 2) apply what they learn to construct an explanation for the changes that have taken place in Yellowstone.

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the assessment questions are included with the suggested answers.

1. **As you can see in Figure 2, "Yellowstone National Park Wolf Packs and their Ranges," wolf packs can range and hunt outside the park.**

   a. **Think of some animal species that may be found within the park. Do you think these animals are likely to stay within the park boundaries? Explain your thinking.**

      Wolves, bears, moose, deer, and bighorn sheep are all mentioned in the text, while the video shows elk and bison. All of these animals are unlikely to always remain within the park boundaries, since humans have created these *boundaries. Food and other animal resources may be available outside of these boundaries.*

b. **How might the movement of animals into and out of the park affect how ranchers and other people in the area feel about wolves?**

This movement of the animals is likely to make ranchers and others, like hunters, dislike the wolves more, because the wolves that move out of the park might attack cattle, deer or elk that hunters go after, or pets. Some people, such as local homeowners, might also be concerned that the wolves will attack people. Tourists and environmentalists who want to see wolves and favor restoring natural environments might be less concerned about the movement of animals in the area.

2. **What questions do you have about the interaction of animals and people in the Yellowstone environment? Share your ideas with your class. As a class, record these ideas on your KWL chart.**

> **Assessment – DCI - MS LS2.A**
> Analysis Question 2 provides an opportunity to check for students' initial understanding of patterns of interaction. Use students' questions to begin a KWL chart for this chapter, as further described in Teaching Step 4a.

Students may have a range of questions, such as: What other animals are in the ecosystem? Have wolves attacked humans in the area? (While there have been some encounters between people and wolves, there are no documented attacks in the area). Do tourists get to see the wolves? (Wolves are shy, so are not seen very often, although special tours and rangers help people observe them.) The table on the following page is an example of a completed KWL chart.

3. **Do you think people should try to restore wild environments (like they have when reintroducing the wolf to Yellowstone)? Why or why not?**

> **Assessment – SEP - Engaging in Argumentation, CCC - Connections to the Nature of Science**
> Analysis Question 3 provides an early opportunity to check for students' initial ideas related to taking and supporting a position in a scientific argument. After allowing students to share their positions, expand this discussion by asking whether a decision like this can be determined solely by science. Use the discussion to build the idea that science can describe the consequences of an action, but doesn't necessarily determine what action should be taken. People base decisions about questions such as whether to restore a wild ecosystem on a variety of factors, and these decisions can be controversial because of the various perspectives people bring to the question.

Student responses will vary. Use this question to check for students' thinking about the role of humans in ecosystems.

Sample KWL Chart for Activity 1.1

What do I Know?	What do I Want to know?	What did I Learn?
Local environment (local park) Squirrels, birds, ducks, rats, insects, trees, and raccoons live in the park. People feed pigeons. People eat and drop food. Dogs play in the park. Squirrels eat nuts, and the ducks eat plants and bugs. There are rocks, dirt, ponds, and sidewalks in the park. The park looked different a long time ago.	What do raccoons eat? Was there always a park? What did the land look like before? What happens to the animals in the park at night? Do animals drink pond water? Is there enough food for all the animals in the park? Are there fish or frogs in the pond? What happens to the animals in the winter?	There are more kinds of animals living in the park than I knew. The animals get their food and water mostly in the park.
Yellowstone National Park Wolves eat meat. Grizzly bears eat meat. People raise cows for meat. People visit Yellowstone but don't live in it. Geysers like Old Faithful shoot hot water into the air. It snows in Yellowstone in the winter.	What else do grizzly bears eat? Can they kill wolves? What happens to the animals when it doesn't rain (drought)? Do wolves attack people? What other animals live in Yellowstone? Are there trees in Yellowstone? Is it easy to see wolves?	Bison, grizzly bears, moose, and elk live in Yellowstone. Wolves eat moose, deer, elk, sheep, and cattle. Wolves were eliminated from Yellowstone and were reintroduced. Some people wish the wolves were not re-introduced.

Students should suggest some evidence for their thinking. Some students may state that people should act to restore wild environments because humans have significantly changed the wild and restoring it will begin to bring it back to its previous state. Scientific evidence that supports this idea is that: people caused the wolves to disappear from Yellowstone, and the reintroduced wolves are flourishing: the number of packs is increasing and expanding outside of the park's boundaries.

Others might think that environments should not be restored and instead to be allowed to change over time. Scientific evidence that supports this idea is that Yellowstone has changed over thousands of years and is not the same as it was in the geologic past. Changes made by people will continue to change the park in the future.

Extension

Students may wish to find out about ecosystems in other national parks, or explore local parks and natural areas. The following website will be helpful for students interested in locating national parks, monuments, or historic sites near them: https://www.nps.gov/findapark/index.htm

Check your state, county, or local government websites for additional parks and nature sites.

Activity 1.1

Engage: People and Animals Interacting

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  Preview the video clip on wolves in Yellowstone available at the link below. You can stop the video segment at 9 minutes (note that the entire segment is over 16 minutes and goes further into the role of humans in the Yellowstone area). The link to the segment follows.
  http://www.pbslearningmedia.org/resource/7b6479f4-31ce-4883-91e0-0db661e99e73/a-river-runs-through-it-lynn-and-devonna-owens/
- ☐ 1 large computer monitor or projector

For each student

- ☐ 1 Handout 1.1-1, "Video Guide: Wolves in Yellowstone"

Teaching Suggestions

Getting Started

1. **Students share their ideas about a local outdoor environment.** (10 minutes)
   - **a.** Begin by reading the Guiding Question aloud.
   - **b.** Have students work in groups of four to complete Part One of the Procedure and to briefly share their ideas with the class.

Doing the Activity

2. **The class watches a short video segment on Yellowstone.** (10 minutes)
   - **a.** Have students read the introduction to the activity.
   - **b.** Show students the video segment on the re-introduction of wolves into Yellowstone National Park.
3. **(Assessment) Students read and discuss the story of wolves in Yellowstone.** (15 minutes)

Follow-Up

4. **Begin a KWL chart on patterns of interaction in ecosystems, and review the Analysis questions.** (10 minutes)

   a. Use Analysis Question 2 to construct a KWL chart.

   b. Review the Analysis questions.

5. **Revisit the Guiding Question and introduce Crosscutting Concepts** (10 minutes)

   a. Revisit the Guiding Question for the activity.

   b. Introduce Crosscutting Concepts.

   c. Discuss examples of the Crosscutting Concept of Patterns.

   d. Start a Word Wall.

   e. Start a Crosscutting Concepts poster.

6. **Preview the chapter.** (10 minutes)

1–2 class sessions

Ecological Interactions

What effect did the reintroduction of wolves have on the food web in Yellowstone National Park?

Students explore feeding relationships and develop a food web of organisms in Yellowstone National Park. They speculate as to the influence of humans on food webs and how the reintroduction of wolves in Yellowstone might impact the food web.

Rationale and NGSS Integration

This Explore activity builds on prior knowledge from Grade 5 and Activity 1.1 to enhance students' understanding of how to develop food webs as models for thinking about feeding interactions between organisms. This will be essential for deepening their understanding of interactions in ecosystems in subsequent activities in this chapter, and for tracking the transfer of matter and energy in Chapter 2.

The activity specifically builds toward the DCI related to interactions between organisms and introduces the CCC for patterns and cause and effect as students construct their model food webs and use them to develop tentative explanations based on interactions between organisms. More formal explanations should wait until Activity 1.3, which is an Explain activity with specific support for this practice.

Activity Overview

Students use a set of organism cards to explore feeding relationships and develop a food web of organisms in Yellowstone. The cards provide students with an opportunity to develop, discuss, and revise their ideas. Students explore the influence of humans on food webs and how the reintroduction of wolves in Yellowstone might impact the food web. The role of decomposers is introduced.

Key Vocabulary

decomposer (optional)

food chain

food web

scavenger (optional)

Materials and Advance Preparation

For the class

- ☐ KWL chart from Activity 1, "People and Animals Interacting"

For the teacher

- ☐ Sample Yellowstone Food Web

For each group of four students

- ☐ 1 set of 12 Yellowstone Food Web cards: aspen tree, beaver, bison, cowbird, coyote, elk, gray willow plant, grasses, grizzly bear, pine seeds, snowshoe hare, winter tick
- ☐ 1 additional Yellowstone Food Web card: gray wolf

For each student

- ☐ 1 Handout 1.2-1, "Yellowstone Food Web Data"

Teaching Summary

Getting Started

1. Review food chains and food webs as models for feeding interactions in ecosystems.

Doing the Activity

2. (Assessment) Students explore the Yellowstone food web before the reintroduction of the gray wolf.

3. Students explore the impact of reintroducing the gray wolf and the role of bacteria.

Follow-Up

4. Introduce the use of food webs as a model for energy and matter transfer.

5. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Review food chains and food webs as models for feeding interactions in ecosystems.** (10 minutes)

   a. Have students brainstorm animals found in Yellowstone.

   Explain that students are going to take a closer look at feeding relationships between organisms in Yellowstone. This will help them explain the effects of reintroducing wolves into the ecosystem. Have students quickly brainstorm a list of organisms they remember from the previous activity that can be found within Yellowstone National Park and record their ideas. If they are having trouble remembering the organisms, direct them to look back at the introduction, reading passage, and Analysis Question 1. Possible responses include wolves, elk, bison, deer, moose, bighorn sheep, cows, bears, grass, and trees.

   b. Draw a simple food chain and food web based on student responses.

   Ask students to describe how these organisms interact. They are likely to identify feeding interactions. For example, wolves eat elk and bison. Use their responses to begin drawing a simple food chain or web. You may need to prompt students to think about more than wolves: for example ask, *What do bison eat? What might eat an elk?* Bison eat grass and a bear might eat an elk.

   Ask students if the drawing you are making looks familiar. Students may have been introduced to food chains and webs in previous grades. In the Next Generation Science Standards, food webs are introduced as a model for the interaction of living organisms in 5th grade. Elicit and build on any ideas they already have, and use the student introduction to review the difference between a food chain and a food web. Emphasize that the arrows point from the organism being eaten to the organism that eats it. Note that the introduction in the student book provides another example of both a food chain and a food web.

   c. Add questions about possible interactions to the KWL chart from Activity 1.1.

   Identify questions students have about possible interactions and add them to the KWL chart from Activity 1.1, "People and Animals Interacting." Explain that students will work in groups to construct a Yellowstone food web in this activity. Direct students to the Guiding Question, and explain that they will explore this question by constructing food webs for before and after the reintroduction of the wolf.

Doing the Activity

2. **Students explore the Yellowstone food web before the reintroduction of the gray wolf.** (20 minutes)

   a. Provide each group with a set of 12 Yellowstone Food Web cards.

   Read the name of each organism aloud, if needed. Procedure Step 3 suggests sorting the cards. For example, all of the organisms that eat plants might be put into one pile, while those that eat other animals might be placed in another pile.

   As students look at the Yellowstone Food Web cards, informally review the terms herbivore, carnivore, omnivore, and parasite if needed. Note that the suffix " -vore" is Latin for "devour" and is used to indicate what type of diet an animal has. The root "carni-" means meat, "herbi-" refers to plants, and "omni-" means all. Some of these roots sound similar to the equivalents in Spanish. Parasites are formally defined in the next activity; in this activity, provide students with an example of a familiar organism that benefits from living on another organism and harms it at the same time, such as lice or a leech.

   b. Monitor and assist groups as they conduct Steps 4–10.

   > **Assessment – DCI - MS LS2.A - SEP - Constructing Explanations - CCC - Patterns**
   > Steps 4 to 15 provide a formative assessment opportunity to assess students' use of the food web as a model to understand patterns of interaction, make predictions, and create simple explanations. There are also numerous opportunities in this activity in which to assess ELA CCSS SL8.1, specifically Steps 7, 10, and 13 to 15.

   Assess how well groups are working together to discuss their ideas and to construct food webs. Step 5 might be challenging for some groups. However, this is an explore activity, so encourage students to complete the task as a group and to identify the more obvious interactions first. They can then discuss the remaining organisms with their group and identify at least one possible interaction. It is okay for them to make errors; it is more important that they are engaged in thinking about the possible interactions than that their food web be absolutely correct at this point.

   Explain they will receive more information and have a chance to revise their food web in Procedure Step 8. If they are unable to begin Step 5, refer to the Yellowstone food web begun by the class or the food web on the first page of the activity and demonstrate how to begin drawing part of the web with one or more plants at the bottom of the web.

   Encourage students to record their questions as they explore their ideas. Students' questions might include what organisms such as the cowbird and winter tick eat, as well as if one predator, such as the bear, will eat another predator, such as a coyote. Students may ask if the animal that is being eaten has to be alive. Explain that food webs show what is being eaten, regardless of whether it is alive or dead. You may also want to point out that some animals, such as coyotes or vultures, are scavengers; they eat what's left after other animals have eaten their fill. Coyotes will scavenge animals killed by other predators such as gray wolves.

c. Provide students with Handout 1.2-1, "Yellowstone Food Web Data."

Give students time to revise their food webs based on the information on this handout. Encourage students to discuss the questions in Procedure Step 10 with their group after revising their food webs.

If this activity cannot be completed in one period, consider stopping at this point. The next lesson could begin with a review of the previously completed food webs before adding the gray wolf to the web.

3. **Students explore the impact of reintroducing the gray wolf and the role of bacteria.** (10 minutes)

a. Hand out the additional Yellowstone Food Web card for the Gray Wolf.

After adding it to the food web, students may observe that it does not appear to change the existing interactions among organisms in the food web. Instead, it is another predator eating some of the same prey animals as grizzly bears and coyotes. This is an opportunity to informally introduce competition, an ecological concept explained in the next activity.

b. Work with the class to create a complete Yellowstone food web.

Use the food web started in the beginning of this activity to complete the Yellowstone food web. Add the organisms shown on the cards, and if possible, include all of the organisms that students brainstormed at the beginning of the activity. A sample Yellowstone food web (found at the end of this TE) shows the interactions found among the organisms shown on the cards.

c. Briefly discuss the role of bacteria and other decomposers in an ecosystem.

Point out that the food web is missing an important function within an ecosystem: decomposers. After animals die, their remains are broken down by organisms such as bacteria. Briefly discuss the role of bacteria and other decomposers in an ecosystem. Add bacteria to the food web and draw arrows from all of the organisms to bacteria. The role of decomposers will be explored in more detail in Chapter 2.

d. Guide students to add humans and cattle to their food web.

> **Assessment – CCC - Cause and Effect, Connections to Engineering, Technology, and Applications of Science**
> This question can be used to provide insight into students' understanding of cause and effect relationships and human impact on the environment

Build on Procedure Step 16 to introduce human use of resources, such as hunting animals and using land for raising cattle. This resource use can have positive and negative effects on the health of people and the environment.

Students' diagrams should show that cattle are another food source for animals such as grizzly bear, gray wolf, and coyote. Humans most commonly eat elk, bison, hare, and cattle.

Follow-Up

4. Introduce the use of food webs as a model for energy and matter transfer. (10 minutes)

a. Use the Analysis questions to summarize, as well as foreshadow, key ideas and to reinforce the CCCs of patterns and cause-and-effect.

As you discuss the questions in this activity, the ideas that animals eat other animals and that animals compete for resources are explored. Note that the next activity formally introduces predation, competition, and types of symbiosis. It will also introduce the Greater Yellowstone Ecosystem, which extends beyond the borders of the national park.

Analysis questions 2 and 4 can be used to introduce the crosscutting concept of patterns and cause and effect and integrate them with the core concepts and the scientific practices of modeling and creating explanations. Patterns, such as those observed in the predator-prey interactions of organisms, can be used to identify cause-and-effect relationships. These cause-and-effect relationships can then be used to explain and predict outcomes of an event, such as a change in organisms in an environment. In this case, a change in one organism in a food web can have effects that ripple though the food web.

Add Cause and Effect to the Crosscutting Concepts poster. Have students add examples of patterns and cause and effect relationships that they saw in this activity.

b. Introduce the use of a food web as a model for energy and matter transfer.

Revisit the question, "*What do you predict would happen to the food web if all of the plants died?*" from Procedure Step 10. Students are likely to conclude that the other organisms in the food web would all eventually die.

Introduce the scientific practice of developing and using models. Explain that a scientific model is a representation that can be used to explain and predict what happens in the natural world. Point out to students that they are using their food webs and cause-and-effect thinking to develop predictions and explanations based on their understanding of the interactions modeled in the food web. This is an example of how three dimensions of the NGSS are integrated as students make sense of an ecosystem change. The practice of developing and using models is integrated into the Procedure and Analysis of this activity, although it is not assessed until further developed in Chapter 2. This part of the activity is an example of the predictive value of a model. Scientists use models to ask questions and develop causal explanations for how a system works. They also use them to communicate ideas and make predictions for how one change in an ecosystem might cause other changes to occur. Students might think of models only as physical models, such as a globe as a model of the Earth or various sizes of objects to represent the Sun and planets. Emphasize that a model might be presented in a diagram, an arrangement of physical objects, a mathematical equation, or even a computer simulation. Highlight the idea that a food web is way of showing feeding relationships in an environment, and it summarizes the transfer of matter and energy from one organism to another. The sun is the source of the energy, and plants are able to convert this energy into food that is needed by other organisms. These concepts are the focus of Chapter 2 of this unit.

Use Analysis questions 1, 3, and 4 to highlight the use of a food web as a model for illustrating biological interactions within an ecosystem. You may want to discuss the strengths and weaknesses of this model. For example, a food web provides a relatively simple diagram for showing a complex array of feeding relationships. At the same time, it does not show the relative importance of food sources nor easily address the role of decomposers such as bacteria within an ecosystem. Use question 4b to begin to build the idea that there are similar patterns of interactions across all food webs. If students are struggling to understand the direction of the arrows, at the start of the next class period you may wish to review this concept.

5. **Revisit the Guiding Question.** (5 minutes)

Conclude the activity by having students revisit the guiding question "What effect did the reintroduction of wolves have on the food web in Yellowstone National Park?" and summarize what they have learned. Review the KWL chart and record what students have learned and any new things they want to know.

Suggested Answers to Analysis

NOTE: Analysis questions marked with **Assessment** are suggested opportunities to check for student understanding. Hints for using the assessment questions are included with the suggested answers.

1. **The Food Web cards were used to model the interactions in an ecosystem.**

   a. **Did the Food Web cards represent the living or non-living parts of the environment?**

   They represent the living parts of the environment.

   b. **Why do you think only these parts are included on the cards?**

   The cards show the feeding relationships among organisms, which are alive. You may want to explain that a food web represents the flow of matter and energy within that ecosystem. So although the cards show only the living parts of the environment, they also represent non-living components.

2. **Describe the patterns of interaction among the organisms in your food web:**

> **Assessment – DCI - MS LS2.A, CCC - Patterns**
> Use this question to check whether students can use their food webs as a model to identify the various patterns of interaction in their food webs.

   a. **Which animals eat other animals for food?**

   Cowbird, coyote, grizzly bear, and gray wolf eat other animals.

   b. **Which animals compete for the same food source(s)?**

   Beaver, elk, bison, and hare compete. So do grizzly bear, coyote, and wolf.

   c. **What role did the winter tick play in the food web?**

   The winter tick was a parasite of large plant-eaters such as bison.

   d. **What role did the bacteria play in the food web?**

   Bacteria break down living things. (Some students may use the word decomposers.)

   e. **Look again at your food web and Handout 1.2-1. Find an example of a helpful relationship between two animals. Hint: They do not have to be directly connected in your food web.**

   The cowbird eating winter ticks is helpful to the animals the cowbird lives on, such as bison.

f. **Describe how humans and cattle change the food web.**

The cattle provide another food source for humans and animals that eat animals, while humans compete with some of the animals for the same food.

3. **People often think of grizzly bears as carnivores. Grizzlies are omnivores, eating plants, insects, and other animals. More than 80% of their diet comes from seeds, nuts, and other vegetation. Does a food web address the importance of different food sources in an organism's diet? Explain.**

   No, a food web does not show how important different foods are to an animal's diet. It shows all of the food sources an animal eats, and some of these food sources might only be eaten occasionally.

4. **Review the list of organisms in a familiar ecosystem that you developed for Part One of Activity 1.1.**

   a. **Construct a food web for that area.**

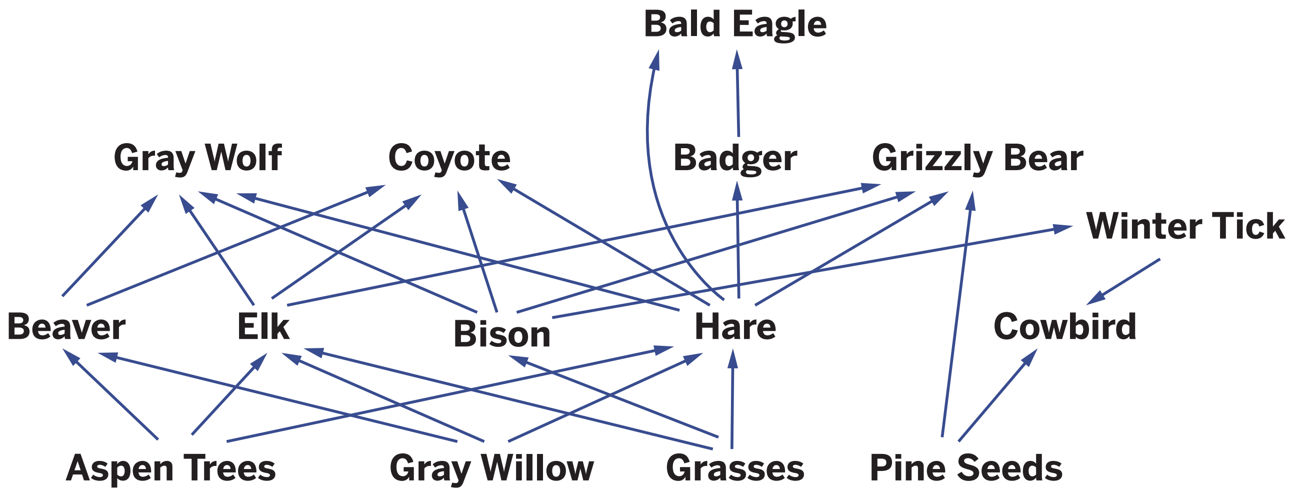
   > **Assessment – DCI - MS LS2.A, CCC - Patterns**
   > Question 4a can be used to determine whether students can apply what they have learned about patterns of interaction to another ecosystem. Use question 4b to add to the third column, What We Learned, of the KWL chart. Help students begin to note similarities in the patterns of interaction between the two environments.

   Student answers will vary. For example, a park or similar environment may include organisms such as: squirrels, pigeons, crows, rats, raccoons, feral cats, ducks, fish, turtles, ants, beetles, crickets, grass, nuts, flowers, leaves, and trees. A cat may eat a squirrel or a rat. A squirrel may eat nuts while the rat eats a cricket. The cricket may eat leaves or an ant. Look for appropriate connections between plants, animals that eat plants, and animals that eat other animals.

   b. **What similarities do you see between the food web you drew for question 4a and the Yellowstone food web? Share your ideas with your class. As a class, record these ideas on your KWL chart.**

   Both have plants, animals that eat plants, and animals that eat other animals.

Sample Yellowstone Food Web



Activity 1.2

Explore: Ecological Interactions

Materials and Advance Preparation

For the class

- ☐ KWL chart from Activity 1, "People and Animals Interacting"

For the teacher

- ☐ Sample Yellowstone Food Web

For each group of four students

- ☐ 1 set of 12 Yellowstone Food Web cards: aspen tree, beaver, bison, cowbird, coyote, elk, gray willow plant, grasses, grizzly bear, pine seeds, snowshoe hare, winter tick
- ☐ 1 additional Yellowstone Food Web card: gray wolf

For each student

- ☐ 1 Handout 1.2-1, "Yellowstone Food Web Data"

Teaching Suggestions

Getting Started

1. **Review food chains and food webs as models for feeding interactions in ecosystems.** (10 minutes)
   - **a.** Have students brainstorm animals found in Yellowstone.
   - **b.** Draw a simple food chain and food web based on student responses.
   - **c.** Add questions about possible interactions to the KWL chart from Activity 1.1.

Doing the Activity

2. **(Assessment) Students explore the Yellowstone food web before the reintroduction of the gray wolf.** (20 minutes)
   - **a.** Provide each group with a set of 12 Yellowstone Food Web cards.

b. Monitor and assist groups as they conduct Steps 4–10.

c. Provide students with Handout 1.2-1, "Yellowstone Food Web Data."

3. **Students explore the impact of reintroducing the gray wolf and the role of bacteria.** (10 minutes)

   a. Hand out the additional Yellowstone Food Web card for the gray wolf.

   b. Work with the class to create a complete Yellowstone food web.

   c. Briefly discuss the role of bacteria and other decomposers in an ecosystem.

   d. Guide students to add humans and cattle to their food web.

Follow-Up

4. **Introduce the use of food webs as a model for energy and matter transfer.** (10 minutes)

   a. Use the Analysis questions to summarize, as well as foreshadow, key ideas and to reinforce the CCCs of patterns and cause-and-effect.

   b. Introduce the use of a food web as a model for energy transfer.

5. **Revisit the Guiding Question.** (5 minutes)

1–2 class sessions

Patterns of Interaction Among Organisms

How do organisms interact with each other?

Students are formally introduced to patterns of ecological interactions, including predator-prey, competition, and symbiosis. They look at examples of these interactions both within and outside of Yellowstone. Students are able to further develop their ideas about patterns of interactions between organisms within an ecosystem.

Rationale and NGSS Integration

This Explain activity builds on the previous activity, which introduced competition and mutually beneficial relationships, to develop formal definitions and expand students' understanding of interactions between different types of organisms. While examining, identifying, and defining these interactions, the crosscutting concepts of patterns and cause and effect are reinforced. Like the previous activities, the content is related to MS LS2.A (patterns of interaction) but this activity also touches upon MS ESS3.C (human impact on Earth) as students discuss Analysis question 4. Although constructing a scientific explanation is not formally introduced until the Elaborate activity, Analysis question 4 provides students with an opportunity to formulate a simple explanation based on their ability to apply cause-and-effect reasoning to their understanding of the disciplinary core ideas in this activity.

Activity Overview

Students view video segments of ecological interactions, including predator-prey, competition, and symbiosis. Groups work together to develop definitions for these patterns of interaction. They read a text passage that provides more explanation of these interactions and revise their definitions. They apply the definitions to organisms in the Yellowstone ecosystem.

Key Vocabulary

commensalism	**competition**	**ecosystem**
food web	**host**	**mutualism**
parasitism	**predator**	**prey**
symbiosis		

Materials and Advance Preparation

For the class

- ☐ KWL chart from Activity 1, "People and Animals Interacting"

For the teacher

- ☐ Access to computer with Internet connection

  Preview and download the three video segments used in this activity. When viewing "Predator-Prey: Wolves," stop the segment after 1 minute, before the focus on wolf adaptations. Cue the three minute segment on grizzly bears and wolves so that the short ad is not viewed by the class. You may also need to close ads prior to viewing the five minute segment on mutualism, commensalism, and parasitism. The links to the segments follow:

  Predator-Prey: Wolves
  http://www.pbslearningmedia.org/resource/idptv11.sci.life.oate.d4kwol/wolves/

  Competition: Grizzlies and Wolves Compete
  http://video.nationalgeographic.com/video/bear_grizzly_wolves?source=relatedvideo

  Symbiosis: Mutualism, Commensalism, and Parasitism
  http://www.teachertube.com/video/symbiotic-relationships-mutualism-commensalism-and-parasitism-youtube-314760

- ☐ 1 large computer monitor or projector

For each student

- ☐ 1 Handout 1.3-1, "Types of Interactions"

Teaching Summary

Getting Started

1. Discuss the concept of ecosystem boundaries.

Doing the Activity

2. The class watches 3 video segments on ecological interactions and develops definitions.

3. (Assessment) Students read about these patterns of interaction and revise their definitions.

4. (Assessment) Students identify patterns of interaction in the Yellowstone food web.

Follow-Up

5. (Assessment) The class discusses additional examples of these interactions.

References

- Holmes, D. (September 2001). The Green Crab Invasion: A Global Perspective, with Lessons from Washington State. Master's Thesis, Evergreen State College. http://archives.evergreen.edu/webpages/projects/greencrabs/index.htm#section-4
- Idaho Public Television. (2007). D4K: Wolves (video segment). PBS Learning Media. http://www.pbslearningmedia.org/resource/idptv11.sci.life.oate.d4kwol/wolves/
- National Geographic. Competition: Grizzlies and Wolves Compete (video segment). http://video.nationalgeographic.com/video/bear_grizzly_wolves?source=relatedvideo
- *Teacher Tube. Untamed Science: Symbiotic Relationships: Mutualism Commensal (video segment).* *http:// www.teachertube.com/video/symbiotic-relationships-mutualism-commensalism-and-parasitism-youtube-314760*

Teaching Suggestions

Getting Started

1. **Discuss the concept of ecosystem boundaries.** (5-10 minutes)

   a. Read the introduction and Guiding Question.

   Remind students that they explored feeding interactions in the previous activity. In this activity, they will expand their focus to additional interactions that might help to explain ecosystem disruptions. If students had difficulty understanding the directionality of the arrows in the food web, use analogies, like buying food in the grocery store—the food is "flowing" from the grocer to the customer.

   Emphasize the definition of an ecosystem as an interacting group of living and non-living things. So far in this chapter, students have been using the word environment. Scientists who study such environments (known as ecologists) are interested not just in the organisms that are present, but how they interact with each other and with the non-living environment.

   Ask students to discuss in their groups how the map in the introduction differs from previous maps of Yellowstone (by showing the Greater Yellowstone Ecosystem, not just the park). Review the concept of an ecosystem boundary. Point out that people establish boundaries, such as those of parks, ranches, and states. The boundaries of a natural environment are not well defined and not easy to determine geographically. In the case of Yellowstone, the ecosystem boundary is greater than that of the Park itself.

   b. Distribute Handout 1.3-1, "Types of Interactions."

   Explain to students that they will watch three video segments, during which they will be introduced to the meanings of the words on the handout.

Doing the Activity

2. **The class watches 3 video segments on ecological interactions and develops definitions.** (20 minutes)

   a. Have the class watch one segment at a time.

   It may be helpful to watch each segment more than one time. Review each segment by asking questions such as, *What animals were shown in the segment? How did these animals interact?* Record student responses on a whiteboard for reference.

   b. Have student groups work to develop definitions on Handout 1.3-1.

After watching all three segments, have students work in groups to complete the first two columns of Handout 1.3-1. This handout is an example of a literacy strategy known as a Directed Activity Related to Text (DART), which supports students' reading comprehension in science. See Section 3 of Teaching Strategies for more background on this strategy.

Student groups should share their definitions and examples with the class. Note that students will revise their definitions in Part Two.

There are numerous opportunities in this activity in which to assess ELA CCSS SL8.1, specifically Steps 1, 2, 3, and 5.

If this activity cannot be completed in one period, consider stopping at the end of Part One.

3. **Students read about these patterns of interaction and revise their definitions.** (15 minutes)

> **Assessment – DCI - MS LS2.A, CCC - Patterns**
> Procedure Steps 2 to 5 provide an opportunity to assess student understanding of patterns of competitive, predatory, and mutually beneficial interactions.

a. Have students read the text and revise their definitions.

Have students read the text in Part Two, either individually or as a class. As in many Explain activities, a number of key vocabulary terms are in bold font and formally defined in the text. As vocabulary is introduced in this activity, make sure to add the new terms to the Word Wall. Students work in groups to complete the remaining two columns of Handout 1.3-1. Some students may be able to write their own revised definitions, while others may need to copy the text directly from the student pages. Decide what is most appropriate for your student population and direct them accordingly.

Students' work in Steps 2 and 5 can be compared to see if they are developing an understanding of the five patterns of interaction. The Procedure can also be used to assess how well students are engaging in collaborative discussions within their groups.

b. Work with the class to make sure that everyone has clear and accurate definitions of the patterns of interaction.

Review examples from the reading. If students are having difficulty understanding any of the interactions, brainstorm additional examples in a familiar ecosystem (either a local one, such as a forest, or one that has been studied often, such as the African savannah). Think of organisms that live in that ecosystem and how they interact with other organisms within the same ecosystem. Emphasize that it is the pattern of behavior that determines the type of interaction, not the individual organism. For example, the Nile crocodile may have a predator-prey relationship with a zebra, but it has a mutualistic relationship with the Egyptian plover.

c. Distinguish between parasites and predators.

Both parasites and predators are consuming other organisms in some way. Emphasize that parasites usually spend a significant portion of their life cycle on a host organism. Most parasitic organisms do not usually cause the death of the intended host organism, since that limits the life of the parasite. Predators typically kill and consume their prey.

Students may have questions about scavengers, organisms that eat dead animals or plants. Scavengers that eat the remains of other animals' kills can be considered predators, since they survive by preying on other animals. Most carnivores that scavenge will hunt (become predators) if not enough food is available from scavenging. For example, hyenas will scavenge animals killed by other predators such as lions, but will also hunt. Other scavengers, such as cockroaches, may eat dead or rotting plant material.

4. (Assessment) Students identify patterns of interaction in the Yellowstone food web. (5–10 minutes)

> **Assessment – DCI - MS LS2.A, CCC - Patterns**
> Procedure Step 6 provides an opportunity to assess student understanding of types of competitive, predatory, and mutually beneficial interactions related to Yellowstone. Sample answers are shown in the table below.

Procedure Step 6 asks students to apply their understanding of patterns of interaction to the Yellowstone food web developed in Activity 1.2, "Ecological Interactions." Students are expected to copy the table and provide an example of each pattern from the Yellowstone ecosystem. Guide students as needed.

Examples of Ecological Relationships in Yellowstone

Pattern of Interaction		Example
Predator-prey		*Gray wolf and beaver, coyote and hare, grizzly bear and bison*
Competition		*Elk and bison, wolf and grizzly bear*
Symbiosis	commensalism	*Grizzly bear and pine trees (seeds), hare and grass*
	mutualism	*Cowbird and bison*
	parasitism	*Winter tick*

Follow-Up

5. The class discusses additional examples of these interactions. (10 minutes)

a. Use the questions to determine if students can identify and describe examples of the five patterns of interaction.

Analysis Question 1 is an opportunity for students to reflect on how their ideas have changed. You might use this question as a focus for group or class discussion, rather than having students prepare a written response. Analysis Questions 2–4 provide opportunities for students to apply their understanding of the different patterns of interaction and cause-and-effect relationships to describe and explain changes in Yellowstone. Discuss student responses to Question 2 by asking: *What type of interaction did you identify it as? Could it be another type of interaction? Explain your reasoning*. Analysis Question 3 applies to humans. Analysis Question 4 has students explain the effects caused by the interaction between humans and organisms in Yellowstone. Through discussion, encourage students to identify how they used the core ideas they have learned, along with the crosscutting concept of cause and effect, to develop preliminary scientific explanations of how humans have affected Yellowstone.

b. Revisit the Guiding Question and add to the KWL chart.

Return to the Guiding Question "How do organisms interact with each other?" and discuss with the class what they have learned about types of interaction and how each interaction affects one or both of the organisms involved.

Have students add what they have learned in this activity to the KWL chart from Activity 1, "People and Animals Interacting." Distinguish between organisms found in different ecosystems (the mutualistic Nile crocodile and Egyptian plover are found along the Nile River in Africa) while noting similarities in patterns of interaction (the cowbird and Yellowstone bison also have a mutualistic relationship). Encourage students to add examples of patterns seen in this activity to the Crosscutting Concepts poster.

If students are struggling to remember the names of the relationship types, encourage them to add the terms to their Personal Vocabulary Logs, described in Teaching Strategies Section 1. Drawing pictures may be particularly helpful for struggling students. Make sure students know they will be able to use this log for reference in later activities.

Suggested Answers To Analysis

NOTE: Analysis Questions 2 and 3 can be used to check whether students are able to identify and describe (Question 3) examples of the five patterns of interaction. There can be more than one correct response for some of these examples. It is important that students explain their answers.

1. **Compare your definitions from Part One of the activity to your revised definitions in Part Two. Think about the changes you made to your definitions. What did you learn that made you make these changes?**

   Students are likely to have learned new terms, such as symbiosis, as well as details that allow them to better distinguish between concepts they are familiar with (such as predator-prey and competition).

2. **Identify each of the following as one of the five patterns of interaction being studied and explain your answers:**

   > **Assessment – DCI - MS LS2.A, CCC - Patterns**
   > Analysis question 2 provides an opportunity to assess student understanding of types of competitive, predatory, and mutually beneficial interactions. Sample answers are shown.

   a. **mountain lions eating deer**

   Predator-prey. The mountain lion is a predator that eats the deer, which is the prey.

   b. **lice on a person's head**

   Parasitism. Lice are parasites that live on a person's head. They harm the person by making his or her scalp itch.

   c. **hummingbirds feeding on plant nectar**

   Commensalism (or mutualism). Hummingbirds get food from the plant, and this does not harm or help the plant. (Alternatively, if the hummingbirds spread pollen, this helps the plant.)

   d. **ladybugs eating aphids**

   Predator-prey. The ladybugs are predators that eat aphids, the prey.

   e. **deer and elk browsing for shrubs in winter**

   Competition. Both deer and elk are eating the same food source (shrubs).

f. **vultures eating the remains of an animal killed by a mountain lion**

Commensalism (or predator-prey). Vultures are eating the leftovers of lions, which helps the vultures and does not help or harm the lions. (Alternatively, vultures are predators that are eating prey animals.)

g. **roundworms living in the intestines of dogs**

Parasitism. Roundworms live in the dog, which helps the roundworms but hurts dogs by taking away nutrition from the dogs.

h. **gophers digging tunnels and exposing insects to nearby birds**

Commensalism. Birds benefit from eating exposed insects. This does not help or harm the gophers. (Note that this is not an example of mutualism because the birds are not helping the gophers in any way.)

i. **bees gathering nectar and pollinating flowers**

Mutualism. Bees get food from the flowers and spread pollen, helping the plant and themselves.

3. **Give an example of how humans interact with another species in each of the following ways:**

> **Assessment – DCI - MS LS2.A**
> Analysis Question 3 provides an opportunity to assess student understanding of types of competitive, predatory, and mutually beneficial interactions related to humans. Sample answers are shown.

a. **predator-prey**

Humans are predators that eat prey such as deer and fish.

b. **competition**

Humans compete with other predators such as wolves for prey such as elk.

c. **mutualism**

Humans raise bees for honey and bees pollinate important commercial crops.

4. **Explain the impact of humans on the food web in and near Yellowstone National Park during each of the following time periods. Use the scientific terms you have learned in this chapter (such as predator-prey, competition, symbiosis) to explain the interactions between humans and other organisms.**

Assessment – DCI - MS ESS3.C, SEP – Constructing Explanations, CCC – Cause & Effect, Connections to Engineering, Technology, and Applications of Science
Analysis Question 4 provides an opportunity to assess student understanding of the types of impact humans can have on Earth's systems. As you discuss the question, you can see whether students realize that humans and human use of resources have had both positive and negative impacts on the Yellowstone ecosystem. You can extend the discussion by asking students to think about how the human population in the Yellowstone area has changed since the early 1800s. Discuss the impact of a growing population, as well as the impact of human decisions such as whether to hunt, set up protected areas, or participate in other activities that might positively or negatively impact people or the environment. This question also provides an opportunity to assess ELA CCSS RST 6-8.1. Sample answers are shown.

a. From the late 1800s to 1994 (Yellowstone was established in 1872)

Human interactions with other organisms caused several effects on the food web. People were predators of elk and deer, and saw wolves and bears as competition. As a result, people killed wolves in the park and nearby to eliminate them. At the same time, parts of the food web, such as bison and bighorn sheep, were protected within the park over time. People were not harmed or helped, while the protected animals were helped. This was commensalism (a type of symbiosis). This changed the food web.

b. From 1995 (when wolves were brought back to Yellowstone) to the present

When people reintroduced wolves, they added back a predator. Wolves may kill cattle and compete with ranchers for land. They may also kill other animals in the park, and cause changes in the moose, deer, and sheep populations they prey on.

Extension

For students who wish to continue exploring a local ecosystem, have them identify feeding interactions in their system. For students who need more practice with identifying types of feeding interactions, have them revisit Analysis 4 in Activity 1.2 and label the types of interactions in that food web.

Activity 1.3

Explain: Patterns of Interaction Among Organisms

Materials and Advance Preparation

For the class

- ☐ KWL chart from Activity 1, "People and Animals Interacting"

For the teacher

- ☐ Access to computer with Internet connection
  Preview and download the three video segments used in this activity. When viewing "Predator-Prey: Wolves," stop the segment after 1 minute, before the focus on wolf adaptations. Cue the three minute segment on grizzly bears and wolves so that the short ad is not viewed by the class. You may also need to close ads prior to viewing the five minute segment on mutualism, commensalism, and parasitism. The links to the segments follow:

  Predator-Prey: Wolves
  http://www.pbslearningmedia.org/resource/idptv11.sci.life.oate.d4kwol/wolves/

  Competition: Grizzlies and Wolves Compete
  http://video.nationalgeographic.com/video/bear_grizzly_wolves?source=relatedvideo

  Symbiosis: Mutualism, Commensalism, and Parasitism
  http://www.teachertube.com/video/symbiotic-relationships-mutualism-commensalism-and-parasitism-youtube-314760

- ☐ 1 large computer monitor or projector

For each student

- ☐ 1 Handout 1.3-1, "Types of Interactions"

Teaching Suggestions

Getting Started

1. **Discuss the concept of ecosystem boundaries.** (5-10 minutes)

   a. Read the introduction and Guiding Question.

b. Distribute Handout 1.3-1, “Types of Interactions.”

Doing the Activity

2. **The class watches 3 video segments on ecological interactions and develops definitions.** (20 minutes)

   a. Have the class watch one segment at a time.

   b. Have student groups work to develop definitions on Handout 1.3-1.

3. **(Assessment) Students read about these patterns of interaction and revise their definitions.** (15 minutes)

   a. Have students read the text and revise their definitions.

   b. Work with the class to make sure that everyone has clear and accurate definitions of the patterns of interaction.

   c. Distinguish between parasites and predators.

4. **(Assessment) Students identify patterns of interaction in the Yellowstone food web.** (5–10 minutes)

Follow-Up

5. **(Assessment) The class discusses additional examples of these interactions.** (10 minutes)

   a. Use the questions to determine if students can to identify and describe examples of the five patterns of interaction.

   b. Revisit the Guiding Question and add to the KWL chart.

Follow-Up

For students who wish to continue exploring a local ecosystem, have them identify feeding interactions in their system. For students who need more practice with identifying types of feeding interactions, have them revisit Analysis 4 in Activity 1.2 and label the types of interactions in that food web.

1–2 class sessions

Living and Non-Living Factors in Ecosystems

What effects do living and non-living factors have on populations?

Students interpret graphs as they examine changes in populations of organisms over time. They try to determine cause and effect relationships related to the changes. In doing so, they learn that populations of organisms are dependent on their environmental interactions both with biotic and with abiotic factors.

Rationale and NGSS Integration

In the previous activities, students were introduced to interactions at the level of individual organisms. In order to understand the impact of interactions on ecosystems, it is important to monitor organisms at the population level. This Explain activity introduces students to interactions between populations and the use of quantitative data to investigate these interactions. The activity builds on students' prior knowledge from Grade 5 and Activities 1.1-1.3 on interactions that may affect the survival of organisms and on prior knowledge of the use of graphical displays to reveal patterns (Grade 3). Students are supported in obtaining information from complex graphs that display two sets of data for comparison. As they use the graphs as a source of evidence, students are introduced to the scientific practice of analyzing and interpreting data. Because interactions between populations can best be understood by looking for patterns in data and investigating what might cause these patterns, this activity also provides a context for formally introducing two crosscutting concepts: patterns, and cause and effect.

Activity Overview

Students begin by predicting the pattern of predator-prey interactions. They interpret and discuss a graph showing the interaction of wolves and moose (both living factors). They then interpret and discuss a graph showing the interaction of antelope (living factor) and rainfall (non-living factor).

Key Vocabulary

predator **prey**

Materials and Advance Preparation

For each student

- ☐ Handout 1.4-1, "Predicting Predator-Prey Interactions"
- ☐ 2 colored pencils

Teaching Summary

Getting Started

1. Student read the introduction and review elements of a graph using Figure 1.
2. (Assessment) Use Handout 1.4-1 to elicit student ideas about predator-prey interactions.

Doing the Activity

3. Students interpret a graph showing the interaction of living factors in an ecosystem.
4. Students interpret a graph showing the interaction of a living and non-living factor in an ecosystem.

Follow-Up

5. Discuss the crosscutting concept of patterns and cause-and-effect relationships as they relate to the graphs.

References

- Bright, J., and J. Hervert. 2005. Adult and fawn mortality of Sonoran pronghorn. Wildlife Society Bulletin, 33:43-50 pp.
- Vucetich, J.A. and Peterson, R.O. (2012) The population biology of Isle Royale wolves and moose: an overview. Retrieved May 2015 from http://www.isleroyalewolf.org

Teaching Suggestions

Getting Started

1. **Students read the introduction and review elements of a graph using Figure 1.** (10 minutes)

   a. Review the idea of living and non-living factors in an ecosystem.

   Have students read the introduction individually or as a class, based on your students. Use the introduction to review the idea of living and non-living factors in an ecosystem, both of which will be examined in this activity. Explain that, in addition to adding to their understanding of factors that affect ecosystems, this activity will introduce students to analysis and interpretation of quantitative information presented in graphs. Analyzing such information and using it to explain population changes are key learning goals of this chapter.

   b. Review elements of a graph using Figure 1, "Deer Population and Average Snowfall."

   Figure 1 in the student book is complex, containing both a bar graph and a line graph. Point out the elements of the graph, including the title, axes labels, scale of each axis, and use of colors (or a key) and labels to represent the variables. The Deer Population is on the left axis and is presented as a line graph. The Average Snowfall is on the right axis and is presented as a bar graph. If students need additional support for identifying the key elements of graphs, consider using Student Sheet 6, "Bar Graphing Checklist" or Student Sheet 7 "Scatterplot or Line Graphing Checklist." These are explained in Section 5 of Teaching Strategies.

Help students analyze the graph by looking for patterns, such as whether the two graphs go up and down at the same time, or seem to be going in opposite directions. In this graph, the deer population seems to go up when snowfall is low, and begins to decline after years when snowfall is more than about 3.5 m. Discuss possible reasons for this pattern. To help students interpret graphs, consider using Student Sheet 8, "Interpreting Graphs," explained in Section 5 of Teaching Strategies.

2. **Use Handout 1.4-1 to elicit student ideas about predator-prey interactions.** (10 minutes)

   a. Distribute and discuss Handout 1.4-1, "Predicting Predator-Prey Interactions."

> **Assessment – CCC - Patterns, Cause & Effect**
> Step 2 provides an opportunity to assess students' understanding of the crosscutting concept of patterns. Steps 1, 5, and 8 provide opportunities to assess students' understanding of the crosscutting concept of cause and effect. There are also numerous opportunities in this activity in which to assess ELA CCSS SL8.1, specifically Steps 1, 4, 7, and 8.

Have students take a moment to examine the graph. Ask, *What is happening to the predator population over time?* Have students observe the pattern and complete the predator line following the same pattern.

Ask, *What is the effect of the predator population on the prey population at the start of the graph? What do you think will happen over time?* Point out that this one graph provides information about two different populations of organisms. At the same time, a person can interpret the interaction between the populations, assuming that nothing else is affecting those populations (e.g. disease, lack of food or water, etc.). Have students use their ideas to predict the shape of prey population line over time.

   b. Discuss graph scales.

Highlight that the scale of the y-axes on Handout 1.4-1 is the same for both populations. Both populations vary between 0-20 organisms. Point out that in some cases, the number of organisms in two different populations could be very different. For example, there might be hundreds of foxes, but thousands of rabbits. This can be graphed by using two different y-axes, one on the left side of the graph and a different one on the right side of the graph. Explain that students will be interpreting graphs with two different y-axes later in this activity.

Doing the Activity

3. Students interpret a graph showing the interaction of living factors in an ecosystem. (10 minutes)

a. Have students read and examine information about the wolves and moose of Isle Royale National Park.

Procedure Step 3 directs students to read the text and examine the graph about the wolves and moose of Isle Royale National Park. Review that this is another ecosystem that is in a different part of the U.S. than Yellowstone. You may want to ask, *Why do you think we are looking at wolves in this park instead of Yellowstone?* Note that the text mentions that this data is a result of one of the longest studies of predator-prey interactions. Ecology is a challenging field of study, and there are a limited number of long-term data sets. In addition, the Isle Royale ecosystem is an island, which makes it easier to have a more accurate count of each species.

You may find it helpful to stop and include information about these wolf and moose populations on the KWL chart, making sure to distinguish among the different ecosystems. Emphasize that the pattern of interaction between wolves and other animals is the same as that seen within the Yellowstone ecosystem (predator-prey). This similarity in patterns is the primary focus of the activity.

b. Have student groups discuss a graph showing the populations of wolves and moose in Isle Royale National Park over time.

Student groups should discuss the relationship between the population of predators (wolves) and prey (moose) shown on the graph. Have groups share their responses with the class. In general, as the wolf population went down, the moose population went up, and vice versa. Note that there could be other factors affecting these populations, such as disease, competition, availability of resources such as water, etc. This is one reason that the study of ecosystems is so complex.

Highlight the role of time: in the case of predator-prey graphs, there is a fairly short time lag between the change in one population and its effect on the other. Ask, *What type of interactions might take longer to see?* Possible responses include interactions such as competition or mutualism, which can affect population size but may take longer to observe.

c. Review the generalized pattern of predator-prey graphs on Handout 1.4-1.

Use the Sample Student Response to Handout 1.4-1 to review the generalized pattern of predator-prey graphs: the generalized pattern is shown as the second graph on the handout and is labeled the Ecological

Model. Have students record this model on their own copy of Handout 1.4-1. Explain that this is an idealized model. Students should be able to see that the wolf-moose graph follows the general pattern of the idealized predator-prey graph, though graphs based on real data sets have a less obvious pattern. Ask, *Why does the real data vary from the model?* Students should realize that, in real ecosystems, there are many factors affecting a population. The idealized model assumes that there are no other factors affecting a population.

Have students complete Handout 1.4-1 by having them compare their initial ideas with the ecological model.

If this activity cannot be completed in one period, consider stopping at the end of Part One.

4. **Students interpret a graph showing the interaction of a living and non-living factor in an ecosystem.** (10 minutes)

    a. Have students read and examine information about Sonoran pronghorn and rainfall.

    Read the information about the Sonoran pronghorn, found in the Arizona desert ecosystem. Again, you may find it helpful to stop and add information to the KWL chart, making sure to distinguish among the different ecosystems. Emphasize that interaction between a living factor (the pronghorn) and an non-living factor (rainfall) is similar to the type of interaction that may be seen in Yellowstone when deer have fawns.

    b. Use Step 7 as a way to guide group discussion of the graph.

    Procedure Step 7 guides student discussion of the graph. Students should observe that there appears to be a correlation between rainfall and number of fawns surviving. When there is more rainfall, more fawns survive, and vice versa. Note that there could be other factors affecting this population, such as disease, competition for space, predation, etc.

Follow-Up

5. **Discuss the crosscutting concept of patterns and cause-and-effect relationships as they relate to the graphs.** (10 minutes)

    a. Use the Analysis questions to guide the class discussion.

    Use Analysis questions 1 and 2 to review and interpret the graphs. Highlight the role of living and non-living factors on the size of populations within an ecosystem. Encourage students to apply the DCIs related to ecosystem interactions and crosscutting concepts of patterns and cause and effect to explain what is happening in the ecosystems represented on the two graphs. This is an opportunity for students to deepen their use of the three dimensions of the NGSS to make sense of ecosystem changes.

This activity's procedure and questions provide a context for formally defining and developing the crosscutting concepts of patterns and cause and effect. Cause-and-effect relationships are often suggested as possible explanations, or causal mechanisms, for observed patterns in data. In these activities, the interactions of organisms with specific living and non-living factors provide likely explanations for the patterns of data observed. Discuss with students whether other factors might be involved in some of the patterns they observed, as asked in questions 1d and 2d. Analysis questions 1 and 2 can be used to check whether students recognize patterns of interaction and are using crosscutting concepts such as patterns and cause and effect to explain their ideas. Add a formal definition of patterns to the Patterns poster you began in Activity 1.1. Also begin a poster for Cause and Effect. Continue to encourage students to add examples of these two crosscutting concepts to the posters throughout the chapter.

b. Revisit the Guiding Question.

Return to the Guiding Question "What effects do living and non-living factors have on populations?" and discuss with the class what they have learned about living and non-living factors and how these factors can affect population size.

Suggested Answers To Analysis

1. Look again at the graph of wolves and moose on Isle Royale, Michigan.

> **Assessment – DCI - MS LS2.A, CCC - Patterns, Cause & Effect**
> Analysis Question 1 provides an opportunity to assess student understanding of patterns of interaction, particularly those related to living factors. Sample answers are shown.

a. Describe the pattern the graph shows in the interaction between wolves and moose on Isle Royale, Michigan.

When the wolf population increased, the moose population decreased. When the wolf population decreased, the moose population increased.

b. What do you think might cause this pattern?

When the large wolf population ate moose, they caused the moose population to decline. When the wolf population decreased and there were fewer wolf predators, this allowed the moose population to increase.

c. **What other living factors could affect the size of the moose population? Hint: Think about your Yellowstone food web.**

A change in the availability of plants, disease, or the presence of harmful parasites could cause changes in the moose population.

d. **What non-living factors could affect the size of the moose population?**

The size of the moose population might be affected by availability of water, significant change in temperature, and/or a change in air quality.

e. **Looking at Figure 1, what do you predict will happen to the size of the wolf and moose populations over the next 10 years? Explain your reasoning.**

The wolf population will increase, following the slight trend it is currently showing. The moose population will remain low with the increase in predators.

2. **Look again at the graph of Sonoran pronghorn antelope and rainfall.**

> **Assessment – DCI - MS LS2.A, CCC - Patterns, Cause & Effect**
> Analysis Question 2 provides an opportunity to assess student understanding of patterns of interaction, particularly those related to non-living factors. Sample answers are shown.

a. **Describe the pattern in the relationship between Sonoran pronghorn antelope and rainfall.**

When rainfall increased, the number of surviving fawns increased. When there was little rainfall, the number of surviving fawns decreased.

b. **What do you think might cause this pattern?**

The lack of water could cause the young fawns to die.

c. **What other non-living factors could affect the survival rate of fawns?**

Temperature or air quality might affect the survival rate,

d. **What living factors could affect the survival rate of fawns?**

Predators, competition from other organisms, disease, and a lack of vegetation are factors that could affect fawns. All of these could cause the death of young fawns.

e. **What do you predict would happen to the survival rate of fawns if rainfall levels stayed high? Explain your reasoning.**

   Many more fawns would survive with high levels of rainfall. In the years that rainfall increased, the number of surviving fawns increased significantly.

3. **What advantage(s) does the Isle Royale ecosystem provide to scientists studying predator-prey relationships that the Yellowstone ecosystem does not?**

   The Isle Royale ecosystem is an island, which limits the interaction with other species and makes population counts simpler. In Yellowstone, other animals can compete with both wolves and moose, and the animals can migrate to other areas.

4. **Pigeons are native to Europe, Asia, and northern Africa. They originally nested on cliffs and ledges. Their diet included seeds, grains, and some fruit and insects. Their predators included large birds, such as hawks, and mammals, such as raccoons and foxes. Pigeons are one of the few animals that are very successful in urban ecosystems with dense human populations.**

   Why are pigeons successful in urban ecosystems? Use what you know about living and non-living factors in your answer.

   > **Assessment – SEP - Constructing Explanations, CCC - Connections to Engineering, Technology, and Applications of Science**
   > Analysis Question 4 provides an opportunity to assess students' early ability to construct a basic explanation relating to human impact (direct and indirect, positive and negative) on the environment. A sample answer is shown.

   Pigeons like to nest on cliffs and ledges. This is an interaction with an non-living factor. Urban areas don't have cliffs, but they have roofs and window ledges. Pigeons eat seeds, grains, fruit, and insects, which are available in cities, so they can get the food they need. In the wild, pigeons are prey to organisms such as hawks, raccoons, and foxes. There are fewer of these predators in urban ecosystems. So their living interactions (with foods and fewer predators) also allow them to succeed in urban ecosystems.

Activity 1.4

Explain: Living and Non-Living Factors in Ecosystems

Materials and Advance Preparation

For each student

- ☐ Handout 1-4.1, "Predicting Predator-Prey Interactions"
- ☐ 2 colored pencils

Teaching Summary

Getting Started

1. **Student read the introduction and review elements of a graph using Figure 1.** (10 minutes)
   - **a.** Review the idea of living and non-living factors in an ecosystem.
   - **b.** Review elements of a graph using Figure 1, "Deer Population and Average Snowfall."
2. **(Assessment) Use Handout 1.4-1 to elicit student ideas about predator-prey interactions.** (10 minutes)
   - **a.** Distribute and discuss Handout 1.4-1, "Predicting Predator-Prey Interactions."
   - **b.** Discuss graph scales.
3. **Students interpret a graph showing the interaction of living factors in an ecosystem.** (10 minutes)
   - **a.** Have students read and examine information about the wolves and moose of Isle Royale National Park.
   - **b.** Have student groups discuss a graph showing the populations of wolves and moose in Isle Royale National Park over time.
   - **c.** Review the generalized pattern of predator-prey graphs on Handout 1.4-1.

4. **Students interpret a graph showing the interaction of a living and non-living factor in an ecosystem.** (10 minutes)

   a. Have students read and examine information about Sonoran pronghorn and rainfall.

   b. Use Step 7 as a way to guide group discussion of the graphs.

Follow-Up

5. **Discuss the crosscutting concept of patterns and cause-and-effect relationships as they relate to the graphs.** (10 minutes)

   a. Use the Analysis questions to guide the class discussion.

   b. Revisit the Guiding Question.

2 class sessions

Analyzing Patterns in Ecosystems

How do biotic and abiotic factors affect patterns of interaction among organisms?

Students interpret data from graphs and match them to ecological scenarios describing patterns of interaction that affect population size. This allows them to deepen their understanding of the concepts of ecological interactions, biotic and abiotic factors, cause and effect relationships, and graphing. Scientific explanations are formally introduced as students use an Explanation Tool to construct a scientific explanation about the pattern of interaction described in one of the scenarios.

Rationale and NGSS Integration

This Elaborate activity builds on students' previous learning related to the primary disciplinary core ideas for this chapter (interactions of organisms with biotic and abiotic things), two crosscutting concepts (patterns and cause and effect), and two science and engineering practices (analyzing and interpreting data, and constructing explanations), by having them develop explanations for additional scenarios across a variety of ecosystems. The Explanation Tool is introduced to support students as they begin to learn how to construct scientific explanations. This explanation tool helps students to integrate the dimensions of disciplinary core ideas and crosscutting concepts with the scientific practice of constructing explanations.

Activity Overview

Students examine a variety of graphs and match them to a set of written scenarios. Each scenario describes the effect of a biotic or abiotic factor over time on a population of organisms. Students are then introduced to the Explanation Tool, which they use to construct a scientific explanation about the pattern of interaction described in one of the scenarios.

Key Vocabulary

abiotic	**biotic**	**claim**
commensalism	**competition**	**evidence**
mutualism	**parasitism**	**predator**
prey	**symbiosis**	

Materials and Advance Preparation

For the class

- ☐ 1 KWL chart (started in Activity 1.1, "People and Animals Interacting")

For each student

- ☐ 1 Student Sheet 1.5-1, "Patterns of Interaction"
- ☐ Explanation Tool
- ☐ Scoring Rubric: Constructing Explanations

Teaching Summary

Getting Started

1. Discuss biotic and abiotic patterns of interaction.

Doing the Activity

2. (Assessment) Students match the scenarios to graphs on Handout 1.5-1, "Patterns of Interaction."

3. (Assessment) Students use the Explanation Tool to construct a scientific explanation using claims, evidence, and reasoning.

Follow-Up

4. Revisit the Guiding Question.

References

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Teaching Suggestions

Getting Started

1. **Discuss biotic and abiotic patterns of interaction.** (10 minutes)

   a. Review the biotic and abiotic patterns of interaction that students have studied in the chapter.

   Explain to students that this activity will expand their understanding of patterns and cause-and-effect relationships in ecosystems by having them apply what they have learned to explain changes across a variety of ecosystems. Up to this point, students have been using the words living and non-living. In ecology and in the NGSS, the terms biotic and abiotic are frequently used. Have students read the introduction (individually or as a class, based on your students). Use the introduction to formally introduce the terms biotic and abiotic. Add these terms to the Word Wall.

   Use your classroom KWL chart to guide the discussion. Ask, *What are the biotic patterns of interaction that we have studied?* Students should be able to identify predator-prey, competition, commensalism, mutualism, and parasitism.

   In the last activity, students were informally introduced to abiotic factors. The introduction to this activity provides a formal definition. Ask, *What are some abiotic factors that could affect a population? What effects could each of these factors have on populations?* Possible responses include rainfall, temperature, and sunlight. Point out that high levels of rainfall or sunlight, or temperatures that are too high or too low can help or harm various populations. For example, ferns and cacti react very differently to these factors.

   b. Use the graphics in the introduction to highlight the differences between biotic and abiotic factors in an urban environment.

   Explain that in this activity, students will be examining graphs as they look for the effects caused by biotic and abiotic patterns of interaction. Foreshadow abiotic factors that are described in the scenarios by noting that some abiotic factors, such as the oxygen levels in the air or water, or nutrients in the soil, are not easily seen or described. Depending on your student population, you may want to extend the discussion to identify oxygen as a gas found in air and dissolved in water that is important in respiration, and phosphorus as a nutrient that is essential in the growth of plants.

Doing the Activity

2. Students match the scenarios to graphs on Handout 1.5-1, "Patterns of Interaction." (30 minutes)

> **Assessment – DCI - MS LS2.A, CCC - Patterns, Cause & Effect**
> Steps 2 to 4 provide an opportunity to assess students' understanding of patterns of interaction. Step 4 can also provide insight into students' abilities in identifying types of biotic interactions. Step 5 is an opportunity to engage students in predicting cause and effect relationships. There are also numerous opportunities in this activity in which to assess ELA CCSS SL8.1, specifically Steps 2, 3, 5, and 7.

a. Have students read the six scenarios described in the student pages.

Have students read, either as a class, a group, or individually, the six scenarios described in the student pages. Students should refer to their Personal Vocabulary Logs if they are struggling to remember the names of different types of relationships.

b. Have students match each scenario to a graph.

Provide each student with a copy of Handout 1.5-1, "Patterns of Interaction," which shows six different graphs. Explain that students will be matching the scenarios to the graphs on the handout. They should begin by analyzing the graphs with their groups, so that they understand the data being presented in each graph. For each graph, students should be able to describe what happens to each population of organisms over time.

If students are struggling making matches, consider using Probe Questions to reveal their thinking process. You might ask, "Are there any matches that you are more certain about?" or, "Tell me why you think these two match," or, "What information are you using to make your match?" For more information on Probe Questions, see Section 2 in Teaching Strategies.

Note that there may be more than one correct response to some of the scenarios. It is important that students support their response with appropriate reasoning. If the graph shows a biotic pattern of interaction, students are asked to identify it (e.g. predator-prey, competition, etc.) If the graph shows an abiotic pattern of interaction, students simply identify it as abiotic. Sample answers follow.

Sample Student Response to Activity 1.5

Scenario	Graph	Biotic/Abiotic
1: Freshwater Fish	C	biotic (competition)
2: Marine Worms and Ocean Temperatures	A	abiotic
3: Insects in Fields and Orchards	E	biotic (parasitism)
4: Phosphorus and Algae Growth	F	abiotic
5: Canadian Lynx and Snowshoe Hare	B	biotic (predator-prey)
6: Oxygen and Fish Populations	D	abiotic

For a typical class period, this may be a suitable break point between periods. Otherwise, consider stopping the lesson after formally introducing scientific explanations and the Explanation Tool. Review its use at the start of the next period.

3. **Students use the Explanation Tool to construct a scientific explanation using claims, evidence, and reasoning.** (30-45 minutes)

Assessment – SEP - Constructing Explanations - DCI - LS2.A - CCC - Patterns and Cause and Effect
Step 8 provides an opportunity to assess students' understanding of constructing a scientific explanation using the framework of claim, evidence, and reasoning. It also can be used in assessing ELA CCSS WHST.6-8.1.

a. Hand out and model the use of the Explanation Tool.

In Procedure Steps 7 and 8, students will begin work on the practice of constructing scientific explanations. To help them Student Sheet 4, an Explanation Tool identifying key elements of the process, is provided. Hand out a copy of the Explanation Tool to each student. A completed sample student response using this Explanation Tool is found at the end of this Teacher's Guide.

Explain that the much of the Explanation Tool is a workspace, where students can informally record their notes and ideas before they go on to write a complete explanation. Go through each step in the list that follows Procedure Step 8 with students this first time they use the tool. They will fill in the Question before they obtain more evidence from the text and graphs in the activity.

Hand out a copy of the Scoring Rubrics for Constructing Explanations. Discuss the use of the rubrics with the class.

b. Have students begin to complete the Explanation tool.

Students should fill in the Evidence, Science Concepts, Scientific Reasoning, and Claim Boxes. Until they are experienced in using the Tool, you will most likely need to work as a class and model how to fill in the boxes on the first page. As you model completing the tool with the class, point out how they are applying disciplinary core ideas related to interactions and crosscutting concepts of patterns and cause-and-effect to create their explanations. Emphasize that the process of constructing a scientific explanation typically involves identifying the cause-and-effect mechanisms for a phenomenon.

c. Have students create a formal written explanation.

Use students' work with the Explanation Tool as a formative assessment, and provide feedback. You might wish to allow students to revise their explanations for further practice. For more suggestions on how to use the Tool, see the Explanation Tool section in Section 4 of Teaching Suggestions.

Follow-Up

4. Revisit the Guiding Question. (5–10 minutes)

Review the Guiding Question of the activity "How do biotic and abiotic factors affect patterns of interaction among organisms?" by discussing and summarizing some of the changes in populations over time on Handout 1.5-1. Then ask students to suggest additional ways these factors might affect populations. Continue to encourage students to add examples of patterns and cause and effect relationships seen in this activity to the Crosscutting Concepts poster.

Suggested Answers To Analysis

1. Think about the Yellowstone ecosystem.

> **Assessment – DCI - MS LS2.A**
> Analysis Question 1 provides an opportunity to assess students' understanding of patterns of predator-prey interaction. It can also be used to assess ELA CCSS WHST.6-8.2.

a. What pattern of interaction resulted from the reintroduction of wolves to Yellowstone?

Reintroducing wolves to Yellowstone brought back another predator into the ecosystem, leading to a new predator-prey interaction.

b. **What do you think a graph showing Yellowstone wolf and elk populations over time would look like? Sketch out your ideas. Discuss your sketched graph with your class.**

Note: Student graphs should look similar to the predator-prey graphs explored in the last activity.

When predator populations go up, prey populations go down, and vice versa. So when the wolf population goes up, a graph should show the elk population going down. Then when there are fewer elk and the wolf population goes down, the elk should go back up.

c. **Would a graph showing Yellowstone bear and elk populations over time look similar or different to the graph you created in Question 1(a)? Explain your reasoning.**

It would look similar because bears are also predators of elk. But there might be less correlation between an increase in bear population and a decrease in elk population because bears are omnivores that eat lots of fruits and berries as part of their diet.

2. **What happens when humans disrupt ecosystems? Share your ideas with your class. As a class, record these ideas on your KWL chart.**

> **Assessment – CCC - Connections to Engineering, Technology, and Applications of Science**
> Analysis Question 2 can be used to provide insights into how student thinking about human impact on ecosystems has changed through the unit. It is also another opportunity to assess ELA CCSS SL8.1.

Student responses will vary. Some students may focus on the negative ways in which humans disrupt ecosystems, by increasing pollution or competing for resources with other animals, for example. Other students may focus on the positive ways in which humans disrupt ecosystems, by establishing parks or working to save endangered species.

Activity 1.5

Elaborate: Analyzing Patterns in Ecosystems

Materials and Advance Preparation

For the class

- ☐ 1 KWL chart (started in Activity 1.1, “People and Animals Interacting”)

For each student

- ☐ 1 Student Sheet 1.5-1, “Patterns of Interaction”
- ☐ Explanation Tool
- ☐ Scoring Rubric: Constructing Explanations

Teaching Summary

Getting Started

1. **Discuss biotic and abiotic patterns of interaction.** (10 minutes)
   - **a.** Review the biotic and abiotic patterns of interaction that students have studied in the chapter.
   - **b.** Use the graphics in the introduction to highlight the differences between biotic and abiotic factors in an urban environment.

Doing the Activity

2. **(Assessment) Students match the scenarios to graphs on Handout 1.5-1, “Patterns of Interaction.”** (30 minutes)
   - **a.** Have students read the six scenarios described in the student pages.
   - **b.** Have students match each scenario to a graph.

3. **(Assessment) Students use an Explanation Tool to construct a scientific explanation using claims, evidence, and reasoning.** (30-45 minutes)

   a. Hand out and model the use of the Explanation Tool.

   b. Have students begin to complete the Explanation tool.

   c. Have students create a formal written explanation.

Follow-Up

4. **Revisit the Guiding Question.** (5–10 minutes)

2 class sessions

Disrupting Ecosystems with Wolves

Should wolves be reintroduced into the northeastern United States?

Students revisit the concept of reintroducing a predator into an ecosystem This time the context is the northeastern United States and the wolves' specific impact on deer. Students begin by constructing a scientific explanation about the deer's impact on the ecosystem. They apply concepts that they have learned from the chapter as they debate the possible reintroduction of wolves to the Adirondacks.

Rationale and NGSS Integration

This Evaluate activity engages students in developing explanations related to the effect of deer populations on ecosystems. They apply this information to the possible reintroduction of wolves into the Adirondacks ecosystem in northeastern New York. This activity draws together the dimensions of the NGSS that support the PEs targeted in this chapter.

Activity Overview

Students read about the deer populations in the northeastern United States and their effect on ecosystems. They use information from the reading to construct a scientific explanation about the deer's impact on the ecosystem. They draw upon their explanations about the deer's impact and other concepts from the chapter as they debate about the possible reintroduction of wolves to the Adirondacks.

Key Vocabulary

claim

evidence

Materials and Advance Preparation

For the class

- ☐ 1 KWL chart (started in Activity 1.1, "People and Animals Interacting")

For each student

- ☐ 1 Handout 1.6-1, "DART: Reading Support for Activity 1.6"
- ☐ Explanation Tool
- ☐ Scoring Rubric: Constructing Explanations

Teaching Summary

Getting Started

1. Review predator-prey interactions in Yellowstone.

Doing the Activity

2. Students read about the impact of deer on ecosystems using the literacy strategy on Handout 1.6-1, "DART: Reading Support for Activity 1.6."

3. (Assessment) Students use the Explanation Tool to construct a scientific explanation using claims and evidence.

4. Students participate in a walking debate on the question: Should wolves be reintroduced into the northeastern U.S. Adirondack ecosystem? Why or why not?

Follow-Up

5. Summarize the activity and the unit.

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Teaching Suggestions

Getting Started

1. **Review predator-prey interactions in Yellowstone.** (10 minutes)

   a. Review predator-prey graphs.

   Draw the beginning of a predator-prey graph over time on the board (see TE Activity 1.4, "Living and Non-Living Factors in Ecosystems," for guidance). Show the predator population slowly increasing and the prey population decreasing. Discuss the interaction of the two populations with the class: *What is the relationship between the two populations? What is happening as the predator population increases?* Draw the predator population declining to zero. Ask, *What is likely to happen to the prey population if the predator population disappears?* Draw students' predictions onto the graph.

   Explain that, at one time, predators such as wolves were found all over the U.S. Today, they are found in Alaska, California, Montana, Wyoming, Idaho, Minnesota, Wisconsin, Washington, Oregon, and Michigan. Changing wolf populations have had an effect on deer and other prey populations.

In this activity, students will find out more about the impact of large deer populations on ecosystems and one possible response to this situation.

b. Read the introduction.

In addition to the text, spend a few minutes discussing the graph in Figure 1, "Wolf and Elk Populations in Yellowstone, 1994—2014." Ask students to first describe the data trends in the graph, and to then discuss what they think is happening. For the first 10 years of the graph, the elk population generally declines while the wolf population increases. For the second 10 years of the graph, it appears that the populations slowly get to the same levels; this is misleading if students do not pay attention to the two y-axes. In 2014, there were about 100 wolves and over 4,000 elk. Without more information, it does look like the two populations are stabilizing at the same levels.

Reasons for these changes may be varied. Ask, *Besides predator-prey relationships, what else could be affecting one or both of these populations?* Possible factors could include competition, disease, lack of resources such as food or water, or bad weather.

Doing the Activity

2. Students read about the impact of deer on ecosystems using the literacy strategy on Handout 1.6-1, "DART: Reading Support for Activity 1.6." (20 minutes)

a. Have students read about deer populations and the Adirondacks ecosystem.

Have students complete the reading, either individually, in small groups, or as a class.

b. Distribute Handout 1.6-1.

Handout 1.6-1 should help guide student understanding of important points in the reading. On the handout, questions 1 and 2 are (1) true/false and (2) finding patterns of interaction from the information in the reading, respectively. Question 3 is a diagram comparing the Adirondacks and Yellowstone ecosystems. Students can use information from the reading to fill in the Adirondacks information, while the Yellowstone information relies on their prior knowledge from this unit. You may find it helpful to direct students to the KWL chart. For more suggestions on Venn diagrams, see Section 2 of Teaching Strategies.

c. Have students complete the handout either individually or in small groups. A Sample Student Response is provided at the end of this activity.

This activity provides several opportunities to assess multiple ELA Common Core State Standards, including RST.6-8.1, WHST.6-8.2, WHST.6-8.9, and SL.8.1. Use the assessment chart to locate the steps which are the best opportunities for assessment of these standards before choosing which ELA standard(s) to assess.

3. **Students use the Explanation Tool to construct a scientific explanation using claims and evidence.** (20-25 minutes)

> **Assessment – PE-MS-LS2-2**
> Step 2 provides an opportunity to assess one of the performance expectations associated with this chapter, specifically MS-LS2-2 "Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems." Students will use the Explanation Tool as they construct their answer to the question posed.

a. Guide students to construct an explanation.

In Procedure step 2, students continue their work on the scientific practice of constructing a scientific explanation. In this case, the question is, "What effect does a large population of deer have on an ecosystem?" Hand out a copy of the Explanation Tool to each student. If your students have just been introduced to the practice of constructing explanations in this chapter, consider letting them work in pairs or groups as they complete the first side of the Explanation Tool. Then they might complete the written explanation on their own, and work together to peer review and improve their explanations. Note that a completed sample student response of this Explanation Tool is found at the end of this Teacher's Guide. Student responses can be scored using the Constructing Explanations Scoring Guide.

Since this activity is expected to take 90 to 100 minutes, consider breaking between periods at an appropriate point while students are working on constructing their explanations. The next period can begin with a review of the task and of using the explanation tool, before students complete their explanations and engage in a walking debate. For guidance on facilitating a walking debate, see Section 2 of Teaching Strategies.

4. **Students participate in a walking debate on the question: Should wolves be reintroduced into the northeastern U.S. Adirondack ecosystem? Why or why not?** (10-15 minutes)

a. Begin the Walking Debate.

Assign two areas of the room, one to represent those who support wolf reintroduction to the Adirondacks and one to those who do not. Have students walk to the area that supports their thinking.

b. Allow students to share scientific evidence and reasoning that supports their position.

Have students form groups to identify 1-2 lines of scientific evidence that support their line of thinking. Have each group from the same side of the argument share their evidence and reasoning with the class. Record it on the board. Do the same for the other side of the argument. As a class, discuss whether all of the ideas qualify as scientific evidence. Adjust the list as needed.

c. Have students walk their opinion again.

With a listing of the evidence on view, have students walk their opinion again. Discuss whether students' thinking changed and why or why not.

Follow-Up

5. **Summarize the activity and the chapter.** (10-15 minutes)

a. Discuss the evidence that supports each side of the wolf reintroduction debate.

Analysis Question 1 provides an opportunity to foreshadow the scientific practice of constructing arguments, which is introduced later in the unit. Hold a brief discussion of the evidence that would support each side of the argument, and the quality and strength of that evidence.

b. Use the KWL chart to review the concepts learned in the chapter.

Revisit the Guiding Question ("What effect does a large population of deer have on an ecosystem?"). After completing the activity, summarize the KWL chart first developed in Activity 1.1, "People and Animals Interacting." In particular, have students record what they have learned over the course of the chapter, and discuss any questions that remain unaddressed: *What have you learned from this chapter? What questions do you still have? How could you find out more about those questions?* Encourage students to think about science as an ongoing process of asking questions, gathering data, revising and asking new questions, and gathering new data. Theoretically, the study of a topic is never finished, and many scientists spend their entire careers investigating a single topic in increasing levels of detail and complexity.

Suggested Answers To Analysis

1. **In this activity, you investigated the question, "Should wolves be reintroduced into the northeastern U.S. Adirondack ecosystem?" Some students may have argued that wolves should be reintroduced, while other students may have argued that wolves should not be reintroduced. As a class, discuss:**

> **Assessment – PE-MS-ESS3-4**
> Analysis Question 1, in conjunction with Procedure Step 4, provides an opportunity for students to be introduced to the scientific practice of argumentation. At this stage students are not expected to construct a written argument, nor are they formally instructed on the practice of scientific argumentation. However, they are encouraged to use scientific evidence to support a position related to human impact on Earth's systems. Argumentation is developed further in later chapters of this unit with the assistance of an Argumentation Tool.

a. **What scientific evidence supports each side of this debate?**

Class discussions will vary widely. Some important points for the discussion are noted below.

Students who argue that wolves should be reintroduced may note that: (1) deer carry ticks which spread disease; (2) deer compete with songbirds, which are also an important species; (3) deer compete with people for plants and space; (3) large deer populations cause damage to healthy forests; (4) wolves are predators and deer is one of their prey; (5) the interaction of biotic factors such as predation can result in changes in population size; (6) the reintroduction of wolves in Yellowstone corresponded to a decrease in one of the prey populations (elk); and (7) the wolf-moose population in Isle Royale showed that there an increase in predator populations result in a decrease in prey populations.

Students who argue that wolves should not be reintroduced may note that: (1) hunting is a successful way to control deer populations; (2) wolves may encroach on land where people live, and possibly compete for land or act as a predator of pets; (3) large populations of people (over 60 million) live in close proximity to the Adirondacks, unlike in Yellowstone National Park; (4) a change in an abiotic factor like drought could reduce the deer population significantly, making reintroduction unnecessary; and (5) deer provide ecosystem benefits such as the spreading of plant seeds.

b. **Discuss the quality and strength of the evidence that supports each side.**

The quality and strength of each line of the evidence varies, but the chapter provides a lot of evidence for wolf reintroduction if reducing deer population *is the goal. This is good place to review the idea that not all arguments are decided solely based on the scientific evidence; people's goals and values play a role as well.*

Activity 1.6

Evaluate: Disrupting Ecosystems with Wolves

Materials and Advance Preparation

For the class

- ☐ 1 KWL chart (started in Activity 1.1, “People and Animals Interacting”)

For each student

- ☐ 1 Handout 1.6-1, “DART: Reading Support for Activity 1.6”
- ☐ Explanation Tool
- ☐ Scoring Rubric: Constructing Explanations

Teaching Summary

Getting Started

1. **Review predator-prey interactions in Yellowstone.** (10 minutes)
   - **a.** Review predator-prey graphs.
   - **b.** Read the introduction.

Doing the Activity

2. **Students read about the impact of deer on ecosystems using the literacy strategy on Handout 1.6-1, “DART: Reading Support for Activity 1.6.”** (20 minutes)
   - **a.** Have students read about deer populations and the Adirondacks ecosystem.
   - **b.** Distribute Handout 1.6-1.
   - **c.** Have students complete the handout either individually or in small groups. A Sample Student Response is provided at the end of this activity.

3. **(Assessment) Students use an Explanation Tool to construct a scientific explanation using claims, evidence, and reasoning.** (20-25 minutes)

    a. Guide students to develop an explanation.

4. **Students participate in a walking debate on the question: Should wolves be reintroduced into the northeastern U.S. Adirondack ecosystem? Why or why not?** (10-15 minutes)

    a. Begin the Walking Debate.

    b. Allow students to share scientific evidence and reasoning that supports their position.

    c. Have students walk their opinion again.

Follow-Up

5. **Summarize the activity and the chapter.** (10-15 minutes)

    a. Discuss the evidence that supports each side of the wolf reintroduction debate.

    b. Use the KWL chart to review the concepts learned in the chapter.

CHAPTER

2 Ecosystem Models

Activity 2.1
Engage

How do organisms get matter and energy?

Students begin the chapter by thinking about where organisms get the matter, or stuff, and energy they need to live, grow, and reproduce. They also begin to think about the fate of matter in dead organisms and wastes.

Activity 2.2
Explore

How do life and death affect the movement of matter and energy in ecosystems?

Students expand their model of a food web from Chapter 1 to include additional higher-level consumers and decomposers (bacteria). They then create a draft model to explore and describe their ideas about the source and fate of matter and energy in a food chain. They will revise this model throughout the chapter.

Activity 2.3
Explain

How does matter move between biotic and abiotic parts of an ecosystem?

Students focus specifically on modeling the movement of matter into and out of the biotic component of the ecosystem in this activity. They use scientific findings (observations and evidence) as they work in groups to develop a consensus model, and use the revised model to develop an explanation for the sources and fate of matter transferred between components of the biotic part of the system and between the abiotic and biotic components.

Activity 2.4
Explain

How does energy flow in an ecosystem?

Students add the transformations and flow of energy in an ecosystem to the models they developed in the previous activity. They focus on the source and fate of energy and movement of energy within the biotic component of the system and between the biotic and abiotic components.

Activity 2.5
Elaborate

How does a disruption affect the flow of energy and cycling of matter in an ecosystem?

Students elaborate on their understanding of the flow of energy and cycling of matter in an ecosystem by exploring the effects of natural disasters on the biotic and abiotic components of an ecosystem. They describe how a fire would affect the food web in Yellowstone and they describe the changes in the ecosystem that would occur over time following a fire.

Activity 2.6
Evaluate

How can a model be used to represent and make predictions about an ecosystem?

Students apply what they have learned to create a model of the movement of matter and energy in their local ecosystem. They use the model to predict the effect of a disruption—a landslide that buries part of a hillside—on the flow of matter and energy in the system.

Chapter 2 Overview

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Engage **2.1 Energy and Matter for Ecosystems** **Guiding Question:** How do organisms get matter and energy? In Part One of this activity, students respond to questions about how organisms in the Yellowstone ecosystem get the matter and energy they need to live, and what happens to the matter in these organisms when they die. In Part Two, students observe as the teacher sets up a compost bag, which will provide evidence students will use in Activity 2.3, "Matter in Ecosystems," to further develop their ideas about what happens to matter after an organism dies.	MSLS2.B.4 Energy & Matter	Developing and Using Models		1
Explore **2.2 Life and Death in an Ecosystem** **Guiding Question:** How do life and death affect the movement of matter and energy in ecosystems? Students expand the model of the Yellowstone Food Web introduced in Chapter 1 to include two higher-level consumers and a decomposer (bacteria). They select four organisms from the food web to create a four-level food chain, which they will use as the basis for increasingly complex models of matter cycling and energy flow throughout the chapter.	MSLS2.B.4 Energy & Matter Stability & Change	Developing and Using Models		1
Explain **2.3 Matter in Ecosystems** **Guiding Question:** How does matter move between biotic and abiotic parts of an ecosystem? Students use scientific findings, including observations of the classroom compost, to revise their ideas about the source, movement, and fate of matter in ecosystems. They work in groups of four to develop a draft consensus model to represent their ideas. Students add captions to describe the changes in matter that go with the events in the Forest Ecosystem cards from the previous activity. They use the Explanation Tool to develop an explanation of where plants get the matter they need to grow, and they revisit the Anticipation Guide items that relate to matter.	MSLS2.B.4 MSPS1.B MSESS2.A Energy & Matter	Developing and Using Models Constructing Explanations Obtaining, Evaluating, and Communicating Information	matter	3

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Explain **2.4 Energy Flow in Ecosystems** **Guiding Question:** How does energy flow in an ecosystem? In Part One, students reveal their initial understanding about the source of energy for plants to engage in photosynthesis, as well as the source of energy that animals and decomposers use for life processes. Students then read text to obtain additional information about energy flow through ecosystems. In Part Two, students track the flow of energy in an ecosystem, incorporating the abiotic components. Students learn that a significant portion of energy transfers to the abiotic environment at each level of the food chain. Students revise their Yellowstone ecosystem models from the previous activities to incorporate their revised understanding. Students return to the Anticipation Guide and complete an "After" column for questions 5-8, which focus on energy.	MSLS2.B.4 MSESS2.A MSPS1.B Energy & Matter	Developing and Using Models Obtaining, Evaluating, and Communicating Information Constructing Explanations	–	3
Elaborate **2.5 Disruptions and Food Webs** **Guiding Question:** How does a disruption affect the flow of energy and cycling of matter in an ecosystem? In Part One of the activity, students consider the effects of four kinds of natural disasters on the biotic and abiotic components of ecosystems. In Part Two, they order a series of Forest Ecosystem cards that illustrate the timeline of changes before, during, and after a fire in Yellowstone. They write captions for the cards to describe the changes in matter and energy that go with the events in the cards.	MSLS2.B.4 MSESS2.A Energy & Matter Stability & Change	Developing and Using Models Constructing Explanations	–	2
Evaluate **2.6 Modeling Energy Flow and Matter Cycling in an Ecosystem** **Guiding Question:** How can a model be used to represent and make predictions about an ecosystem? Student groups construct a 2- or 3-dimensional model of a their local ecosystem and present their model to the class. They focus on explaining the cycling of matter and flow of energy within their ecosystem.	MSLS2.B.4 MSESS2.A MSPS1.B Energy & Matter Stability & Change	Developing and Using Models Constructing Explanations Obtaining, Evaluating, and Communicating Information	–	2–3

Assessment Overview

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explore	Activity 4 Explain	Activity 5 Elaborate	Activity 6 Evaluate
Disciplinary Core Ideas						
MS LS2.B*		Steps 3 & 4 Analysis 1	Step 3 Analysis 1, 2, 3	Step 12 Analysis 3, 4, 5	Step 11 Analysis 2	
MS PS1.B**			Step 3 Analysis 1a	Analysis 4		
MS ESS2.A**				Step 12	Step 11 Analysis 2	
Science and Engineering Practices						
Developing and Using Models */**/**		Steps 3-4	Step 3	Step 12	Step 11	
Constructing Explanations			Analysis 2	Analysis 3, 4		
Connections to the Nature of Science**						
Crosscutting Concepts						
Energy and Matter*/**		Steps 3 & 4 Analysis 1	Step 3 Analysis 1, 2, 3	Step 12 Analysis 3, 4, 5	Step 11 Analysis 2	
Stability and Change***					Analysis 2	
Connections to the Nature of Science*						
Performance Expectations						
MS-LS2-3*						Steps 5 & 6 Analysis 2
MS-PS1-5**						Steps 5 & 6
MS-ESS2-1***						

* Primary PE and supporting elements **Secondary PE and supporting elements ***Not associated with PE

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explore	Activity 4 Explain	Activity 5 Elaborate	Activity 6 Evaluate
CCSS ELA						
RST.6-8.7**			Step 2 Analysis 2	Steps 8-10		Step 5 Analysis 2
(SL.8.5) */***						Step 6
CCSS Math						
MP.2 **				Steps 11 & 12		
MP.4**				Steps 11 & 12		
6.RP.A.3**						
(6.EE.C.9)*						

* Primary PE and supporting elements **Secondary PE and supporting elements ***Not associated with PE

PE	**MS-LS2-3:** Develop a model to describe the cycling of matter and flow of energy among living and non-living parts of an ecosystem.
	MS-PS1-5: Develop and use a model to describe how ~~the total number of atoms does not change in a chemical reaction and thus~~ mass is conserved.
	MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
DCI	**MS-LS2.B:** Food webs are models that demonstrate how matter and energy is transferred between producers, consumers and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant of animal material back to the soil in terrestrial environments or to the water in aquatic environments. ~~The atoms that make up the organisms in an ecosystem~~ are cycled repeatedly between the living and nonliving parts of the ecosystem.
	MS PS1.B: Substances react chemically in characteristic ways. ~~In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.~~ The total ~~number of each type of atom is conserved, and thus the~~ mass does not change.
	MS ESS2.A: All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.

SEP	**DUM:** Develop (and use) a model to describe phenomena. Develop a model to describe unobservable mechanisms.
	CEDS: Apply scientific ideas, principles, and evidence to construct an explanation for real-world phenomena. Construct an explanation using models or representations.
	(CNOS): Laws are regularities or mathematical descriptions of natural phenomena.
CCC	**E&M:** The transfer of energy can be tracked as flows through a natural system. Matter is conserved ~~because atoms are conserved in physical and chemical processes.~~
	S&C: Explanation of stability and change in natural or designed systems can be constructed by examining the changes over time and processes at different scales, ~~including the atomic scale~~.
	CNoS: Science assumes that objects and events in natural systems occur in consistent patterns and are understandable through measurements and observation.
CC ELA	**(RST.6-8.7)** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (*e.g.*, in a flowchart, diagram, model, graph, or table).
	(SL.8.5) Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.
CC MATH	**MP.2** Reason abstractly and quantitatively.
	MP.4 Model with mathematics.
	6.RP.A.D Use ratio and rate reasoning to solve real-world and mathematical problems.
	(6.EE.C.9) Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express on quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

Teacher Background

Producers transfer matter and energy from the abiotic to biotic environment

Producers, such as plants, are at the base of food chains. Producers are able to produce complex organic compounds, in the form of sugars, from carbon dioxide in the air or dissolved in water. As they make these compounds, they transfer matter (from substances in the environment) into the food web. At the same time, they transform light energy (from sunlight) into chemical energy (in food). Most producers, including green plants, use the process of photosynthesis to produce organic compounds. Light serves as the energy source for photosynthesis, which takes place in the chloroplasts in green plant cells. However, some producers, such as certain bacteria and archaea, are able to use chemical energy in the process of chemosynthesis.

Because producers make their own organic compounds, scientists say they make their own food. This idea that plants make their own food can be confusing, especially since stores sell "plant food." This supports the misconception held by many that plants get food from the soil. They do get certain nutrients, such as nitrogen, phosphorus, and potassium, from the soil, and these substances are replenished by adding fertilizer or "plant food." However, most of the matter in a plant is composed of the carbon, hydrogen, and oxygen that are the major components of such organic substances as carbohydrates, lipids, and proteins. Furthermore, none of the nutrients obtained from soil serve as a source of energy.

The food produced by plants serves as a source of both matter and energy for the plants themselves and for all other organisms in the food web. Plants make sugars for their own use, and store the sugars and use them when they need energy to live and grow. Other organisms that eat the plants are also able to use the sugars they obtain by feeding on plants. Sugars and other substances in food provide both plants and the organisms that eat them with matter and energy they need to survive and grow. Both plants and animals break down the substances in food. Some of the breakdown products are used to synthesize other organic substances, such as the specific proteins needed by each organism, in the various metabolic reactions. Other breakdown products are further broken down through cellular respiration to release energy that can be used by the organisms.

Ecosystems need a steady supply of energy

The energy that flows from the Sun and is used by plants is in fact the source of energy for nearly all life on Earth. Plants transform the energy transferred by the light from the Sun into chemical energy, stored in the bonds of sugars and other organic molecules. As plants and animals use the energy from food, most of the chemical energy stored in the food is transformed into thermal energy. And when decomposers break down dead organisms, the chemical energy stored in their bodies is also transformed into thermal energy. This thermal energy, which we detect as heat when it transfers from a higher-temperature system to a lower-temperature system, cannot be used by plants. It eventually radiates from the Earth and dissipates into space. (Some students may have the misconception that this energy can return to the Sun.) Because plants can't recapture the thermal energy that leaves the biotic component of the system as heat, ecosystems require a steady input of energy from the Sun.

Matter cycles in an ecosystem

Matter is the physical material in living and non-living things. Specific kinds of matter are called substances. For example, water, carbon dioxide, and sugars are all substances. Plants use the substances water and carbon dioxide to make sugars, thereby transferring matter from the abiotic environment into the biotic food web.

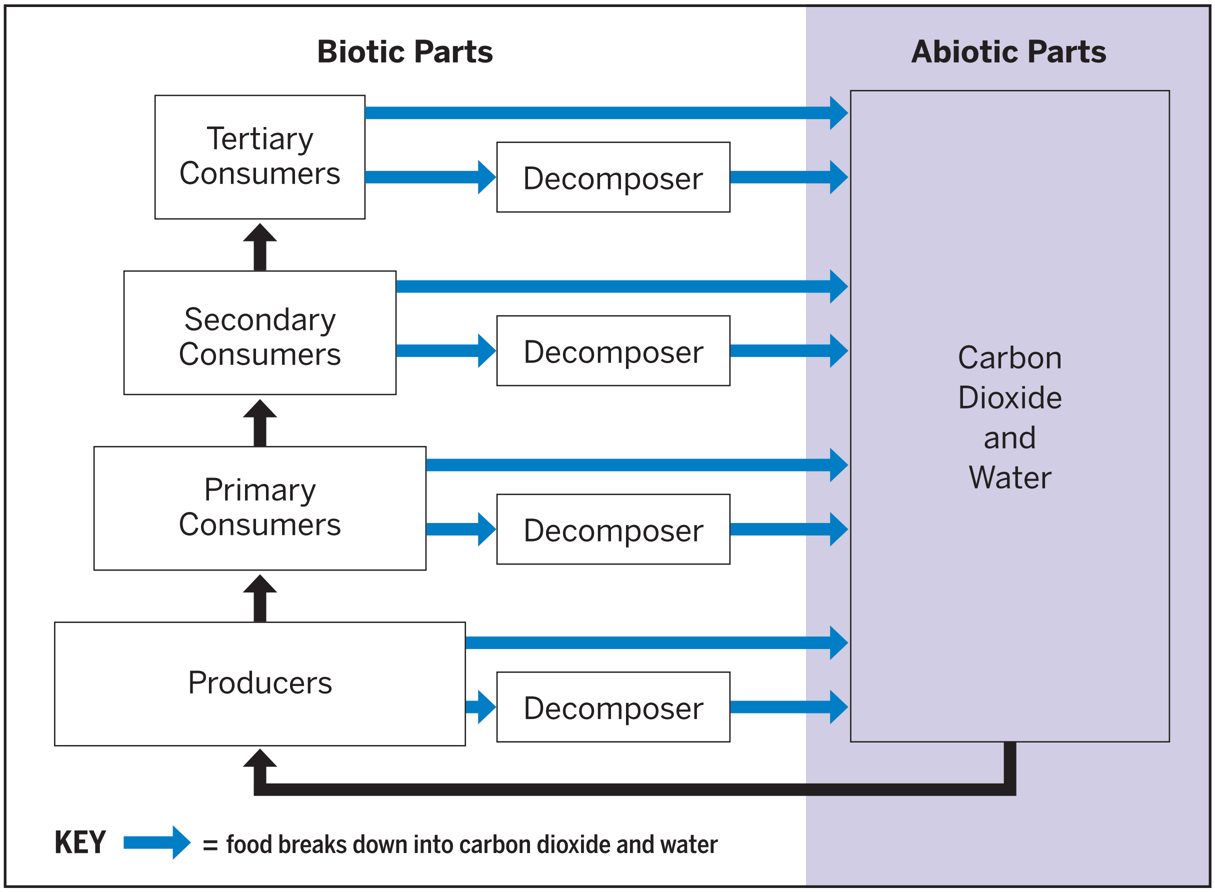
Some of the matter in organisms at any level of the food chain moves to the next level as the organisms are eaten. At each level in a food chain, organisms break down food, and release carbon dioxide and water. This returns some of the matter in a food chain back from the living organisms to non-living air, soil, and water.

However, organisms produce wastes, and some organisms die before they are eaten. Decomposers feed on wastes and dead matter and cause it to break down, or decompose. Decomposers in many ecosystems, including Yellowstone, include worms, fungi, and bacteria.

Decomposition releases carbon dioxide and water back into the air and soil—the abiotic parts of the ecosystem. When organisms die, decomposers break down their bodies and return their matter back to the environment. Without decomposers, wastes and dead organisms would accumulate, and the carbon needed for plants to make food would be unavailable to plants.

As matter cycles within an ecosystem, it can be used again and again by plants to produce food. The water and carbon dioxide released to the environment when organisms break down food or are decomposed can be reused again and again by plants. In this way, the same matter continually cycles between biotic and abiotic

Matter Cycles in an Ecosystem



parts of an ecosystem.

Very little new matter enters or leaves the Earth system. Instead of flowing into and out of an ecosystem like energy, matter cycles (moves continuously back and forth) between biotic and abiotic parts of the system. The specific substances can change as atoms rearrange during chemical reactions, but the total amount of each kind of atom (and therefore the total mass) in the Earth system stays the same. Matter in a closed system is conserved, meaning the total amount of matter stays the same.

1 class session

Energy and Matter for Ecosystems

How do organisms get matter and energy?

Students begin the chapter by thinking about where organisms get the matter, or stuff, and energy they need to live, grow, and reproduce. They also begin to think about the fate of matter in dead organisms and wastes.

Rationale and NGSS Integration

In this chapter, students use the scientific practices of developing and using models and constructing explanations as they make sense of phenomena related to the crosscutting concept of matter and energy and the specific disciplinary core ideas related to matter cycling and energy flow in ecosystems. In grades 3–5, they should have developed the ability to develop and/or use models to describe and/or predict phenomena. This element of the modeling practice is deepened in Grades 6–8, and students are also expected at this grade level to use models to describe unobservable mechanisms. This integrates with the added expectation that students in Grades 6–8 will construct explanations using models or representations. The chapter also builds students' understanding of the crosscutting concept of energy and matter by further exploring the cycling of matter introduced in earlier grades and adding the Grade 6–8 element of tracking energy flows through the ecosystem.

Early in the chapter, students develop initial models of the movement of matter and energy in ecosystems, which they revise and build on throughout the chapter, refining their ability to use models to describe and predict phenomena related to interactions between organisms and between organisms and the abiotic environment, as well as to construct explanations. Towards the end of the chapter they will use these models to make predictions about the impact of disruptions on ecosystems.

This Engage activity elicits students' ideas about where organisms obtain the matter and energy necessary for growth and life processes, and what happens to this matter and energy when organisms are eaten or die. Because this is an Engage activity, students do not begin developing models but they do begin to surface their current thinking and explanations for how organisms get the matter and energy they need to grow. They start by thinking about fundamental questions related to matter and energy in ecology, including "How do organisms get the matter and energy they need to grow and conduct life processes?" and "What happens to matter and energy in an organism after the organism dies?" This sets the stage for students to explore phenomena related to changes in ecosystems after natural disasters, such as the effects of a forest fire.

Review the chapter overview and assessment chart for an overview of the NGSS taught and assessed in this activity and how the standards are woven together throughout the chapter. Decide in advance which assessments you plan to emphasize.

Activity Overview

In Part One of this activity, students respond to questions about how organisms in the Yellowstone ecosystem get the matter and energy they need to live, and what happens to the matter in these organisms when they die. In Part Two, students observe as the teacher sets up a compost bag, which will provide evidence students will use in Activity 2.3, "Matter in Ecosystems," to further develop their ideas about what happens to matter after an organism dies.

Materials and Advance Preparation

For the teacher

- ☐ 1 compostable bag
- ☐ a mixture of plant-based materials to compost
- ☐ 1 plastic tub to hold the compost bag and mixture

Obtain the materials for the activity. They should include a mixture of vegetable and fruit wastes. Tender lettuce leaves or celery stalks, some grass or non-waxy leaf clippings, and wastes from fruit such as cores, peels, and pieces of ripe fruit, should provide a mixture that will decay fairly rapidly (within 4–7 days). ***Do not include any meat or other animal products in the compost.***

Teaching Summary

Getting Started

1. Students discuss in small groups the sources and fate of matter and energy in a forest ecosystem.

Doing the Activity

2. The class discusses students' ideas about the sources and fate of matter and energy in a forest ecosystem.

3. Students observe as you prepare a bag of compostable plant matter for observation over the next few days.

Follow-Up

4. The class previews the chapter and revisits the Guiding Question.

Teaching Suggestions

Getting Started

1. **Students discuss in small groups the sources and fate of matter and energy in a forest ecosystem.** (15 minutes)

   a. Have students read the introduction.

      In an Engage activity, it is important to keep the class and group discussions very open-ended and not to correct students' ideas. This phase serves to elicit students' prior knowledge and begins to surface any misconceptions. As the teacher, make a note to yourself of misconceptions students have so that you can revisit them when the students are further through the chapter. At that point students will be better able to correct many misconceptions through their own growth in understanding. The use of Elicit Questions, described in Section 2 of Teaching Strategies, during this Engage activity can help reveal students' preconceptions about energy and matter.

   b. Review the illustration of a Yellowstone Forest Ecosystem.

      Have a student describe the system and organisms shown and suggest what other organisms are likely to be present, but not shown. If necessary, point out the mature trees and the clearing, or meadow, in this forest.

c. If necessary, review expectations for collaborative group work.

See the More Information section at the end of this activity.

d. Facilitate small group discussions of the questions in the Procedure.

Students should discuss the questions in Procedure Step 1. This discussion is intended to elicit students' thinking about where organisms get the matter and energy they need to grow, and where the matter and energy "go" after the organisms die. This can be done as a think-pair-share or in groups of 3 to 4 students. Encourage them to listen to each others' ideas and prepare for one of the pair or group to summarize their ideas with the class. You may wish to have students use Student Sheet 1, "Developing Communication Skills," to help them engage in productive talk with their group members.

Doing the Activity

2. The class discusses students' ideas about the sources and fate of matter and energy in a forest ecosystem. (10 minutes)

a. Have student pairs or groups share their ideas.

Post the questions from Part One on a piece of chart paper and record key points from students' responses. Consider asking each group to share their ideas in response to Procedure 1a, b, or c. Each group should either add a new idea or indicate their agreement with an idea already recorded. Accept their ideas, and record any questions or uncertainties that arise. This sets a foundation for grade-appropriate use of models and construction of explanations of phenomena related to LS2.B (cycle of matter and energy transfer in ecosystems), and the CCC of matter and energy (tracking of energy). Explain that students will have a chance to explore these ideas throughout the chapter.

b. Work with the class to synthesize their key ideas.

Although the NGSS call for some of these concepts in the late elementary grades, some students won't have had much instruction and others will retain misconceptions. They may realize that animals need to obtain food by eating other organisms, which may be plants or animals, but not understand that plants essentially make their own food. They might suggest that plants get most of their matter and/or energy from the soil or that animals get energy by sleeping. They may have little idea about the role of decomposers in returning matter and energy to the abiotic component of the ecosystem. Record their ideas on chart paper to revisit later.

In this activity, matter is informally defined as "stuff," and energy is not defined. Students are likely to have been introduced to energy in previous grades, and formal definitions of energy, such as energy is the ability to do work, tend not to be helpful. As the chapter progresses, stress that energy can be transferred by moving objects, sound, light, heat, electric currents, or chemical reactions. In this chapter, the energy transferred by light and heat, and energy stored in food (in the bonds of substances in the food) and released as food breaks down, are especially relevant.

You might wish to explain to students the difference between the way scientists use the terms thermal energy and heat. Thermal energy is energy due to motion of atoms or molecules in a substance. Heat refers to the transfer of that energy (due to a temperature difference). Since this chapter generally refers to thermal energy transfer, the term heat is usually acceptable.

3. **Students observe as you prepare a bag of compostable plant matter for observation over the next few days.** (10 minutes)

    a. Display the materials you will compost, and place them in the bag.

    Have students record the date and their observations of the bag in their science notebooks or record them on a chart paper.

    b. Ask students to predict what they think will happen to the materials in the bag.

    Students may say they will rot, get moldy, or break down. Accept whatever they say, and ask them to record their ideas in their science notebooks or record their ideas on the chart paper. Explain that their observations over the next several days will help them understand what happens when an organism dies.

    If you need to break the activity, the best time to do so is after this step.

Follow-Up

4. **The class previews the chapter and revisits the Guiding Question.** (10 minutes)

    a. Preview the chapter with the students.

    Begin by discussing students' ideas about Analysis question 1. Remind them that they are studying ecosystems and ecosystem disruptions throughout this unit. In this unit, they will develop models and construct explanations of how disruptions, such as fires, affect ecosystems. This question elicits students' ideas, which they will develop further through the chapter. Consider creating a Student Question Poster to help surface students' questions about disruptions and ecosystems. Accept all reasonable questions at this point, and revisit this poster and the end of the Explore and Explain activities in this chapter.

Use the Chapter Overview to guide you as you preview the rest of the chapter with the class. Note that there are two guiding questions for the chapter, "Where do organisms get the matter and energy they need to grow, and what happens to this matter and energy when the organisms die?" Point out that these questions were introduced in Part One of the Activity. Briefly preview the content they will be learning, including the disciplinary core ideas, and the crosscutting concepts and science and engineering practices they will use to build conceptual understanding and to develop explanations for how natural disasters affect ecosystems, and how systems recover from these disasters.

Explain to students that their main learning goals for this chapter are to develop and revise models to explain how matter and energy move in ecosystems and to use their models to explain the effects of certain natural disasters.

b. Revisit the Guiding Question

Conclude the activity by revisiting the Guiding Question, "How do organisms get matter and energy?" with the whole class. Students' answers may vary, but they will likely suggest that they get matter and energy from food (animals) or the soil (plants). If they think of food in terms of matter and energy, they might begin to make connections to the core ideas and crosscutting concepts of the chapter.

Suggested Answers To Analysis

NOTE: Analysis question 1 asks students to think about how a disruption would affect matter and energy movement. This question foreshadows the forest fire scenario that students will encounter in Activity 2.5, the Elaborate activity in this sequence.

1. **How do you think a major disruption, such as a forest fire, would affect the ability of animals in a forest ecosystem to get matter and energy?**

   Note: Answers will vary. A possible answer follows.

   A fire will kill many of the plants and some of the animals that can't run away fast enough. Since animals eat plants, I think this would make it hard for the animals that are still alive to get enough matter and energy to live.

Extension

Encourage students to set up their own compost bin at home so that they can compare their results with the class results. Make sure they use a composting bag, rather than a plastic bag. Also be sure to share the safety note that they should not put any animal products in the bag as that can lead to the growth of harmful bacteria.

Activity 2.1

Engage: Energy and Matter for Ecosystems

Materials and Advance Preparation

For the teacher

- ☐ 1 compostable bag
- ☐ a mixture of plant-based materials to compost
- ☐ 1 plastic tub to hold the compost bag and mixture

Teaching Suggestions

Getting Started

1. **Students discuss in small groups the sources and fate of matter and energy in a forest ecosystem.** (15 minutes)

   a. Have students read the introduction.

   b. Review the illustration of a Yellowstone Forest Ecosystem.

   c. If necessary, review expectations for collaborative group work.

   d. Facilitate a discussion of the questions in Procedure Part One.

Doing the Activity

2. **The class discusses students' ideas about the sources and fate of matter and energy in a forest ecosystem.** (10 minutes)

   a. Have student pairs or groups share their ideas.

   b. Work with the class to synthesize their key ideas.

3. **Students observe as you prepare a bag of compostable plant matter for observation over the next few days.** (10 minutes)

   a. Display the materials you will compost, and place them in the bag.

b. Ask students to predict what they think will happen to the materials in the bag.

Follow-Up

4. The class previews the chapter and revisits the Guiding Question. (10 minutes)

a. Preview the chapter with the students.

b. Revisit the Guiding Question.

1 class session

Life and Death in an Ecosystem

How do life and death affect the movement of matter and energy in ecosystems?

Students expand their model of a food web from Chapter 1 to include higher-level consumers and decomposers. They create a draft model to explore and describe their ideas about the source and fate of matter and energy in a food chain. They will revise this model throughout the chapter.

Rationale and NGSS Integration

This Explore activity provides an opportunity for students to explore and describe their initial thinking about how energy and matter move in ecosystems. The crosscutting concept of energy and matter is further emphasized as students build on the food webs they developed in Chapter 1 to develop models of the movement of matter and energy in ecosystems.

Through these activities, students will engage in the three dimensions of the NGSS as they further develop their ability to use models to describe unobservable mechanisms. Specifically, their models will describe how energy, as well as matter, transfers between producers, consumers, and decomposers, and between organisms and the physical environment.

Activity Overview

Students expand the model of the Yellowstone Food Web introduced in Chapter 1 to include two higher-level consumers and a decomposer (bacteria). They select four organisms from the food web to create a four-level food chain, which they will use as the basis for increasingly complex models of matter cycling and energy flow throughout the chapter.

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models

For each group of four

- ☐ 1 set of 13 Yellowstone Food Web Cards from Activity 1.2
- ☐ 1 badger card
- ☐ 1 bald eagle card

Teaching Summary

Getting Started

1. Students review the organisms and interactions introduced in Chapter 1.

Doing the Activity

2. Students add organisms to the Yellowstone Food Web and identify a four-level food chain for future models.

Follow-Up

3. Discuss students' current models and their answers to the Analysis questions.
4. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Students review the organisms and interactions introduced in Chapter 1.** (5 minutes)

   a. Review the idea that a food web is a model of some of the interactions in an ecosystem.

      These interactions included feeding relationships (including predator-prey), competition, and symbiosis. Explain that in this Explore activity, students will be taking a closer look at the importance of feeding relationships at the level of the entire ecosystem. They will expand on their food web models to develop the beginning of a model that they will revise and enhance over the course of the chapter. Through these activities, they will further develop their ability to use models to describe unobservable mechanisms. Specifically, their models will describe how energy, as well as matter, transfers between producers, consumers, and decomposers, and between organisms and the physical environment.

b. Explain that in this activity students will explore how to develop models to show some of their ideas about energy and matter from the last activity.

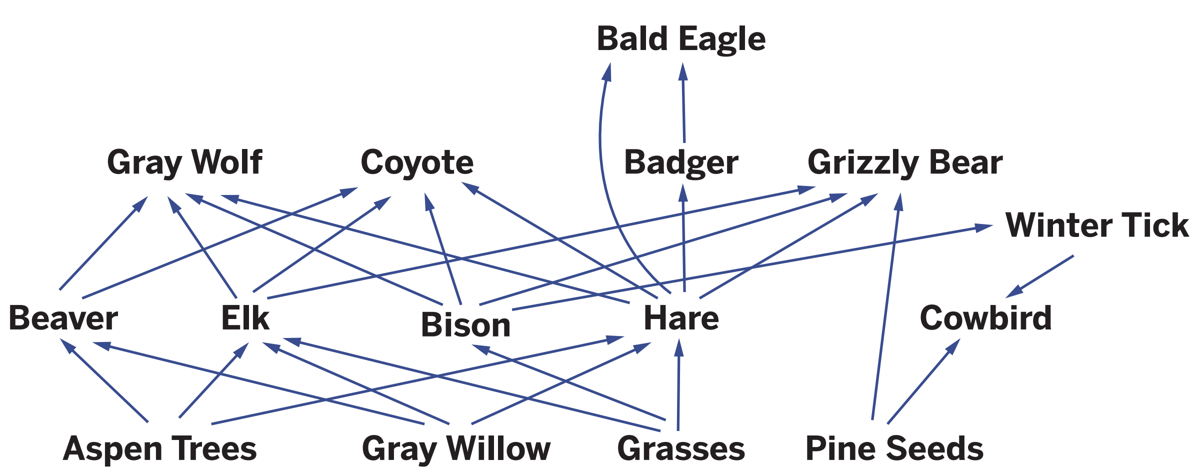
Briefly introduce the crosscutting concept of matter and energy, and explain that scientists in many fields track and try to explain the movement of matter and energy. Add the words matter and energy to the word wall. For matter, you can add the informal definition "stuff." Explain that energy is not stuff, and is harder to define. In general, it's easier to talk about types of energy (such as light and sound) and movement of energy, than to try to develop a broad definition of energy.

Doing the Activity

2. Students add organisms to the Yellowstone Food Web and identify a four-level food chain for future models. (20 minutes)

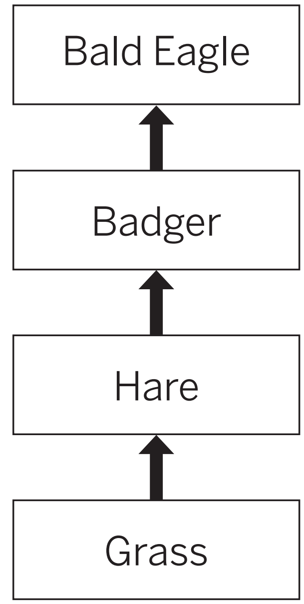
a. Have students recreate the Yellowstone Food Web and add two new organisms.

Monitor them to see if they are able to quickly recreate the web they developed in Chapter 1 and are able to add the badger and bald eagle to the food web. A sample answer is provided on the following page.



b. If needed, help students identify a four-level food chain.

One possibility is plant, hare, badger, bald eagle. Another is plant, hare, coyote, wolf, although wolves usually eat herbivores (elk and bison), and only rarely eat coyotes. The badger and bald eagle were added to include a carnivorous animal and top-level predator. A sample of one of the food chains is on the right. Note that, although badgers are not a major source of food for eagles, eagles occasionally eat young badgers, so they are part of the food web.



c. Circulate and observe as students begin to create models of the movement of matter and energy.

> **Assessment—DCI-MSLS2.B, SEP-Developing and Using Models, CCC-Energy and Matter**
> Procedure Steps 3 and 4 can be used as an initial assessment of students' ability to identify a food chain and add bacteria. This food chain will be important for their development of a more complete model of the movement of matter and energy throughout the chapter.

Encourage students to use arrows, labels, and captions to show the movement, or transfer, of matter and energy. Their models at this point will be very simple, and are likely to show matter and energy moving from plants to each successive organism up the food chain. Look to see if they also show a source of energy and a source of matter for plants. They may have little idea of what happens to dead organisms, and show them decaying into the soil (which some do at first), being eaten (which does frequently happen), or just disappearing. For more information on how models and scientific representations help students understand and explain phenomena, see the "More Information" section at the end of this activity.

d. Students add bacteria to their models, and use their models to explain their thinking about matter and energy.

When students get to Step 4, introduce decomposers. Explain that decomposers include bacteria and fungi. Students may be puzzled about how to show the role of the bacteria (decomposers), since it consumes all organisms in the food chain when they die. Have them work in their groups for 2-3 minutes to suggest ways to represent this. You can have them implement their ideas, or if you think they will become frustrated, discuss and identify an option with the class. Some ways they might come up with follow.

- Put an arrow from each organism to the bacteria, with a label on the arrow indicating this happens after the organism dies. This is accurate, but students might find it too complicated and messy to draw.
- Put a bracket to the right of the food chain, and an arrow from that bracket to the bacteria to show that eventually all of the organisms will die and be decomposed.
- Put a circle around all the organisms, and an arrow to show that all eventually die and are decomposed by the bacteria.

Procedure Step 5 integrates the three dimensions of the NGSS as students add to their models and use the models to explain their thinking about energy and matter transfer within the food web and between the organisms of the food web and the physical environment.

Follow-Up

3. **Discuss students' current models and their answers to the Analysis questions.** (15 minutes)

   a. Have a few groups share their models and ask others to share modifications and suggestions.

   Explore the similarities and differences between students' models, and help students to identify any questions that arise. Be sure students understand that they will have several chances to revise and add to their models throughout the chapter. If students are struggling with providing feedback for their peers, you might use the Discussion Starters found in Section 2 of Teaching Strategies. For example, "This group shows an arrow going from grass to rabbits. Do you agree or disagree?" followed up with "Explain why you agree (or disagree)."

   b. Discuss the Analysis questions.

   Again, elicit their ideas so they can be revisited and examined throughout the unit. Listen for whether students are able to describe unobservable mechanisms to make predictions based on an understanding of the model and elements of the crosscutting concept (energy transfer) and disciplinary core idea (food webs as models of energy and matter transfer).

4. **Revisit the Guiding Question** (5 minutes)

   a. Revisit the guiding question, "How do life and death affect the movement of matter and energy in ecosystems?"

Use their models to explore the idea that matter and energy flow from plants up the food chain to animals at the higher levels, but that death of any organism stops this movement through the food chain, and diverts the matter and energy to the decomposers that feed on dead organisms and their wastes. Revisit the Student Question Poster to determine if any of the students' previous questions have been answered, and to record any new questions.

Suggested Answers To Analysis

NOTE: Analysis question 1, marked with (Assessment), can be used to assess students' understanding that plants must be available as a food source for the next level of the food chain, and that each succeeding level will also die without plants.

1. **What do you think would happen to your ecosystem if a disease killed all the plants? Explain your thinking.**

   Assessment—DCI-MSLS2B, CCC—Energy and Matter
   This question is an opportunity to assess whether students are able to predict that plants are needed for all other organisms to live, and that the death of all organisms would lead to more food for decomposers, at least temporarily.

   I think that if a disease killed all the plants, all of the animals would eventually die, because they would have no food. Because of all the dead organisms, the decomposers would increase, until they ran out of food.

2. **What do you think would happen to your ecosystem if there were no bacteria? Explain your thinking.**

   Note: Students' responses will vary. Some might think it wouldn't matter, or only think of the consequences in terms of the build up of dead organisms. Accept their ideas at this time.

More Information

Scientific Representations

Scientists use a variety of representations, including pictures, diagrams, and physical models, to model scientific phenomena, concepts, and ideas. This activity introduces representations used to model the flow of energy and cycling of matter in ecosystems. In most cases that present diagrams or pictures, the text specifically refers to the representations, to help students know when to spend time viewing and thinking about the representation. Encourage students to spend time needed to relate the representations to the information in the text, and think about how the representations help them understand and learn from the text. Consider modeling this process by thinking aloud as you read a passage and relate it to the text. Point out the ways that titles, legends, labels, and colors are sometimes used to represent ideas, and captions are used to summarize or extend information in the representation. It is also important to emphasize the strengths and weaknesses of any representation. Weaknesses may include simplifications of ideas or components of a system, variations in size and scale, or other features that may be misleading if students don't understand the representation and how it relates to the phenomenon it is intended to represent.

Activity 2.2

Explore: Life and Death in an Ecosystem

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models

For each group of four

- ☐ 1 set of 13 Yellowstone Food Web Cards from Activity 1.2
- ☐ 1 badger card
- ☐ 1 bald eagle card

Teaching Suggestions

Getting Started

1. **Students review the organisms and interactions introduced in Chapter 1.** (5 minutes)
   - **a.** Review the idea that a food web is a model of some of the interactions in an ecosystem.
   - **b.** Explain that in this activity they will explore how to develop models to show some of their ideas about energy and matter from the last activity.

Doing the Activity

2. **Students add organisms to the Yellowstone Food Web and identify a four-level food chain for future models.** (20 minutes)
   - **a.** Have students recreate the Yellowstone Food Web and add two new organisms.
   - **b.** If needed, help students identify a four-level food chain.
   - **c.** Circulate and observe as students begin to create models of the movement of matter and energy.

d. Students add bacteria to their models, and use their models to explain their thinking about matter and energy.

Follow-Up

3. Discuss students' current models and their answers to the Analysis questions. (15 minutes)

a. Have a few groups share their models and ask others to share modifications and suggestions.

b. Discuss the Analysis questions.

4. Revisit the Guiding Question (5 minutes)

3 class sessions

Matter in Ecosystems

How does matter move between biotic and abiotic parts of an ecosystem?

Students focus on modeling the movement of matter into and out of the biotic component of the ecosystem in this activity. They use specific scientific findings as they work in groups to develop a consensus model, and use the revised model to develop an explanation for the sources and fate of matter transferred between components of the biotic part of the system and between the abiotic and biotic components.

Rationale and NGSS Integration

This Explain activity builds on students' prior ideas about matter and energy in ecosystems, focusing on matter. They use a set of scientific findings to add to and revise their models from the previous activity. They learn that the original source of most of the matter in all organisms is water and carbon dioxide, which plants use to make sugars that serve as food for the plants themselves and the organisms that eat plants. The matter flows, or transfers, to higher levels of the food chain, and to decomposers when organisms die. The matter that moves from plants through the biotic part of the ecosystem is released as carbon dioxide and water when all organisms, including plants and decomposers, conduct cellular respiration. This carbon dioxide and water can be reused by plants and reenter the biotic part of the ecosystem.

This activity builds on the representations students used to model the food chain, and further builds the crosscutting concept of energy and matter. While this activity focuses on matter, the next Explain activity will focus on energy. In both activities, students are asked to reflect on how their ideas about energy and matter are changing.

Activity Overview

Students complete an Anticipation Guide that elicits their ideas about matter and energy. They then use scientific findings, including observations of the classroom compost, to revise their ideas about the source, movement, and fate of matter in ecosystems. They work in groups of four to develop a draft consensus model to represent their ideas. Students use the Explanation Tool to develop an explanation of where plants get the matter they need to grow, and they revisit the Anticipation Guide items that relate to matter.

Key Vocabulary

matter

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models
- ☐ Scoring Rubric: Constructing Explanations

For each student

- ☐ 1 Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems"
- ☐ 1 Handout 2.3-2, "Making Sense of Scientific Findings"
- ☐ Explanation Tool

Teaching Summary

Getting Started

1. Introduce the activity and have students complete Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."

Doing the Activity

2. Students read and discuss scientific findings about matter in ecosystems.
3. Students work in groups to incorporate what they have learned about matter into consensus Yellowstone Ecosystem Models.

4. Students reflect on how their ideas about matter and energy in ecosystems are changing.

Follow-Up

5. Students complete the Analysis items, including the "After" column for items 1–3 on the Anticipation Guide.

6. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Introduce the activity and have students complete Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."** (15 minutes)

   a. Review the introduction and Guiding Question.

   Emphasize that in Activity 2.2 they focused on the movement of matter and energy into and through the food chain. In Activity 2.1, matter was informally defined as stuff. You can continue to use this definition, or expand the definition of matter as anything that has mass. If you introduce this more formal definition, add it to the word wall. In this activity they will focus more closely on matter and look at both the biotic and abiotic parts of the ecosystem.

   b. Distribute the handout and explain how students use the Anticipation Guide.

   Tell students that they will use the "Before" column to indicate whether they think each statement is correct based on what they think now about matter and energy in ecosystems, and will use the "After" column to indicate what they think after they learn more about what scientists have figured out about matter and energy.

   Explain that they aren't expected to know all the answers, and the purpose of completing the "Before" column is to get an idea of what they think now. Students will be able to revise their ideas after they complete the reading. They should be open to changing their ideas based on evidence and information in the text, and they should pay attention to how their ideas change.

   Emphasize that it is part of the scientific process to change ideas as new evidence comes to light.

c. Clarify the statements on the Anticipation Guide.

Discuss any unfamiliar words or statements that might be unclear. You can have students complete this individually, in pairs, or in groups.

d. Circulate as students respond to the statements.

Emphasize that students only need to write one sentence in response to Procedure Step 1b. Review their responses as a pre-assessment of their initial ideas.

e. Begin a poster for the crosscutting concept of Energy and Matter.

Scientists and engineers track the movement of energy and matter in and between systems. Movements of energy and matter help explain how many systems operate, from body systems such as the digestive system, to the whole body system, to ecosystems. Explain that students will focus on matter in this activity, and on energy in the next activity. Create a crosscutting concepts poster for Energy and Matter, and have students add to it throughout the unit when they counter examples or when it serves as a helpful lens for thinking about scientific phenomena.

Doing the Activity

2. Students read and discuss scientific findings about matter in ecosystems. (30 minutes)

a. Use Handout 2.3-2, "Making Sense of Scientific Findings," to support students as they read the findings.

Explain that students should first read through all of the findings. You may wish to have them do this individually, in small groups, or as a class. Then they should focus on each finding to decide how it supports or changes their earlier ideas about where matter in organisms comes from and goes. Depending on your class, you may need to provide very little to a great deal of support to students.

b. Model how to use one or two of the findings to build understanding of how matter moves within ecosystems.

Help them complete one or more of the findings on Handout 2.3-2. For example, share your thinking out loud by saying, "The first finding states that all organisms are made up partly of carbon. This must mean that all organisms need carbon. I wonder where that carbon comes from." For the second finding, you might ask, "How could the plant gain so many kg when the soil lost such a tiny amount of soil? Scientists know mass can't come from nothing, so where did it have to come from?" As students are working, consider asking them Challenge questions, described in Section 2 of Teaching Strategies. During this Explain activity, students should be revising their understanding to become more scientifically accurate. Some examples include, “Why does that happen?” and “What if that didn’t happen?”

For each finding, a summary of how it might affect students’ thinking and their models follows. A Sample Response for Handout 2.3-2 is at the end of this activity.

A. This finding establishes the importance of carbon, hydrogen, and oxygen in making up the substances that account for most of the matter in living things. Any explanation of the source of matter in organisms should account for how these elements are obtained.

   You might wish to stress that carbon in particular is characteristic as a building block for substances in organisms. There is no need to go into the elements unless students have already been introduced to them. If so, you can point out that carbon, hydrogen, and oxygen are three of the elements. Otherwise, you can just refer to them as building blocks.

B. This finding provides evidence against the commonly held idea that plants get most of their food from soil. Van Helmont’s experiment showed that this is not the case. Allow plenty of time and discussion for students to process this idea, which contradicts a common misconception that plants get food from the soil. Plants do get some trace materials from soil, and these substances are what is present in “plant food” and fertilizer, but this accounts for relatively little of their total mass. (Note that Van Helmont dried the soil before weighing it, so the weight of the soil does not include water.)

C. This finding provides additional evidence that soil itself is not needed for plant growth. It is likely to surprise many students. Terrestrial plants can be grown hydroponically, without soil. This finding suggests that the source of nearly all of the mass of the plant is from somewhere other than the soil, which means it has to come from water and/or air.

D. This finding indicates that all organisms release carbon dioxide and water, transferring matter back to the environment, and should help students to begin to build the idea that matter cycles between the biotic (food web) and abiotic (air, water, etc) environment. Students might have trouble understanding that carbon dioxide, a gas, is matter. You might be able to address this by blowing up a balloon, to make the point that the gases exhaled are able to fill the balloon--so they must be some sort of matter.

E. This finding supports the idea that plants make their own sugars (food) from carbon dioxide absorbed from the air and water absorbed through the roots of the plants. Most of the matter in the plant is transferred into the plant through this process.

You might wish to add that table sugar (sucrose) is one of many substances called sugars, and that another kind of sugar (glucose) is the first product made by plants. In this sense, plants essentially make their own food. As they do so, they transfer matter from the abiotic environment into the biotic component of the environment. They also transfer energy (from the sun) into the biotic component of the environment. You might also wish to tell students that plants can use the glucose as the basis for making all the other carbon-containing substances (starches, fats, proteins) they need to live and grow.

F. Students should observe that the plant material is breaking down and becoming liquid. Ask what they think the liquid is, and help them understand that it is water, with breakdown products from the plant matter. This material is in the early stages of breaking down, so it isn't completely broken down to carbon dioxide and water yet.

G. This finding provides evidence that decomposers like bacteria break down dead organisms and their waste.

H. This finding indicates that decomposers are essential for dead organisms to rot (break down). Students might struggle with this idea. You might give other examples of food that does not decompose, such as food preserved by canning. Decomposers are killed by high temperatures during the canning process, so the food remains stable for a long time. Irradiating and drying food also slows down decomposition by killing decomposers or creating unfavorable conditions for their growth.

Depending on the length of your class periods, consider breaking the activity after step 2.

3. **Students work in groups to incorporate what they have learned about matter into consensus Yellowstone Ecosystem Models.** (30 minutes)

   a. If necessary, work with the class to model how they might add to their food chain the information from some of the findings.

   Some findings provide useful background, while others lead directly to additions to the model. For example, based on finding B, the soil itself should not be included as a major source of matter for organisms. But based on Findings C and E, carbon dioxide (from the air) and water (absorbed by roots) should be included as a source of matter that plants use to make sugars.

   b. After you help with an example or two, have students work to see what they can figure out.

Provide support only when needed. A complete sample consensus model is provided at the end of this activity. Each part of the model is labeled with a letter that shows which finding it models.

> **Assessment—DCI-MSLS2.B, SEP-Developing and Using Models, CCC-Energy and Matter**
> Students' models from Procedure Step 3 can be used to assess their growing understanding and help you to decide what support they need to further understand the cycling of matter in ecosystems. Student responses may be scored using the Modeling rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. A sample answer is provided at the end of this activity.

4. **Students reflect on how their ideas about matter and energy in ecosystems are changing.** (10 minutes)

   a. Ask each group of students to complete the following in their science notebooks: I used to think ________, but now I understand _______.

   Ask three or four students to share out their ideas. Then ask students with different responses to add theirs as you record them on chart paper.

   b. Reinforce the concept that matter in the ecosystem is not created or destroyed. Instead, it is reused, or recycled between ecosystem components.

   If you need to continue the activity into a third class period, this might be a good place to stop.

Follow-Up

5. **(Assessment) Students complete the Analysis items, including completing the "After" column for items 1–3 on the Anticipation Guide.** (25 minutes)

   Stress that both energy and matter are conserved. The energy released from the biotic part of the ecosystem is not destroyed, but it is in a form that can't be used by plants and is no longer available to the biotic part of the ecosystem.

   a. Discuss Analysis questions 1 and 2, which get at the ultimate fate and the source of the matter in organisms.

   Distribute the Explanation Tool for students to use to develop their explanation for Analysis 2. A completed sample response is provided at the end of this activity. Consider having students review one another's first drafts using Student Sheet 3, "Writing Review." Providing peer feedback benefits both students, giving them practice identifying the different components of an explanation and revising the response to become stronger. For further explanation of how to use this strategy, see Section 4 of Teaching Strategies.

b. Explain how to complete the "After" column of the Anticipation Guide.

The instructions ask students to cite specific text from the findings that they used in answering each statement. Model how to do this with one of the statements. Citing text passages as evidence relates to the CC-ELA standards for reading in science.

The findings that should be cited follow.

Statement 1: A tree gets most of the matter (or "stuff") it needs to grow from the soil.

Students should cite Findings B, C, and perhaps E as providing evidence to refute this statement.

Statement 2: All living things have a material called carbon in their bodies and that carbon moves back and forth from living to nonliving things. For example, the carbon that makes up a tree can end up in the air, a plant, or even in a 6th grader.

Students should cite Finding A as evidence that all organisms have carbon, and cite findings D and E as evidence that carbon moves back and forth between the biotic and abiotic environment.

Statement 3: All the plants and animals in an ecosystem depend on decomposers like worms and bacteria to break down dead plants and animals and their wastes. Students should mark this statement as correct, citing text from Findings F, G, and H.

Sample answers to the Anticipation Guide are provided at the end of this activity.

c. Use students' responses to the Anticipation Guide to assess changes in their thinking about matter.

Students' responses can be used to assess how their ideas about the movement of matter in ecosystems have changed, and they can use them themselves to reflect on how their ideas have changed.

6. **Revisit the Guiding Question** (10 minutes)

a. The Guiding Question is "How does matter move between the biotic and abiotic parts of an ecosystem?" Refer to students' models to summarize these main points:

- Plants transfer matter from the abiotic to the biotic parts of the ecosystem when they use carbon dioxide and water to produce sugars.

- Introduce the term producers to describe plants' role in ecosystems, and consumers to describe all organisms that obtain food by eating other organisms.
- As living organisms break down food, they release matter as carbon dioxide and water, transferring them back to the abiotic part of the ecosystem.
- This carbon dioxide and water can be recycled back into the biotic part of the ecosystem by plants.
- Matter cycles continually through transfers between the abiotic and biotic parts of ecosystems, and thus is conserved.

Revisit the Student Question Poster to determine if any of the students' previous questions have been answered, and to record any new questions.

Suggested Answers To Analysis

Analysis questions 1 and 2 can be used to assess key ideas related to the cycling of matter.

1. An animal dies. Explain:

> **Assessment—DCI-MSLS2.B, CCC-Energy and Matter**
> Students should be able to describe the transfer (movement, or release) of matter and energy from the biotic to the abiotic component by the action of decomposers.

a. What happens to the matter the animal was made of?

The matter the animal was made of is decomposed by decomposers, and carbon dioxide and water are released to the non-living (abiotic) part of the environment.

b. What happens to the energy stored in the animal?

The energy stored in the animal is transferred as heat to the abiotic part of the environment.

2. Using the Explanation Tool, construct a scientific explanation that answers the question: What substances provide the matter a plant needs to grow, where does the plant get those substances, and how does the plant use those substances? Use the steps below to guide you as you use the Explanation Tool.

- **Question:** Record the question "What substances provide the matter a plant needs to grow, where does the plant get those substances, and how does the plant use the substances to grow?"
- **Evidence:** Examine the data in the findings that help to answer this question. Include data (with units) as evidence to support your answer.
- **Science Concepts:** List any science concepts that are connected to the evidence and might help answer the question.
- **Scientific Reasoning:** Describe the scientific reasoning that connects the evidence and science concepts to the question you are trying to answer.
- **Claim:** Based on the evidence and on your scientific reasoning, state your claim about where plants get the matter they need to grow.

Assessment—DCI-MSLS2.B, SEP-Constructing Explanations, CCC-Energy and Matter
Student responses may be scored using the Explanation rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. A sample answer is provided at the end of this activity.

3. **(Assessment) Complete the "After" Column for statements 1–3 on Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."**

   a. **In the "After" column, mark whether you think each statement is correct (+) or incorrect (-).**

   b. **Under each statement, explain how the activity gave evidence to support or change your ideas. Cite specific evidence from the scientific findings that you used.**

   Statement 1. Incorrect. A tree gets most of the matter (or "stuff") it needs to grow from the soil.

Assessment – DCI-MSLS2.B, CCC-Energy and Matter
Students should cite Finding B as evidence against Statement 1.

Statement 2. Correct. All living things have sugars and other matter made of carbon in their bodies. The carbon moves back and forth from living to nonliving things. For example, the carbon that makes up a tree can end up in the air, a plant, or even in a 6th grader.

Assessment – DCI-MSLS2.B, CCC-Energy and Matter
Students should cite Finding A as evidence for the first part of the statement, and Findings D and E together, as well as their models, as evidence that the same carbon cycles between organisms and between organisms nonliving things.

Statement 3. Correct. All the plants and animals in an ecosystem depend on decomposers like bacteria and fungi to break down dead plants and animals and their wastes.

Assessment – DCI-MSLS2.B, CCC-Energy and Matter
Students should cite Findings F, G, and H as supporting Statement 3.

Answers in the Before column will vary.

Before	After	Statement
______	–	1. A tree gets most of the matter (or "stuff") it needs to grow from the soil.
______	+	2. All living things have sugars and other matter made of carbon in their bodies. The carbon moves back and forth from living to nonliving things. For example, the carbon that makes up a tree can end up in the air, a plant, or even in a 6th grader.
______	+	3. All the plants and animals in an ecosystem depend on decomposers like bacteria and fungi to break down dead plants and animals and their wastes.
______	–	4. Matter and energy both **cycle**—move continuously back and forth—between biotic (living) and abiotic (non-living) parts of the ecosystem.
______	–	5. Light from the Sun is one of many energy sources for plants. Other energy sources include soil, water, and air.
______	+	6. Both plants and animals get the energy they need by breaking down food.
______	+	7. Energy flows in one direction within a food chain, from plants to animals and decomposers.
______	+	8. In a food chain, most of the energy stored in organisms is transfered to the non-living environment.

Name *SAMPLE STUDENT RESPONSE*

Activity 2.3

Explanation Tool

Question

What is the scientific question you are investigating?

What substances provide the matter a plant needs to grow, where does the plant get those substances, and how does the plant use these substances?

Evidence What are the science observations or data that address your question?	**Science Concepts** What science concepts are connected to the evidence and might help answer the question?
A willow tree gained 74 kg over 5 years, but the soil lost only 0.05 kg. *Plants can be grown in the presence of sunlight with only air plus water containing some dissolved minerals.* *Plants use carbon dioxide and water as the source of matter they need to make sugars. The carbon dioxide is in either the air or the water.* *All living things are made up of carbon and other elements.*	*Photosynthesis is the process that plants use to make their own food (sugars) from oxygen and water*

Scientific Reasoning

How do the science concepts connect to the evidence and to the question you are trying to answer?

If plants got the matter that they need to make their own food from the soil, then the soil from the willow tree experiment would have decreased by 74 kg. Plants would not be able to grow in just air and water if they got the matter from something else.

Claim

What claim can you make based on the evidence and reasoning?

Plants get the matter that they need to make their own food from carbon dioxide and water.

Explanation Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 2.3

Construct a Scientific Explanation

Using the information in the boxes you have completed, write a scientific explanation that includes:

- The scientific question
- Your claim
- Relevant evidence that supports your claim
- Science concepts that are connected to the evidence
- Scientific reasoning that links the evidence and science concepts to the claim

Scientific Explanation

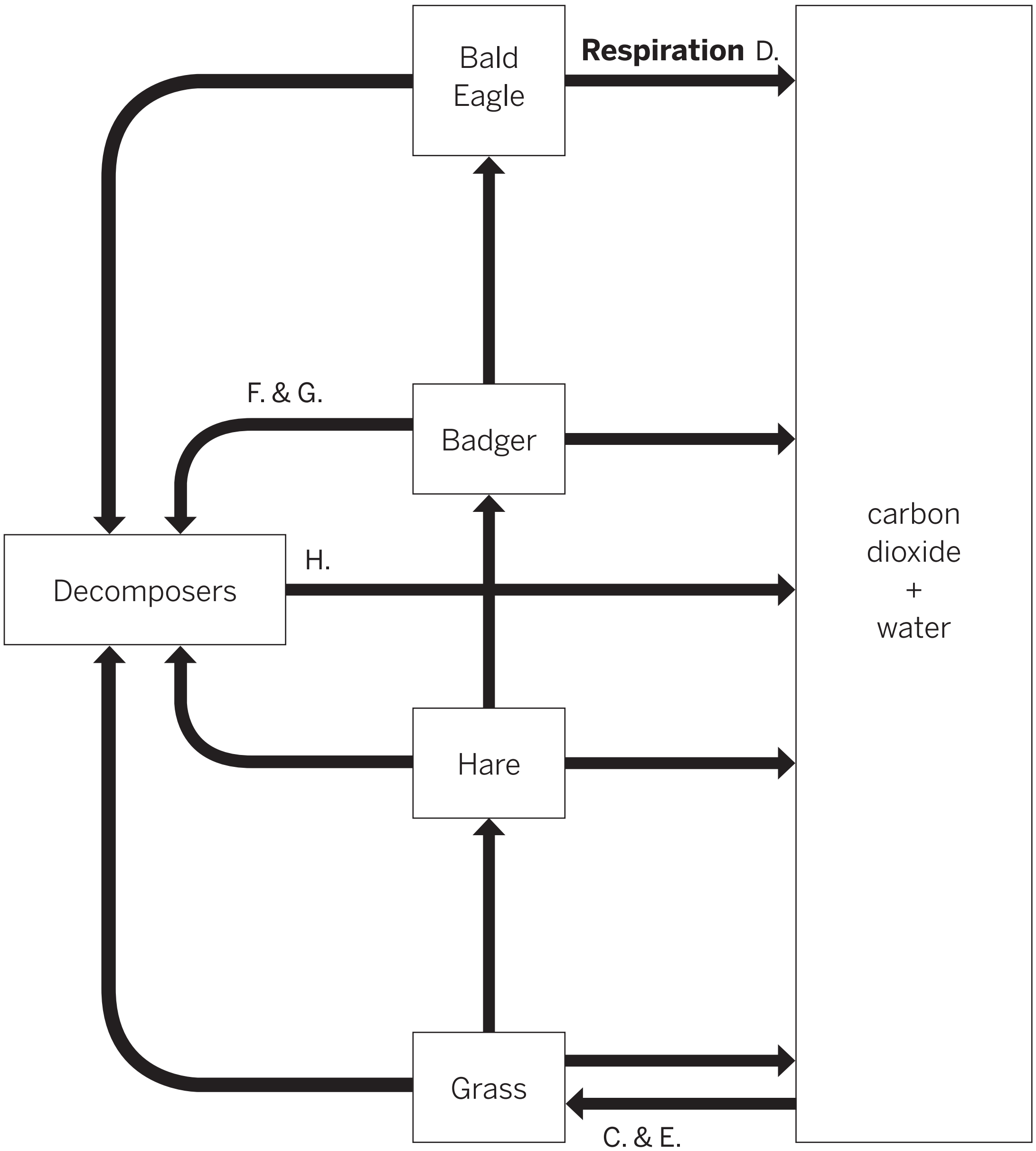
What substances provide the matter a plant needs to grow, where does the plant get those substances, and how does the plant use these substances?

Plants get the matter that they need to make their own food from carbon dioxide and water. A scientist named Van Helmont grew a willow tree in soil, and after five years the tree gained 74 kg but the soil lost only 0.05 kg. If the plant got the matter from the soil, then the soil should have decreased by 74 kg. This means that the plant was not getting most of its matter from the soil.

Plants can grow with just sunlight, air, water, and dissolved minerals. This means that the plants are getting some of the matter they need to grow from water. All living things are made of carbon and other elements. Plants must get the carbon they need from carbon dioxide. The carbon dioxide comes from the air for land plants or is dissolved in water for aquatic plants. Plants use carbon dioxide and water during photosynthesis to make their own sugars. The sugars are food for the plant.

Activity 2.3

Sample Group Consensus Model for Yellowstone Ecosystem



Activity 2.3

Explain: Matter in Ecosystems

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models
- ☐ Scoring Rubric: Constructing Explanations

For each student

- ☐ 1 Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems"
- ☐ 1 Handout 2.3-2, "Making Sense of Scientific Findings"
- ☐ Explanation Tool

Teaching Summary

Getting Started

1. **(Assessment) Introduce the activity and have students complete Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."** (15 minutes)

   a. Review the introduction and Guiding Question.

   b. Distribute the handout and explain how students use the Anticipation Guide.

   c. Clarify the statements on the Anticipation Guide.

   d. Circulate as students respond to the statements.

   e. Begin a poster for the crosscutting concept of Energy and Matter.

Doing the Activity

2. **Students read and discuss scientific findings about matter in ecosystems.** (30 minutes)

   a. Use Handout 2.3-2, "Making Sense of Scientific Findings," to support students as they read the findings.

b. Model how one or two of the findings provide evidence that can be used to build understanding of how matter moves within ecosystems.

3. **Students work in groups to incorporate what they have learned about matter into consensus Yellowstone Ecosystem Models.** (30 minutes)

   a. If necessary, work with the class to model how they might add to their food chain the information from some of the findings.

   b. After you help with an example or two, have students work to see what they can figure out for a while.

4. **Students reflect on how their ideas about matter and energy in ecosystems are changing.** (10 minutes)

   a. Ask each group of students to complete the following in their science notebooks: I used to think ________, but now I understand _______.

Follow-Up

5. **(Assessment) Students complete the Analysis items, including completing the "After" column for items 1–3 on the Anticipation Guide.** (25 minutes)

   a. Discuss Analysis questions 1 and 2, which get at the ultimate fate and the source of the matter in organisms.

   b. Explain how to complete the "After" column of the Anticipation Guide.

   c. Use students' responses to the Anticipation Guide to assess changes in their thinking about matter.

6. **Revisit the Guiding Question** (10 minutes)

   a. The Guiding Question is "How does matter move between the biotic and abiotic arts of an ecosystem?"

3 class sessions

Energy Flow in Ecosystems

How does energy flow in an ecosystem?

Students add the transformations and flow of energy in an ecosystem to the models they developed in the previous activity. They focus on the source and fate of energy and movement of energy within the biotic components of the system and between the biotic and abiotic components.

Rationale and NGSS Integration

This Explain activity builds on students' prior learning about the cycling of matter among the biotic and abiotic components in ecosystems, and formally builds the concept of energy flow in ecosystems. This activity introduces representations that can be used to model energy flow into, through and out of an ecosystem, between living and non-living parts of the ecosystem. Students formalize their understanding of the crosscutting concept of the cycling of matter and the flow of energy between components of the ecosystem as they further revise their models.

Activity Overview

In Part One, students reveal their initial understanding about the source of energy for plants to engage in photosynthesis, as well as the source of energy that animals and decomposers use for life processes. Students then read text to obtain additional information about energy flow through ecosystems. In Part Two, students revise their Yellowstone ecosystem models from the previous activities to incorporate their revised understanding. Students return to the Anticipation Guide and complete an "After" column for statements 4-8, which focus on energy.

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models

For each student

- ☐ 1 partially completed Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems" from the previous activity

Teaching Summary

Getting Started

1. Introduce the activity and explain that now students will focus on energy instead of matter.
2. Elicit students' ideas to the first two questions in the Procedure.

Doing the Activity

3. Students return to their Yellowstone ecosystem model and add red arrows to show how energy is flowing in the ecosystem.
4. Students read the text.
5. Students revise their understanding about the flow of energy in ecosystems.
6. Students evaluate possible models for the flow and amount of energy transferred among the biotic components of the food chain in Yellowstone.
7. Students read a series of scientific findings and make any necessary revisions to their choice of the most accurate model.
8. Students revisit their group's Yellowstone ecosystem model to incorporate the flow of thermal energy to the abiotic components of the ecosystem.

Follow-Up

9. Review the Analysis questions.
10. Students complete the "After" column for statements 4-8 of the Anticipation Guide.
11. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Introduce the activity and explain that now students will focus on energy instead of matter.** (10 minutes)

   a. Review the introduction and Guiding Question.

   Ask students to briefly summarize what they learned about matter, ensuring that they understand that matter cycles throughout the ecosystem, moving among the biotic and abiotic components of the system.

   b. Instruct students to check in on the compost bag.

   Encourage them to make note of whether the rotting material is warmer, and record their observations in their science notebooks. Undisturbed composting matter will become warmer as a consequence of cellular respiration. It may not be possible to detect this temperature change in the class compost bag.

2. **Elicit students' ideas to the first two questions in the Procedure.** (10 minutes)

   a. Direct students to the first question: "Where do plants get the energy for photosynthesis?"

   Students should first briefly discuss in their groups and record their preliminary ideas in their science notebooks. Then ask students to share their brief answers, accepting all reasonable answers.

   The goal at this point is not to arrive at the correct answer, but to gauge student understanding. While the correct answer is the sun, student misconceptions include water and soil. Students may also suggest insects that get caught in the leaves. Consider using a "four corners" strategy where you condense all of the initial responses into four responses or categories of responses, and have students walk to the corner of the room that represents the answer they think is correct. If there are fewer than four responses, consider using just two or three corners. Ask a few students to share why they chose that corner. If one of the corners remains empty, ask students to explain why no one selected that response. After sufficient sharing, have students return to their groups and record any revised thinking in their science notebooks.

   b. Now follow the same process for the second question. "Where do animals and decomposers get the energy they need for life processes?"

The correct answer is food, but there are likely to be more students with misconceptions for this question than the first one. Common misconceptions include water, sleep/rest, and vitamins/minerals. Remember that the goal for this process is to elicit student ideas, not arrive at the correct answer.

Doing the Activity

3. **Students return to their Yellowstone ecosystem model and add red arrows to show how energy is flowing in the ecosystem.** (10 minutes)

   a. Direct students to Procedure step 3.

   This step instructs students to return to the model that they worked on in the previous activity, which has the food web and blue arrows showing the cycling of matter. Students now add red arrows to indicate how energy is transferred. Students may need to add the sun to their system if they have not already included it. At this point, students are still not necessarily expected to have a complete understanding of how energy flows.

4. **Students read the text.** (15 minutes)

   a. Instruct students to read the text box after Procedure step 4.

   The first two paragraphs after Procedure step 4 provide information that allows students to understand that the sun's light energy is transformed by plants into chemical energy stored in food. This transfers energy from the abiotic to biotic components of the environment. Without the sun, plants would not be able to photosynthesize.

   The remaining paragraphs help students understand that the chemical energy stored in food is the only source of energy for animals and decomposers, and that plants use the chemical energy stored in the food they make for themselves. The reading addresses commonly held misconceptions about water, sleep, vitamins and minerals providing energy.

   If you need to break the activity, this is a good break point.

5. **Students revise their understanding about the flow of energy in ecosystems.** (15 minutes)

   a. Revisit the first two questions.

   These questions are: "Where do plants get the energy for photosynthesis?" and "Where do animals and decomposers get the energy they need for life processes?" Have a class discussion to check that students understand that the correct answers are "the sun" and "food," respectively. Students should record their final understanding in their science notebooks. Use

Challenge questions during this Explain lesson to encourage students to use scientific terminology correctly to provide accurate explanations.

b. Have students revise their Yellowstone ecosystem models.

If they need to redraw the red arrows representing the flow of energy, consider providing an additional sheet of chart paper. A sample model might look like the example on the following page.

6. Students evaluate possible models for the flow and amount of energy transferred among the biotic components of a food chain from Yellowstone. (15 minutes)

a. Direct students to Procedure step 8 and have them consider four models for the flow of energy in a food chain in Yellowstone: grass, hare, badger, and bald eagle.

Students are presented with four models in the Student Book, one of which is accurate and three of which are inaccurate. At this point, students select the model they believe is best based on their current understanding and record their answer with justification in their science notebooks. It is not important if students select the best representation at this point.

Inaccurate: Model A shows energy cycling, including energy flowing from the bald eagle to the grass.

Inaccurate. Model B shows the amount of energy being the same at all four levels.

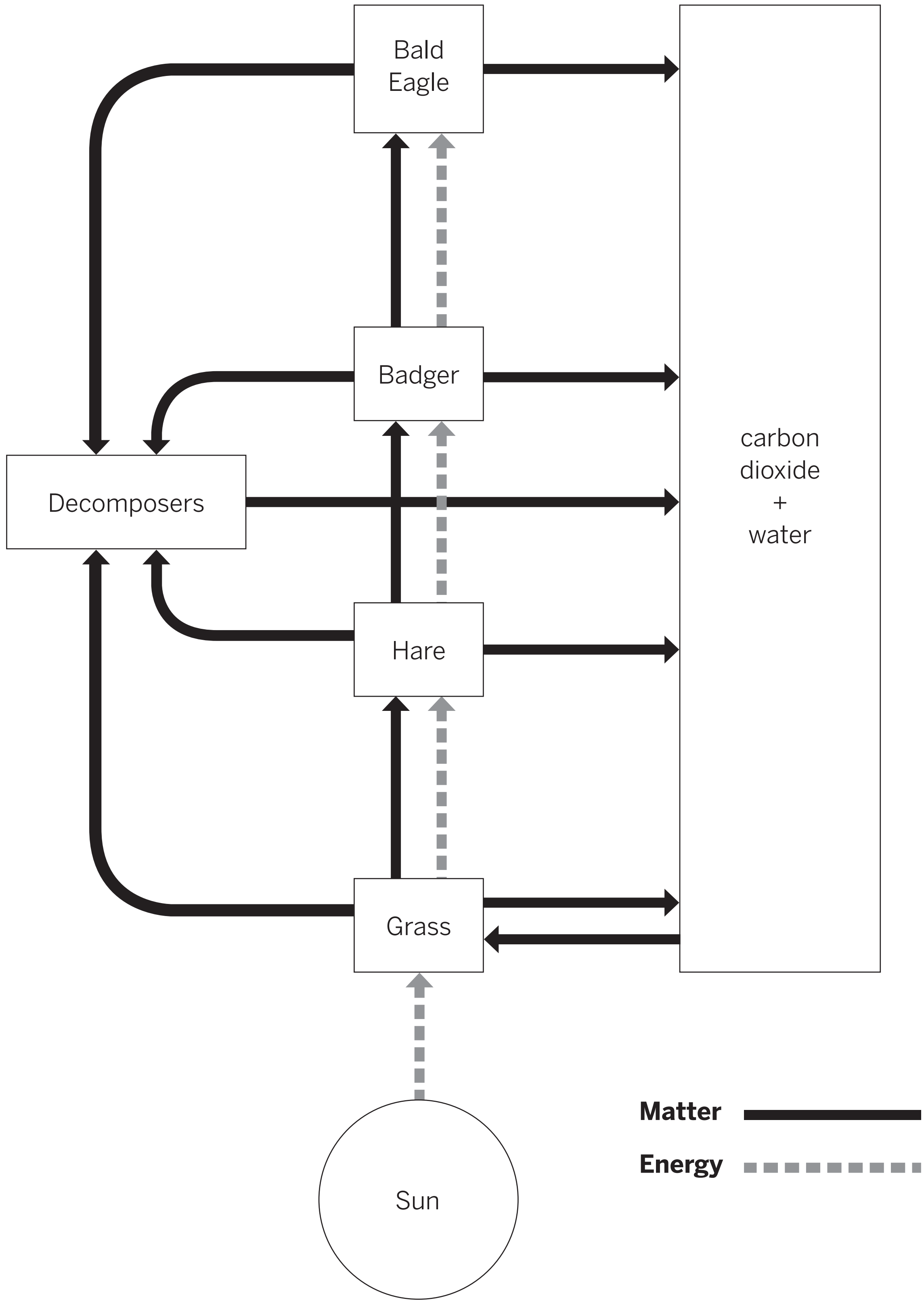
Accurate: Model C shows an energy pyramid, with the amount of energy decreasing from the base (grass) to the top (bald eagle).

Inaccurate: Model D show an upside-down pyramid, with the amount of energy increasing from the pointed base (grass) to the top (bald eagle).

Students are likely to have a wide variety of ideas. Some students will think there is more energy at the highest level because top predators tend to be large animals. Others may think the levels are the same because all energy from one level transfers to the next. Others may realize that plants make up a much greater percentage of an ecosystem than consumers, and correctly choose Model C. Some students may incorrectly choose A because of the popular notion of recycling.

If you need to break the activity, you may choose to do so before or after Step 7.

Sample Group Consensus Model for Matter and Energy (For Step 5)



7. **Students read a series of scientific findings and make any necessary revisions to their choice of the most accurate model.** (15 minutes)

   a. Direct students to read and make sense of several scientific findings after Procedure step 9.

      These findings will help them understand how energy flows through an ecosystem, and how the amount of chemical energy available at each level is less than the total amount of energy in the level below.

      This is because some chemical energy is transformed into thermal energy at each level, and organisms are unable to use thermal energy for growth. This chemical energy transformed into thermal energy flows as heat to the abiotic components of the environment, leaving the food chain (the biotic components).

   b. Instruct students to revisit their choice of the most accurate of the four models.

      They should begin realizing that Model C is the only one that shows the amount of available energy decreasing form the base of the food chain (grass) to the top of the food chain (bald eagles).

   c. Instruct students to read the box under Procedure step 11.

      Students should make their final choice of the most accurate model, Model C.

   d. Hold a class discussion about why the other models are inaccurate, encouraging students to explain their reasoning.

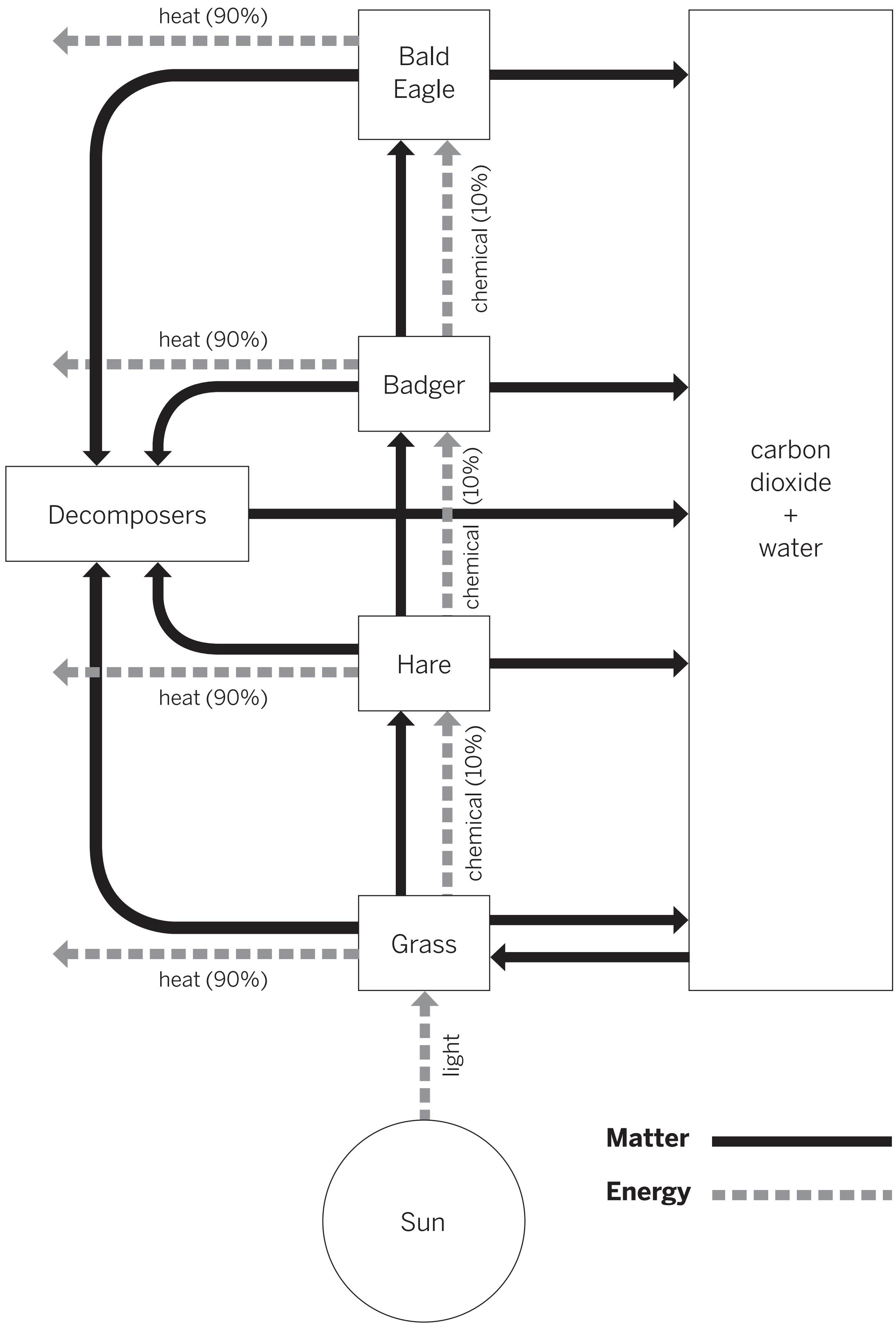
      Consider using the four corners procedure used earlier if a number of students are arguing for any of the other models. Elaborating on why Models A, B, and D are inaccurate can be helpful to all students, even those who chose Model C. The goal is for the class to come to consensus around Model C.

8. **Students revisit their group's Yellowstone ecosystem model to incorporate the flow of thermal energy to the abiotic components.** (10 minutes)

   a. Have students revise their Yellowstone ecosystem models, adding abiotic components.

> **Assessment—DCI-MSLS2.B, DCI-MSESS2.A, CCC-Energy and Matter, SEP-Developing and Using Models**
> Step 12 allows students to revise and expand their models from the previous activity to incorporate the flow of energy between the biotic and abiotic components. Student responses may be scored using the Modeling rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. A sample answer is provided on the following page.

Sample Group Consensus Model Including Qualitative Aspects of Energy (For Step 8)



Follow-Up

9. Review the Analysis questions. (10 minutes)

a. Check for student understanding.

Analysis questions 1–5 provide several opportunities to check students' understanding of the flow of energy in ecosystems, the role of plants in using sunlight as an energy source for producing food, and the crosscutting concept of energy transfer. For example, Analysis 3 challenges them to use their models to explain whether they think there could be 10 levels in a food chain or food web. To answer this question, they must integrate their three-dimensional understanding of the model and how it represents the flow of energy in the food web.

10. Students complete the "After" column for statements 4-8 of the Anticipation Guide. (10 minutes)

a. Allow students time to complete the "After" column of the Anticipation Guide.

Check students' before and after responses to assess their initial ideas, what they have learned from the reading, and where they are still struggling. Review and clarify any persistent ideas that are nonscientific. If students are still struggling to distinguish between the cycling of matter and flow of energy, consider having them create a model in their science notebook of a simple food chain in their local environment (e.g., plant, butterfly, and bird) and have them practice explaining the model to other students or family members.

11. Revisit the Guiding Question (5 minutes)

a. Discuss the Guiding Question, "How does energy flow in an ecosystem?"

Emphasize the importance of the Sun as the primary energy source for most producers, and the food chains that depend on them. Referring to one group's Yellowstone ecosystem, summarize these main points:

- Plants transfer energy from the abiotic to the biotic parts of the ecosystem.
- Without plants' ability to use energy from the Sun to make their own food from carbon dioxide and water, all other organisms would die due to lack of food.
- Energy flows up the food chain as organisms are eaten by animals higher on the food chain.
- Energy flows from the biotic to the abiotic environment at each level as organisms give off thermal energy and when organisms die and are decomposed.

- The thermal energy that flows to the abiotic environment as heat isn't gone (energy is conserved), but plants can't reuse this thermal energy, and so the energy that flows to the environment does not cycle back to the biotic part of the ecosystem.

Revisit the Student Question Poster to determine if any of the students' previous questions have been answered, and to record any new questions.

Suggested Answers To Analysis

1. **Use your revised model to explain why sunlight is essential for the flow of energy throughout the ecosystem.**

   Only plants can make their own food, and they need sunlight for the energy they need to make the food. All other organisms must eat plants or animals that eat plants, to get food, so without plants and sunlight, there would be no way for energy to get into the living part of the ecosystem.

2. **Explain what happens to the energy in an animal:**

   a. **while it is alive?**

      The animal uses it to live and grow.

   b. **when it is eaten by another animal?**

      Some of it transfers to the animal that eats it.

   c. **when it dies, but isn't eaten by another animal?**

      It transfers to decomposers, and is released as thermal energy.

3. **Do you think there could be 10 levels in a food chain or food web? Why or why not?**

   > **Assessment—DCI-MSLS2.B, DCI-MSESS2.A, CCC-Energy and Matter**
   > This question is an opportunity for students to use their models to develop a simple prediction that it is unlikely there would be enough energy for ten levels in the food chain.

   No, it is not possible to have so many energy transfers in an ecosystem because of the high "loss" of energy transferred to the environment at each level. At each level, 90% of the energy moves into the abiotic part of the system. After a few levels, there would be little energy left to flow up the food chain. There wouldn't be enough energy to support higher levels of the food chain because the model *shows that there is less energy at each higher level.*

4. **Scientists describe the movement of energy with the word "flows" and the movement of matter with the word "cycles." Why do they use these two different words to describe the movement of energy and matter?**

> **Assessment—DCI-MSLS2.B, DCI-MSESS2.A, CCC-Energy and Matter**
> This question is an opportunity for students to revise and articulate their understanding of the differences between energy flow and matter cycling in an ecosystem.

Scientists describe the movement of energy as a flow, because it goes from the abiotic to the biotic and then back to the abiotic parts of the environment. Once released back to the abiotic environment as heat, it can't be reused, so it can't be considered to cycle. However, matter released to the abiotic part of the environment can be transferred back into the biotic part of the environment over and over by plants. For this reason, scientists say it cycles.

5. **(Assessment) Complete the "After" Column for statements 4–8 on Handout 2.3-1, "Anticipation Guide: Matter and Energy in Ecosystems."**

   a. **In the "After" column, mark whether you think each statement is correct (+) or incorrect (-).**

   b. **Under each statement, explain how the activity gave evidence to support or change your ideas. Cite specific evidence from the reading and anything you learned while revising your Yellowstone Ecosystem Model.**

> **Assessment—DCI-MSLS2.B, CCC-Energy and Matter**
> These questions allow students to revisit their initial understanding of energy flow in ecosystems and see how their understanding may have changed.

Statement 4: Incorrect. Matter and energy both cycle—move continuously back and forth—between biotic (living) and abiotic (non-living) parts of the ecosystem.

Students should mark this statement as incorrect, citing evidence from the third paragraph in the text box that plants never get energy from animals. Energy never cycles back to plants or the sun from any of the other components in the ecosystem.

Statement 5: Incorrect. Light from the Sun is one of many energy sources for plants. Other energy sources include soil, water, and air.

Students should mark this statement as incorrect, citing evidence from the first paragraph in the text box that the Sun is the only source of energy for plants. Without the sun, plants would not be able to use carbon dioxide and water to make sugars.

Statement 6. Correct. Both plants and animals get the energy they need for breaking down food.

Students should agree with this statement citing the second paragraph in the text box. While plants need light energy for photosynthesis, both plants and animals use the chemical energy stored in food for all of their life processes.

Statement 7. Correct. Energy flows in one direction within ecosystems, from plants to animals and decomposers.

Students should agree with this statement, citing the third paragraph in the text box. Energy never flows the other way around. Plants can use only energy transferred by light for photosynthesis. They cannot use thermal energy transferred from consumers and decomposers.

Statement 8: Correct. In a food chain, most of the energy stored in organisms is transferred to the non-living environment.

Students should agree with this statement, citing the text box under Procedure Step 11. Approximately 90% of the thermal energy at each level is transferred as heat to the abiotic component of the ecosystem, and only 10% is transferred (as chemical energy) to the next level in the food chain.

Activity 2.4

Explain: Energy Flow in Ecosystems

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models
- ☐ Scoring Rubric: Constructing Explanations

For each student

- ☐ Partially completed 1 Handout 2.3-1, "Anticipation Guide: Energy in Ecosystems," from the previous activity

Teaching Summary

Getting Started

1. **Introduce the activity and explain that now students will focus on energy instead of matter.** (10 minutes)
   - **a.** Review the introduction and Guiding Question.
   - **b.** Instruct students to check in on the compost bins.
2. **Elicit students' ideas to the first two questions in the Procedure.** (10 minutes)
   - **a.** Direct students to the first question, "Where do plants get the energy for photosynthesis?"
   - **b.** Now follow the same process for the second question, "Where do animals and decomposers get the energy they need for life processes?"

Doing the Activity

3. **Students return to their Yellowstone ecosystem model and add red arrows to show how energy is flowing in the ecosystem.** (10 minutes)
   - **a.** Direct students to Procedure step 3.
4. **Students read the text.** (15 minutes)
   - **a.** Instruct students to read the text box after Procedure step 4.

5. **Students revise their understanding about the flow of energy in ecosystems.** (15 minutes)

   a. Revisit the first two questions.

   b. Have students revise their Yellowstone ecosystem models.

6. **Students revise their understanding about the flow and amount of energy transferred in ecosystems.** (15 minutes)

   a. Direct students to Procedure step 8 and have them consider four models for the flow of energy in a food chain in Yellowstone: grass, hare, badger, and bald eagle.

7. **Students read a series of scientific findings and make any necessary revisions to their choice of the most accurate model.** (15 minutes)

   a. Direct student to read and make sense of several scientific findings after Procedure step 8.

   b. Instruct students to revisit their choice of the most accurate of the four models.

   c. Instruct student to read the box under Procedure step 10.

   d. Hold a class discussion about why the other models are inaccurate, encouraging student to explain their reasoning.

8. **Students revisit their group's Yellowstone ecosystem model to incorporate the flow of thermal energy to the abiotic components.** (10 minutes)

   a. Have students revise their Yellowstone ecosystem models, adding abiotic components.

Follow-Up

9. **Review the Analysis questions.** (10 minutes)

   a. Check for student understanding.

10. **Students complete the "After" column for statements 4-8 of the Anticipation Guide.** (10 minutes)

    a. Allow students time to complete the "After" column of the Anticipation Guide.

11. **Revisit the Guiding Question** (5 minutes)

    a. Turn to the Guiding Question in the Student Book and discuss with the class what they have learned about energy flow.

2 class sessions

Disruptions and Food Webs

How does a disruption affect the flow of energy and cycling of matter in an ecosystem?

Students elaborate on their understanding of the flow of energy and cycling of matter in an ecosystem by exploring the effects of natural disasters on the biotic and abiotic components of an ecosystem. They describe how a fire would affect the food web in Yellowstone and they describe the changes in the ecosystem that would occur over time following a fire.

Rationale and NGSS Integration

In this Elaborate activity, students apply their understanding of the cycling of matter and flow of energy in an ecosystem to describe how large-scale disruption would impact these processes. The crosscutting concept of stability and change is highlighted as students describe and explain how fire in Yellowstone affects the ecosystem.

Activity Overview

In Part One of the activity, students consider the effects of four kinds of natural disasters on the biotic and abiotic components of ecosystems. In Part Two, they order a series of Forest Ecosystem cards that illustrate the timeline of changes before, during, and after a fire in Yellowstone. They write captions for the cards to describe the changes in matter and energy that go with the events in the cards.

Key Vocabulary

stable

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  Preview the video clip on Yellowstone Fire Ecology available at the link below. The link to the segment follows.
  http://www.teachertube.com/video/427478
- ☐ 1 large computer monitor or projector
- ☐ 1 set of Forest Change Description, Matter, and Energy Captions (optional)

For each group of four students

- ☐ 1 set of Forest Change cards

For each student

- ☐ 1 Handout 2.5-1, "Changes Due to Fire in a Forest Ecosystem"

Teaching Summary

Getting Started

1. Students briefly review what they know about the flow of energy and cycling of matter in ecosystems.

Doing the Activity

2. Students describe and compare the effects of four disasters on a forest ecosystem.
3. Students consider another kind of major disruption, fire, and its effects on a forest ecosystem like the Yellowstone ecosystem.
4. Students order Forest Change cards and describe the changes that result from a fire.

Follow-Up

5. Review the Analysis and revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Students briefly review what they know about the flow of energy and cycling of matter in ecosystems.** (5 minutes)

   a. Review the ideas that energy flows through an ecosystem whereas matter cycles within an ecosystem.

   Explain that in this Elaborate activity, students will extend their understanding of these processes by considering what would happen to them if an ecosystem experienced a large disruption.

   b. Introduce the Crosscutting Concept of Stability and Change.

   Add the word stable to the word wall, and explain that it relates to the word stability—or the state of being stable. The crosscutting concept of stability and change relates to mechanisms that sometimes cause a system to return to its previous state after a disruption and to events that can lead to short or long-term changes. A system can be relatively stable over the short-term, but change gradually to lead to significant changes in the long-term. Create a crosscutting concepts poster for stability and change. Have students use the ideas of stability and change as they think about the events that follow the disruptions introduced in this chapter, and add examples to the poster throughout the unit. For example, the fire and pond succession in this activity are examples, as are the short- and long-term effects of zebra mussels in Chapter 4.

Doing the Activity

2. **Students describe and compare the effects of four disasters on a forest ecosystem.** (15 minutes)

   a. Assign each group of four students to examine one of the four disasters.

   More than one group will work on each disaster. Allow just a few minutes for them to discuss their ideas in their groups. Then ask each group to briefly (less than a minute) share their observations. The second group for each disaster need only add new observations.

   b. Have students compare the results of the disasters.

   Ask students to share similarities and differences between the disasters and their effects. For example, each disaster will lead to death of organisms, but each disaster is likely to affect certain organisms more than others. In all cases, the result is likely to be a dramatic change in the ecosystem. Develop the idea that the food web is likely to be disrupted and that it might take a long time before the system returns to its original condition or reaches a new condition.

3. **Students consider another kind of major disruption, fire, and its effects on a forest ecosystem like the Yellowstone ecosystem.** (5 minutes)

   a. Have students discuss their initial ideas for how a fire would disrupt both the abiotic and biotic parts of the Yellowstone ecosystem.

   Students are likely to say that the fire would cause most of the biotic parts to be killed, and that all that would be left are the abiotic parts. Some might say that certain kinds of plants or animals might be able to survive.

4. **Students order Forest Change cards and describe the changes that result from a fire.** (35 minutes)

   a. Introduce the Forest Change Cards.

   Distribute the Forest Change cards to each group of students. Circulate as they describe the system, discuss how the drawings are similar to and different from real forest ecosystems, and identify the mature forest card (Card C). Encourage them to think of the complexity of real ecosystems, which are likely to have greater numbers and types of organisms, including decomposers, than those represented on the cards.

   b. Monitor the groups as they order the cards and describe their thinking.

   Students will use the model to explore the transfer of energy among the biotic and abiotic components of the Yellowstone ecosystem.

   Note that they should first record the order of the cards (the correct order is C, A, E, F, D, B) and then explain how they figured out the order. Highlight how the higher levels of the food chain/web cannot be supported until the lower levels are established after a major disturbance like a fire. Sample responses follow.

   If your students are having difficulty describing the cards and order, you might wish to copy, cut apart and provide the simple descriptions on the optional Forest Change Descriptions Handout in the handout section for this activity. You can provide a few of the descriptions to get them started, or have them match all of the descriptions to the cards if they are struggling.

   Card C: This is first because it is the mature forest before the fire. It has many large trees and all four levels of the food chain.

Card A: The fire breaks out and is burning all the trees and other plants. Animals have left or are leaving.

Card E: This follows Card A because the trees are more burnt and the fire has ended. The other organisms are also burned away or have left. There are no living organisms.

Card F: This is next because there are starting to be some small plants growing in the soil. No animals have returned. There are some decomposers (fungi).

Card D: This is next because there is still some evidence of the fire, such as burned stumps of trees, but more of the plants are coming back, including some small trees. Some animals that eat plants have returned.

Card B: This is last because the forest has mostly regrown. There are still some dead tree stumps and branches that haven't decomposed. All of the animals, including predators like wolves and the large bird, have returned.

c. Bring the class together to reach a consensus on the ordering of the cards.

If there is disagreement, have students engage in argument by explaining what is happening in the ecosystem in the cards. Students should be able to decide based on these arguments which is the more accurate order.

This is a good point to break the activity.

d. Students use Handout 2.5-1, "Changes Due to Fire in a Forest Ecosystem" to write captions explaining what is happening to the energy and matter in each card.

Assessment—DCI-MSLS2.B, SEP-Constructing Explanations, CCC-Energy and Matter
Student captions in Handout 2.5-1 can be used to assess students' use of models to demonstrate their understanding of the movement of matter and energy.

Students complete the handout, writing captions for each of the cards. The captions should include a description of what is happening to the energy and matter in the biotic and abiotic components of the ecosystem. If this will be too challenging for your students, you can copy, cut apart and provide the captions on the optional Forest Change Matter Captions and Energy Captions in the handout section for this activity. You can provide a few of the captions to get them started, or have them match all of the captions to the cards if they are struggling. The matter and energy captions are separate so you can tell if students are still struggling with matter cycling, energy flow, or both. A sample completed student sheet follows Handout 2.5-1.

e. Show a video clip to introduce the importance of fire in mature forests and in dry ecosystems.

This brief video clip, "CNN Yellowstone Fire Ecology," addresses the massive fire that swept through Yellowstone in 1988. Ecologists in the video explain that fire has been a natural part of the Yellowstone ecosystem for at least centuries.

You might wish to further explain the ecological role of fire. Mature forests often have depleted soil and little sunlight near the forest floor. This limits growth of smaller plants. Soil is also often poor in dry ecosystems, where decomposition is very slow. Fire opens areas to sunlight, clears away forest litter so that new trees and plants can grow, and is necessary to release the seeds of some plants. In undisturbed ecosystems, this can sometimes happen as a result of small fires that then burn themselves out. In the past, people managed many forest ecosystems and tried to prevent fires, resulting in the build-up of dry forest litter. This build-up fuels the large forest fires seen in the western United States. Today, forest management practices have changed and park managers often create "controlled burns" to manage forests, and sometimes allow natural fires that don't threaten people or buildings to burn.

You may wish to point out to students that when a fire burns, combustion takes place. This combustion releases the matter from burned organisms to the air as carbon dioxide and water vapor. In this way, combustion and cellular respiration are the same process, with the same inputs and the same outputs.

Follow-Up

5. Review the Analysis and revisit the Guiding Question. (20 minutes)

a. Review the students' answers to the Analysis questions.

Use question 3 to discuss the role of science in developing ecological concepts and data about the effects of fires. This information must then be used by people to make decisions about what to do, or not do, about fires. Have students use Student Sheet 1, "Developing Communication Skills," if they need ideas for how to constructively respond to their peers in the discussion.

b. Discuss the Guiding Question, "How does a disruption affect the flow of energy and cycling of matter in an ecosystem?"

Have students refer to their models of matter and energy transfer in ecosystems and the models and captions on Handout 2.5-1 as you discuss this question. Encourage three dimensional thinking by asking students to think about how disruptions affect the flow of energy and cycling of matter as illustrated by their models. Ask, "How are the models changed by a fire?" By disrupting any level of the food chain (frequently the plants), it prevents the movement of both matter and energy to the next level of the chain. For example, a fire results in a transfer of energy and matter to the physical environment. When you affect any part of the food chain, you affect the entire ecosystem.

Suggested Answers To Analysis

1. **Explain how fire helps matter cycle through the biotic and abiotic parts of an ecosystem.**

   Fire converts the matter stored in the plants and animals (the biotic components) of an ecosystem into carbon dioxide and water, which are abiotic components of the ecosystem. Plants can then utilize the carbon dioxide and water in photosynthesis. In this way, the matter cycles through the entire ecosystem.

2. **Which type of organism is the last to return to an ecosystem after a major disaster? Explain your answer in terms of matter and energy.**

   Assessment—DCI-MSLS2.B, SEP-Constructing Explanations, CCC-Energy and Matter, Stability and Change
   Analysis question 2 can be used to assess students' ability to use their models and the concepts of energy and matter to create an explanation. Student responses may be scored using the Explanation rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. A sample answer is provided at the end of this activity.

   The last organism to return to an ecosystem is the highest level consumer. The highest level consumer would have nothing to eat to get the matter and energy it needs to grow. The plants would come back first because the only matter they need to grow and reproduce is carbon dioxide and water, which is in the abiotic part of the ecosystem. The only energy they need is the sun. Once plants return, then the animals that eat the plants can return. Eventually, the top consumer can return.

3. **Do you think large fires in national parks should be put out or left to burn?**

   The fires should be allowed to burn. In a forest ecosystem like Yellowstone, there are not many decomposers to convert the matter in dead organisms to a form that can be used by plants. Fires act like decomposers by converting the matter *in the biotic components of the ecosystem into carbon dioxide and water, which plants can use. So fires are a natural part of the Yellowstone ecosystem, and without them, the ecosystem won't function as it normally does. But if fires get too big, then they should be put out because it might kill all the forest, and it wouldn't be able to return after the fire is put out.*

Extension

For students who need more practice elaborating on the effects of disruptions, encourage them to complete the first extension in this activity in the student book where they apply their understanding to a pond ecosystem.

For students who are interested in exploring more about disruptions in their local areas, encourage them to visit the U.S. Geological Survey website (usgs.gov) or the website of your equivalent state organization.

Activity 2.5

Elaborate: Disruptions and Food Webs

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  Preview the video clip on Yellowstone Fire Ecology available at the link below.
  The link to the segment follows.
  http://www.teachertube.com/video/427478
- ☐ 1 large computer monitor or projector
- ☐ 1 set of Forest Change Description, Matter, and Energy Captions (optional)

For each group of four students

- ☐ 1 set of Forest Change cards

For each student

- ☐ 1 Handout 2.5-1, "Changes Due to Fire an a Forest Ecosystem"

Teaching Summary

Getting Started

1. **Students briefly review what they know about the flow of energy and cycling of matter in ecosystems.** (5 minutes)
   - **a.** Review the ideas that energy flows through an ecosystem whereas matter cycles within an ecosystem.
   - **b.** Introduce the Crosscutting Concept of Stability and Change.

Doing the Activity

2. **Students describe and compare the effects of four disasters on a forest ecosystem.** (15 minutes)
   - **a.** Assign each group of four students to examine one of the four disasters.
   - **b.** Have students compare the results of the disasters

3. **Students consider another kind of major disruption, fire, and its effects on a forest ecosystem like the Yellowstone ecosystem.** (5 minutes)

    a. Have students discuss their initial ideas for how a fire would disrupt both the abiotic and biotic parts of the Yellowstone ecosystem.

4. **Students order Forest Change cards and describe the changes that result from a fire.** (35 minutes)

    a. Introduce the Forest Change Cards.

    b. Monitor the groups as they order the cards and describe their thinking.

    c. Bring the class together and to reach a consensus on the ordering of the cards.

    d. Students use Handout 2.5-1, "Changes Due to Fire in a Forest Ecosystem" to describe what is happening to the energy and matter in each card.

    e. Show a video clip to introduce the importance of fire in mature forests and in dry ecosystems.

Follow-Up

5. **Review the Analysis and revisit the Guiding Question.** (20 minutes)

    a. Review the students' answers to the Analysis questions.

    b. Discuss the Guiding Question, "How does a disruption affect the flow of energy and cycling of matter in an ecosystem?"

2–3 class sessions

Modeling Energy Flow and Matter Cycling in an Ecosystem

How can a model be used to represent and make predictions about an ecosystem?

Students apply what they have learned to create a model of the movement of matter and energy in their local ecosystem. They use the model to predict the effect of a disruption—a landslide that buries part of a hillside—on the flow of matter and energy in the system.

Rationale and NGSS Integration

In this Evaluate activity, students are assessed on their ability to use models to explain the key concepts of the unit: energy flow and matter cycling in ecosystems.

Activity Overview

Student groups construct a 2- or 3-dimensional model of a their local ecosystem and present their model to the class. They focus on explaining the cycling of matter and flow of energy within their ecosystem, and use their models to predict what would happen as a result of a disruption.

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models
- ☐ Scoring Rubric: Constructing Explanations

For each group of four students

- ☐ Decide in advance if you want students to create a 2- or 3-dimensional model or if you will let students choose for themselves. Gather a variety of materials, which might include:
  - – chart paper
  - – disposable containers (shoe boxes, aluminum trays, etc.)
  - – model organisms (simple sketches, stickers, buttons, plastic models, photos, etc.)
  - – clear plastic film
  - – sheets of stickers (dots, stars, etc.)
  - – different colors of construction paper
  - – yarn and/or string
  - – tape
  - – glue
  - – scissors
  - – colored markers or pencils

For each student

- ☐ Explanation Tool

Teaching Summary

Getting Started

1. Review the models students have used in this chapter.

Doing the Activity

2. Student groups construct 2- or 3-dimensional models.

Follow-Up

3. Groups present their work to the class.

4. Revisit the Guiding Question

Teaching Suggestions

Getting Started

1. **Review the models students have used in this chapter.** (15 minutes)

   a. Explain that this final Evaluate activity provides students with an opportunity to demonstrate what they have learned in this chapter, and they will be evaluated on their work.

   Point out that, throughout the chapter, they have worked with scientific models. Ask the class to brainstorm examples of scientific models from the chapter. If necessary, use the student introduction to review these models.

   b. Let students know they will construct a 2- or 3-dimensional depiction or diorama as a model of their local ecosystem.

   They will use their models to show the cycling of matter and flow of energy between the abiotic and biotic parts in that ecosystem and to explain how natural disasters might affect their ecosystems.

   Explain that their work will be scored for how well their models for Procedure Step 5 and answers to Analysis question 1 explain the student's understanding of key concepts of energy and matter in the chapter.

Doing the Activity

2. **(Assessment) Student groups construct 2- or 3-dimensional models.** (50 minutes)

   > **Assessment—PE-MS-LS2-3**
   > Students' models and presentations for Procedure Steps 5 and 6 provide an opportunity to assess one of the performance expectations associated with this chapter, specifically, MS-LS2-3 "Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem." Student responses may be scored using the Modeling rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. A sample answer is provided at the end of this activity.

   a. Consider brainstorming a list (or lists) of organisms as a class.

   If students are having difficulty with Procedure Step 2, you might refer to the list provided on the following page to facilitate this process. You might also consider taking the class outside to take pictures of common organisms that the students can use in their models.

Producers

- Bushes
- Flowers
- Grass
- Moss
- Trees (ash, maple, oak, other)

Animals that Eat Plants

- Insects (butterflies, cicadas, grasshoppers)
- Rabbits
- Slugs
- Snails

Animals that Eat Plants and Animals

- Birds (cardinals, crows, house sparrows, pigeons, robins, starlings)
- Chipmunks (eat primarily plants)
- Coyotes (eat primarily animals)
- Insects (ants, beetles, cockroaches, crickets, fireflies)
- Mice (eat primarily plants)
- Raccoons
- Rats
- Squirrels (fox, gray) (eat primarily plants)

Animals that Eat Animals

- Cats
- Hawks (Cooper's, red-tailed)
- Spiders

Decomposers

- Mold
- Mushrooms

b. Before handing out materials, let students know what kinds of materials are available for their models, which can be either 2- or 3-dimensional.

Encourage students to use string, stickers, or other materials to demonstrate energy flow and matter cycling. Most groups will need to include a key to clarify these relationships. This is an opportunity for students to integrate information with a visual representation in their presentations (CC ELA SL.8.5).

You may also need to decide if the materials need to be re-used for other classes or in the future. If so, inform students that the models will need to be able to be deconstructed at some later time. Note that some groups may tend to use enough glue to make their model semi-permanent.

As students work, spend some time with each group, assisting as needed. You may need to break the activity before students complete their models. Designate a place for them to store their work.

Follow-Up

3. (Assessment) Groups present their work to the class. (40 minutes)

a. After students have completed their model, have them present their work to the class.

This is an opportunity for the observing students to identify strengths and weaknesses of models, with an emphasis on how matter cycling and energy flow are explained within the model. Students can be asked to identify two strengths and one weakness of each scientific model. In some cases, it may be appropriate to brainstorm ideas on how to improve the model.

You might also consider having the models on display for other groups to provide feedback. Students could leave sticky notes with warm (positive) and cool (negative/room for improvement) feedback.

b. Discuss how these models can be used to make predictions about ecosystems.

Their models can help them predict: What might happen if another plant-eating animal was introduced? What might happen if a disruption such as a flood or fire occurred? How else could you use your model to make predictions about an ecosystem? After using the models to make predictions, students may want to re-visit the nature of their models and discuss additional ways to improve them.

c. Have students use the Explanation Tool to support them in constructing an explanation for Analysis item 2.

Note that students may want to use their models to help them answer Analysis Item 2.

> **Assessment—DCI-MSLS2.B, SEP-Constructing Explanations, CCC-Energy and Matter**
> Student responses to Analysis 2 may be scored using the Explanation rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. A sample answer is provided at the end of this activity.

4. Revisit the Guiding Question. (5 minutes)

Return to the Guiding Question "How can a model be used to represent and make predictions about an ecosystem?" and discuss briefly with the class.

Suggested Answers To Analysis

1. **Imagine that a science museum is making a very large version of your model for a museum display. Write three captions explaining the model for members of the public who will view the display. The captions should describe:**

   a. **interactions between living organisms**

   Acorns from oak trees and seeds from maple trees (producers) are eaten by squirrels and rats (first level consumers). Coyotes and dogs (second level consumers) eat the squirrels and rats. Hawks can eat any of these organisms. Bacteria (decomposers) help break down dead organisms.

   b. **the cycling and conservation of matter between abiotic and biotic parts of the ecosystem**

   Matter is transferred from the abiotic environment to the biotic food web by producers when they use carbon dioxide and water to produce sugars. When consumers eat the producers, the matter is transferred up the food chain to the consumers. After organisms die, their matter is cycled back into the environment by decomposers. This matter can then be reused by the producers. Matter is constantly recycled, and is conserved.

   c. **the source, flow, and loss of energy from abiotic and biotic parts of the ecosystem**

   The Sun provides energy for the ecosystem. Producers use the Sun's energy to make food. Every time a consumer eats an organism, energy is transferred up the food chain. But not all of the energy transfers up the chain—some of the energy is transferred from the biotic food chain to the environment as heat. There is a steady flow of energy from the Sun (abiotic), to the food chain (biotic), and back to the abiotic environment.

2. **Using the Explanation Tool, construct a scientific explanation for the following. A disease kills off the consumers in the top level of the Yellowstone ecosystem. Predict how the flow of energy and the cycling of matter would be affected both in the short term and in the long term. Use the steps below to guide you as you use the Explanation Tool.**

> **Assessment—PE-MS-LS2-3**
> This question provides an opportunity to assess one of the performance expectations associated with this chapter, specifically, MS-LS2-3 "Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem."

Name *SAMPLE STUDENT RESPONSE*

Activity 2.6

Explanation Tool

Question

What is the scientific question you are investigating?

What would happen to the flow of energy and cycling of matter if a disease killed off the top level of the Yellowstone ecosystem?

Evidence What are the science observations or data that address your question?	**Science Concepts** What science concepts are connected to the evidence and might help answer the question?
The top level of the Yellowstone ecosystem includes wolves, grizzly bears, and bald eagles. *The top level eats organisms in the level(s) below. In Yellowstone, this level includes fish, other large and small mammals, other birds, nuts and berries.* *The bottom level of the ecosystem is made up of plants, which are producers that make their own food during photosynthesis.* *All organisms in the Yellowstone ecosystem are connected through a food web, either directly or indirectly.* *Wolves, grizzly bears, and eagles are not eaten by any other organisms while they are still alive. After they die, decomposers obtain matter and energy from them*	*Food webs represent the feeding relationships of the biotic components of an ecosystem.* *All biotic components in an ecosystem are connected, either directly or indirectly.* *Food contains matter and stored energy.* *All organisms get the energy for life processes from energy stored in food.* *Energy flows from plants to consumers and decomposers, and never in the opposite directions.*

Scientific Reasoning

How do the science concepts connect to the evidence and to the question you are trying to answer?

The science concept of food webs connects to the evidence that all of the organisms in the Yellowstone ecosystem are connected either directly or indirectly. If you remove one organism from the food web, then all other organisms are affected. I reason that if you remove the top level of an ecosystem, then the level below will increase. The level below that will decrease, because they will be eaten by the level above. Because food contains matter and energy, the cycling of matter and flow of energy would be affected.

Claim

What claim can you make based on the evidence and reasoning?

At first, the next level down would increase, causing a chain reaction in the food web. Eventually, the entire ecosystem would be disrupted. This disruption might lead to the decrease or disappearance of some organisms from the food web and increases in other organisms. The cycling of matter would be a shorter cycle, and the energy would flow through fewer levels.

Explanation Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 2.6

Construct a Scientific Explanation

Using the information in the boxes you have completed, write a scientific explanation that includes:

- The scientific question
- Your claim
- Relevant evidence that supports your claim
- Science concepts that are connected to the evidence
- Scientific reasoning that links the evidence and science concepts to the claim

Scientific Explanation

What would happen to they flow of energy and cycling of matter if a disease killed off the top level of the Yellowstone ecosystem?

If the top levels disappeared, at first, the next level down would increase. If wolves disappeared, then elk would increase. If eagles disappeared, then fish would increase. If grizzly bears disappeared, then hares would increase. Once this second level increased, then the organisms they feed on would decrease. Then the level below that would increase. It would be like chain reaction. This would happen because all organisms in a food web are connected, and if you remove one organism, or level, then all other organisms would be affected either directly or indirectly. Eventually, the entire ecosystem would be disrupted, and the disruption might lead to the disappearance of some organisms from the food web and increases in other organisms. In Yellowstone, for example, if elk increase, and grass decreases, then other organisms that feed on grass might decrease or disappear. It would also mean that matter is cycling through fewer components, and the energy would flow through fewer levels.

Activity 2.6

Evaluate: Modeling Energy Flow and Matter Cycling in an Ecosystem

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing and Using Models
- ☐ Scoring Rubric: Developing Explanations

For each group of four students

- ☐ Depending on whether your students will make 2- or 3-dimensional models, a variety of materials, which might include:
  - – chart paper
  - – disposable containers (shoe boxes, aluminum trays, etc.)
  - – model organisms (simple sketches, stickers, buttons, plastic models, photos, etc.)
  - – clear plastic film
  - – sheets of stickers (dots, stars, etc.)
  - – different colors of construction paper
  - – yarn and/or string
  - – tape
  - – glue
  - – scissors
  - – colored markers or pencils

For each student

- ☐ Explanation Tool

Teaching Suggestions

Getting Started

1. **Review the models students have used in this chapter.** (15 minutes)

   a. Explain that this final Evaluate activity provides students with an opportunity to demonstrate what they have learned in this chapter, and they will be evaluated on their work.

b. Let students know that their groups will construct a 2- or 3-dimensional depiction or diorama as a model of their local ecosystem.

Doing the Activity

2. Student groups construct 2- or 3-dimensional models. (50 minutes)

a. Consider brainstorming a list (or lists) of organisms as a class.

b. Before handing out materials, let students know what kinds of materials are available for their models, which can be either 2- or 3-dimensional.

Follow-Up

3. (Assessment) Groups present their work to the class. (45 minutes)

a. After students have completed their model, have them present their work to the class.

b. Discuss how these models can be used to make predictions about ecosystems.

c. Have students use the Explanation Tool to support them in constructing an explanation for Analysis item 2.

4. Revisit the Guiding Question. (5 minutes)

CHAPTER

3 Interactions Between Populations and Resources

Activity 3.1 ***Engage***	**What factors should you consider when purchasing fish to eat?** Students begin the chapter thinking about fishing as an example of human use of natural resources. Students start considering how the health of one population might affect the ecosystem it lives in.
Activity 3.2 ***Explore***	**Can fishing limits prevent the overuse of an ecosystem?** Students explore how fishing limits can change the effect of human natural resource use, and examine how changes to the surrounding ecosystem can be a compounding factor. This allows students to investigate their initial ideas about natural resource use and about how multiple factors can affect populations.
Activity 3.3 ***Explain***	**What effect have humans had on the health of fisheries?** Students transition from analyzing their own data about a fictitious fishery to an analysis of long-term data from three real fisheries. Students use this analysis to develop an initial explanation about humans' effect on fisheries and a formal argument about the health of one fishery.
Activity 3.4 ***Elaborate***	**How do humans affect the size of dead zones?** Students expand on their understanding of human disruption of ecosystems by looking at a more complex problem: the creation and expansion of dead zones. Students use their analysis of a variety of data to inform a debate on limiting human use of fertilizers to prevent dead zones.
Activity 3.5 ***Evaluate***	**How do increases in the human population affect the resources available to organisms?** Students conclude the chapter with an investigation that examines the effects of fishing and dead zones on the Chesapeake Bay Oyster fishery. This allows for the evaluation of students' understanding of the effects of resource availability on organisms and populations of organisms as well as how increases in the human population impact the Earth's systems. This also prepares them to investigate another complex ecosystem disruption, invasive species, in the next chapter.

Chapter 3 Overview

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Engage **3.1 Shopping for Fish** **Guiding Question:** What factors should you consider when purchasing fish to eat? In this activity, students analyze data about purchasing fish in a grocery store. They use this data to decide what fish they would buy, and what other information they would want to have before making their decision. The class discusses the factors they think are important to consider when deciding what fish to purchase.	MS LS2.A.1 Cause & Effect Science Knowledge Describes Consequences	Analyzing & Interpreting Data	overfished	1
Explore **3.2 Gone Fishin'** **Guiding Question:** Can fishing limits prevent the overuse of an ecosystem? Students model resource consumption and overuse through a game that models fisheries. In the first game students are able to overfish the available fish populations. In the second game the fishing limits are set such that the fish populations are able to survive and increase. In the third game students model the effect of changes in ecosystem conditions.	MS LS2.A.1 Cause & Effect	Analyzing & Interpreting Data	overfished	1-2
Explain **3.3 Three Fisheries** **Guiding Question:** What effect have humans had on the health of fisheries? Students analyze data about three fisheries. They then use the data to try and identify the fisheries based on short text passages that describe each fishery, their historical and current fishing limits and practices, and key regulation dates. Students use their analysis to construct an argument about the health of a fishery.	MS LS2.A.2 MS ESS3.C.2 Consequences of Human Activity	Analyzing & Interpreting Data Engaging in Argument from Evidence	overfished	2

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Elaborate **3.4 Dead Zones** **Guiding Question:** How do humans affect the size of dead zones? Students analyze data about nitrogen input, streamflow, and the size of dead zones. They use this data and additional evidence from a video to construct an explanation about the effect of these factors on the size of the dead zone in the Gulf of Mexico. They then gather additional evidence from a short reading to inform a debate on fertilizer use and dead zones.	MS LS2.A.1 MS ESS3.C.2 Cause & Effect Consequences of Human Activity Science Knowledge Describes Consequences	Analyzing & Interpreting Data Constructing Explanations Engaging in Argument from Evidence	dead zones	2
Evaluate **3.5 Chesapeake Bay Oysters** **Guiding Question:** How do increases in the human population affect the resources available to organisms? Students learn about the Chesapeake Bay ecosystem and the oyster harvests in the Bay. They analyze and interpret data about the nitrogen run-off, dead zone size, and oyster harvests to develop an argument about the effect of the human population on the Chesapeake Bay oysters.	MS LS2.A.1 MS LS2.A.2 MS LS2.A.3 MS ESS3.C.2	Engaging in Argument from Evidence	dead zones argument	2

Assessment Overview

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explain	Activity 4 Elaborate	Activity 5 Evaluate
Disciplinary Core Ideas (DCI)					
MS LS2.A.1*	Analysis 3	Steps 4, 5, 7	Step 7	Step 4 Analysis 1 & 2	
MS LS2.A.2*			Step 9		
MS LS2.A.3*					
DMS ESS3.C.2**			Step 9	Step 4 Analysis 2	
Science and Engineering Practices (SEP)					
Constructing Explanations and Designing Solutions			Step 7	Step 4	
Engaging in Argument from Evidence*			Step 9	Step 7	
Analyzing and Interpreting Data		Steps 4, 5, 7	Steps 2-6 Analysis 1	Steps 2 & 3	
Crosscutting Concepts (CCC)					
Cause and Effect*	Analysis 3	Steps 4, 5, 7		Steps 3 & 4 Analysis 1	
Connections to Engineering, Technology and Applications of Science**			Steps 7 & 9 Analysis 1	Step 7	
Connections to Nature of Science**	Analysis 3			Step 7	

* Primary PE and supporting elements **Secondary PE and supporting elements

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explain	Activity 4 Elaborate	Activity 5 Evaluate
Performance Expectations (PE)					
LS2-1*					Step 6 Analysis 1
ESS3-4**					Step 6
CCSS ELA					
RST.6-8.1					Step 6
RST.6-8.7				Analysis 3	Analysis 1
WHST.6-8.1					Step 6
WHST.6-8.9			Steps 5 & 6		Step 6

* Primary PE and supporting elements **Secondary PE and supporting elements

PE	**LS2-1 :** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
	ESS3-4 : Construct an argument supported by evidence for how increases in human population ~~and per-capita consumption of natural resources~~ impact Earth's systems.
DCI	**LS2.A.1:** Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
	LS2.A.2: In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
	LS2.A.3: Growth of organisms and population increases are limited by access to resources.
	ESS3.C: Typically as human populations ~~and per-capita consumption of natural resources~~ increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
SEP	**EAE:** Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
	AID: Analyze and interpret data to provide evidence for phenomena.
CCC	**C&E:** Cause and effect relationships may be used to predict phenomena in natural or designed systems.
	(CET&S): All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.
	(CNoS): Science knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.
CCSS ELA	**RST.6-8.1:** Cite specific textual evidence to support analysis of science and technical texts.
	RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
	WHST.6-8.1: Write arguments focused on discipline-specific content.
	WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research.

1 class session

Shopping for Fish

What factors should you consider when purchasing fish to eat?

Students begin the chapter thinking about fishing as an example of human use of natural resources. Students start considering how the health of one population might affect the ecosystem it lives in.

Rationale and NGSS Integration

This Engage activity is designed to pique students' curiosity about the use, and potential overuse, of fish as a resource. Commercial fishing, as an example of human natural resource use and management, will be the focus of the storyline in this chapter. The decline of certain fisheries, and the appearance of dead zones, serve as anchoring events exemplifying human impacts on the environment. This activity provides an opportunity for students to shift their foci from the human interactions in the previous activity to humans utilizing a natural resource (fisheries). Students' prior knowledge of food webs and interactions is utilized and expanded upon throughout this chapter.

The questions initiated in this activity will be addressed in the activities that follow. Overall, the science practices developed in this chapter are analyzing and interpreting data, constructing explanations and designing solutions, and engaging in argument from evidence. In this activity students begin to engage in the practice of analyzing and interpreting data using simple data about purchasing fish. Class discussion around the students' data analysis will begin to frame students' thoughts about human use of natural resources. As students apply the practice of analyzing data, they will be incorporating the crosscutting concept of cause and effect in terms of human use of resources, as well as the concept that science knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society makes, a connection to the nature of science.

Review the chapter overview and assessment chart to see how the three dimensions of the NGSS are woven together throughout this chapter, and how they are assessed in each activity. Decide in advance which assessments you plan to emphasize.

Activity Overview

In this Engage activity, students analyze data about purchasing fish in a grocery store. They use this data to decide what fish they would buy, and what other information they would want to have before making their decision. The class discusses the factors they think are important to consider when deciding what fish to purchase.

Key Vocabulary

overfished

Teaching Summary

Getting Started

1. Facilitate a class discussion to determine what the students know about fishing.

Doing the Activity

2. Students analyze information about purchasing fish.

Follow-Up

3. The class discusses factors to consider when purchasing fish.
4. Preview the chapter and revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Facilitate a class discussion to determine what the students know about fishing.** (15 minutes)

   a. Have students read the introduction as a class read aloud or in pairs.

   This activity introduces the concept that people have many reasons for choosing which fish to eat, and introduces a criterion that may be new to many, if not most, of the students—the environmental impact of the fishery. This frames the phenomenon for this chapter, that populations and ecosystems can be affected by human use of natural resources.

   Students will need to understand the key term, overfished, which is defined in the introduction as: so many fish being caught that the population cannot reproduce fast enough to maintain its population. Consider adding this term to the Word Wall. If students are keeping a Personal Vocabulary Log, consider having them add overfishing and other terms from this activity to their logs. Both strategies are described in Section 1 of Teaching Strategies. Note that the Guiding Question could be used as a written warm up at the beginning of the class session.

   For the class discussion in Step 1, focus on what students know about fish, fishing, fisheries, overfishing, and any related topics. Encourage students to discuss what connections people have to fish, for example as a food source, tourism and recreation, industry, etc. If students in your class do not consider fish a major part of their diet, stress that fish provides an important source of protein for many cultures worldwide and plays an important role in fighting hunger and malnutrition. Be sure students also discuss connections that are not about the consumption of fish, e.g. aquariums, snorkeling, etc. This conversation will begin to frame the chapter focus, looking at resource use and human disruption of ecosystems.

Doing the Activity

2. **Students analyze information about purchasing fish.** (20 minutes)

   a. Have the students complete the Procedure.

   Note that there is no "best" or "correct" choice, rather the students should be able to rationalize their choice based on the evidence from the chart.

Students may not initially conclude that the label colors on the fish indicate the health of the fishery. During the class discussion in Step 4 first give students the opportunity to offer up their ideas about the color-coding system. As part of this discussion, have the students discuss what biotic and abiotic factors might affect fisheries, and what role humans might have in controlling (or not controlling) their effect on fisheries. Then explain to them that for the past several decades, scientists, fishers, and concerned citizens have been working together to develop systems that rate the health status of a fish population. Once they determine a rating, that information is shared with the public so that people who are buying fish to cook at home or in restaurants know if they are buying fish that are coming from a healthy population. One method for categorizing the health of a fish population is to label the fish red, yellow, and green, just like the colors on a traffic light. If a fish population is in the red category it is being overfished, yellow means the fish population is doing okay but there are still some concerns, and green means the size of the fish population is healthy. The red snapper that Sara looked at in the grocery store used to be categorized as red, because the population was severely overfished. In 2013 the red snapper was moved into the yellow category. Students will learn more about this, in particular for the Pacific halibut, red snapper, and orange roughy fisheries, in the activities that follow.

Follow-Up

3. **The class discusses factors to consider when purchasing fish.** (15 minutes)

   a. Conclude the class with a class discussion about the Analysis questions.

   Analysis question 3 examines what factors to consider when deciding what fish to purchase. You may wish to have students discuss Analysis question 3 in groups or as a class, instead of writing responses. Consider closing class with a discussion of all of the Analysis questions, or just Analysis question 3, as time permits. This is a good point to introduce the term criteria, which will be used in subsequent activities and chapters. In this activity, the criteria concern the health of the fishery. For example, scientists might consider a fishery healthy if it meets the criteria of not decreasing more than 5% from a target population level. Another example of criteria for determining the health of the population might be that the geographic range of where the fish are found does not decrease more than 3% year to year. If student responses to the question focus primarily on choosing fish based on taste, encourage them to discuss other factors that might be relevant such as cost and the current state of the fishery. This is also a good point to have them add the term overfished to the class word wall.

4. **Preview the chapter and revisit the Guiding Question.** (10 minutes)

   a. Preview the chapter with the students.

   Use the Chapter Overview to guide you as you preview the rest of the chapter with the class. Introduce the guiding question for the chapter, "How do environments change when people use up resources?" Write this question on chart paper, a board, or some other location where it can be seen by the students as the class works through the rest of the chapter. Be sure to refer back to the question at appropriate points in subsequent activities. Briefly preview the content they will be learning including the disciplinary core ideas, crosscutting concepts, and science and engineering practices they will use to build conceptual understanding.

   Explain to the students that they have two main learning goals for this chapter:

   1. to investigate how human fishing is affecting the resource availability for other organisms and populations of organisms in ecosystems through the scientific practices of analyzing and interpreting data, and,

   2. constructing an argument supported by scientific evidence. In order to develop their arguments they will also be engaging in the scientific practice of constructing explanations.

   The guiding question, "*What factors should you consider when purchasing fish to eat?*" is the same as Analysis question 3.

   You may wish to point out that working together as a group will be essential for the next activity. If students need additional supports for cooperating, consider using Student Sheet 2, "Evaluating Group Interactions." This sheet allows students to reflect on their own contributions to successful group work. For more explanation on this sheet, see Section 2 in Teaching Strategies.

   Consider creating a Student Question Poster to capture students' questions about fisheries and human resource use. Accept all reasonable questions at this point and revisit this poster at the end of the Explore and Explain activities in this chapter.

Suggested Answers To Analysis

NOTE: Analysis questions marked with Assessment are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **How might the health of a fish population affect the ecosystem where the fish lives?**

   An unhealthy fish population might have a negative effect on the food web for that ecosystem. For example, if the fish is a prey species for a shark, the sharks wouldn't have as much food to eat so the shark population would decrease. It might also mean that whatever the fish eats, like plankton, would increase.

2. **Is it important to monitor the health of fish populations? Why or why not?**

   It is important to monitor the health of fish populations because they are part of the ecosystem and food web. If one population in a food web is unhealthy it can affect the whole food web.

3. **What factors do you think are important to consider when deciding what fish to purchase? Explain your answer.**

   > **Assessment – CNOS**
   > Use this question as an initial, informal assessment on students' ideas about the connection to the nature of science, science knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

   When you are deciding what fish to purchase, it is important to consider how much it costs, how healthy the fish is for you, and if you like the flavor of that fish. These three factors are about your personal needs and preferences. It may also be important to consider if the population of that fish is being overfished, because that can lead to bigger problems in the ecosystem that the fish lives in.

Extension

Your students may be interested in learning more about any labeling systems used for the meat or seafood sold at their local markets. You may wish to identify a couple of stores where students are likely to encounter labeling that addresses sustainability of the fishery.

Activity 3.1

Engage: Shopping for Fish

Teaching Summary

Getting Started

1. **Facilitate a class discussion to determine what the students know about fishing.** (15 minutes)
    a. Have students read the introduction as a class read aloud or in pairs.

Doing the Activity

2. **Students analyze information about purchasing fish.** (20 minutes)
    a. Have the students complete the Procedure.

Follow-Up

3. **The class discusses factors to consider when purchasing fish.** (5 minutes)
    a. Conclude the class with a class discussion about the Analysis questions.
4. **Preview the chapter and revisit the Guiding Question.** (10 minutes)
    a. Preview the chapter with the students.

1–2 class sessions

Going Fishin'

Can fishing limits prevent the overuse of an ecosystem?

Students explore how fishing limits can change the effect of human natural resource use, and examine how changes to the surrounding ecosystem can be a compounding factor. This allows students to investigate their initial ideas about natural resource use and about how multiple factors can affect populations.

Rationale and NGSS Integration

This activity provides students with an opportunity to engage in the science and engineering practice of analyzing and interpreting data that they have generated via their investigation. The activity models the impacts of overfishing and fishing limits, which ties back to the introduction of the issue of fishing and overfishing introduced in the Engage activity they just completed. As students engage in the practice of analyzing data about the core idea, they are applying the concepts of crosscutting concepts of cause and effect and the consequences of human activity. Ideas and concepts that students develop in this activity will lead into the next where they will analyze data from actual fisheries.

Activity Overview

In this Explore activity, students model natural resource consumption and overuse through a game that models fisheries. Each round of the game has different fishing limits. In the first game students are able to overfish the available fish populations. In the second game the fishing limits are set such that the fish populations are able to survive and increase. In the third game students model the effect of changes in ecosystem conditions.

Materials and Advance Preparation

For each group of four students

- ☐ 100 fish crackers (orange)
- ☐ 30 fish crackers (yellow or color other than orange)
- ☐ tray or dish
- ☐ set of 4 Game A Character Cards
- ☐ set of 4 Game B Character Cards
- ☐ set of 4 Ecosystem Disruptions Cards
- ☐ timer that beeps

Count the fish crackers into plastic zip-top bags ahead of time. If students have access to smart phones with a stopwatch feature that can be set to beep when an allotted time has been reached, they may be used for this activity. Otherwise, provide timers that beep when the allotted time has been reached.

For each student

- ☐ Handout 3.2-1, " Populations Over Time"
- ☐ 1 pair of chopsticks**
  (**You may want to have some plastic spoons available for activity modification. See Teaching Suggestions, Doing the Activity, for more information.)
- ☐ cup
- ☐ paper towel

Safety Note

Make sure students do not consume the fish crackers. Check with your students in advance to see if any of them have severe food allergies, such as a nut allergy, to be sure the food products being used will not cause any allergic reactions.

Teaching Summary

Getting Started

1. Introduce the game to the students.

Doing the Activity

2. Students play four rounds each of Game A, Game B and Game C.

Follow-Up

3. Facilitate a class discussion about the game as a model of fisheries.

4. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Introduce the game to the students.** (10 minutes)

   a. Read the brief introduction aloud to the whole class.

   Explain to students that in this activity they will be modeling what happens to a population of fish when various fishing limits are introduced. This connects to the concept of a healthy fishery, introduced int he previous activity. Fishing limits are one way that human effects on a fish population can be controlled. Review the materials for the activity and the flow chart with the instructions for the game. Show students one model round, and how to make fish reproduce at the end of each round (if there are any fish left). Make sure students understand how to record their data on Handout 3.2-1, "Populations Over Time". Make sure students also understand that after four rounds of Game A they reset the entire game (go back to 100 orange fish and 30 yellow fish) before they begin Game B.

   You may wish to only pass out the Character Cards for Game A initially, reserving the Game B cards until students show you their completed data tables for Game A and that they have properly reset the game for Game B, and the same for Game C. Note that in some games, the Character Cards are duplicated, or all the same, depending on what roles students are playing and the outcomes of the model.

Doing the Activity

2. **(Assessment) Students play four rounds each of Game A, Game B and Game C.** (25 minutes)

   a. Have students play Game A.

The game is designed to work with four students. If there are five students per group have one student act as the group timer and data recorder, rotating the roles within the group between games. Try to maximize the number of four-person groups in the class. Groups of three will likely not have the desired outcomes for the game. Note that each game focuses on the following:

Game	Focus
A	Effects of no fishing limits
B	Effects of sustainable fishing limits
C	Effects of environmental disruptions on fisheries with “sustainable” fishing limits

As they are working, observe each group to make sure the students who are not as well-practiced with chopsticks are engaged. If students have not caught enough fish to continue in Game A, they can practice with their chopsticks on the side, or they can serve as the group data recorder. If necessary, explain to students that having varying abilities with the chopsticks is a good model of fishing. Some fishers have the most modern equipment in top condition that allows them to catch as many fish as are available, while others may have older equipment. If you have students who are extremely frustrated, or who have trouble with fine motor skills, you may wish to provide them with a plastic spoon in place of the chopsticks, but this should be in very limited circumstances and these students should still only be allowed to use the spoon (and not the cup or their fingers) to catch one fish at a time.

b. Check student results and have them move to Games B and C.

When students finish Game A be sure they fill out their data tables and discuss the questions in Step 5 before proceeding to Game B. Results will vary by group, but most groups will run out of fish in Game A. If Game B is played according to the instructions there should be more yellow and orange fish at the end of the game than at the beginning. See the sample student response for Handout 3.2-1, “ Populations Over Time” at the end of this Activity. The results for Game C should vary significantly depending on which cards are drawn. Some groups may see very little effect from changes in the environment, while others may see dramatic changes in their fish populations.

Depending on how quickly students are able to complete the Games, you may wish to teach this activity over two class periods. If so, conclude the first period after students have completed at least one full game. Do not stop in the middle of a Game.

Use the students' answers to the questions at the end of each game (Steps 5, 6, and 8) to informally assess their analysis and interpretation of the data from the games, their initial understanding of the core idea of the dependence of populations on environmental interactions, and cause and effect relationships. Students should begin to incorporate all three of these dimensions in their understanding of the phenomenon of human use of natural resources affecting populations and ecosystems. As they continue working in the chapter, students will have multiple opportunities to deepen their understanding of these three dimensions in the context of human resource use. They will also analyze and interpret data in a variety of contexts, deepening their experience with this practice over time. This is also a good point in the chapter to have students reflect on what they learned in previous chapters about ecosystem interactions and how those interactions come into play when humans are using a natural resource, such as fish.

Follow-Up

3. **Facilitate a class discussion about the game as a model of fisheries.** (10 minutes)

   a. Have a class discussion about what happened in the three games.

   Have student groups share the results of the three games, including what Ecosystem Disruptions Cards they drew and how they affected their fisheries. Have them discuss if their predictions for each game were accurate. In order to prevent groups repeating similar findings, consider having one group share and then other groups add new or different findings if they had them. Have students discuss how these games modeled fisheries, and what limitations there were with the models. Encourage students to think about how fisheries might set and adjust fishing limits (e.g. revise every 10 years? every year? based on what type of data?) and what that might mean for the long-term health of the fishery. Students will expand on these points in the Analysis questions. Analysis questions 3 and 4 provide opportunities to connect back to Chapter 2 where students engaged in the practices of developing models to predict and/or describe phenomena and to describe unobservable mechanisms. For suggestions on types of questions to ask while facilitating a class discussion, see Discussion Starters in Section 2 of Teaching Strategies.

4. **Revisit the Guiding Question** (5 minutes)

   a. Conclude the class with a discussion about the Guiding Question, "Can fishing limits prevent the overuse of an ecosystem?" based on the data students gathered in the activity.

      This discussion will segue into the next activity where students will be looking at data and text passages about three fisheries with different approaches to fishing limits. Have students add to the crosscutting concepts poster for cause and effect, which relates to the core of this activity. Ask the students how scientists might think about the challenges fisheries face in terms of cause and effect. Students will likely suggest that the limits humans set on fisheries can affect the health of the fish populations in an ecosystem. They will also likely bring up that external factors, such as changes in the ecosystem like a plankton die-off, can also affect the health of the fish populations.

      If you distributed Student Sheet 2, "Evaluating Group Interaction," consider having students self- or peer-evaluate their contributions to their group's use of the fishing model. Revisit the Student Question Poster to determine if any of the students' previous questions have been answered, and to record any new questions.

Suggested Answers To Analysis

1. **Describe the three games and what happened to the two fish populations over time in each game.**

   In Game A, we had no fishing limits on anyone. Even though Sam only caught one fish in Round 1 and couldn't keep fishing, the rest of us caught so many fish that the fish were all gone by the end of Round 2. In Game B we all had a fishing limit of 3 orange fish per round. Everyone caught enough fish to survive and at the end of the game there were more orange and yellow fish than there were at the beginning. In Game C we had a plankton die off and unusual warm weather, both of which meant fewer fish, and by the end of Round 4 we had almost no fish in Blue Bay.

2. **How did the reproduction of the fish (adding one fish for every live fish at the end of each round) affect fish population levels? Explain.**

   In Game B, when we weren't catching too many fish, the reproduction of the fish meant that the fish we did catch got replaced, and the population even grew.

But in Game A we had no limits and the fish did not reproduce fast enough to make up for the fishing so the populations disappeared. In Game C we had two ecosystem disruptions that limited reproduction of our fish, which meant we had almost no fish left by the end of Round 4.

3. **How was the effect of humans modeled in this activity?**

   The effect of humans was modeled in this activity by us pretending to be fishers that were catching the fish and by us setting and following fishing limits.

4. **What is missing from this model?**

   This model was missing other abiotic and biotic factors affecting the fish populations, like pollution or predators and prey in the ecosystem.

Activity 3.2

Explore: Going Fishin'

Materials and Advance Preparation

For each group of four students

- ☐ 100 fish crackers (orange)
- ☐ 30 fish crackers (yellow or color other than orange)
- ☐ tray or dish
- ☐ set of 4 Game A Character Cards
- ☐ set of 4 Game B Character Cards
- ☐ set of 4 Ecosystem Disruptions Cards
- ☐ timer that beeps

Count the fish crackers into plastic zip-top bags ahead of time. If students have access to smart phones with a stopwatch feature that can be set to beep when an allotted time has been reached, they may be used for this activity. Otherwise, provide timers that beep when the allotted time has been reached.

For each student

- ☐ Handout 3.2-1, " Populations Over Time"
- ☐ 1 pair of chopsticks**
  (**You may want to have some plastic spoons available for activity modification. See Teaching Suggestions, Doing the Activity, for more information.)
- ☐ cup
- ☐ paper towel

Safety Note

Make sure students do not consume the fish crackers. Check with your students in advance to see if any of them have severe food allergies, such as a nut allergy, to be sure the food products being used will not cause any allergic reactions.

Teaching Suggestions

Getting Started

1. **Introduce the game to the students.** (10 minutes)

    a. Read the brief introduction aloud to the whole class.

Doing the Activity

2. **(Assessment) Students play four rounds each of Game A, Game B and Game C.** (25 minutes)

    a. Have students play Game A.

    b. Check student results and have them move to Games B and C.

3. **Facilitate a class discussion about the game as a model of fisheries.** (10 minutes)

    a. Have a class discussion about what happened in the three games.

4. **Revisit the Guiding Question.** (5 minutes)

    a. Conclude the class with a discussion about the Guiding Question, "Can fishing limits prevent the overuse of an ecosystem?" based on the data students gathered in the activity.

2 class sessions

Three Fisheries

What effects have humans had on the health of fisheries?

Students transition from analyzing their own data about a fictitious model fishery to an analysis of long-term data from three real fisheries. Students use this analysis to develop an initial explanation about humans' effects on fisheries and a formal argument about the health of one fishery.

Rationale and NGSS Integration

Students analyze and interpret data in order to investigate the effects of humans on three fisheries. Students apply this analysis to the development of a general, preliminary explanation of human effects on fisheries as a natural resource. Students then move into constructing a formal argument about the health of one fishery at a specific point in time. Interpreting the long-term, real data in this activity provides students with a deeper understanding of the core ideas of competition for resources within ecosystems and how human populations can impact Earth's resources if actions are not engineered otherwise. This helps to deepen their understanding of connections to the engineering, technology and applications of science, namely natural resource use and overuse, building on what they have learned in the two previous activities. It also prepares them to transfer this knowledge into a new setting with a different challenge in the next activity.

Activity Overview

In this Explain activity, students analyze data about three fisheries. They then use the data to try and identify the fisheries based on short text passages that describe each fishery, including their historical and current fishing limits and practices, and key regulation dates. Students extend their understanding of one fishery by analyzing additional data on average mass of individual fish over time. Students then use their analysis to construct an argument about the health of a fishery.

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing Arguments

For each student

- ☐ Argument Tool

Teaching Summary

Getting Started

1. Student pairs discuss the effects of humans on fishery health.

Doing the Activity

2. Student pairs analyze total catch data on fisheries and match the data with text descriptions.
3. The class develops a preliminary explanation of human effects on fisheries.

Follow-Up

4. Students construct a scientific argument about the health of one fishery.
5. Revisit the Guiding Question.

References

- Fisheries and Aquaculture Department. (2018) Species Fact Sheets: Hoplostethus atlanticus. Food and Agriculture Organization of the United Nations. http://www.fao.org/fishery/species/2249/en
- International Pacific Halibut Commission. (2016) Report of Assessment and Research Activities 2015. https://iphc.int/uploads/pdf/rara/iphc-2015-rara25.pdf
- NOAA Fisheries Southeast Regional Office. (2018) Historical Overview (1880s-present): How has the red snapper fishery changed over time? National Oceanic and Atmospheric Administration. http://sero.nmfs.noaa.gov/sustainable_fisheries/gulf_fisheries/red_snapper/overview/

Teaching Suggestions

Getting Started

1. **Student pairs discuss the effect of humans on fishery health.** (10 minutes)

   a. Have students share ideas on what a "healthy" fishery is.

   Briefly have students offer suggestions for what it means for a fishery to be "healthy." Encourage them to consider what they have learned in the previous activities. Record their ideas to revisit later in the activity. Explain to the students that in this activity they will be examining total catch data from real fisheries, and analyzing the fishing limits that have been implemented in those fisheries and what effects, if any, those limits have had on the health of those fisheries.

   b. Have student pairs read the introduction and Guiding Question, then complete Step 1.

   Do not have a class discussion at this point, as students will use their discussion with their partners from this step to frame the rest of the activity and their explanations at the end of the activity.

Doing the Activity

2. **(Assessment) Student pairs analyze total catch data on fisheries and match the data with text descriptions.** (30 minutes)

   a. Have the students work in pairs to analyze the graphs.

   Depending on their level of comfort with analyzing line graphs, students may need support to analyze the data. Remind students to look for patterns in the data, to look at when the line changes direction and if it goes up, down, or stays relatively flat. You may also want to point out that while the x-axes (year) are all the same, the y-axes (total catch) have different scales. The total catch for Species A is much smaller (between 2 and 42 thousands of kilograms) per year and over time than the other two species. If appropriate, review one graph as a class, and then have students continue the analysis working in pairs.

   b. Have student pairs match graphs to text descriptions.

   Consider having students use Student Sheet 8, "Interpreting Graphs," if they need continued scaffolding with analyzing and interpreting graphs. If students are unable to match the graph with the fishery, have them use the process of elimination with the three graphs and the text descriptions. They should be able to easily identify the orange roughy graph (Species A), as the catch for this species has dropped dramatically with no sign of recovery. To help them distinguish between the Pacific halibut (Species B) and red snapper (Species C), encourage them to look at which population seems to have stayed steady, as the Pacific halibut fishery is described in the text, and which has decreased but seems to be recovering toward the end of the graph, as one would expect with the new regulations for the red snapper that were instituted in 2007.

Note that students' answers may differ for Step 6 based on what they think defines a healthy fishery. As long as the students' reasoning is sound and consistent, accept their answers. Generally, the Pacific halibut fishery is considered a healthy (green label/category) fishery by scientists and industry. The red snapper has recently been moved from the yellow label/category to the green label/category by most organizations that analyze the fisheries, due to the stricter fishing regulations and apparent beginning of the recovery of the fishery. Orange roughy is considered a red label/category fish by all organizations that analyze fisheries, due to the population crash and lack of regulations on the fishery.

Steps 2 – 5 provide an opportunity to assess students' analysis and interpretation of the data in the activity. Step 6 can be used to assess the students' understanding of connections to engineering, technology and applications of science.

3. **(Assessment) The class develops a preliminary explanation of human effects on fisheries.** (10 minutes)

   a. The class discusses how humans affect different fisheries.

   This step provides the students the opportunity to develop a general, informal explanation of how humans affect different fisheries. Students should be able to explain that the effects differ depending on the fishery, limits enforced by the fishers, and by other factors such as how long it takes the fish to reproduce. Students should be bringing in knowledge from the previous activity, with the fishery model, and linking it to the new information about real fisheries in this activity. This is a good opportunity to informally assess students' current level of skill with developing explanations. Encourage students who are struggling to use "If…then…" statements, such as "If the catch level on the graph is decreasing, then it probably means the fish population has decreased." Students will use this informal explanation to support their construction of a scientific argument in Step 9.

   This is a good point to conclude the first class session.

   b. Students analyze more data on the Pacific halibut fishery.

Part B has students analyze data on the average mass of Pacific halibut at three time points. Students may need support in their initial analysis of the graph. If necessary, point out that the graph shows the average mass per fish, not per whole catch. Have students pick one age and one sex to analyze first. For example, have them look only at 14-year-old female halibut. Students should notice that these halibut were, on average, much smaller in 2014 than in previous years. This trend is true for both sexes and all ages on the graph, although it is less pronounced in males and younger females. Scientists generally consider this to be a possible sign of pressure from fishing, as larger fish are often more "desirable" catch, although other factors may be causing, or influencing, this trend.

Follow-Up

4. **(Assessment) Students construct a scientific argument about the health of one fishery.** (40 minutes)

   a. Introduce and use the Argument Tool

   Show students Student Sheet 5, the Argument Tool, and discuss the various sections of the tool. Because this is the first time the students have used the tool, you may want to do the first few sections as a class, have the students complete the tool in pairs, or provide other support as needed. You may wish to have students engage in peer reviews of their arguments, using Student Sheet 3, "Writing Review." For more explanation on both the Argument Tool and peer review of writing, see Section 4 in Teaching Strategies.

   You may wish to use this as an opportunity to assess students' developing skills with analyzing and interpreting data. You can also use this as a point for an informal, baseline assessment of their skills with constructing a scientific argument, a practice they will be utilizing throughout the rest of the chapter, and incorporating crosscutting concepts in addition to disciplinary core ideas in their argument. A sample answer for this argument is provided in the Handouts section of the Teacher's Guide.

5. **Revisit the Guiding Question.** (10 minutes)

   a. The guiding question, *What effect have humans had on the health of fisheries?* is the focus of the informal explanation students develop in Step 7, however, students' opinions may have changed after completing the argument in Step 9.

   Have students share their thoughts and opinions. At this point in the chapter, students should have a basic understanding of the idea that the effect humans have on the health of many fisheries depends largely on how those fisheries are regulated. Have the class review their ideas of what makes a healthy fishery from the beginning of the activity, and adjust the list if applicable. Students may wish to add to the crosscutting concept poster for cause and effect, depending on how much their ideas have changed from the previous chapter.

Revisit the Student Question Poster to determine if any of the students' previous questions have been answered, and to record any new questions.

Suggested Answers To Analysis

1. **Give two examples of criteria scientists might use to determine if the Pacific halibut fishery is healthy.**

   Scientists might consider the size of the fish population. They might also consider the average size of fish and if that is decreasing or staying the same.

2. **Why might scientists want to look at more than one type of data to determine the health of the fishery?**

   Assessment – SEP - Analyzing and Interpreting Data
   Use this question to assess students' broader understanding of data analysis and what types of data are needed for more complex analysis.

   Scientists should look at more than one type of data to determine the health of the fishery because it gives them a better overall picture of how healthy the fish population is. For example, if they only looked at how many fish were caught and that number stayed the same it might seem like the fish population was healthy even if over time all of the older, larger fish were being caught and only small, young fish were left.

Extension

Students may be interested to learn more about natural resources in their local areas, and what impact these industries are having on the environment and people. You may wish to gather websites from your state or local departments of natural resources, agriculture, forestry, or mining, and make these available to your students for their investigation.

Activity 3.3

Explain: Three Fisheries

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing Arguments

For each student

- ☐ Argument Tool

Teaching Suggestions

Getting Started

1. **Student pairs discuss the effect of humans on fishery health.** (10 minutes)
   - **a.** Have students share ideas on what a "healthy" fishery is.
   - **b.** Have student pairs read the introduction and Guiding Question, then complete Step 1.

Doing the Activity

2. **(Assessment) Student pairs analyze total catch data on fisheries and match the data with text descriptions.** (30 minutes)
   - **a.** Have the students work in pairs to analyze the graphs.
   - **b.** Have student pairs match graphs to text descriptions.
3. **(Assessment) The class develops a preliminary explanation of human effects on fisheries.** (10 minutes)
   - **a.** The class discusses how humans affect different fisheries.
   - **b.** Students analyze more data on the Pacific halibut fishery.

Follow-Up

4. **(Assessment) Students construct a scientific argument about the health of one fishery.** (40 minutes)

    a. Introduce and use the Argument Tool

5. **Revisit the Guiding Question.** (10 minutes)

2 class sessions

Dead Zones

How do humans affect the size of dead zones?

Students expand on their understanding of human disruption of ecosystems by looking at a more complex problem: the creation and expansion of dead zones. Students use their analysis of a variety of data to inform a debate on limiting human use of fertilizers to prevent dead zones.

Rationale and NGSS Integration

This Elaborate activity challenges students to apply their understanding of the core ideas of population dynamics and resource use, as well as human impacts on Earth, to the issue of dead zones. Students use what they have learned in the previous activities about population limits in ecosystems to analyze a more complex situation where both biotic and abiotic factors are being changed. This provides students an opportunity to expand their understanding of the complexity of factors that influence ecosystem stability and change, how that concept relates to the interactions and relationships in an ecosystem, and how ecosystems can be affected by changes in abiotic and biotic factors. Students apply this understanding of the core ideas to constructing and explanation and to engaging in argument, integrating the crosscutting concept of cause and effect.

Activity Overview

In this Elaborate activity, students analyze data about nitrogen input, streamflow, and the size of dead zones. They use this data and additional evidence from a video to construct an explanation about the effect of these factors on the size of the dead zone in the Gulf of Mexico. They then gather additional evidence from a short reading to inform a debate on fertilizer use and dead zones.

Key Vocabulary

dead zone

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip, "Big River: A King Corn Companion | Agricultural Runoff and the Gulf of Mexico Dead Zone," is available from PBS Learning Media. You may need to register for a free account to access the video. A direct link to the segment follows.
  http://ca.pbslearningmedia.org/asset/envh10_vid_deadzone/
- ☐ 1 large computer monitor or projector

For each student

- ☐ Explanation Tool

Teaching Summary

Getting Started

1. Introduce the concept of dead zones.

Doing the Activity

2. Students investigate the effects of abiotic factors on the size of dead zones.
3. Students construct an explanation for the effect of water flow on nitrogen input.

Follow-Up

4. Facilitate a class debate about fertilizer use and dead zones.
5. Revisit the Guiding Question.

References

- Goolsby, D. & W. Battaglin (December 2000) Nitrogen in the Mississippi Basin – Estimating Sources and Predicting Flux to the Gulf of Mexico. United States Geological Survey. https://ks.water.usgs.gov/pubs/fact-sheets/fs.135-00.html

- National Oceanographic and Atmospheric Administration. (August 4, 2014) NOAA-, EPA-supported scientists find average but large Gulf dead zone. U.S. Department of Commerce. https://oceanservice.noaa.gov/new/aug14/gomex-deadzone.html
- United States Geological Survey. (May 8, 2015) Streamflow and Nutrient Flux of the Mississippi-Atchafalaya River Basin and Subbasins Through Water Year 2014. https://toxics.usgs.gov/hypoxia/mississippi/flux_ests/delivery/graphics/index.html

Teaching Suggestions

Getting Started

1. **Introduce the concept of dead zones.** (10 minutes)

    a. Have students read the introduction independently, in pairs, or as a class.

    Explain to students that in this activity they will be looking at other factors, besides the fishing limits they have studied in the last two activities, that might affect fisheries. Ask students to share their ideas about what some of these other factors might be. Accept student answers, then explain that in this activity they will investigate one factor that affects fisheries and is not related to fishing limits. Review the map of the Mississippi Watershed with the students, making sure they understand that the entire watershed, including all of the fertilizer run-off from all of the farms, drains into the Gulf of Mexico (because water flows downhill). You may need to explain to students that most organisms that live under water get their oxygen from the dissolved oxygen in the water (not from the air). Note that the key vocabulary term, dead zone, is defined in the introduction as an area in a body of water where the water at the bottom has little or no dissolved oxygen. Have a short class discussion about how dead zones are created, based on the information given in the introduction. Students will learn more about this in the activity.

Doing the Activity

2. **Students investigate the effects of abiotic factors on the size of dead zones.** (25 minutes)

    a. Show the students the video segment on the dead zone in the Gulf of Mexico.

Ask the students to list any new information they have learned from the video, listing the students' answers on the board for them to reference.

b. Have students work in groups of four to analyze and interpret the graph in Step 3.

You may need to work with individual groups, or the class as a whole, to help them understand the graph in Step 3 with two y-axes. Students should come to the conclusion that nitrogen input and water flow from the Mississippi Basin to the Gulf of Mexico are fairly closely correlated. This is a good point to bring in the crosscutting concept of cause and effect. Have students consider what might cause water flow to change and what effect they would expect to see in the nitrogen input graph as water flow changes. Ask students why they think the correlation is not perfect. Students should be able to suggest additional factors affecting nitrogen input such as changes in fertilizer use by farmers upstream, storms and other weather conditions affecting when and how much water flows at different times of year, etc. Point out to students that these graphs are data from a real scientific study, which often means that patterns can be more challenging to determine. Scientists have to consider all possible factors that might affect the data.

You may also wish to review the difference between causation and correlation. Scientists often find correlations in data, where two variables seem to be related. However, this does not always mean causation. For example, if scientists measured an increase in water flow in the Mississippi River during a year of heavy storms, as well as an increase in nitrogen input into the Gulf, they can say the two events are correlated. However, if further study showed that farms along the Mississippi had significantly decreased their nitrogen use that year, the increase in nitrogen input might not be caused by the increase nitrogen flow. Scientists would need to investigate further to determine if there was another cause, for instance a new source of nitrogen input along the river or in the Gulf. Note that there are numerous reliable, peer-reviewed studies demonstrating that increased water flow in the Mississippi River Basin does cause an increase in nitrogen input into the Gulf of Mexico, and that increased nitrogen input does cause the size of dead zones to increase. There are a number of compounding factors that can affect the specific changes to the size of dead zones, but nitrogen input is considered one, if not the most, significant factor.

3. **Students construct an explanation for the effect of water flow on nitrogen input.** (15 minutes)

a. Have students use the Explanation Tool to construct their explanations.

Depending on the class, you may wish to encourage students to try constructing their explanations without the scaffolding of the

Explanation Tool, or to give individual students that option.

This is a good point to conclude the first class period for the activity.

Follow-Up

4. **Facilitate a class debate about fertilizer use and dead zones.** (40 minutes)

   a. Have the students analyze data on dead zone size.

   Assist students as needed with analysis of the graph on the size of dead zones in the Gulf of Mexico. Students should notice that the size of the dead zone does not necessarily have a direct correlation to the nitrogen input and water flow data from the previous graph. If necessary, have a short class discussion about other factors that might affect the dead zone size (changes in temperature, currents in the Gulf of Mexico, storms or other weather events that affect the Gulf, etc).

   b. Have students complete the reading on the Gulf of Mexico dead zone.

   Have students complete the reading in pairs or groups. Students should note from the data table in the reading that a majority of the nitrogen input in the Gulf of Mexico is from human-made sources.

   c. Have the class conduct a Walking Debate to debate the question "Should fertilizer use be limited to help prevent dead zones?"

   See Section 2 of Teaching Strategies for more details on how to conduct a Walking Debate. Designate one area of the room as "limit fertilizer use" and a second area as "do not limit fertilizer use." If students are not relatively equally distributed at the beginning of the debate you may choose to assign them a viewpoint. For example, you could assign half the class to take the position they think a fisher would take, and half to take a farmer's position. This debate provides an opportunity to evaluate students understanding of the connection to the nature of science crosscutting concept, science knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes. This is also a good time to briefly introduce the idea of constraints on potential solutions, an important concept in Chapter 5. Have student suggest possible solutions to the problem of dead zones, then ask what the limitations, or constraints, are on those solutions. For example, the solution of not using any fertilizer means farmers will not be able to grow as many crops and will make less money.

   d. Review the Analysis Questions

Analysis questions 1 and 2 are an opportunity to assess students deepening understanding of the crosscutting concept of cause and effect, as it connects to the core ideas in this chapter. Consider having students respond to the Analysis questions as homework, to get a better sense of their individual growth in understanding.

Note that for Analysis question 3, students may need some scaffolding to construct their answers. You may wish to draw a template on the board for students, with four numbered panels. Note the sample student response in the Suggested Answers to Analysis section.

5. **Revisit the Guiding Question.** (5 minutes)

   a. Revisit the guiding question, how do humans affect the size of dead zones?

   At this point students should understand that the effect of humans on the size of dead zones is not entirely straightforward, but that there clearly is an effect due to human use of fertilizers. Have students add this example to the crosscutting poster for cause and effect if they have not done so already, as well as the phrase "dead zone" to the class word wall. Point out to students that in the next activity they will be applying their understanding of dead zones in a new context, the oyster fishery in Chesapeake Bay.

   Revisit the Student Question Poster to determine if any of the students' previous questions have been answered, and to record any new questions.

Suggested Answers To Analysis

1. **What are the abiotic and biotic factors that are affected in a dead zone? How do they differ from a healthy ecosystem?**

> **Assessment – DCI and CCC**
> Use this question to assess students' understanding of the core idea of population dependence on environmental interactions (DCI – MS LS2.A.1) and cause and effect (CCC).

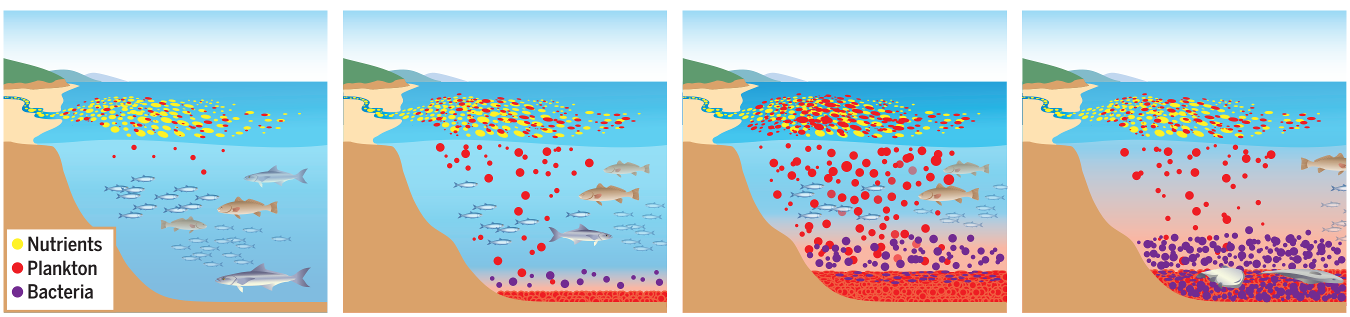
In a dead zone abiotic factors that are affected include oxygen levels and the amount of nitrogen. The oxygen levels are much lower than in a healthy ecosystem and the nitrogen levels are much higher. The biotic factors that are affected are the amount of plankton, bacteria, and fish and other organisms. The *plankton increase because of the higher nitrogen levels. When the plankton die they feed the bacteria, which increase and consume more oxygen. This causes the fish and other organisms to either die or leave the ecosystem. When nitrogen levels are lower, plankton remain at lower level, oxygen levels increase, and fish populations increase.*

2. **How might an increase in the size of the dead zone in the Gulf of Mexico affect the red snapper fishery, or other fisheries?**

> **Assessment – DCI and CCC**
> Use this question to assess students' understanding of the core ideas of population dependence on environmental interactions and how the increase of human populations affects the Earth (DCI MS ESS3.C.2) and cause and effect (CCC).

An increase in the dead zones might cause a decrease in the red snapper fishery, or other fisheries in the Gulf of Mexico, because there would not be enough oxygen for the fish to survive. This would mean fewer fish, and that the fishermen would not have as much to catch so they would make less money.

3. **Draw a diagram with four panels showing the main stages in the creation of a dead zone. The panel below[see student book] is an example of what the fourth panel in your diagram might look like. Include a caption for each panel that explains what is happening in the diagram.**



Panel 1: Nutrients in the water, like nitrogen, increase from runoff from farms

Panel 2: Plankton population increases. As they die they sink to the bottom.

Panel 3: An increase in dead plankton causes an increase in bacteria (decomposers).

Panel 4: Increased bacteria populations use up the oxygen, causing fish and other organisms to die or leave the ecosystem.

Extension

Students may be curious to learn about local water quality issues. In addition to suggesting the U.S. Environmental Protection Agency website (epa.gov) as a source of information, you may wish to gather additional websites from state and local organizations that deal with water quality issues. These might include state environmental protection agencies, departments of natural resources, or municipal water districts.

Activity 3.4

Elaborate: Dead Zones

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip, "Big River: A King Corn Companion | Agricultural Runoff and the Gulf of Mexico Dead Zone," is available from PBS Learning Media. You may need to register for a free account to access the video. A direct link to the segment follows.
  http://ca.pbslearningmedia.org/asset/envh10_vid_deadzone/

- ☐ 1 large computer monitor or projector

For each student

- ☐ Explanation Tool

Teaching Suggestions

Getting Started

1. **Introduce the concept of dead zones.** (10 minutes)

   a. Have students read the introduction independently, in pairs, or as a class.

Doing the Activity

2. **Students investigate the effects of abiotic factors on the size of dead zones.** (25 minutes)

   a. Show the students the video segment on the dead zone in the Gulf of Mexico.

   b. Have students work in groups of four to analyze and interpret the graph in Step 3.

3. **Students construct an explanation for the effect of water flow on nitrogen input.** (15 minutes)

   a. Have students use the Explanation Tool to construct their explanations.

Follow-Up

4. Facilitate a class debate about fertilizer use and dead zones. (40 minutes)

a. Have the students analyze data on dead zone size.

b. Have students complete the reading on the Gulf of Mexico dead zone.

c. Have the class conduct a Walking Debate to debate the question "Should fertilizer use be limited to help prevent dead zones?"

d. Review the Analysis Questions.

5. Revisit the Guiding Question. (5 minutes)

a. Revisit the guiding question, how do humans affect the size of dead zones?

2 class sessions

Chesapeake Bay Oysters

How do increases in the human population affect the resources available to organisms?

Students conclude the chapter with an investigation that examines the effects of fishing and dead zones on the Chesapeake Bay Oyster fishery. This allows for the evaluation of students' understanding of the effects of resource availability on organisms and populations of organisms as well as how increases in the human population impact the Earth's systems. This also prepares them to investigate another complex ecosystem disruption, invasive species, in the next chapter.

Rationale and NGSS Integration

This Evaluate activity concludes the chapter with an investigation of data on the Chesapeake Bay oyster fishery, which has been affected by both overfishing and dead zones. Students analyze and interpret data to provide evidence for an argument focused on if the increase in the human population in the Chesapeake Bay area is a cause of changes in the oyster fishery in the Bay. This allows students to bring together multiple practices and crosscutting concepts while demonstrating their understanding of content and performance expectations for the chapter.

This Evaluate activity draws together the three dimensions of the NGSS that support the two performance expectations that are the focus of this chapter.

Activity Overview

In this activity, students learn about the Chesapeake Bay ecosystem and the oyster harvests in the Bay. They analyze and interpret data about the nitrogen run-off, dead zone size, and oyster harvests to develop an argument about the effect of the human population on the Chesapeake Bay oysters.

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing Arguments

For each student

- ☐ Argument Tool

Teaching Summary

Getting Started

1. Students learn about the ecosystem and oyster fishery in Chesapeake Bay.

Doing the Activity

2. Students analyze data on dead zones in Chesapeake Bay.

Follow-Up

3. Students develop an argument about the effect of increasing human populations on the Chesapeake Bay oyster harvest.

4. Revisit the Guiding Question.

References

- Chesapeake Bay Foundation. (July 2010) On the Brink: Chesapeake's Native Oysters www.cbf.org/document-library/cbf-reports/Oyster_Report_for_Release02.aJ.pdf

- Chesapeake Bay Program. (2015) Nitrogen Loads and River Flow to the Chesapeake Bay. https://www.chesapeakebay.net/indicators/indicator/nitrogen_loads_and_river_flow_to_the_bay1

- Integration & Application Network. (2013) Summer (June through September) 2013 Hypoxia Forecast. http://ian.umces.edu/ecocheck/forecast/chesapeake-bay/2013/indicators/average_hypoxia/#_Data

Teaching Suggestions

Getting Started

1. **Students learn about the ecosystem and oyster fishery in Chesapeake Bay.** (20 minutes)

   a. Have student pairs read the introduction and complete Steps 1 through 3.

   Explain to students that in this activity they will be bringing together what they have learned over the entire chapter and applying their knowledge to a new scenario: the oyster fishery in Chesapeake Bay. Be sure students review the map, and that they understand the graph in Step 1.

   Ask students if they think there has been an increase in the human population in the area around Chesapeake Bay since 1950. You may want to point out that Washington D.C., the nation's capital, is in this area. Students will likely say there has been an increase in the human population. Explain to students that because the Chesapeake Bay ecosystem extends into several states, and does not have a specific geographic land boundary, there is no single data set showing human population growth in the Chesapeake Bay ecosystem area. However, there has been significant growth in the human population since 1950 in each state that borders the Bay, including the specific land areas, towns, and cities surrounding and on the edges of the Bay.

   b. Have a class discussion about students' predictions.

   Discuss students' predictions of how the oyster population change might affect other organisms in the ecosystem. Student responses will vary depending on which organisms they chose to focus on in Step 2, but ultimately all students should conclude that as the oyster population decreases there is less competition for organisms similar to the oyster, but also that there will be increased pressure from predators on those organisms. For example, the food web shows two predators of the eastern oyster – the blue crab and sea ducks. With fewer eastern oysters available the pressure on the softshell and hardshell clams will be increased as the blue crab utilizes more of an alternative food source. Similarly the pressure on aquatic plants will be increased from sea ducks.

Doing the Activity

2. **Students analyze data on dead zones in Chesapeake Bay.** (20 minutes)

   a. Have student pairs analyze the graphs in Part B.

Students should notice a clearer correlation between increased nitrogen and increased dead zone size than in the previous activity. They should also notice that increases in the dead zone correlate with decreases in the oyster harvest. In some years, the decrease in the oyster harvest occurs in the year (or years) just after an increase in the dead zone. If needed, point out to students that the graph in this section only shows data from 1990 to 2013, while the graph in the introduction shows data beginning in 1950. This means the graphs are on a different scale, so the fluctuations in the population levels in this graph do not necessarily indicate that the population is returning to historic levels.

If students are struggling to determine patterns in the data, encourage them to compare specific data points. For example, in 2004 the nitrogen run off increased, as did dead zone size, and the oyster harvest was very low. Also, after high nitrogen run-off between 1997-1999, the dead zone peaked in 1999 and oyster harvests went into decline the following year and for several years after that.

This is a good point to conclude the first class period for this activity.

Follow-Up

3. **Students develop an argument about the effect of increasing human populations on the Chesapeake Bay oyster harvest.** (25 minutes)

   a. Students develop a scientific argument around the question "Is an increasing human population in the Chesapeake Bay area affecting the number of oysters in the Bay?"

   As this is an Evaluate activity, students should construct their arguments independently, not in pairs or groups. Their arguments can also be used to assess the performance expectation "Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations in an ecosystem" and "Construct an argument supported by evidence for how increases in human population…impact Earth's systems." See the sample student response in the Handouts Section of the Teacher's Guide. Student responses may be scored using the Argument rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. For more information about peer review of writing, see Section 4 of Teaching Strategies.

4. **Revisit the Guiding Question.** (15 minutes)

   a. Return to the Guiding Question, "How do increases in the human population affect the resources available to organisms?"

It is a generalized version of the question that students use to develop their arguments in this activity. To conclude this chapter, have a brief class discussion about this question after students have completed writing their arguments.

Suggested Answers To Analysis

1. **Suppose two species of fish that live in the Chesapeake Bay only reproduce during July. For the fish eggs to mature properly and hatch, there must be at least 2 mg/L of oxygen in the water. Based on the diagram below [see student book], answer the following:**

> **Assessment – PE LS2-1**
> Use this question to assess students understanding of the performance expectation "Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem."

a. **Which resources will the two species of fish have to compete for in order to breed successfully?**

The fish will have to compete for space and for water with enough oxygen for their eggs to mature and hatch.

b. **What effect might this competition have on the populations of the two fish, both long- and short-term?**

In the short term this competition might mean that some fish in both populations have fewer or no offspring, depending on where they lay their eggs. In the long term it will probably affect fish species 2 the most, because their breeding zone is lower in the water where there is less oxygen. Their population will probably decrease. Fish species 1 will probably not decrease very much because only a very small portion of their breeding zone is in the area with not enough oxygen to support their eggs.

Activity 3.5

Evaluate: Chesapeake Bay Oysters

Materials and Advance Preparation

For the teacher

- ☐ Scoring Rubric: Developing Arguments

For each student

- ☐ Argument Tool

Teaching Suggestions

Getting Started

1. **Students learn about the ecosystem and oyster fishery in Chesapeake Bay.** (20 minutes)
   - **a.** Have student pairs read the introduction and complete Steps 1 through 3.
   - **b.** Have a class discussion about students' predictions.

Doing the Activity

2. **Students analyze data on dead zones in Chesapeake Bay.** (20 minutes)
   - **a.** Have student pairs analyze the graphs in Part B.

Follow-Up

3. **Students develop an argument about the effect of increasing human populations on the Chesapeake Bay oyster harvest.** (25 minutes)
   - **a.** Students develop a scientific argument around the question "Is an increasing human population in the Chesapeake Bay area affecting the number of oysters in the Bay?"
4. **Revisit the Guiding Question.** (15 minutes)
   - **a.** Return to the Guiding Question, "How do increases in the human population affect the resources available to organisms?"

CHAPTER

4 Zebra Mussels

Activity 4.1
Engage

How might the introduction of the zebra mussel affect the health of the Great Lakes and Hudson River ecosystems?

Students begin the chapter with an introduction to a different type of ecosystem disruption, an invasive species. Students draw on what they have learned previously in the unit to begin to ask questions about how the introduction of the zebra mussel might disrupt the Hudson River and Great Lakes ecosystems.

Activity 4.2
Explore

What biotic and abiotic factors are affected when a new species is introduced to an ecosystem?

Students explore how the introduction of the zebra mussel has affected the Hudson River and Great Lakes ecosystems. Students use this knowledge to develop a testable question to investigate their initial ideas about the effect of an invasive species prior to looking at real-world data.

Activity 4.3
Explain

How did the zebra mussel initially affect the health and biodiversity of the Hudson River ecosystem?

Students investigate short-term data on the effects of the introduction of the zebra mussel to the Hudson River ecosystem. Students analyze data on three biotic and abiotic factors to determine the accuracy of their predictions from the previous activity about the effect of the zebra mussel.

Activity 4.4
Elaborate

What are the long-term effects of the zebra mussel invasion of the Hudson River?

Students transition to looking at long-term data on the effects of the zebra mussel. This allows them to deepen their understanding of dynamic ecosystems, and the importance of looking at disruption of ecosystems in both the short- and long-term.

Activity 4.5
Evaluate

Has the quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?

Students conclude the chapter with an investigation of another invasive species in the Great Lakes ecosystem, the quagga mussel, which has displaced much of the zebra mussel population. This allows for the evaluation of students' understanding of dynamic ecosystems and the effects of invasive species, while setting them up to investigate possible solutions for ecosystems disruptions in the following chapter.

Chapter 4 Overview

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Engage **4.1 Hudson River Ecosystem** **Guiding Question:** How might the introduction of the zebra mussel affect the health of the Great Lakes and Hudson River ecosystems? Students begin the chapter with an introduction to a different type of ecosystem disruption, an invasive species. Students will investigate the Hudson River ecosystem by constructing a food web before the introduction of the zebra mussel. Students will then predict what affects the zebra mussel introduction would have on that food web.	MSLS2C.1 Patterns Cause & Effect	Analyzing and Interpreting Data Using Models	health of the ecosystem	2
Explore **4.2 Introducing a New Species** **Guiding Question:** What biotic and abiotic factors are affected when a new species is introduced to an ecosystem? Students explore further how the introduction of the zebra mussel might disrupt the Hudson River and Great Lakes ecosystems. They will choose three biotic and/or abiotic factors that might be affected by the zebra mussels and develop a testable question about the possible affects. Students will predict the answers to their questions, which they will test in the next activity.	MSLS2C.1 (prior knowledge)	Obtaining and Evaluating Information	biotic/abiotic factors dynamic ecosystem	1-2
Explain **4.3 Biodiversity in Ecosystems** **Guiding Question:** How did the zebra mussel initially affect the health and biodiversity of the Hudson River ecosystem? Students will use a web-based graphing tool to graph and analyze how the zebra mussel affects the abiotic and biotic factors they chose in the last activity. Students will then read about the short-term effects of the zebra mussel on both the Hudson River and Great Lakes ecosystems, and engage in an oral debate about the effect of the zebra mussel on the Hudson river ecosystem.	MSLS2C.1 MSLS2A.1 MSLS2A.2 MSLS4D.1 Cause & Effect Stability & Change	Asking Questions Planning & Carrying Out an Investigation Analyzing & Interpreting Data Constructing Explanations Engaging in Argument from Evidence	biodiversity ecosystem services biotic/abiotic factors health of the ecosystem	2-3

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Elaborate **4.4 The Zebra Mussel Problem: 20 Years of Data** **Guiding Question:** What are the long-term effects of the zebra mussel invasion of the Hudson River? Students extend the prior investigation to analyze and interpret long-term data on the effects of the zebra mussel invasion on the Hudson River. Focusing on the same biotic/abiotic factors as in prior activities, students plan and carry out an investigation. Students graph and analyze long-term data and look for patterns. Students watch a video on the long-term monitoring by scientists of the Hudson River. They construct a scientific explanation about the long-term effects of the zebra mussels on the river ecosystem. Students read about the long-term changes in the river ecosystem and revise their explanations. They then construct a scientific argument to debate the question, "Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?" Students consider how the effects of the zebra mussel in the Hudson River relate to stability and change in ecosystems.	MSLS2C.1 MSLS2A.1 MSLS2A.2 MSLS4.D.1 Patterns Cause & Effect Stability & Change	Analyzing & Interpreting Data Obtaining and Evaluating Information Constructing Explanations Engaging in Argument from Evidence	biotic/ abiotic factors health of the ecosystem	2-3
Evaluate **4.5 A New Mussel in Town** **Guiding Question:** Has the quagga mussel had a positive or negative effect on the Lake Michigan ecosystem? Students construct a scientific argument about whether the quagga mussel has had a positive or negative effect on the Lake Michigan ecosystem. Students read about the quagga mussel invasion and look for patterns in long-term data by analyzing and interpreting both biotic and abiotic factors over time in Lake Michigan. Students use the prior scientific explanations about the short- and long-term impact of the zebra mussel in the Hudson River to help construct their scientific argument.	MSLS2C.1 MSLS2A.1 MSLS2A.2 Patterns Cause & Effect Stability & Change	Analyzing & Interpreting Data Obtaining and Evaluating Information Engaging in Argument from Evidence	biotic/ abiotic factors health of the ecosystem	2

Assessment Overview

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explore	Activity 4 Explain	Activity 5 Elaborate
Disciplinary Core Ideas					
MS LS2.C.1*	Step 10	Analysis 2	Stop to Think 3	Step 11	
MS LS2.A.1**			Stop to Think 1,3,4	Step 14	
MS LS2.A.2**	Steps 7 & 10			Step 11	
MS LS4.D.1***			Stop to Think 4 Analysis 4		
Science and Engineering Practices					
Asking Questions		Step 7			
Analyzing and Interpreting Data**			Stop to Think 2 Analysis 2	Steps 8 & 9	
Constructing Explanations and Designing Solutions				Step 11	
Engaging in Argument from Evidence*			Step 11	Step 12	
Obtaining Evidence and Communicating Information		Step 1	Step 10		
Crosscutting Concepts					
Stability and Change*		Analysis 1 & 2	Analysis 1	Analysis 2 & 4	
Cause and Effect**	Step 10 Analysis 1	Step 7 Analysis 3	Stop to Think 3	Stop to Think 1	
Patterns				Analysis 3	

* Primary PE and supporting elements **Secondary PE and supporting elements ***Not associated with PE

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explore	Activity 4 Explain	Activity 5 Elaborate
Performance Expectations					
MS-LS2-4*					Step 1 & 2
MS-LS2-1**					Step 1 & 2 Analysis 2
CCSS ELA					
RST.6-8.1			Stop to Think 1–4	Stop to Think 1	
RST.6-8.8					Step 1
WHST.6-8.1				Step 13	Step 1
WHST.6-8.9				Analysis 4	

* Primary PE and supporting elements **Secondary PE and supporting elements ***Not associated with PE

PE	**MS-LS2-4** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
	MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resources availability on organisms and populations of organisms in an ecosystem.
DCI	**MS LS2.C.1** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.
	MS LS2.A.1 Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with non-living factors.
	MS LS2.A.2 In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constraints their growth and reproduction.
	MS LS4.D.1 Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on.

SEP	**AQ:** Ask questions to determine relationships between independent and dependent variables and relationships in models.
	AID: Analyze and interpret data to provide evidence for phenomena.
	CEDS: Apply scientific ideas, principles, and evidence to construct an explanation for real-world phenomena.
	CEDS: Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
	EAE: Construct an oral or written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
	OECI: Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).
CCC	**S&C:** Small changes in one part of a system might cause large changes in another part.
	C&E: Cause and effect relationships may be used to predict phenomena in natural or designed systems.
	P: Patterns can be used to identify cause and effect relationships.
CC ELA	**RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts.
	WHST.6.8.1 Write arguments focused on discipline-specific content.
	WHST.6-8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
	WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.
	SL.8.1 Engage effectively in a range of collaborative discussions (e.g., one-on-one, in groups, teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

2 class sessions

Hudson River Ecosystem

How might the introduction of the zebra mussel affect the health of the Great Lakes and Hudson River ecosystems?

Students begin the chapter with an introduction to a different type of ecosystem disruption, an invasive species. Students draw on what they have learned previously in the unit to begin to ask questions about how the introduction of the zebra mussel might disrupt the Hudson River and Great Lakes ecosystems.,

Rationale and NGSS Integration

In this Engage activity students use the science and engineering practices of developing and using models and asking questions. They build a model of the food web in the Hudson River ecosystem before the introduction of the zebra mussel. Students use their models to understand the mechanism for the disruption caused by the zebra mussel on the ecosystem. Their explorations of this disruption contextualize the crosscutting concepts of stability and change and cause and effect as they begin to explore the phenomenon of the effect of an introduced species on an ecosystem.

This activity introduces the concept of invasive species and is intended to elicit students' ideas and engage them in the story of invasive species in the Hudson River and Great Lakes. This story provides the example of an environmental disruption—the invasive zebra mussel—that students focus on in this chapter. Students revisit and build on their ideas and questions from this activity throughout the chapter. Overall, the scientific practices developed in this chapter are constructing explanations and engaging in argument from evidence, with a secondary emphasis on analyzing and interpreting data. Students engage in these practices when they analyze data and develop their own explanations and arguments about the effects of the invasive zebra mussels on the Hudson River and Great Lakes ecosystems. Because this is an Engage activity, students do not delve deeply into the practices. They do begin thinking about how the crosscutting concept of stability and change relates to the Great Lakes and Hudson River ecosystems, and also begin generating questions about the effects of the zebra mussel on these ecosystems.

Review the chapter overview and assessment chart for an overview of the NGSS taught and assessed in this activity and how the standards are woven together throughout the chapter. Decide in advance which assessments you plan to emphasize.

Activity Overview

In this Engage activity students are introduced to the invasive zebra mussel through a video clip. Students investigate the Hudson River ecosystem by constructing a food web before the introduction of the zebra mussel. Students then predict what effects the zebra mussel introduction would have on that food web. The class generates a KWL chart that they will use to express, monitor and revise their thinking throughout the chapter.

Key Vocabulary

estuary

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the first video clip, "The Problem." The other clips will be used later in the chapter. The link to the segment follows.
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each group of four students

- ☐ 1 set of 9 Hudson River Ecosystem cards
- ☐ 1 additional Hudson River Ecosystem card: Zebra Mussel

For each student

- ☐ 1 Handout 4.1-1, "Ecosystems Comparison"

- ☐ 1 Handout 4.1-2, “Hudson River Food Web before Zebra Mussels” (optional)
- ☐ 1 Handout 4.1-3, “Hudson River Food Web after Zebra Mussels” (optional)

Teaching Summary

Getting Started

1. The class starts a KWL chart.

Doing the Activity

2. The class watches the video clip “The Problem.”

3. Students construct a food web for the Hudson River ecosystem.

Follow-Up

4. The class returns to the KWL chart.

5. Preview the chapter and revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. The class starts a KWL chart. (10 minutes)

a. Have students read the introduction to the activity.

Use the introduction as a starting point for eliciting students’ prior knowledge about river and ocean ecosystems, the Hudson River, and invasive species. Encourage them to think about what they learned in the previous chapter about fisheries and dead zones. In this Engage activity, it is important to keep the class and group discussions very open ended. This phase serves to elicit students’ prior knowledge and begins to surface any misconceptions. As students express their ideas, simply make a note to yourself of misconceptions students have so that you can revisit them when the students are further through the chapter. At that point students will be able to correct many misconceptions through their own growth in understanding.

b. Start a KWL chart with the class by asking the students what they already know about the Gulf of Mexico, Great Lakes, and Hudson River.

You will be using this chart throughout this chapter, so be sure to create it in such a way that it can be revisited (e.g. create an electronic file to project, put it on chart paper on the wall, etc.). Ask students for answers for the first column, What We Know, about the Gulf of Mexico, Great Lakes, and Hudson River. This could be done as a warm-up that students complete individually, followed by having the students offer their ideas to add to the class chart. Students' ideas will vary depending on students' prior knowledge. If necessary, ask the students questions to draw on their prior knowledge. For example the question, "If the Great Lakes is a lake ecosystem, what do we know about the water?" might lead students to the answer "It's probably fresh water." Then move to the second column, What We Want to Know, and have student suggest questions about what they want to know about these three ecosystems. For additional information on the use of KWL charts see Section 2 in Teaching Strategies.

Doing the Activity

2. **The class watches the video clip, "The Problem."** (10 minutes)

   a. Have the class watch the video clip, "The Problem."

   b. Have students suggest information to add to the W and L columns on the KWL chart.

      Have students add what they have learned from the video clip to the KWL chart. There is no specific information in the video clip that students need to remember. It is used to get students to begin thinking about the problem of an invasive species.

3. **Students construct a food web for the Hudson River ecosystem.** (30 minutes)

   a. Once students have constructed their food web and discussed the patterns of interactions they see, give them the Zebra Mussel card to add into their food webs.

      Once they add the card students should notice that the zebra mussel, as a filter feeder, is competing with native mussels and other organisms for the plankton, which will lead to smaller populations of native filter feeders. They should also notice that because the secondary consumers in the ecosystem do not prey on the zebra mussels, lower populations of native filter feeders means less food for the secondary consumers.

      Two optional handouts are provided for this activity, a sample food web before and after the zebra mussel introduction. These handouts can be used to scaffold the activity for ELLs or special needs students, or to shorten the activity if needed.

4. Have students work in groups of four to begin filling in Handout 4.1-1.

More details on the chart the students are filling out, a DART (Directed Activity Related to Text), can be found in the Section 2 of Teaching Strategies. Once students have filled in as much information as they can, have them discuss in groups of four what they still want to know about these ecosystems and record their group's questions.

A sample answer can be found in the Handouts section of the Teacher's Guide. It includes information students will add in Activities 4.2 and 4.3.

Follow-Up

5. **The class returns to the KWL chart.** (10 minutes)

a. Have the class add questions to the "Want to Know" column, and new information to the "What We Have Learned" column of the KWL chart.

Be sure to keep the class discussion very open-ended, and do not correct any misconceptions students might bring up, since this is an engage activity. If students independently correct their own, or another student's misconception, it is appropriate to correct them on the chart.

6. **Preview the chapter and revisit the Guiding Question.** (15 minutes)

a. Preview the chapter with the students.

Use the Chapter Overview to guide you as you preview the rest of the chapter with the class. Introduce the guiding question for the chapter, "How do new organisms affect the environment?" Write this question on chart paper, a board, or some other location where it can be seen by the students as the class works through the rest of the chapter. Be sure to refer back to the question at appropriate points in subsequent activities. Briefly preview the content they will be learning, including the disciplinary core ideas, crosscutting concepts, and science and engineering practices they will use to build conceptual understanding.

Explain to students that in this chapter they will continue to develop their skills with three scientific practices they have already utilized in previous chapters: analyzing and interpreting data, constructing explanations, and engaging in argumentation supported by scientific evidence. They will do this by investigating the phenomenon of how the introduction of the zebra mussel is affecting the resources and patterns of interaction in the Hudson River and Great Lakes ecosystem, an example of a cause-and-effect relationship that impacts the stability of an ecosystem.

b. Revisit the Guiding Question

Conclude the activity by revisiting the Guiding Question, "How might the introduction of the zebra mussel affect the health of the Great Lakes and Hudson River ecosystems?" with the whole class. The Analysis section will encourage students to develop their ideas and formulate their responses to the Guiding Question. Students' predictions may vary, but they will likely suggest that the zebra mussel will change the patterns of interactions in both ecosystems because they will change the food web. Students may point out that zebra mussels might consume a lot of the plankton, leaving little for other organisms in the ecosystem. Students may suggest that the effects could be different in the portion of the Hudson River that is an estuary.

Suggested Answers To Analysis

NOTE: Analysis questions marked with **Assessment** are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **How do you predict the introduction of the zebra mussel will affect each of the following in the Hudson River ecosystem:**

   a. **the flow of energy.**

   b. **the location and cycling of matter.**

   I predict that the zebra mussel will change the flow of energy and the location and cycling of matter in the Hudson River ecosystem because a) a lot more of the energy will go into the zebra mussels and b) a lot more of the matter will flow into the zebra mussels then stay there until they die because the zebra mussels will eat a lot of the plankton in the ecosystem and they do not have any natural predators in the Hudson River.

Activity 4.1

Engage: Hudson River Ecosystem

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the first video clip, "The Problem." The other clips will be used later in the chapter. The link to the segment follows:
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each group of four students

- ☐ 1 set of 9 Hudson River Ecosystem cards
- ☐ 1 additional Hudson River Ecosystem card: Zebra Mussel

For each student

- ☐ 1 Handout 4.1-1, "Ecosystems Comparison"
- ☐ 1 Handout 4.1-2, "Hudson River Food Web before Zebra Mussels" (optional)
- ☐ 1 Handout 4.1-3, "Hudson River Food Web after Zebra Mussels" (optional)

Teaching Suggestions

Getting Started

1. **The class starts a KWL chart.** (10 minutes)
   - **a.** Have students read the introduction to the activity.
   - **b.** Start a KWL chart with the class by asking the students what they already know about the Gulf of Mexico, Great Lakes, and Hudson River.

Doing the Activity

2. **The class watches the video clip, "The Problem."**
   - **a.** Have the class watch the video clip, "The Problem."
   - **b.** Have students suggest information to add to the W and L columns on the KWL chart.
3. **Students construct a food web for the Hudson River ecosystem.** (30 minutes)
   - **a.** Once students have constructed their food web discussed the patterns of interactions they see, give them the Zebra Mussel card to add into their food webs.
   - **b.** Have students work in groups of four to begin filling in Handout 4.1-1.

Follow-Up

4. **The class returns to the KWL chart.** (10 minutes)
   - **a.** Have the class add questions to the "Want to Know" column, and new information to the "What We Have Learned" column of the KWL chart.
5. **Preview the chapter and revisit the Guiding Question.** (15 minutes)
   - **a.** Preview the chapter with the students.
   - **b.** Revisit the guiding question, "How might the introduction of the zebra mussel affect the health of the Great Lakes and Hudson River ecosystems?" to conclude the activity.

1–2 class sessions

Introducing a New Species

What biotic and abiotic factors are affected when a new species is introduced to an ecosystem?

Students explore how the introduction of the zebra mussel has affected the Hudson River and Great Lakes ecosystems. Students use this knowledge to develop a testable question to investigate their initial ideas about the effect of an invasive species prior to looking at real-world data.

Rationale & NGSS Integration

In this Explore activity students read a case study on the effects of the zebra mussel on the Hudson river ecosystem. Using the information obtained from this reading and their prior knowledge the students develop questions and predictions about cause-and-effect relationships impacting ecosystem stability and change that they will test in the following activities as they investigate the zebra mussels' effects in more depth and in the long term.

Activity Overview

In this Explore activity students are introduced to the invasive zebra mussel through a video clip and a case study on the ecological disruption the mussel has caused in the Hudson River and the Great Lakes. They choose three biotic and/or abiotic factors that might be affected by the zebra mussels and develop a testable question about the possible effects. Students predict the answers to their questions, which they will test in the next activity.

Key Vocabulary

dynamic ecosystem

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the first video clip, "Observation" The other clips will be used later in the chapter. The link to the segment follows:
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each student

- ☐ 1 Handout 4.1-1, "Ecosystems Comparison" (from Activity 4.1)

Teaching Summary

Getting Started

1. Review the introduction with the class.

Doing the Activity

2. Students complete the reading, "An Unwelcome Newcomer," using the Read, Think, and Take Note strategy.

3. Students watch a video clip about scientists collecting data in the Hudson River ecosystem.

4. Students choose three biotic and/or abiotic factors to investigate further and develop testable questions for their investigations.

Follow-Up

5. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Review the introduction with the class.** (10 minutes)

    a. Have students read the introduction to the activity or read it aloud.

    Explain to students that in this activity they will be exploring the introduction of the zebra mussel to the Hudson River ecosystem in more depth. Discuss the definition of dynamic ecosystem in the introduction and have students suggest other examples, such as Yellowstone or a local ecosystem they are familiar with, and why they think those ecosystems are dynamic. It may help to remind students to think about patterns of interactions in ecosystems they have observed in previous chapters and when and how those patterns change. If necessary, prompt students to discuss changes in ecosystems without natural or human-caused disturbances, such as the natural fluctuation of predator and prey population size. Add dynamic ecosystem to the word wall.

Doing the Activity

2. **Students complete the reading, "An Unwelcome Newcomer," using the Read, Think, and Take Note strategy.** (45 minutes)

    a. Have students complete the reading individually as they use the Read, Think, and Take Note strategy.

    Model the strategy for the students using the first paragraph and/or the map from the reading. As you read aloud, stop periodically and tell the students what you are thinking as you read. Write your thoughts on the reading, using a document camera or other system to show students what you are doing. For example, while modeling looking at the map you might note the thought "Lake Ontario and Lake Erie both border New York." This strategy makes transparent for students the thoughts going through their heads as they read, which is particularly important for struggling readers. It may be helpful to have students chose one or two types of responses to focus on, for example just identifying words they do not know and places in the text where they are confused. As students become more familiar with the strategy they can increase the types of responses they record.

    If a read aloud is necessary make sure to stop periodically to give students a chance to make notations according to the strategy, or have students read a few sections on their own, then go through them again as a class. For additional information on this strategy see Section 2 of Teaching Strategies.

Depending on time you may need to break the reading up over two class sessions, or do a preview of the reading with the students during the first class session and have them read individually during the second.

3. **Students watch a video clip about scientists collecting data in the Hudson River ecosystem.** (10 minutes)

   a. Show students the video clip, "Observation."

   Have students focus on why it is important for scientists to collect data on abiotic factors.

   Have the class add this information to the KWL chart, as well as any new questions they now have.

   This can be used as a conclusion to the first class session.

4. **Students choose three biotic and/or abiotic factors to investigate further and develop testable questions for their investigations.** (30 minutes)

   a. Allow students time to review abiotic factors and chose one abiotic and two biotic factors to investigate.

   Review, but do not comment on, students' choice of factors. Be sure students have chosen at least one factor that is clearly affected by the zebra mussel. If necessary, without explaining why, have students change their factors so that they are investigating at least one factor that is clearly affected by the zebra mussel. The chart on the following page indicates the effect of zebra mussels on the various factors in the short term. Do not share this information with the students, as they will be drawing their own conclusions in the activity based on the data they analyze. Factors with "some effect" may be difficult for students to interpret. Note that Unionidae data is only available for long-term investigation in Activity 4.4.

   b. Guide students in developing a testable question and prediction for each factor they chose.

   Have students write a formal question, asking how the introduction of the zebra mussel affects the factor they want to study. For example, "How did the zebra mussel affect the phytoplankton?"

   Have students write an if-then-because statement as their prediction for each factor. For example, "I predict that IF the zebra mussel population increases THEN the phytoplankton population will decrease BECAUSE zebra mussels eat plankton."

   Use Probe Questions during this Explore activity to encourage students to elaborate on their questions. See Section 2 of Teaching Strategies for more information on Elicit, Probe, and Challenge Questions. This step can be used to check for students' understanding of developing and asking questions, as well as cause and effect relationships.

Short-Term Effect of Zebra Mussel Invasion on Biotic and Abiotic Factors in the Hudson River Ecosystem

Factor	Clear Effect	Some Effect	No Effect
Alosa (pelagic fish)	✔		
Bacteria	✔		
Centrachidae (littoral fish)	✔		
Cladocera (zooplankton)	✔		
Copepods (zooplankton)		✔	
Dissolved Oxygen			✔
Phytoplankton	✔		
Rotifers (zooplankton)	✔		
Sphaeriidae (mollusk)	✔		
Suspended Solids		✔	
Unionidae (mollusk)	*no data available*	*no data available*	*no data available*
Water Clarity	✔		
Water Temperature			✔

Follow-Up

5. **Revisit the Guiding Question** (5 minutes)

   a. Revisit the guiding question, "What biotic and abiotic factors are affected when a new species is introduced to an ecosystem?" to conclude the activity.

   Have students add to the crosscutting concepts posters. The crosscutting concepts of stability and change, cause and effect, and matter and energy relate to the core ideas in this activity. Ask the students how these cross cutting concepts might help scientists to think about how problems and questions in ecology, and specifically about the introduction of the zebra mussel to the Hudson River ecosystem. For stability and change, students may suggest that the zebra mussel is a source of a variety of potential changes in the ecosystem, yet some factors remained stable or changed only a little. Similarly, for cause and effect, students will likely suggest examples of how the zebra mussels may cause such effects in the Hudson River ecosystem such as a decrease in plankton or an increase in water clarity. For energy and matter, students may suggest that more matter and energy flow to zebra mussels, and less to some other populations.

b. Have students suggest additions to the word wall and crosscutting concept posters.

Estuary is a key vocabulary term that is introduced and defined in the reading. See the More Information section at the end of this activity for suggestions on using Key Vocabulary. The crosscutting concept of stability and change is helpful for thinking about the phenomena described in this activity, particularly in Analysis 2. Students will likely suggest that the zebra mussel and the Hudson is an example of stability and change because the ecosystem was stable, but with the introduction of the zebra mussel it may be changing.

Suggested Answers To Analysis

NOTE: Analysis questions marked with **Assessment** are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **Explain how the Hudson River is an example of a dynamic ecosystem. Use observations from the activity to support your answer.**

> **Assessment – DCI - MS LS2.A.1**
> Use this question to assess students understanding of populations, dependence on interactions with biotic and abiotic factors (DCI MS LS2.A.1), in particular in the context of the term "dynamic ecosystem."

Students' responses will vary depending on the factors they chose to explore. You may wish to have a class discussion about this question so that students can share varying ideas about how the Hudson River ecosystem changes based on their predictions from the activity. This is also a good opportunity to check that students understand that all ecosystems are dynamic to some extent, and that the Hudson River ecosystem was dynamic prior to the introduction of the *zebra mussel. This discussion could be before or after students write responses to the question independently or in groups. A sample answer is provided on the following page.*

The Hudson River is an example of a dynamic ecosystem because it is always changing. As one population increases a little another may decrease. Different organisms eat the plankton, like the native mussel, native clam, Alosa, and zebra mussel. If the number of plankton change, that could change the size of the populations of these organisms. For example, if there is less plankton there would be less of all of these organisms.

2. **Think about the differences and similarities between abiotic and biotic factors in the Hudson River, the Great Lakes, and the Gulf of Mexico. Do you think the zebra mussels will spread to the Gulf of Mexico? Explain why or why not.**

   I do not think zebra mussels will spread to the Gulf of Mexico because it is salt water and the zebra mussels live in fresh water. If there is enough fresh water from the Mississippi where it runs into the Gulf of Mexico the zebra mussels might spread to the top of the Gulf.

3. **How do you think the zebra mussel will change the Hudson River ecosystem?**

   > **Assessment – DCI - MS LS2.C, CCC - Stability and Change**
   > Use this question to gauge students initial ideas about the dynamic nature of ecosystems (DCI MS LS2.C).

   Note that students' ideas will vary because they do not have much information yet about the effects of the zebra mussel on the Hudson River ecosystem. The accuracy of their predictions is not important at this point, but it is important that they suggest some type of change to the ecosystem. A sample answer follows.

   I think the zebra mussel will eat a lot of the plankton in the Hudson River. This might leave less food for some animals in the Hudson River ecosystem and might in turn cause changes in the size of their populations.

4. **Suppose a group of scientists wants to monitor the effect of zebra mussels on an ecosystem. What data about the ecosystems might scientists collect to investigate this question?**

   The scientists should measure the amount of plankton in the river over time. They should also count the populations of any organisms in the ecosystem that eat plankton, including the zebra mussels.

Extension

Students may be curious if there are invasive species in their local environment. In fact, they are found throughout the world. The following are good resources which include a comprehensive collection of research publications and educational materials on introduced species, as well as searchable databases.

- **Sea Grant Nonindigenous Species Site**
  http://www.seagrant.wisc.edu/home/Topics/InvasiveSpecies.aspx
- **National Invasive Species Information Center**
  https://www.invasivespeciesinfo.gov/index.shtml
- **Global Invasive Species Database**
  http://www.iucngisd.org/gisd/
- **Nonindigenous Aquatic Species**
  https://nas.er.usfs.gov/

Activity 4.2

Explore: Introducing a New Species

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the second video clip, "Observation." The other clips will be used later in the chapter.
  The link to the segment follows.
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each student

- ☐ 1 Handout 4.1-1, "Ecosystems Comparison" (from Activity 4.1-1)

Teaching Suggestions

Getting Started

1. **Review the introduction with the class.** (10 minutes)
   - **a.** Have students read the introduction to the activity or read it aloud.

Doing the Activity

2. **Students complete the reading, "An Unwelcome Newcomer," using the Read, Think, and Take Note strategy.** (45 minutes)
   - **a.** Have students complete the reading individually as they use the Read, Think, and Take Note strategy.
3. **Students watch a video clip about scientists collecting data in the Hudson River ecosystem.** (10 minutes)
   - **a.** Show students the video clip, "Observation."

3 class sessions

Changing Ecosystems

How did the zebra mussel initially affect the health and biodiversity of the Hudson River ecosystem?

Students investigate short-term data on the effects of the introduction of the zebra mussel to the Hudson River ecosystem. Students analyze data on three biotic and abiotic factors to determine the accuracy of their predictions from the previous activity about the effect of the zebra mussel.

Rationale & NGSS Integration

Students analyze and interpret data in order to investigate possible short-term effects of the zebra mussel on a variety of variables in the Hudson River ecosystem. The activity also introduces the concepts of biodiversity and ecosystem services, and formally introduces the term invasive species, so that students will be able to draw on these concepts when they develop arguments about the positive or negative effect of the zebra mussel in the next activity. Interpreting the short-term data in this activity provides students with a deeper understanding of the core ideas of ecosystem dynamics and competition for resources, while providing compelling examples of how the crosscutting concepts of stability and change and cause and effect help scientists think about ecological disruptions. Students' understanding of the short-term effects of zebra mussels in the Hudson River and Great Lakes ecosystems is a foundation for more elaborate analysis of long-term data in the next activity.

Activity Overview

In this Explain activity, students use a web-based graphing tool to graph and analyze how the zebra mussel might affect the abiotic and biotic factors they chose in the last activity. Students then read about the short-term effects of the zebra mussel on both the Hudson River and Great Lakes ecosystems, and engage in an oral debate about the effects of the zebra mussel on the Hudson river ecosystem.

Key Vocabulary

biodiversity **ecosystem services** **invasive species**

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the second video clip, "Results." The final clip will be used later in the chapter. The link to the segment follows.
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each pair of students

- ☐ computer with Internet access

For each student

- ☐ 1 Handout 4.1-1, "Ecosystems Comparison" (from Activity 4.1)

Teaching Summary

Getting Started

1. Review the introduction with the class.

Doing the Activity

2. Students use the River Ecology graphing tool to investigate testable questions from previous activity.

3. The class watches the video clip, "Results" and updates Handout 4.1-1

4. Students read about the effect of zebra mussels on the Hudson River and Great Lakes ecosystems.

Follow-Up

5. Engage students in a debate about the effect of the zebra mussel.

6. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Review the introduction with the class.** (10 minutes)

   a. Read the introduction aloud to the class.

   Explain to the students that in this activity they will be analyzing data about a variety of biotic and abiotic factors in the Hudson River ecosystem. They will look at short-term data to determine if the introduction of the zebra mussel has affected the stability of the Hudson River Ecosystem. Use the illustration to elicit student ideas about biodiversity prior to reading the introduction. Ask students what they notice about the illustration (it shows a variety of organisms, as well as a large number of zebra mussels) before you read the introduction aloud to the class. Make sure students understand that the key vocabulary term, biodiversity, refers to variation within a species, between species, and between populations of species. When an invasive species is introduced to an ecosystem it increases the biodiversity in terms of number of species, but decreases it in terms of changing the other populations in the ecosystem. Encourage students to consider the integrity of the ecosystem as a whole, in particular in regards to the relative population sizes within the ecosystem. Add biodiversity and invasive species to the class word wall.

Doing the Activity

2. **Students use the River Ecology graphing tool to investigate testable questions from the previous activity.** (30 minutes)

   a. Give students a brief overview of how to use the River Ecology graphing tool.

Make sure they are using the "Kingston" location and graphing over time. Remind them to only look at the data from 1988 to 1996 so they are only looking at short-term data.

The end of this step or after the next is a good place to conclude the first class session.

Although the graphs in this activity are constructed by the online data tool, your students may benefit from using Student Sheet 6, "Bar Graphing Checklist," or Student Sheet 7, "Scatterplot and Line Graphing Checklist," to review the essential elements of the graphs generated here and in Activity 4.5. If your students are not experienced with interpreting graphs, use this opportunity to model an interpretation for them. Use one of the factors that is not being analyzed in this activity, such as bacterial production, and talk students through how to interpret the data on the graph. You may also wish to refer students to Student Sheet 8, "Interpreting Graphs."

3. **The class watches the video clip, "Results," and updates Handout 4.1-1.** (15 minutes)

   a. Show the class the video clip.

   The video clip serves as a bridge between the data students explored in the previous activity and the information they will be reading in the next step. It also highlights for the students some of the particularly interesting data on the short-term effects of the zebra mussel on the Hudson River ecosystem.

   You can use the clip to close the first class session of this activity or begin the second. You can also have students update Handout 4.1-1 to close or begin a class session.

4. **Students read about the effect of zebra mussels on the Hudson River and Great Lakes ecosystems.** (45 minutes)

   a. Have students complete the reading alone or in pairs.

   Remind students of how you prefer for them to use the Stop to Think questions. More details on this literacy strategy can be found in Section 3 of Teaching Strategies. Sample answers for each question are provided below. The term ecosystem services is introduced in the reading. You may wish to provide additional examples of ecosystem services for your students, such as logging, mining, and using land for grazing livestock. After the reading have the students update Handout 4.1-1. A sample answer is included in the Handouts section of the Teacher's Guide. Add ecosystem services to the word wall.

   You can conclude the second class session before or after the class discussion of the Stop to Think questions, or after students update the handout.

“What characteristics of zebra mussels make them likely to succeed in a new area?”

Zebra mussels produce more than 1 million eggs a year starting when they are less than a year old, eat nearly all types of plankton, attach to most hard surfaces, and can live in water as cold as 3°C. They will also eat most types of plankton.

“Why did the introduction of one species, the zebra mussel, cause changes to so many of the other populations in the Great Lakes and Hudson River?”

Because the zebra mussels eat most plankton, and plankton forms the foundation of the food webs in the Great Lakes and Hudson River, when they consume a lot of the plankton the other plankton-eaters do not have enough food and their populations decline. Zebra mussels competing with other organisms for plankton causes a decline in the organisms above plankton in the food web, because they also will not have enough to eat.

“Describe some of the biotic and abiotic factors that were affected by the zebra mussels in the Great Lakes and Hudson River.”

Many of the populations of other organisms in both ecosystems declined, including native mussels, plankton, and fish. Visibility increased because there was less plankton.

“Why might people be concerned about the effects of zebra mussels on ecosystem services?”

The zebra mussels cause damage to power plants and other facilities by blocking their pipes. They also cause declines in fisheries, and can cause harmful bacteria in the water to increase.

The Stop to Think questions provide an opportunity to check for students’ understanding of the core idea that organisms and populations are dependent on interactions with each other and abiotic factors. They also can be used to assess students’ progress on obtaining evidence from text. Students should notice that in both ecosystems there is competition for resources (e.g. food, space) and that the zebra mussels are changing the patterns of interactions in the ecosystems. Question 2 also examines the cause and effect relationship between zebra mussels and the factors the students are investigating.

Follow-Up

5. **Engage students in a debate about the effect of the zebra mussel.** (30 minutes)

a. Have the class conduct a Walking Debate to debate the question "Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?"

See Section 2 in Teaching Strategies for more details on how to conduct a Walking Debate. Designate one area of the room as "positive effect" and a second area as "negative effect." If significantly more students choose one side to debate, assign students to sides so that the numbers are approximately even. Encourage students to use examples from their data analysis as evidence for their argument, and to focus on the crosscutting concepts of cause and effect and stability and change as they formulate their arguments. If students need help structuring their arguments, consider having them use cause-and-effect statements, starting with "The zebra mussel…, which means that…", for example, "The zebra mussel ate a lot of the phytoplankton which means that there is less food for other filter feeders." These statements can also serve as informal assessments of students understanding of the effects of the zebra mussel invasion on the Hudson River ecosystem.

b. Have the students add new information to the KWL chart

Students will likely suggest adding more details about the short-term effects of the zebra mussel, and some of the effects on ecosystem services such as the damage to power plants and the increase in harmful algae blooms. They will likely have new questions to add as well.

6. **Revisit the Guiding Question.** (10 minutes)

a. Revisit the guiding question, "How did the zebra mussel initially affect the health and biodiversity of the Hudson River ecosystem?"

A class discussion of Analysis question 1 is a good lead-in to revisiting the Guiding Question. Have students share what factors they examined and what their data showed. This is also a good point for students to add to the crosscutting concepts posters. Students should have more concrete examples of how the zebra mussel has led to change in both the Hudson River and Great Lakes ecosystems, including changes to ecosystem services and biodiversity. This discussion will lead in to the next activity where they will examine long-term data on the zebra mussels' effect on factors in the Hudson River ecosystem.

Suggested Answers To Analysis

1. **For each factor you examined, do the data show stability or change in the Hudson River ecosystem? Explain your answers.**

> **Assessment – SEP - Analyzing and Interpreting Data, CCC - Stability and Change**
> This question is an assessment of both analyzing and interpreting data (SEP) and stability and change (CCC).

Student responses will vary depending on the factors they chose to analyze. Factors that show the most change are chlorophyll, cladocera, Alosa, Sphaeriidae, copepod nauplii, and rotifers. See the following table for general relationships between the introduction of zebra mussels and each factor.

Short-term Effects of Zebra Mussels on Factors in the Hudson River Ecosystem

Factor	General Effect
Alosa	significant decrease
Bacterial Abundance	significant increase
Centrarchidae	significant increase
Chlorophyll	significant decrease
Cladocera	significant decrease
Copepod nauplii	significant decrease
Copepods	slight decrease
Dissolved Oxygen	no change
Oxygen Saturation	no change
Rotifers	significant decrease
Secchi Depth	significant increase
Sphaeriidae	significant decrease
Temperature	no change
Total Suspended Solids	significant decrease

We chose the factors rotifers, Sphaeriidae, and suspended solids to analyze. All three of these factors showed change in the Hudson River ecosystem, because *all three factors decreased significantly after the introduction of the zebra mussel to the ecosystem. If they had stayed the same it would show stability in the ecosystem.*

2. **In Activity 4.2, Hudson River Ecosystem, you made predictions about how each of the three factors would be affected by the introduction of the zebra mussels. Describe whether the data supported your predictions.**

> **Assessment – SEP - Analyzing and Interpreting Data, CCC - Cause and Effect**
> This question is an assessment of both analyzing and interpreting data (SEP) and cause and effect (CCC).

Students' responses will vary depending on the factors they chose to analyze and what their predictions were. A sample answer is shown below.

We predicted that the introduction of the zebra mussel would cause the rotifer and Sphaeriidae populations to decrease and the total suspended solids to decrease. The data supported our predictions for rotifers and Sphaeriidae. The rotifer population went from between 1,000 and 2,000 per square meter before the zebra mussel to 150 or less after the zebra mussel. The Sphaeriidae population decreased from between 500 to 1,200 per square meter down to about 150 per square meter after the zebra mussel was introduced. The data for the total suspended solids was hard to analyze for a clear effect from the zebra mussels because the amount went up and down a lot and a lot of the time was at similar levels to before zebra mussels, but there were fewer high peaks after the zebra mussels were introduced.

3. **Your observations covered data that spanned from a few years before to a few years after the zebra mussels arrived in the Hudson River. Predict what the data might show 20 years or more after the introduction of the zebra mussels. Explain the reasons for your prediction.**

> **Assessment - DCI - MS LS2.C.1, SEP - Constructing Explanations**
> This question assesses students' ability to make predictions based on data. This is an important aspect of constructing explanations (SEP).

Student answers may vary based on the factors they investigated in the activity. It is important that they incorporate a coherent explanation for their prediction that is based on the data they have already analyzed. This allows for an assessment of their understanding of the nature of dynamic ecosystems (DCI MS LS2.C.1) A sample answer for three variables follows.

My group analyzed data from rotifers, cladocera, and total suspended solids. All three of these factors decreased after the zebra mussel was introduced to the ecosystem. I predict that in 20 years, the zebra mussels will still be in the

Hudson River, and that the rotifers, cladocera, and total suspended solids will still be low. Because the zebra mussels eat the rotifers and cladocera, if the zebra mussels are still present the populations will stay low. The zebra mussels will also eat other plankton, keeping the total suspended solids low.

4. **An invasive species is a species that is brought from its native area to a new place where it causes harm to the environment, the economy, or human health. Scientists consider the zebra mussel an invasive species in North America. What evidence supports this?**

   The zebra mussel has harmed the environment by changing the biodiversity and decreasing plankton, a major food source for many organisms. It has harmed the economy by causing the fisheries to decline so there are fewer fish for the fishermen, therefore less income and fewer jobs. The zebra mussel has harmed human health by increasing the harmful bacteria causing the water to be unsafe to swim in.

Activity 4.3

Explain: Biodiversity in Ecosystems

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the second video clip, "Results." The final clip will be used later in the chapter. The link to the segment follows.
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each pair of students

- ☐ computer with Internet access

For each student

- ☐ 1 Handout 4.1-1, "Ecosystems Comparison" (from Activity 4.1)

Teaching Suggestions

Getting Started

1. **Review the introduction with the class.** (10 minutes)
   - **a.** Read the introduction aloud to the class.

Doing the Activity

2. **Students use the River Ecology graphing tool to investigate testable questions from previous activity.** (30 minutes)
   - **a.** Give students a brief overview of how to use the River Ecology graphing tool.
3. **The class watches video clip, "Results" and updates Handout 4.1-1.** (15 minutes)
   - **a.** Show students the video clip, "Observation."

4. **Students read about the effect of zebra mussels on the Hudson River and Great Lakes ecosystems.** (40 minutes)

    a. Have students complete the reading alone or in pairs.

Follow-Up

5. **Engage students in a debate about the effect of the zebra mussel.** (30 minutes)

    a. Have the class conduct a Walking Debate to debate the question "Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?"

    b. Have the students add new information to the KWL chart

6. **Revisit the Guiding Question.** (10 minutes)
   Revisit the guiding question, "How did the zebra mussel initially affect the health and biodiversity of the Hudson River ecosystem?"

3–4 class sessions

The Zebra Mussel Problem: 20 Years of Data

What are the long-term effects of the zebra mussel invasion of the Hudson River?

Students transition to looking at long-term data on the effects of the zebra mussel. This allows them to deepen their understanding of dynamic ecosystems, and the importance of looking at disruption of ecosystems in both the short- and long-term.

Rationale & NGSS Integration

Students use this Elaborate activity to continue to deepen their understanding of the core ideas of dynamic ecosystems and competition for resources. Students analyze data to investigate the long-term effects of zebra mussels on the Hudson River ecosystem. This data analysis gives students the context to further explore stability and change and the relationships in the ecosystem. They apply what they have learned to the scientific practices of developing explanations and constructing arguments to demonstrate their understanding of the dynamic nature of the Hudson River ecosystem and the long-term effects of the zebra mussel.

Activity Overview

In this Elaborate activity, students investigate the long-term data on the factors they investigated in Activity 4.3, and use that data to develop an explanation for the long-term effect of zebra mussels. Students also watch a video clip and complete a short reading about scientists' interpretation of the long-term data and what effects the zebra mussel invasion is having on the Hudson River ecosystem. The activity concludes with students constructing an argument about whether the zebra mussel has had a positive or negative effect on the Hudson River ecosystem.

Materials and Advance Preparation

For the teacher

- ☐ Scoring Guide: Constructing Explanations
- ☐ Scoring Guide: Developing Arguments
- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the final video clip, "Going Further." The other clips have already been used earlier in the chapter. The link to the segment follows.
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each pair of students

- ☐ Access to computer with Internet connection

For each student

- ☐ Explanation Tool
- ☐ Argument Tool

Teaching Summary

Getting Started

1. Hold a class discussion about students' predictions for the long-term data.

Doing the Activity

2. Students investigate the data on the long-term effect of the zebra mussel.

3. Students develop an explanation.

4. Students read about the long-term effects of the zebra mussel and revise their explanations.

Follow-Up

5. Students construct an argument about the effect of the zebra mussel on the Hudson River ecosystem.

6. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Hold a class discussion about students' predictions for the long-term data.** (15 minutes)

   a. Have a brief discussion with the class about why they think scientists might want to look at data on the Hudson River ecosystem over a long period of time instead of just a few years.

   Students will likely suggest the idea that there might be changes over the long term in the ecosystem that would not be apparent in the first few years of data collection, therefore looking at long-term data can give the scientists a more accurate picture of the whole story. Explain that in this activity they will look at the long-term data for the same factors they investigated in the previous activity.

   b. Have student pairs read the introduction to the activity.

Doing the Activity

2. **Students investigate the data on the long-term effect of the zebra mussel.** (30 minutes)

   a. Have students use the River Ecology graphing tool to examine the long-term data for the factors they investigated in Activity 4.3, "Hudson River Ecosystem."

   Note that the data in this activity will show as bar graphs, not line graphs, showing the average over each time period. This presentation of the data makes it easier to see any long-term trends. You may want to model for your students how to interpret a bar graph, compared to the line graphs they were interpreting in the previous activity.

   The general effects of the phenomenon of the zebra mussel introduction on the factors are shown in the table on the following page. Note that the first time frame in the graph, 1973 to 1990, was before the zebra mussel was introduced, so it can be considered baseline data.

b. Show students the video clip "Going Further."

Have students focus on the reasons scientists give for monitoring long term, and what long-term changes they saw in the zebra mussel population of the Hudson River ecosystem.

Before or after this step is a good point to conclude the first class session.

Long-term Effects of Zebra Mussels on Factors in the Hudson River Ecosystem

Factor	Time Frame 2 (1990-2000)	Time Frame 3 (2000-2010)
Alosa	significant decrease	continued decrease, not as dramatic
Bacterial Abundance	slight increase	slight decrease from Time Frame 2
Bacterial Production	significant increase	Slight decrease from Time Frame 2
Centrarchidae	significant increase	major decrease, far below pre-zebra levels
Chlorophyll	significant decrease	continued decrease, not as dramatic
Cladocera	significant decrease	continued decrease, not as dramatic
Copepod nauplii	significant decrease	significant increase but not to pre-zebra level
Copepods	slight decrease	increase to above pre-zebra levels
Dissolved Oxygen	no change	no change
Oxygen Saturation	no change	no change
Rotifers	significant decrease	slight increase from Time Frame 2
Secchi Depth	slight increase	return to pre-zebra level
Sphaeriidae	significant decrease	increased some, but not dramatically
Temperature	no change	no change
Total Suspended Solids	slight decrease	increase, not completely to pre-zebra level
Unionidae	no data*	no data*

*There is no data for Unionidae with the split dates used in this activity because scientists did not start collecting data on Unionidae until 1991.

3. **Students develop an explanation.** (30 minutes)

   a. Have students develop explanations about the long-term effect of zebra mussels on one of the factors they chose.

   As students will be constructing an argument later in the activity, instead of written explanations you may wish to have the students provide their explanations orally, in pairs, groups, or as a whole-class explanation. This would be particularly appropriate if you are working with English Language learners or students with special needs, in order to reduce the overall amount of writing in the chapter. Encourage students to use academic terms to develop scientifically accurate explanations. For more guidance on development of academic language, see Section 1 of Teaching Strategies. Because student responses may vary widely, depending on the factors they chose, have a class discussion after students construct their explanations if you opt to have the students work in pairs or groups.

   Step 11 provides an opportunity to check students' understanding of the core ideas of the dynamic nature of ecosystems and resource competition, and can also be used to informally evaluate students on constructing explanations, and on integrating the crosscutting concepts of stability and change, cause and effect, and patterns, as can Step 13 after they revise their explanations to add new information from the reading. See Section 4 of Teaching Strategies for additional details about the Explanation Tool. A sample answer is provided in the Handouts section of the Teacher's Guide.

   Conclude the second class session after this step, or preview the reading with the class if time permits.

4. **Students read about the long-term effects of the zebra mussel and revise their explanations.** (40 minutes)

   a. Have students complete the reading alone or in pairs.

   The Stop to Think question can be used to check students' understanding of the crosscutting concept of cause and effect relationships. A sample answer is provided below.

   "What effect do you think the smaller and younger zebra mussel population might have on the rest of the food web?"

   The smaller and younger zebra mussels would probably eat less plankton than the larger ones. This might mean more plankton would be available for other filter feeders like the native mussels, allowing their population to increase.

   b. Have students revise their explanations.

   Conclude the third class session after this step.

Follow-Up

5. **Students construct an argument about the effect of the zebra mussel on the Hudson River ecosystem.** (30 minutes)

   a. Have students construct an argument around the question "Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?"

   A sample answer is provided in the Handouts section of Teaching Strategies. Student responses may be scored using the Argument rubric. As appropriate, have students use a copy of the rubric for peer or self evaluation of a draft response, then revise their response as needed. Encourage students to check that their responses include all three dimensions: the core ideas, their data analysis, and the crosscutting concepts of stability and change, cause and effect, and patterns. See Section 4 of Teaching Strategies for additional details about the Argument Tool and peer review of writing.

6. **Revisit the Guiding Question** (10 minutes)

   a. Briefly review the long-term effects of the zebra mussel on the Hudson River ecosystem.

   Have students share what factors they examined and what the data showed. Ask the students how relating the effects of the zebra mussel to crosscutting concepts such as cause and effect and stability and change helps scientists (and students) think about and explain the impact of zebra mussels on ecosystems. Then have the students add to the KWL chart based on what they learned from the long term data, and add any new questions that have arisen for them.

Suggested Answers To Analysis

1. **Explain why it is important to monitor ecosystems over long periods of time.**

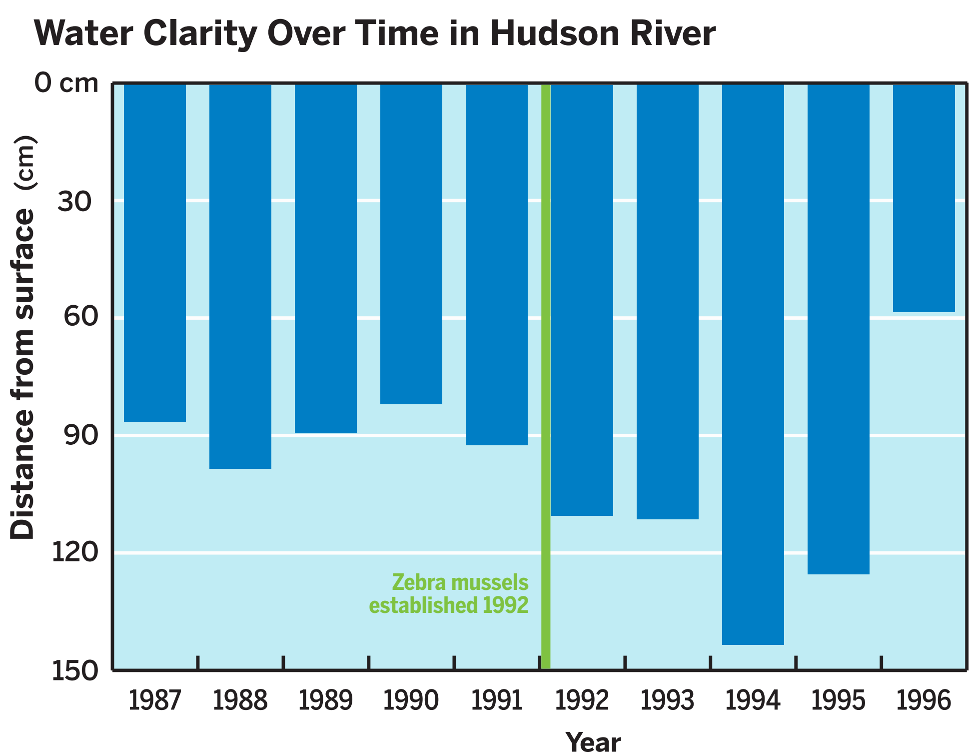
   It is important to monitor ecosystems over long periods of time because ecosystems are dynamic and they can change significantly over time. For example, when the zebra mussel first arrived in the Hudson River ecosystem it spread quickly and ate most of the zooplankton and phytoplankton. However, recently the zebra mussel population has decreased – they are physically smaller and are not living as long. This means they aren't eating as much zooplankton, so the zooplankton population is increasing. The ecosystem might *eventually become more stable, or might keep changing, but we only know if we have long-term data to analyze.*

2. **How do the effects of zebra mussels in the Hudson River relate to stability and change in ecosystems?**

> **Assessment – CCC - Cause and Effect and Stability and Change**
> This question assesses students' ability to relate the concepts of stability and change and cause and effect (CCC) to an ecological phenomenon they have now studied in some depth.

The zebra mussels in the Hudson River show that a small change, the introduction of just one organism, can cause a big effect on the stability of an ecosystem. In the short-term the zebra mussels caused many factors in the Hudson River ecosystem to change, such as large decreases in the phytoplankton, zooplankton, and native mussel populations. Over the long-term some of the factors that changed seem to be getting more stable and recovering, like the zooplankton population.

3. **The graph below shows water clarity over time in the Hudson River. What do the patterns in the data tell you about the effect of zebra mussels on water clarity?**



This question introduces students to a style of bar graph that they will be analyzing in the Evaluate activity of this chapter. Make sure students understand the layout of the graph, and that the y-axis is in negative numbers. This style of graph is used to help visualize how deep in the water the secchi disc is visible. The longer the bar, the deeper the disc is visible, indicating higher water clarity.

The patterns on the graph show that after zebra mussels were introduced in 1992 the water was much clearer. Before 1992 the water clarity ranged from 82 to 98 cm. After 1992, when the zebra mussel was introduced, the water clarity ranged from 110 to 143 cm, except in 1996 when it is only 58 cm. Maybe in 1996 there were a lot of storms or something making the water really cloudy.

4. **Consider the statement "A small change to one factor can lead to large changes in an ecosystem." If introduction of one species is considered a "small change," do you think this statement is accurate? Explain your answer.**

> **Assessment – DCI - MS LS2.C.1, CCC - Stability and Change**
> Use this question to assess students' understanding that ecosystems are dynamic in nature (DCI - MS LS2.C.1) and as an example of cause and effect relationship as well as stability and change (CCC). A sample answer follows.

I think this statement is accurate because the zebra mussel is only one species, but when it was introduced to the Hudson River and Great Lakes ecosystems it caused a lot of changes in the biodiversity and other factors like water clarity. It also caused changes to the ecosystem services, like decreasing fish populations that fishermen rely on and increasing harmful algae so the water was not safe to swim in. This is an example of a cause and effect relationship.

Activity 4.4

Elaborate: The Zebra Mussel Problem: 20 Years of Data

Materials and Advance Preparation

For the teacher

- ☐ Scoring Guide: Constructing Explanations
- ☐ Scoring Guide: Developing Arguments
- ☐ Access to computer with Internet connection
  The video clip can be downloaded prior to class. Note that in this activity you are only showing the final video clip, "Going Further." The other clips have already been used earlier in the chapter. The link to the segment follows.
  http://www.amnh.org/education/resources/rfl/web/riverecology/watch.html
- ☐ 1 large computer monitor or projector

For each pair of students

- ☐ Access to computer with Internet connection

For each student

- ☐ Argument Tool

Teaching Suggestions

1. **Hold a class discussion about students' predictions for the long-term data.** (15 minutes)
   - **a.** Have a brief discussion with the class about why they think scientists might want to look at data on the Hudson River ecosystem over a long period of time instead of just a few years.
   - **b.** Have student pairs read the introduction to the activity.

Doing the Activity

2. **Students investigate the data on the long-term effect of the zebra mussel.** (30 minutes)

    a. Have students use the River Ecology graphing tool to examine the long-term data for the factors they investigated in Activity 4.3, "Hudson River Ecosystem."

    b. Show students the video clip "Going Further."

3. **Students develop an explanation.** (30 minutes)
    Have students develop explanations about the long-term effect of zebra mussels on one of the factors they chose.

4. **Students read about the long-term effects of the zebra mussel and revise their explanations.** (40 minutes)

    a. Have students complete the reading alone or in pairs.

    b. Have students revise their explanations.

Follow-Up

5. **Students construct an argument about the effect of the zebra mussel on the Hudson River ecosystem.** (30 minutes)
    Have students construct an argument around the question "Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?"

6. **Revisit the Guiding Question.** (10 minutes)
    Briefly review of the long-term effects of the zebra mussel on the Hudson River ecosystem.

2 class sessions

A New Mussel in Town

Has the quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?

Students conclude the chapter with an investigation of another invasive species in the Great Lakes ecosystem, the quagga mussel, which has displaced much of the zebra mussel population. This allows for the evaluation of students' understanding of dynamic ecosystems and the effects of invasive species, while setting them up to investigate possible solutions for ecosystems disruptions in the following chapter.

Rationale & NGSS Integration

This Evaluate activity concludes this chapter with an analysis of data on quagga mussels that have displaced the zebra mussels in Lake Michigan. Students analyze and interpret data from different sources and use that analysis to construct an argument about the effect of the quagga mussel on stability of the Lake Michigan ecosystem. Their written arguments can be used to assess both performance expectations for the chapter, as well as their understanding of the core ideas of dynamic ecosystems and competition for resources, their use of the practices of analyzing and interpreting data and engaging in argument from evidence, and their integration of the crosscutting concepts of stability and change, cause and effect, and patterns.

Activity Overview

In this Evaluate activity, students investigate data on the quagga mussels that have invaded Lake Michigan and out-competed the zebra mussels. Students also analyze data about the steep decline in Diporeia, a shrimp-like organism eaten by the quagga as well as several species of fish that are the basis of commercial fisheries in the lake. Students develop an argument about whether the effect of the quagga has been positive or negative.

Materials and Advance Preparation

For the teacher

- ☐ Scoring Guide: Developing Arguments

For each student

- ☐ Argument Tool

Teaching Summary

Getting Started

1. Facilitate a class discussion on potential reasons an invasive species might decline or disappear from an ecosystem.

Doing the Activity

2. Students develop an argument about the quagga mussel invasion.

Follow-Up

3. Facilitate a class discussion about the differences between the zebra mussel and quagga invasions.

4. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Facilitate a class discussion on potential reasons an invasive species might decline or disappear from an ecosystem.** (15 minutes)

   a. Have a brief discussion about other factors that might cause an invasive species, such as the zebra mussel, to go into decline once it has invaded an ecosystem.

Explain to the students that in this activity they will be using their understanding of the phenomenon of the zebra mussels' effect on the Husdon River ecosystem and applying what they have learned to a similar ecosystem where zebra mussels have been introduced. Ask the students, *Suppose the zebra mussel had invaded an ecosystem similar to the Hudson River, but there were no blue crabs or other predators. What other factors might cause the zebra mussel population to decline?* Use Elicit questions described in Section 2 of Teaching Strategies. Do not guide the class to any particular answer, but encourage students to listen to and react to each other's ideas while you record them. This could also be done as a written warm-up, followed by a brief class discussion.

Doing the Activity

2. **(Assessment) Students develop an argument about the quagga mussel invasion.** (30 minutes)

   a. Have students construct an argument about the question "Has the quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?"

   Have students read the introduction then complete the Procedure. As an Evaluate activity the students' written arguments can be used to assess both Performance Expectations (PEs) for this unit, as well as their understanding of the core ideas of dynamic ecosystems and competition for resources, their use of the practices of analyzing and interpreting data and engaging in argument from evidence, and their integration of the crosscutting concepts of stability and change, cause and effect, and patterns.

   You may wish to have them analyze the Information Items in pairs or groups of four before they move to constructing their arguments. Encourage students to refer to Student Sheet 1, "Developing Communication Skills," if they need reminders of how to engage in productive scientific argumentation. Based on students' proficiency with developing their arguments, determine if they need the scaffold of the Argument Tool. One option would be to project a blank copy of the tool for student reference, but have them write their arguments without a physical copy. Note that scientists agree that the recent decrease of the zebra mussel is due to displacement by the quagga. Scientists therefore treat this as the same overall problem for the ecosystem, an invasive species out-competing native species, and not as if the zebra mussels decline indicates the ecosystem is returning to its pre-invasive state. A sample answer for the argument can be found in the Handouts section of Teaching Strategies.

Follow-Up

3. **Facilitate a class discussion about the differences between the zebra mussel and quagga invasions.** (20 minutes)

   a. Have the students discuss as a class the differences between the zebra and quagga mussel invasions.

   Encourage students to think about information related to biotic and abiotic factors that have an effect on the ability of either species to invade a new ecosystem.

   b. Return to the class KWL chart and complete it for the chapter.

   Students should suggest adding information about the quagga mussel and how it has affected the Lake Michigan ecosystem. Ask students to share their analysis of the data from the activity and if they concluded that the quagga had a positive or negative effect on the ecosystem. Encourage the students to reflect on what they have learned over the chapter, how they learned things (e.g. from analyzing data), and how their thinking has changed about the Guiding Question for the chapter: "How do new organisms affect the environment?" For a reminder on how to use the "L" in KWL, refer to Section 2 in Teaching Strategies.

4. **Revisit the Guiding Question.** (10 minutes)

   a. Have students revisit the crosscutting concepts for the chapter.

   The guiding question, "Has the quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?", is also the question framing the students' arguments that they develop in this activity. Because that has already been discussed, return to the cross cutting concepts of stability and change, cause and effect, and patterns.

Suggested Answers to Analysis

1. **What additional information would have been useful to know in developing your argument?**

   It would have been useful to have data about the levels of phytoplankton and zooplankton, besides Diporeia, in Lake Michigan for the time period we were analyzing. It also would have been useful to have data from other Great Lakes that are connected to Lake Michigan on the quagga and zebra mussel population levels.

2. **Compare the change in distribution of the zebra mussels in Lake Michigan to that in the Hudson River over the last 20 years. Do you think that the changes have occurred because of the same reasons? Explain.**

   I do not think that the changes in distribution of zebra mussels in these two ecosystems have occurred because of the same reasons. It seems like the main reason there are no longer zebra mussels in Lake Michigan is because the quagga mussels have out-competed them for food and space. As far as we know, there are no quagga mussels or similar organisms in the Hudson River. However, in the Hudson River we know that the native blue crabs have started eating zebra mussel, causing a decrease in the population numbers and size of individual zebra mussels that survive. We do not know if there are blue crabs in Lake Michigan, or if there are whether they eat the zebra mussels there.

Extension

Students may be curious to find out if there are new invasive species like the quagga mussels that local officials are concerned about. If possible, find an appropriate local official from an organization such as the Fish and Wildlife Service who is willing to be interviewed by students. Arrange for students to conduct an interview in class or through virtual conferencing.

Activity 4.5

Evaluate: A New Mussel in Town

Materials and Advance Preparation

For the teacher

- ☐ Scoring Guide: Developing Arguments

For each student

- ☐ Argument Tool

Teaching Suggestions

Getting Started

1. **Facilitate a class discussion on potential reasons an invasive species might decline or disappear from an ecosystem.** (15 minutes)

   a. Have a brief discussion about other factors that might cause an invasive species, such as the zebra mussel, to go into decline once it has invaded an ecosystem.

Doing the Activity

2. **(Assessment) Students develop an argument about the Quagga mussel invasion.** (30 minutes)

   a. Have students construct an argument about the question "Has the Quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?"

Follow-Up

3. **Facilitate a class discussion about the differences between the zebra mussel and Quagga invasions.** (20 minutes)

   a. Have the students discuss as a class the differences between the zebra and Quagga mussel invasions.

   b. Return to the class KWL chart and complete it for the chapter.

4. **Revisit the Guiding Question.** (10 minutes)

   a. Have students revisit the crosscutting concepts for the chapter.

CHAPTER

5 Designing Solutions

Activity 5.1
Engage

What are some of the ways to deal with an insect problem?

This chapter engages students with a phenomenon that is woven throughout this unit, that of humans using more and more resources which causes environmental problems and thus creates the need for the development of solutions. Students begin the chapter by looking at a particular environmental problem, that of a crop infestation. They consider various solutions to the problem and discuss the advantages and disadvantages of each. In doing so they learn that for each course of action there are consequences, some foreseen and some not.

Activity 5.2
Explore

How can we balance human needs with those of the environment?

Human impact plays an important role in this activity as students play a game where each member of a group manages a connected area of a fictitious community. As a group they make decisions that affect ecosystem services and the environment, concepts that were introduced in the previous chapter. Each decision has consequences, some of them immediate and some delayed. Some of the consequences are also unanticipated by the group. By the end of the game, students realize that balancing environmental needs with human needs can be difficult.

Activity 5.3
Explain

What factors should be considered when choosing, or designing, a solution to an environmental problem?

Students revisit the previous two activities as they analyze the impacts of decisions made in terms of the effects on the environment, people, and communities. They learn that solutions are designed to operate within constraints and that criteria are used to develop or choose the optimal solution. Finally, they apply criteria and constraints as they use a framework to evaluate potential solutions to the crop infestation problem from an environmental, economic, and social perspective.

Activity 5.4
Elaborate

How can we evaluate solutions to decide how well they might work?

In the previous activity, students were introduced to a system that could be used in designing and evaluating solutions. In this Elaborate activity they apply the system to potential solutions for real world environmental problems. They develop and use environmental, economic, and social criteria to choose the best combination of solutions that fall within the limits of identified constraints. They complete the activity by suggesting refinements to their solutions.

Activity 5.5
Evaluate

How can the negative impact of humans on coral reefs be reduced?

Students are introduced to a broad range of threats to coral reefs around the world. They draw upon their understanding of designing solutions as groups develop and present a solution to one of the threats. As part of their presentation, groups make an argument for why their solution is a good response to minimizing human impact on the reef. After the presentations the class evaluates how well the solutions meet the specified criteria and constraints and how the threat illustrates how increases in human populations and resource use negatively impact the environment.

Chapter 5 Overview

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Engage **5.1 Solving a Problem** **Guiding Question:** What are some of the ways to deal with an insect problem? Students examine a fictitious scenario of an insect infestation at a farm. They brainstorm possible solutions before discussing the advantages and disadvantages of four actual solutions that have been tried at different times and places. The class then watches a short video about one of the solutions - the introduction of the cane toad into Australia and the unexpected consequences of the introduction.	MS.LS2.C MS.LS4.D MS.ESS3C Connections to the Nature of Science	Asking Questions and Defining Problems	invasive species	1
Explore **5.2 Stability and Change** **Guiding Question:** How can we balance human needs with those of the environment? Students act the role of managers of adjacent environmental areas in a simulated environment. Each group of four managers makes decisions that affect the areas. These decisions have both short and long term consequences. Students track the effects of the group's decisions by recording changes to their environmental, money, and happiness points.	MS.LS4.D MS.ESS3.C Stability & Change Cause & Effect Connections to Engineering, Technology, and Applications of Science	Developing and Using Models Analyzing and Interpreting Data Engaging in Argument from Evidence	ecosystem services environmental	2
Explain **5.3 Designing a Solution** **Guiding Question:** What factors should be considered when choosing, or designing, a solution to an environmental problem? Students design a solution to the crop infestation problem by evaluating how well various courses of action meet the designated criteria and constraints, and how each addresses environmental, economic, and social considerations. In doing so, students realize that solutions to environmental problems often involve trade-offs and that decisions are influenced by more than scientific considerations.	MS.ETS1.B MS.ESS3.C Cause & Effect Connections to Engineering, Technology, and Applications of Science Connections to the Nature of Science	Constructing Explanations and Designing Solutions	criteria constraints economic social	2

Activities	Science Concepts	Science Practices	Science Vocabulary	Teaching Periods
Elaborate **5.4 Evaluating Solutions** **Guiding Question:** How can we evaluate solutions to decide how well they might work? Groups are assigned a current environmental problem. They brainstorm solutions and develop a criterion-based system which they use to rank their solutions from best to worst. Groups then use the same system to evaluate several solutions to their assigned problem. They suggest a solution to the problem, which may be a combination of previously examined solutions.	MS.LS2.C MS.LS4.D MS.ETS1.B MS.ESS3.C Stability & Change Cause & Effect Connections to Engineering, Technology, and Applications of Science Connections to the Nature of Science	Engaging in Argument from Evidence Constructing Explanations and Designing Solutions	biodiversity ecosystem services	2
Evaluate **5.5 Coral Reefs** **Guiding Question:** How can the negative impact of humans on coral reefs be reduced? Groups choose a threat to the health of coral reefs that is caused by humans. They design a solution to reduce or minimize the threat and present it to the class. They evaluate each of the solutions presented and construct an argument for the one that is most effective and sustainable.	MS.LS2.C MS.LS4.D MS.ETS1.B MS.ESS3.C Stability & Change Cause & Effect Connections to the Nature of Science	Engaging in Argument from Evidence Constructing Explanations and Designing Solutions	biodiversity ecosystem services	3

Assessment Overview

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explore	Activity 4 Explain	Activity 5 Elaborate
Disciplinary Core Ideas (DCI)					
MS LS2.C*				Steps 8 & 9	
MS LS4.D*				Steps 8 & 9	
MS ETS1.B*			Steps 6 & 10 Analysis 1 & 2	Steps 8 & 9 Analysis 1 & 2	
MS ESS3.C**/***		Analysis 3	Analysis 3	Steps 2, 8 & 9	
Science and Engineering Practices (SEP)					
Engaging in Argument from Evidence */***		Analysis 3		Step 8	
Constructing Explanations and Designing Solutions**			Step 10	Step 9	
Crosscutting Concepts (CCC)					
Stability and Change*		Analysis 3		Steps 2, 8 & 9	
Cause and Effect**/***		Analysis 1 & 3	Step 10	Step 2	
Connections to Engineering, Technology and Applications of Science*/**/***		Analysis 3	Analysis 2	Analysis 3	
Connections to the Nature of Science*/***	Analysis 1		Analysis 3	Analysis 3	
Performance Expectations (PE)					
MS-LS2-5*					Step 6
MS-ESS3-3**					Step 4
MS-ESS3-4***					Step 6

* Primary PE and supporting elements   **Secondary PE and supporting elements   *** Tertiary PE and supporting elements

Embedded Formative Assessment	Activity 1 Engage	Activity 2 Explore	Activity 3 Explore	Activity 4 Explain	Activity 5 Elaborate
CCSS ELA					
WHST.6-8.1***				Step 8	Step 6
CCSS Math					
MP4*			Steps 10-12		

* Primary PE and supporting elements **Secondary PE and supporting elements *** Tertiary PE and supporting elements

PE	**MS LS2-5*** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
	MS ESS3-3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
	MS ESS3-4*** Construct an argument supported by evidence for how increases in human population ~~and per-capita consumption of natural resources~~ impact Earth's systems.
DCI	**MS LS2.C*** Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
	MS LS4.D* Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.
	MS ETS1.B* There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
	MS ESS3.C** Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.
	MS ESS3.C/***** Typically as human populations ~~and per-capita consumption of natural resources~~ increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.
SEP	**EAE*** Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.
	CEDS** Apply scientific principles to design an object, tool, process, or system.
	EAE*** Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

CCC	**S&C*** Small changes in one part of a system might cause large changes in another part.
	CET&S*/** The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.
	CNoS*/*** Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.
	C&E** Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
	C&E*** Cause and effect relationships may be used to predict phenomena in natural or designed systems.
	CET&S*** All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.
CC ELA	**WHST.6-8.1***** Write arguments focused on discipline-specific content.
CC Math	**MP.4*** Model with mathematics.

1 class session

Solving a Problem

What are some of the ways to deal with an insect problem?

This chapter engages students with a phenomenon that is woven throughout this unit, that of humans using more and more resources which causes environmental problems and thus creates the need for the development of solutions. Students begin the chapter thinking about possible solutions for a particular environmental problem, that of a crop infestation. They consider various solutions to the problem and discuss the advantages and disadvantages of each. In doing so they learn that for each course of action there are consequences, some foreseen and some not. Later in the chapter these ideas are tied into human resource use.

Rationale & NGSS Integration

The previous chapters in this unit examined various ecosystem disruptions and have used the crosscutting concepts of cause and effect and stability and change to develop arguments and explanations for how disruptions affect a variety of ecosystems. Although this theme is continued in this final chapter, the focus shifts towards students examining and evaluating potential solutions. During this chapter, students will employ the science and engineering practice of evaluating solutions for maintaining biodiversity and ecosystem services. They will apply the crosscutting concepts of cause and effect and stability and change as they identify cause and effect relationships and examine or suggest methods to minimize the changes experienced by ecosystems. A common thread throughout this chapter relates to the aspect of the nature of science that pertains to the understanding that "when making decisions scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions to take." Understanding the disciplinary core ideas of human impact on the environment, biodiversity, and ecosystem services will help inform the solutions that students develop and evaluate.

Activity Overview

In this Engage activity students examine a fictitious scenario, based on real situations, of an insect infestation at a farm. They brainstorm possible solutions before discussing the advantages and disadvantages of four actual solutions that have been tried at different times and places. The class then watches a short video about one of the solutions—the introduction of the cane toad into Australia and the unexpected consequences of the introduction.

Key Vocabulary

invasive species

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  Preview the video clip on cane toads available at the link below and cue up the video. The link to the segment follows:
  http://www.nationalgeographic.org/media/cane-toads/
- ☐ 1 large computer monitor or projector

For each student

- ☐ Handout 5.1-1, "Control Methods"

Teaching Summary

Getting Started

1. Students read the scenario and brainstorm questions.

Doing the Activity

2. Students examine ways to solve the insect problem.

3. Students recommend a solution.

Follow-Up

4. (Assessment) Students watch a video segment about the cane toad invasion in Australia.

5. Preview the chapter and revisit the Guiding Question.

References

- Australian Government, Department of the Environment and Energy. (2009). *Australian Government Policy on Cane Toads*. www.environment.gov.au/biodiversity/invasive-species/publications/cane-toad-policy

- Molloy, K. and Henderson, W. (2006). *Science of Cane Toad Invasion and Control. Proceedings of the Invasive Animals CRC/CSIRO/Qld NRM&W Cane Toad Workshop*. Brisbane, Australia. https://www.pestsmart.org.au/wp-content/uploads/2010/03/CaneToadProc.pdf

- Olsen, P. (1998). *Australia's Pest Animals: New solutions to old problems.* Bureau of Resource Sciences and Kangaroo Press, NSW.

- Phillips, B.L., Brown, G.P., Webb, J.K., Shine, R. (2006). *Invasion and the evolution of speed in toads*. Nature, Volume 493, page 803.

Teaching Suggestions

Getting Started

1. **Students read the scenario and brainstorm questions.** (15 minutes)

   a. Have students read the scenario at the beginning of the activity or read it aloud.

   The fictitious scenario is used to engage students and set the context for this chapter, that of designing solutions to environmental problems. Encourage students to use their imaginations to picture themselves living on the farm depicted in the scenario, tasked with helping the family think through possible solutions. Although the scenario is fictitious, it is based on an historical example, as described later in this Guide. Be careful not to reveal information related to the historical insect infestation problem prematurely. To do so would inhibit eliciting student's ideas which is a key component of the Engage phase.

   b. Begin to create a KWL chart by asking the class what they know from the scenario.

Write students' responses in the K column of the KWL chart (Holly is a middle school student who lives on a farm; the farm has an insect problem, etc.). For more information on the use of KWL charts see Section 2 of Teaching Strategies.

c. Have students work in groups of four to complete Procedure Step 1.

d. Write students' responses on the W column of the KWL chart during Procedure Step 2.

Students may come up with questions similar to the following: what type of crop; what type of insect; what has the family already tried to do, etc.? This is an opportunity for students to engage in the practice of asking questions as they attempt to define the problem.

e. Provide a limited amount of additional information in the L column of the KWL.

Use the following bullet points to provide more information, if relevant to the questions asked by the class:

- The climate in the region is mainly hot and dry, with periods of heavy rain.
- The crops are mainly sugar cane, with smaller amounts of corn and sweet potatoes.
- The insect—a beetle—is damaging all of these crops.
- Sugar cane grows up to 6 to 8 m high.
- The crops generate income for the family.
- The crops are important to the community because the farm hires workers and purchases products and services from local businesses.
- The adult beetle feeds on the top of the crops.
- The larvae of the beetle (grubs) burrow into the ground and eat the roots of the crops.
- The beetles damage structures, such as buildings, by burrowing into soft materials such as caulking or sealants.

Doing the Activity

2. Students examine ways to solve the insect problem. (15 minutes)

a. Ask the class to identify the problem and the needs of a solution.

Guide a short discussion as necessary so that students identify the problem as the insects damaging the crops. Suggestions as to what the solution should address may vary. For example, students may suggest that all of the insects need to be removed or that all of the crops must recover.

b. Provide a few minutes for groups to brainstorm ways of solving the insect problem.

Begin by telling the class that at this stage there are no right answers to the problem. Allow a few minutes for brainstorming and then allow groups to share their ideas. Do not comment on their ideas just yet. Make a note to yourself of misconceptions students have so that you can revisit them when the students are further through the chapter. At that point students will be better able to correct many misconceptions through their own growth in understanding.

c. Give a copy of Handout 5.1-1 to each student.

Explain that the handout describes four solutions to the insect problem that have actually been tried somewhere in the world. Explain that each group is to discuss the advantages and disadvantages of each solution and to write them in the appropriate place on the handout.

3. Students recommend a solution. (5 minutes)

a. Ask each group to recommend the solution that they think is best for Holly's family.

Accept any solution but make sure that groups provide the reasoning for their choice. Use Probe Questions described in Section 2 of Teaching Suggestions to encourage students to explain their reasoning. You may want to tally which solutions each group chose to see which solution was favored by the class.

b. Ask students to consider how their choice of solution would affect the environment, the family, and the community.

Encourage students to think about environmental consequences (such as harm to other organisms), costs (such as how expensive a treatment might be), and effect on the family and community (for example, loss of jobs or home). This is a precursor to developing a system to evaluate solutions and will be developed further in the next activity.

Follow-Up

4. Students watch a video segment about the cane toad invasion in Australia. (10 minutes)

a. (Assessment) Discuss Analysis questions 1 and 2 with the class.

Allow time for a short discussion of each question. Analysis question 2 provides an additional opportunity for students to engage in the science and engineering practice of asking questions and defining problems.

Revisit the KWL chart to see if students want to add more questions to the W column or things they have learned to the K column. Emphasize that scientists and engineers often develop new questions as they acquire more information.

b. Direct students' attention to Analysis question 3.

Explain to the class that the insect problem described in the scenario is based on a real problem that occurred in the sugar cane fields in Queensland, Australia in the 1930's.

Point out that cane toads were introduced to control the insects that were destroying the crops. The cane toads had been used successfully in other countries but had never been introduced to Australia.

c. Show the video and briefly discuss the meaning of biological control.

Explain that biological control involves using another organism to try to solve a problem. In this case, the cane toad was used to try to solve the insect problem.

d. Refer students back to Analysis question 3.

Ask the class to think back to the zebra mussel in Chapter 4 and try to recall the term used when describing a non-native species that causes harm to the environment, human health, or the economy (an invasive species).

e. Summarize the insect infestation problem and the use of biological control.

Prompt students to consider how a solution may address one aspect of a problem but can cause other problems. They will encounter this idea further in Activity 2 where they will make decisions to solve problems. They will see that each decision has consequences, some intended and some unanticipated. Ask students to reflect about when they (or someone that they know) may have made a decision that had unintended consequences. Allow students to share their thoughts.

5. Preview the chapter and revisit the Guiding Question. (5 minutes)

a. Preview the chapter with the students.

Use the Chapter Overview to guide you as you preview the rest of the chapter with the class. Introduce the guiding question for the chapter, "How can the effects of environmental problems be reduced?" and briefly preview the content they will be learning, including the disciplinary core ideas, and the crosscutting concepts and science and engineering practices they will use to build conceptual understanding.

Explain to students that the main learning goals for this chapter are: 1) to evaluate competing design solutions (based upon jointly developed and agreed-upon design criteria), 2) apply scientific principles to design a solution, and 3) construct an oral argument to support or refute a solution to a problem. Tell students that they will engage in these practices as they encounter a variety of environmental problems.

b. Revisit the guiding question.

Conclude the activity by revisiting the Guiding Question, "What are some of the ways to deal with an insect problem?" Draw students' attention to the ideas that "when making decisions scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions to take" (from Connections to the Nature of Science in the Crosscutting Concepts strand). Analysis question 1 can be used to frame a conversation around whether scientific knowledge is the only basis on which environmental decisions are made. Help students realize that none of the four solutions they examined were without drawbacks. This will be a recurrent theme throughout this chapter.

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. What factors did you consider when deciding which solution to recommend?

> **Assessment – CCC – Connections to the Nature of Science**
> This question provides an opportunity to gauge students' initial understanding of the idea that scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes (CNoS). The intent of this question is to foreshadow the concept of a solution that meets humans and environmental needs which is introduced in Activity 3. At this stage it is sufficient to discuss students' responses and potentially organize them into categories such as environmental impact and human impact.

Note: Students' answers will vary. Some may look for the most effective environmental solution. Others may consider how much Holly and her family were affected.

2. **What other information would have been useful when you were examining solutions?**

   Note: Students' responses will vary. Some may suggest that knowing the actual costs of the solutions would have made it easier to compare them. Others suggestions might include having more information about past successes of the solutions, or detailed information about the toad and the environment or the pesticide, etc.

3. **Holly's story is based on a real-life problem. Your teacher will give you more information about the problem and the solution that was tried. Describe how the solution relates to an environmental problem that you have studied in this unit.**

   The solution that was tried was the introduction of cane toads. The cane toad became an invasive species in Australia. We studied an invasive species (zebra mussels) in the last chapter.

More Information

Science Content Information

The cane toad (*Bufo marinus)* is a large and poisonous animal that is native to Central and South America. Since the toad had been introduced to various regions in the world in an attempt to control pests in cane fields, Australian authorities approved importation of cane toads to the Australian province of Queensland in 1935. About 100 were shipped in, allowed to breed in captivity, and were released into several sugar plantations where two types of beetles were ruining the crop.

Although the cane toads would certainly eat the beetles, it turned out that they didn't encounter the beetles frequently enough to eat many of them. One reason is that the beetles lived mainly in the higher parts of the sugar cane plants out of the toad's jumping range. Another reason is that the beetle only invaded the sugar cane fields at the time of year when the cane toad didn't go there because of the lack of protective plant cover. In addition, the beetles were most active during the day, but the cane toads fed mainly at night. The cane toads didn't go hungry though, as they ate pretty much anything that would fit into their mouths–including insects, frogs, small reptiles, mammals, and birds–eventually diminishing the biodiversity of the areas they were invading.

A female cane toad can produce around 35,000 eggs every time she mates, which can happen several times a year. Because cane toads can survive in a wide range of conditions, they adjusted well to the environment in Queensland. They can also travel 50 km in a single day and have spread to other parts of Australia. They have no natural predators in Australia, and most predators that do attempt to eat them die of heart failure since the adults have poison glands in their skin. Cane toads have a voracious appetite and can feed as often as 200 times a night. The current cane toad population is estimated to be over 200 million. This invasive species has caused significant disruptions to ecosystems throughout the northern and eastern parts of Australia.

Activity 5.1

Engage: Solving a Problem

Materials and Advance Preparation

For the teacher

- ☐ Access to computer with Internet connection
  Preview the video clip on cane toads available at the link below and cue up the video.
  The link to the segment follows: http://www.nationalgeographic.org/media/cane-toads/
- ☐ 1 large computer monitor or projector

For each student

- ☐ Handout 5.1-1, "Control Methods"

Teaching Suggestions

1. **Students read the scenario and brainstorm questions.** (15 minutes)
   - **a.** Have students read the scenario at the beginning of the activity or read it aloud.
   - **b.** Begin to create a KWL chart by asking the class what they know from the scenario.
   - **c.** Have students work in groups of four to complete Procedure Step 1.
   - **d.** Write students' responses on the W column of the KWL chart during Procedure Step 2.
   - **e.** Provide a limited amount of additional information in the L column of the KWL.

Doing the Activity

2. **Students examine ways to solve the insect problem.** (15 minutes)
   - **a.** Ask the class to identify the problem and the needs of a solution.
   - **b.** Provide a few minutes for groups to brainstorm ways of solving the insect problem.
   - **c.** Give a copy of Handout 5.1-1 to each student.
3. **Students recommend a solution.** (5 minutes)
   - **a.** Ask each group to recommend the solution that they think is best for Holly's family.

b. Ask students to consider how their choice of solution would affect the environment, the family, and the community.

Follow-Up

4. **Students watch a video segment about the cane toad invasion in Australia.** (10 minutes)

   a. (Assessment) Discuss Analysis questions 1 and 2 with the class.

   b. Direct students' attention to Analysis question 3.

   c. Show the video and briefly discuss the meaning of biological control.

   d. Refer students' back to Analysis question 3.

   e. Summarize the insect infestation problem and the use of biological control.

5. **Revisit the Guiding Question.** (5 minutes)

   a. Preview the chapter with the students.

   b. Revisit the guiding question.

2 class sessions

Stability and Change

How can we balance human needs with those of the environment?

Human impact plays an important role in this activity as students play a game where each member of a group manages a connected area of a fictitious community. As a group they make decisions that affect ecosystem services and the environment, concepts that were introduced in the previous chapter. Each decision has consequences, some of them immediate and some delayed. Some of the consequences are also unanticipated by the group. By the end of the game, students realize that balancing environmental needs with human needs can be difficult.

Rationale & NGSS Integration

In the previous activity students saw that each proposed solution had advantages and disadvantages. This Explore activity continues developing that concept as students are challenged to manage assigned environmental areas in such a way that the decisions that they make cause as few detrimental effects as possible. Students interact with the core idea of human activities impacting the environment in both positive and negative ways. They also engage with the crosscutting concepts of cause and effect, stability and change, the nature of science, and connections to engineering, technology, and applications of science.

Students continue to build on their skill of constructing an argument based on evidence to decide which solution to an environmental problem is the best. However, now as they make decisions students will see that sometimes what is good for people is not great for the environment. They do this when, after each decision, they add or subtract points in three categories – environmental, economic, and social. The latter two categories specifically relate to effects on humans. The process of examining effects from both an environmental and human perspective is used in the remaining activities of this chapter as students first evaluate, and later design, solutions.

Activity Overview

In this Explore activity students act as managers of adjacent environmental areas in a simulated environment. Each group of four managers makes decisions that affect the areas. These decisions have both short and long term consequences. Students track the effects of the group's decisions by recording changes to their environmental, money, and happiness points.

Key Vocabulary

ecosystem services **environmental**

Materials and Advance Preparation

For each group of four students

- ☐ 1 set of 6 Round 1 event cards*
- ☐ 1 set of 5 Round 2 event cards*
- ☐ 1 set of 4 Round 3 event cards*
- ☐ 1 map

*Note that each group needs four Event cards for each Round. Six Round 1 cards and five Round 2 cards have been provided. This allows for some differences in experiences between groups. Shuffle (or have students shuffle) each set of Event cards before use.

For each student

- ☐ Handout 5.2-1, "Score Sheet"**

** You may want to prepare a second set of Handout 5.2-1, "Score Sheet" for each class. They will use one sheet during the practice and will likely need a fresh sheet for the actual game.

Teaching Summary

Getting Started

1. Discuss ways in which humans impact the environment.

Doing the Activity

2. Students learn the rules of the game in a practice round.

3. Groups complete playing three rounds of the game.

Follow-Up

4. (Assessment) Discuss the patterns shown by the scores from the game.

5. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. Discuss ways in which humans impact the environment. (15 minutes)

a. Ask the class to describe examples from previous chapters where humans have had an impact on the environment.

Ask the class to think about what they have learned in the unit so far and to describe examples of ways that humans impact the environment. They may suggest hunting and wolf reintroduction from Chapter 1, overfishing and dead zones from Chapter 3, and introducing invasive species from Chapter 4. Ask students to think of other examples that they know of but have not been included in the unit. Encourage them to think of local examples, even if the problem does not seem large. Examples might include pollution, building structures, building roads, damming rivers, etc.

b. Confirm that human actions often have consequences for the environment.

Summarize this part of the lesson by confirming that human actions often have consequences for the environment. Sometimes these consequences are known and sometimes they are unknown; sometimes the effects are short-term and sometimes they are long-term.

c. Introduce the game.

Explain that in this activity they will play a game where members of the group manage different but related environmental areas. They will make various decisions and measure the consequences by recording a score in a table. Their challenge is to manage their area so that it is in a better condition at the end of the game than at the beginning.

Doing the Activity

2. **Students learn the rules of the game in a practice round.** (25 minutes)

   a. Organize students into groups of four.

   For this activity, students will work in groups of four. If you have groups with fewer than four it is possible for a student to manage more than one area. If you have to create a group with more than four students it is possible for a pair of students to manage an area together. Remind students that effective group work is essential as they engage in scientific and engineering practices. If you used Student Sheet 2, "Evaluating Group Interaction," earlier in the unit, have students refer to their self evaluations to reflect on how they can contribute more productively to their group. For more information on group work, see Section 2 in Teaching Strategies.

   b. Distribute the map and Handout 5.2-1, "Score Sheet."

   Explain that the first thing to do is for each student to select one of the four areas on the map. This will be the environmental area that they manage. Discuss the score sheet with the class, pointing out that there are three rounds in the game and three columns in which to record scores. Explain that the scores in the table are an indication of the conditions of the area—the higher the numbers, the better the conditions.

   c. Explain how to use the Event cards and the scoring system.

   Project one of the Event cards from Round 1 so that students can see the format. Point out that at the top of the card there is a description of an action that the group will decide whether to approve or to ignore. The tables on the cards show how the effects of their decision will affect each of the point columns. This provides a simple numerical representation of cause and effect. Spend a little time discussing what the three columns represent. Environmental points provide an indication of how healthy the environment is. Money points reflect how strong the local economy is (whether people and businesses have money), and happiness points reflect how satisfied (and happy) the local people are.

   Consider drawing symbols to represent the meaning of each of the columns. For example, use a tree to represent the environment, a dollar sign to represent money, and a smiley face to represent happiness. These may help students to better connect the terms with their meaning. In the next activity, the terms "money" and "happiness" will be replaced by "economic" and "social." You can reinforce the connection between money and economic factors, and between happiness and social factors, by using the same set of symbols in both activities.

d. Direct students' attention to Procedure Step 4.

Explain that the person who takes the card should read the Action item and the choices. Emphasize that they should NOT tell the rest of the group the information about how the scores change in the tables on the card. Point out that in Step 5 the other members of the group should predict whether the scores will increase or decrease based on the possible choices. Members of the group should then make a choice and the card reader should reveal how the scores in each column should be adjusted based on the decision made. Make sure that the role of the card taker/reader rotates with each new card, so that all members of the group have a chance to read and also to predict.

e. Allow groups time to play a practice round.

Hand out the Round 1 Event cards and allow groups to try playing and scoring a couple of events. Monitor groups to see which ones need help and which have got the hang of the game. Allow the class to ask clarifying questions regarding game play and scoring. Consider whether to hand out the remaining Event cards and allow students to continue or whether to collect the cards and start again the next day.

Depending on the length of your class periods, consider breaking the activity here.

3. **Groups complete playing three rounds of the game.** (30 to 40 minutes)

a. When confident that the class understands how to play the game, hand out a full set of Event cards for all three rounds. Explain that a round (four Event cards) should be completed before moving on to the next round. Emphasize that the point total in each column is carried over to the next round (see sample answer for Handout 5.2-1 for an example of this). As groups are playing the game, walk around and check that each student is entering a brief description of each event in the appropriate column. This will help students during the analysis part of the activity.

Follow-Up

4. **Discuss the patterns shown by the scores from the game.** (15 minutes)

a. Use the Analysis questions to discuss the results of the game.

When discussing Analysis question 1, remind students that they learned about ecosystem services in Chapter 4. The pattern described in Analysis question 3 should be evident to students no matter which Event Cards they used during the simulation. Use the question to generate a short discussion of reasons for the pattern, i.e. why there might be negative environmental effects when there are positive economic and social events such as building schools, resorts, factories, and roads. At this stage do not go too deeply into the discussion as this relationship will be revisited in the next activity. This discussion foreshadows the introduction of trade-offs in the next activity.

b. Discuss whether students were able to improve their area by the end of the game.

Analysis question 4 can be used to raise the concept of criteria, which are further discussed in the next activity. In some cases students will find it difficult to state whether their area was in a better condition at the end of the game than at the beginning, since some point totals may have decreased while others increased. Point out that if the group had previously agreed on criteria for measuring success then it would be easier to determine if their area had been improved.

5. **Revisit the Guiding Question.** (5 minutes)

a. Revisit the guiding question "How can we balance human needs with those of the environment?" before concluding the activity. Ask students how difficult it was to balance the needs of humans (housing, schools, roads, energy, recreation, etc.) with protecting the environment. Ask students to reflect on whether their decisions tended to favor addressing human or environmental needs. Encourage students to incorporate the crosscutting concepts of stability and change, cause and effect, and connections to engineering, technology and applications of science (use of technologies is driven by individual or societal needs, desires, and values, etc.) as they reflect on their decisions. In the next activity, students will begin to formally evaluate solutions from environmental, economic, and social perspectives. They will do so after being introduced to the importance of setting criteria and working within constraints.

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **Describe an example of a cause and effect relationship that occurred during the game.**

> **Assessment – CCC - Cause & Effect**
> This question provides an opportunity to assess students' understanding of the crosscutting concept of cause and effect in relation to the actions that they took (or declined to take) during the early part of the game and the consequences (effects) that occurred during the latter parts of the game.

Note: There are numerous examples that students could describe. They could use examples from the events on individual cards, such as building a large farm near the river reduced the environmental points of the river and gulf areas. They could also use examples that had long term consequences, such as deciding not to build the dam in Round 1 leading to an increased loss of environmental, money, and happiness points during the flooding event in Round 3.

2. **Describe any patterns that you saw in the way that the environmental, money, and happiness points changed.**

   Note: Student responses will vary but the main pattern will likely be that actions which increased the money and happiness points frequently decreased the environmental points. Students might suggest that there is a cause and effect relationship between human action and impact on the environment. Help students to see that the impact is often negative unless engineered otherwise.

3. **Explain how an event in one area could affect another area.**

> **Assessment – DCI – ESS3.C; SEP – Engaging in Argument from Evidence; CCC – Cause and Effect, Stability & Change, and Connections to Engineering, Technology, and Applications of Science**
> This question provides an opportunity for students to engage in argument, using their understanding of the crosscutting concepts of stability and change and cause and effect in the context of ESS3.C (Typically as human populations…increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.)

Note: Student responses will vary depending on the examples that they choose. There are many examples where an event in one environmental area affected one or more other areas. These include events along the river that also affect the gulf. This will happen since the river feeds into the gulf. Events in the lake can also affect the river and gulf, since the lake is connected to the river. Other effects might be a little less obvious such as building schools, roads, or new housing. These will benefit people from several areas although the environmental impacts might be felt only in the immediate area. Students may point out that a small change in one area may cause a large change later. Use student responses to gauge if students understand that actions in one place can sometimes have effects far away. If students are struggling to understand this idea, be prepared at the start of the next activity to share local examples that students might relate to.

4. **Do you believe that your area was in a better condition at the end of the game than at the beginning? Explain your reasoning.**

   Note: Students' responses will vary depending on their scores. Check the reasoning behind their answer. Some students may consider that their area has improved if they finished with a higher point total than they started with. Other students may have increased the total number of points but the points may be high in two categories (such as money and happiness) and low in one (such as environmental). In such a case they may decide that the decrease in the one category outweighed the increase in the other categories and therefore the condition of their area had worsened.

5. **How difficult was it to balance human needs with those of the environment? Explain your answer using examples from the activity.**

   Note: Student responses will vary depending on what events occurred in their game and how they responded to them. Most students will likely find that it is not easy to balance human needs with those of the environment.

Activity 5.2

Explore: Stability and Change

Materials and Advance Preparation

For each group of four students

- ☐ 1 set of 6 Round 1 event cards*
- ☐ 1 set of 5 Round 2 event cards*
- ☐ 1 set of 4 Round 3 event cards*
- ☐ 1 map

* Note that each group needs four Event cards for each Round. Six Round 1 cards and five Round 2 cards have been provided. This allows for some differences in experiences between groups. Shuffle (or have students shuffle) each set of Event cards before use.

For each student

- ☐ Handout 5.2-1, "Score Sheet"**

** You may want to prepare a second set of Handout 5.2-1, "Score Sheet" for each class. They will use one sheet during the practice and will likely need a fresh sheet for the actual game.

Teaching Suggestions

1. **Discuss ways in which humans impact the environment.** (15 minutes)
    - **a.** Ask the class to describe examples from previous chapters where humans have had an impact on the environment.
    - **b.** Confirm that human actions often have consequences for the environment.
    - **c.** Introduce the game.

Doing the Activity

2. **Students learn the rules of the game in a practice round.** (25 minutes)
    - **a.** Organize students into groups of four.
    - **b.** Distribute the map and Handout 5.2-1, "Score Sheet."

c. Explain how to use the Event cards and the scoring system.

d. Direct students' attention to Procedure Step 4.

e. Allow groups time to play a practice round.

3. **Groups complete playing three rounds of the game.** (35 minutes)

Follow-Up

4. **Discuss the patterns shown by the scores from the game.** (15 minutes)

a. (Assessment) Use the Analysis questions to discuss the results of the game.

b. Discuss whether students were able to improve their area by the end of the game.

5. **Revisit the Guiding Question.** (5 minutes)

2 class sessions

Designing a Solution

What factors should be considered when choosing or designing a solution to an environmental problem?

Students revisit the previous two activities as they analyze the impacts of decisions made in terms of the effects on the environment, people, and communities. They learn that solutions are designed to operate within constraints and that criteria are used to develop or choose the optimal solution. Finally, they apply criteria and constraints as they use a framework to evaluate potential solutions to the crop infestation problem from an environmental, economic, and social perspective.

Rationale & NGSS Integration

In the two prior activities in this chapter, students saw that every course of action has consequences. They saw that the consequences could be short- or long-term, intended or unintended, and included impacts on humans and the environment. In this Explain activity, students are formally introduced to a framework where they consider the environmental, economic, and social impacts of decisions or proposed courses of action. Students apply their understanding of cause and effect relationships to explain both the desirable and undesirable effects caused by different solutions. Students are also introduced to the concepts of criteria and constraints as applied to designing or evaluating a solution. Through their analysis of potential solutions to an environmental problem, students see that decisions that society makes are not solely based on scientific knowledge.

Activity Overview

In this Explain activity, students design a solution to the crop infestation problem by evaluating how well various courses of action meet designated criteria and constraints, and how each affects environmental, economic, and social considerations. In doing so, students realize that solutions to environmental problems often involve trade-offs and that decisions are influenced by more than scientific considerations.

Key Vocabulary

criteria (criterion)	constraints
economic	social

Materials and Advance Preparation

For the teacher

- ☐ 1 set of 6 Round 1 event cards (from Activity 5.2)
- ☐ 1 set of 5 Round 2 event cards (from Activity 5.2)
- ☐ 1 set of 4 Round 3 event cards (from Activity 5.2)

For each group of four students

- ☐ 1 set of 2 Insect Solution cards

For each student

- ☐ 1 Handout 5.3-1, "Analyzing the Insect Solutions"
- ☐ 1 Handout 5.3-2, "Designing Solutions"

Teaching Summary

Getting Started

1. Discuss decisions made in the previous activity.

Doing the Activity

2. Students complete the reading.
3. Groups complete and discuss Handout 5.3-1.

4. (Assessment) Students apply criteria and constraints to evaluate the insect solutions.

5. (Assessment) Groups design a solution using Handout 5.3-2.

Follow-Up

6. Review criteria and constraints.

7. Revisit the Guiding Question.

References

- United Nations World Commission on Environment and Development, 1987. Report of the world commission on environment and development: Our common future. Retrieved August 2015 from http://www.un-documents.net/wced-ocf.htm

Teaching Suggestions

Getting Started

1. **Discuss decisions made in the previous activity.** (5 minutes)

   a. Use the Event Cards from Activity 2 to begin a conversation about the consequences of decisions.

   Read aloud an Event Card from Round 1 or 2 of the game from Activity 2 and ask the class to recall what consequences there were from the decisions they made relating to that event. If necessary, remind students that sometimes there are consequences far away from where the problem originates. Give a local example to emphasize this point (e.g., a minor traffic accident in one location can cause traffic delays for long distances and prolonged periods of time.) Repeat this procedure using another card. Ask students if the consequences affected people or the environment. Student responses should typically indicate that both were affected.

   b. Ask students to recall situations where decisions had unintended consequences.

   Ask the class to provide examples of decisions from the game where there were unintended consequences, such as deciding not to dam the river and later suffering from flooding. Follow up this discussion by calling on students to describe situations that they have experienced or heard about where there were unintended consequences of decisions. Encourage students to share any local environmental examples they are aware of.

Doing the Activity

2. **Students complete the reading.** (10 to 15 minutes)

   a. Assist students with the reading as necessary.

   Draw students' attention to the words in bold type. If you used symbols to represent "money" and "happiness" in the previous activity, use the same symbols with "economic" and "social" so that students can connect these terms across the activities. Explain that "economic" and "social" are broader terms than "money" or "happiness," using examples from the reading to support your explanation. Add words to the word wall and/or have students add the words to their Personal Vocabulary Log. Refer to Section 1 of Teaching Strategies for more information about both of these strategies.

   b. Introduce the concepts of criteria and constraints.

   Review the reading and use familiar examples to help students understand the difference between criteria and constraints. For example, the criteria for choosing a new cell phone might include that it has a fast processor and a good camera, whereas constraints might include it costing less than $150 and at least an 8 MP camera. Another example might be choosing a backpack for school. Constraints may include cost and size. Criteria may include quality of build, durability, number of pockets, range of colors, style, etc. Add the terms criteria and constraints to the Word Wall.

   c. Discuss how the best solutions address environmental, economic, and social needs.

   Use the Venn diagram to illustrate how some solutions might address just one or two needs (environmental, economic, and/or social) by asking students to point to the relevant sections of the diagram as you describe the area(s) of need met. Point out that the intersection of all three circles represents where all three areas of need are met and that this would be indicative of a good solution. Ask the class if they think it is always possible to develop a solution that addresses all three areas of need. See the More Information section for additional detail about this Venn diagram.

3. **Groups complete and discuss Handout 5.3-1.** (25 minutes)

   a. Assist groups in completing their row of the handout.

Distribute Handout 5.3-1 and assign groups to one of the four solutions from Activity 1. Make sure that at least one group is assigned to each solution. Provide five to ten minutes for groups to discuss and record how their assigned solution pertains to environmental, economic, and social considerations. Student responses on the handout provide a quick way of checking how well students have understood the distinction between environmental, economic, and social considerations.

b. Organize groups for sharing the impact of their solution.

Have groups meet with another group that was assigned the same problem to compare their responses. Allow each pair of groups to report out to the class. Students should listen to the group reports and record information for the other rows of the handout. When all the rows have been completed, discuss with the class which solution had the smallest economic impact, which had the smallest social impact, and which had the least environmental impact. Students should realize that no one solution had the smallest impact in all three categories. A sample completed handout 5.3-1 is provided in the Handouts section of the Teacher Guide.

This is a suitable place to end day 1 of this activity.

4. Students apply criteria and constraints to evaluate the insect solutions. (15 minutes)

> **Assessment – DCI – MS-ETS1.B**
> Procedure Steps 6 to 9 provide an opportunity to assess how well students have understood the concepts of criteria and constraints.

a. Hand out the Insect Solution cards.

There are two cards (labeled A and B) for each group of four students. One pair of students in the group should examine Card A, while the other pair examines Card B.

b. Assist students as needed in choosing the best solution for their card.

Cards A and B contain different sets of criteria and constraints. For each card, the constraint will eliminate one of the four solutions. The constraint on Card A will eliminate the Relocation option. The constraint on Card B will eliminate the Chemical Control option.

The criteria should narrow the choices down further. For Card A, students are likely to select the Chemical Control option as best meeting the criteria. For Card B, students might choose Biological Control as the best match. Some variation in choice of solutions is possible depending on how students interpret some of the information about each solution.

c. Instruct students to share their choice of solution within the group.

Have the pair of students with Card A share their choice of solution and their reasons for making that choice. Repeat the process with the pair of students with Card B.

d. Ask the class to share how the different criteria and constraints affected their choice of solution.

Use student responses to emphasize how the design or choice of a solution is greatly influenced by the criteria and constraints that are applied.

5. **Groups design a solution using Handout 5.3-2.** (20 minutes)

> **Assessment – DCI – MS-ETS1.B; SEP – Constructing Explanations and Designing Solutions; CCC – Cause and Effect**
> Procedure Steps 10 to 12 provides an opportunity to assess how well students can design a solution to an environmental problem. Step 10 also provides an opportunity for assessment of ELA Common Core State Standard WHST6-8.1

a. Explain how to use Handout 5.3-2.

Remind students of the discussion in Activity 1, where the problem and the needs of the solution were identified. Guide the class to enter information from that discussion into boxes 1 and 2 of handout 5.3-2.

b. Tell the class that each group will use the handout to design a solution to the insect problem.

Inform groups that they will need to decide on one constraint and at least two criteria to apply to the design of their solution to the insect problem. They should enter the constraint information into box 3 and the criteria into box 4. Encourage groups to choose criteria related to at least two sections of the Venn diagram in the student book (environmental, economic, and social.) If students are having difficulty deciding on criteria, consider making a decision through a class discussion.

c. Guide groups in filling out section 5 of the handout.

Tell groups that they can use a previous solution, combine solutions, or come up with a new solution of their own. After groups have completed section 5 of the handout, ask students if there are any disadvantages associated with their solution. If necessary, refer students back to the disadvantages that they identified on Handout 5.1-1 in Activity 5.1 and remind them of any negative consequences of decisions made in Activity 5.2.

d. Introduce the concept of a trade-off.

Explain that trade-offs involve giving up something that is a benefit or an advantage in exchange for something that may be more desirable. Provide examples of trade-offs, for example, when asked, "Paper or plastic?" at a store checkout counter, most shoppers make the choice quickly. But there are several trade-offs attached to choosing paper or plastic. A shopper who chooses paper over plastic may do so to avoid generating plastic waste. In requesting the paper bag, though, they are contributing to other environmental problems, such as increased water and energy use, and the higher amounts of solid waste and carbon dioxide emissions associated with making paper bags. Neither choice is ideal, and both choices have a downside. Identifying the trade-offs helps clarify the reasoning that is being applied to make a decision.

e. Facilitate a class discussion about the best solution.

Discuss competing criteria and any changes that the class may want to make to the criteria or constraints. After some discussion encourage the class to use section 6 of the handout to come up with a better solution. Make sure that students provide their reasoning for why the new solution is better than the previous one. Use Challenge questions, which are appropriate during this Explain activity, when students should be refining their explanations using scientific reasoning. See Section 2 in Teaching Strategies for more information on Challenge questions.

Follow-Up

6. Review criteria and constraints. (5 minutes)

a. Use Analysis items 1 and 2 in a discussion of criteria and constraints.

Students should note that human-related criteria can often be in opposition to environmentally related criteria.

b. Use Analysis item 3 in a discussion of the role of science in making decisions.

Help students understand that scientific knowledge can describe the consequences of actions but does not necessarily determine the decisions that society takes. Be ready with some local or regional examples (for example, development/preservation issues) in case students struggle to come up with their own.

7. Revisit the Guiding Question. (5 minutes)

a. Revisit the guiding question "What factors should be considered when choosing, or designing, a solution to an environmental problem?" before concluding the activity. Students should be able to explain that one way to examine solutions to environmental problems is by considering the environmental, economic, and social impacts. They should also be able to explain how criteria and constraints guide a solution and that sometimes criteria can conflict, in which case the solution will likely involve some degree of trade-offs. During the discussion, encourage students to include the cross cutting concept of influence of science, engineering, and technology on society and the natural world (all human activity draws on natural resources and has both short- and long-term consequences, positive and negative, for the health of people and the natural environment. The uses of technologies, and limitations on their use, are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions).

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **How do criteria and constraints affect the development of a solution?**

> **Assessment – DCI – MS-ETS1.B**
> This question provides an opportunity to learn more about students' understanding of the role of criteria and constraints in developing solutions.

Criteria describe the desired features of a solution. Constraints are limits that apply to solving the problem. As a solution is developed, efforts are made to meet the criteria and stay within the limits of the constraints.

2. **Which types of criteria were often in competition with one another? Suggest reasons why.**

> **Assessment – DCI – ETS1.B; CCC- Influence of Science, Engineering, and Technology on Society and the Natural World**
> This question provides an opportunity to assess understanding of the difficulties of satisfying competing criteria.

Note: Student answers will vary. A sample answer follows.

Environmental criteria were often competing with economic and social criteria. For example, physical removal of the insects will help preserve the environment but will cost a lot of money and people may lose their jobs, at least for a while. This is because reducing human impact on the environment requires people to take action and/or apply suitable technologies.

3. **Scientific knowledge is valuable when making decisions because it can describe the consequences of actions. However, science is not usually the only consideration when making a decision. Explain why, using an example from a problem that has affected your own community.**

> **Assessment – DCI– MS-ESS3.C; CCC-Connections to the Nature of Science**
> This question provides an opportunity to assess student understanding of the concept of human impact on the environment and that scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Note: Student answers will vary. A sample answer is shown below.

Decisions that affect the environment usually affect people and decisions that affect people often affect the environment. So the decisions need to be made by considering both the environmental impact and the impact on people and communities. A few years ago the school district built a new bus garage on land that was made available by filling in part of a wetland area next to a school. This decision reduced the total area of wetland by almost 50%. Although this affected the habitat of many organisms it was felt that the need for the new bus garage was important to the community. The school district felt that by keeping some of the wetland area the environmental effects would be small.

More Information

Sustainability

Although the term "sustainability" is not used in this unit, the general concepts introduced in Chapter 5 pertain to sustainable development. In 1987, the United Nations World Commission on Environment and Development (WCED) reported, "Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs." There are three generally accepted dimensions to sustainability: environmental, economic, and social. In the student book, they are represented as a Venn diagram with sustainability being at the intersection of all three circles. An alternative visual utilizes concentric circles with the economy circle inside the society circle, which is inside the environment circle. This is helpful in showing that the economy and society are constrained by environmental limits. For more information on Venn Diagrams, see Section 2 in Teaching Strategies.

Activity 5.3

Explain: Designing a Solution

Materials and Advance Preparation

For the teacher

- ☐ 1 set of 6 Round 1 event cards
- ☐ 1 set of 5 Round 2 event cards
- ☐ 1 set of 4 Round 3 event cards

For each group of four students

- ☐ 1 set of 2 Insect Solution cards

For each student

- ☐ 1 Handout 5.3-1, "Analyzing the Insect Solutions"
- ☐ 1 Handout 5.3-2, "Designing Solutions"

Teaching Suggestions

Getting Started

1. **Discuss decisions made in the previous activity.** (5 minutes)
    - **a.** Use the Event Cards from Activity 2 to begin a conversation about the consequences of decisions.
    - **b.** Ask students to recall situations where decisions had unintended consequences.

Doing the Activity

2. **Students complete the reading.** (15 minutes)
    - **a.** Assist students with the reading as necessary.
    - **b.** Introduce the concepts of criteria and constraints.
    - **c.** Discuss how the best solutions address environmental, economic, and social needs.

3. **Groups complete and discuss Handout 5.3-1.** (25 minutes)
    - **a.** Assist groups in completing their row of the handout.
    - **b.** Organize groups for sharing the impact of their solution.
4. **Students apply criteria and constraints to the insect solutions.** (15 minutes)
    - **a.** Hand out Insect Solution cards.
    - **b.** Assist students as needed in choosing the best solution for their card.
    - **c.** Instruct students to share their choice of solution within the group.
    - **d.** Ask the class to share how different criteria and constraints affected their choice of solution.
5. **Groups design a solution using Handout 5.3-2.** (20 minutes)
    - **a.** Explain how to use Handout 5.3-2.
    - **b.** Tell the class that each group will use the handout to design a solution to the insect problem.
    - **c.** Guide groups in filling out section 5 of the handout.
    - **d.** Introduce the concept of a trade-off.
    - **e.** Facilitate a class discussion about the best solution.

Follow-Up

6. **(Assessment) Review criteria and constraints.** (5 minutes)
    - **a.** Use Analysis items 1 and 2 in a discussion of criteria and constraints.
    - **b.** Use Analysis item 3 in a discussion of the role of science in making decisions.
7. **Revisit the Guiding Question.** (5 minutes)

2 class sessions

Evaluating Solutions

How can we evaluate solutions to decide how well they might work?

In the previous activity, students were introduced to a system that could be used in designing and evaluating solutions. In this Elaborate activity they apply the system to potential solutions for real-world environmental problems. They develop and use environmental, economic, and social criteria to choose the best combination of solutions that fall within the limits of identified constraints. They complete the activity by suggesting refinements to their solutions.

Rationale & NGSS Integration

In this activity students apply the framework used in the previous activity to evaluate solutions to an assigned environmental problem. Students interact with the core ideas of human activities impacting the environment in both positive and negative ways, increasing human populations typically causing negative environmental impacts, and that there are systematic processes for evaluating solutions. They engage in the science and engineering practice of (constructing explanations and) designing solutions as they develop criteria before evaluating and refining solutions to complex real world problems. In doing so, students prioritize criteria and consider trade-offs. They also engage with the crosscutting concepts of cause and effect, stability and change, and connections to the nature of science as they see firsthand how developing solutions to environmental problems involves more than scientific considerations.

Activity Overview

In this Elaborate activity groups are assigned a real-world, current environmental problem. They brainstorm solutions and develop a criterion-based system which they use to rank their solutions from best to worst. Groups then use the same system to evaluate several solutions to their assigned problem. They suggest a solution to the problem, which may be a combination of previously examined solutions.

Key Vocabulary

biodiversity **ecosystem services**

Materials and Advance Preparation

For each group of four students

- ☐ 1 Handout 5.4-1,"Possible Solutions"

For each student

- ☐ 1 Handout 5.3-2,"Designing Solutions" (blank copy, from Activity 5.3, optional)

Teaching Summary

Getting Started

1. Discuss environmental disruptions previously encountered in the unit.

Doing the Activity

2. (Assessment) Groups brainstorm solutions to a specific environmental problem and develop criteria applicable to the solutions.

3. (Assessment) Groups apply their criteria to a list of possible solutions before choosing a combination of solutions and designing their own.

Follow-Up

4. (Assessment) Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Discuss environmental disruptions previously encountered in the unit.** (10 minutes)

   a. Ask the class to describe the types of environmental disruptions that they have encountered in the unit so far.

      Delve deeper into a few of the disruptions to see if the class can identify the causes and effects of each one. For example, hunting wolves to extinction reduced biodiversity and affected the food web, and the introduction of an invasive species (zebra mussels) altered the food web, changed the clarity of the water, and affected ecosystem services.

   b. Read the Introduction to the class.

      As needed, refer to the Word Wall and remind students of the meaning of terms such as biodiversity and ecosystem services. Tell the class that in this activity they are going to examine several current environmental problems and evaluate potential solutions to them before choosing a combination of the solutions and then refining them.

Doing the Activity

2. **Groups brainstorm solutions to a specific environmental problem and develop criteria applicable to the solutions.** (30 minutes)

   a. Assign one of the four environmental problems to each group.

      If possible, have at least two groups assigned to each problem as they will compare their thinking at various points during the activity. Allow time for students to read about their assigned problem. Provide assistance in understanding the readings as needed

   b. Have groups identify cause and effect for their assigned problem.

> **Assessment – DCI– MS-ESS3.C; CCC- Stability and Change, Cause and Effect**
> Procedure Step 2 provides an opportunity to check for understanding of the crosscutting concepts of cause and effect and stability and change and human impact on Earth systems as groups write down the cause of the problem and describe its effects.

A sample answer is provided on the next page.

Environmental Problem 1

- *Cause: Overfishing of predators of crown-of thorn starfish.*
- *Effects: Increase in number of crown-of-thorn starfish. Increase in damage to coral reefs.*

Environmental Problem 2

- *Cause: Villagers using the protected area to hunt animals and expand their farms.*
- *Effects: Decrease in biodiversity of the forest. Increase in soil erosion. Increase in sediment in the lake producing reduction in water quality and changes to the food web of the lake.*

Environmental Problem 3

- *Cause: Invasive species (zebra mussel) in states near to Yellowstone Lake.*
- *Effects: None yet, but people are trying to avoid the introduction of the zebra mussel to the lake. The mussels would cause disruptions to the food web and to ecosystem services.*

Environmental Problem 4

- *Cause: Destruction of habitat, overfishing, and increased runoff into Chesapeake Bay.*
- *Effects: Reduction in water quality of the bay. Large decrease in oyster populations. Increase in dead zones.*

c. Have each group agree on the constraints and criteria that they wish to apply to a solution for their environmental problem.

Provide some time for groups to first brainstorm constraints and criteria that they wish to apply to a solution to their problem. Then have them brainstorm possible solutions before using the criteria to rank their solutions from best to worst. Bring groups together who are studying the same problem and allow them to compare their solutions, rankings, constraints and criteria. Remind students of ways to agree and disagree constructively using Student Sheet 1, "Developing Communication Skills."

Depending on the length of your class periods, you may want to break the activity here.

3. **Groups apply their criteria to a list of possible solutions before choosing a combination of solutions and designing their own.** (30 minutes)

   a. Distribute Handout 5.4-1, "Possible Solutions" to each group.

   Allow time for the groups to discuss the positive and negative effects of the possible solutions for their assigned problem. Encourage groups to separate the possible effects of each solution into environmental, economic, and social impacts. An example of a possible response for the solutions for Environmental Problem 1 is provided below.

Sample Student Response to Environmental Problem 1

Solution	Environmental Impact	Economic Impact	Social Impact
A	*Poison in starfish might get into other organisms.*	*Will provide employment for divers.*	*People may not be happy with a poison being used where they live.*
B	*Will probably allow the area to recover.*	*Will reduce employment for fishers but might increase tourism.*	*Some people will see the protected area as a good thing. Families of fishers may have to leave the area.*
C	*Doesn't solve the problem.*	*No effect.*	*Some people may feel they are making a useful contribution to solving the problem.*
D	*Could become an invasive species and affect the food web.*	*Unknown effect depending on how the food web is affected.*	*People might not want a non-native fish in the area.*
E	*Will allow the area to recover some.*	*Will provide employment for fishers.*	*The families of fishers would likely be able to stay as there is more work.*

b. Distribute Handout 5.3-2, "Designing Solutions" to each student.

Groups should fill out the front side of the Handout. Tell the class to add one constraint for the final solution for each environmental problem—a maximum budget of $500,000. Allow time for groups to make adjustments to their criteria (if they wish) and to make sure that they have at least one criterion related to each category—environmental, economic, and social. Note: some criteria may apply to more than one category.

c. Help students to complete Handout 5.3-2, "Designing Solutions" for their assigned environmental problem.

> **Assessment – DCI – MS-LS2.C, MS-LS4.D, ESS3.C, MS-ETS1.B; SEP – Engaging in Argumentation, Constructing Explanations and Designing Solutions; CCC – Stability and Change**
> Step 8 is aligned to the practice of Engaging in Argument from Evidence, specifically to evaluating competing design solutions based on jointly developed and agreed-upon design criteria. Step 9 ties to the practice of Constructing Explanations and Designing Solutions, specifically to applying scientific principles to design an object, tool, process, or system.

Assist groups as necessary as they decide on a solution. Most groups will choose a combination of solutions. There is no single correct answer to each problem. Look for logic in each group's reasoning and use of criteria and constraints. Use Probe questions, described in Section 2 of Teaching Strategies, to encourage students to articulate their reasoning. The solutions that groups propose will likely weigh one category of criteria more than another and thus will involve trade-offs. Section 6 of the handout provides an opportunity for students to refine their solutions.

d. Allow groups to share their solutions.

Have groups share with the other group(s) studying the same problem. Then provide time for each pair of groups to report out to the class.

Follow-Up

4. Revisit the Guiding Question. (15 minutes)

a. Use a whole class discussion to summarize the processes that groups used in developing criteria and designing solutions.

Use Analysis questions 1 and 2 as part of the discussion.

b. Revisit the Guiding Question.

As you revisit the guiding question, "How can we evaluate solutions to decide how well they might work?" remind students of the process that they used to evaluate their assigned solution. Once again emphasize the need to use a systematic approach and to use criteria that include environmental, economic, and social considerations. As in the previous activity, point out that all solutions have to operate within a set of constraints. These constraints may be economic (for example, not enough money to carry out all of the actions), temporal (actions have to happen within a certain time span, etc.), environmental (for example, certain land areas or species must be protected), etc.

c. Use Analysis question 3 to discuss the role of human needs and values in designing solutions to environmental problems.

Encourage students to apply their understanding of the practice of constructing explanations and designing solutions, and of the crosscutting concept of cause and effect as they discuss Analysis question 3. You may also wish to bring up the nature of science crosscutting concept (scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes). Ask students to describe whether this concept applies to their solutions. Tell the class that in the final activity, groups will design a method to stop or reduce a threat to coral reefs. To do so they will apply the system that they used in this activity.

Suggested Answers To Analysis

NOTE: Analysis questions marked with (Assessment) are suggested opportunities to check for student understanding. Hints for using the questions are included with the suggested answers.

1. **Describe how your criteria were similar to those of the other group who had the same environmental problem.**

> **Assessment – DCI – MS-ETS1.B**
> This question provides an opportunity to assess understanding of the need for a systematic process for evaluating solutions that takes into account criteria and constraints.

Note: Answers will vary but students should note that the criteria used to evaluate all of the solutions were related to environmental, economic, and social considerations.

2. **Describe how your criteria were different from those of the other group who had the same environmental problem.**

> **Assessment – DCI – MS-ETS1.B**
> This question provides an opportunity to assess understanding of the need for a systematic process for evaluating solutions that takes into account criteria and constraints.

Note: Answers will vary depending on students criteria. Some groups may have prioritized criteria differently than other groups, discounted some criteria, or added additional criteria.

3. **Can environmental problems be solved by technology alone? Explain your answer.**

> **Assessment – CCC – Connections to Engineering, Technology, and Applications of Science; Connections to the Nature of Science.**
> This question provides an opportunity to assess understanding of the role that individual or societal needs, desires, and values play in formulating solutions.

Note: Student responses will vary. Look for appropriate, sound reasoning in the response. In particular, look to see if students understand that although technology can play a big role in solving problems, it also requires humans to understand the problems and solutions and for policies and procedures to be put in place and to be followed. Thus, although scientific knowledge can describe the consequences of actions, it does not necessarily prescribe the decisions that society takes. A sample response follows.

Technology can be part of the solution to some environmental problems, but it is not the whole solution. For example, scientists might use special tools to monitor the Yellowstone Lake ecosystem for invasive zebra mussels, but in order to keep the mussels out of Yellowstone Lake there need to be rules to help protect the lake and people need to follow those rules so they do not accidentally bring zebra mussels to Yellowstone Lake.

Extension

Students may wish to learn about local efforts to address environmental problems. Several websites are suggested in the student book. This topic also provides good context for a field trip that ties together many of the issues addressed in this chapter and the entire unit, such as a visit to a local ecosystem under restoration.

Activity 5.4

Elaborate: Evaluating Solutions

Materials and Advance Preparation

For each group of four students

- ☐ 1 Handout 5.4-1,"Possible Solutions"

For each student

- ☐ 1 Handout 5.3-2,"Designing Solutions"

Teaching Suggestions

Getting Started

1. **Discuss environmental disruptions previously encountered in the unit.** (10 minutes)
   - **a.** Ask the class to describe the types of environmental disruptions that they have encountered in the unit so far.
   - **b.** Read the Introduction to the class.

Doing the Activity

2. **(Assessment) Groups brainstorm solutions to a specific environmental problem and develop criteria applicable to the solutions.** (30 minutes)
   - **a.** Assign one of the four environmental problems to each group.
   - **b.** Have groups identify cause and effect for their assigned problem.
   - **c.** Have each group agree on the constraints and criteria that they wish to apply to a solution to their environmental problem.
3. **(Assessment) Groups apply their criteria to a list of possible solutions before choosing a combination of solutions and designing their own.** (30 minutes)
   - **a.** Distribute Handout 5.4-1, "Possible Solutions" to each group.
   - **b.** Distribute Handout 5.3-2, "Designing Solutions" to each student.

c. Help students to complete Handout 5.3-2, “Designing Solutions” for their assigned environmental problem.

d. Allow groups to share their solutions.

Follow-Up

4. **(Assessment) Revisit the Guiding Question.** (15 minutes)

   a. Use a whole class discussion to summarize the processes that groups used in developing criteria and designing solutions.

   b. Revisit the Guiding Question.

   c. Use Analysis question 3 to discuss the role of human needs and values in designing solutions to environmental problems.

3 class sessions

Coral Reefs

How can the negative impact of humans on coral reefs be reduced?

Students are introduced to a broad range of threats to coral reefs around the world. They draw upon their understanding of designing solutions as groups develop and present a solution to one of the threats. As part of their presentation, groups make an argument for why their solution is a good response to minimizing human impact on the reef. After the presentations the class evaluates how well the solutions meet the specified criteria and constraints and discuss how the threat illustrates how increases in human populations and resource use negatively impact the environment.

Rationale & NGSS Integration

In this activity students apply what they have learned in this chapter and in the unit to develop a solution to minimize human impact on coral reefs. With minimal guidance they use a systematic approach to first developing and later evaluating solutions. As has been the case throughout this chapter students interact with the core ideas of human activities impacting the environment in both positive and negative ways, increasing human populations typically causing negative environmental impacts, and that there are systematic processes for evaluating solutions. They apply the practice of argumentation and engage with the crosscutting concepts of stability and change, and cause and effect. Finally, they demonstrate an understanding of the nature of science as they acknowledge that solutions, especially to global problems, are often influenced by factors other than science.

Activity Overview

In this Evaluate activity groups choose a threat to the health of coral reefs that is caused by humans. They design a solution to reduce or minimize the threat and present it to the class. They evaluate each of the solutions presented and construct an argument for the one that is most effective and sustainable.

Key Vocabulary

biodiversity **ecosystem services**

Materials and Advance Preparation

For each student

- ☐ 1 Handout 5.3-2, "Designing Solutions" (optional)

Teaching Summary

Getting Started

1. Facilitate a class discussion about coral reefs.

Doing the Activity

2. Groups complete the reading on threats to coral reefs using a literacy strategy.
3. Groups choose and summarize a threat.
4. (Assessment) Groups use a systematic approach to design a sustainable solution to stop or reduce the threat.

Follow-Up

5. (Assessment) Groups present their solutions to the class.
6. Revisit the Guiding Question.

Teaching Suggestions

Getting Started

1. **Facilitate a class discussion about coral reefs.** (10 minutes)

   a. Remind the class about the environmental problems they studied in the previous activity.

   Draw the attention of the class to Environmental Problem 1 in the previous activity, the issue of overfishing of predators of the crown-of-thorn sea star and the consequent damage done to coral reefs by an overabundance of these starfish. Use the introduction to this activity to provide more detail about coral reefs, emphasizing both their fragility and importance in marine ecosystems.

Doing the Activity

2. **Groups complete the reading on threats to coral reefs using a literacy strategy.** (15 minutes)

   a. Assist students as needed with the coral reef reading.

   If necessary, review the "Read, Think, and Take Note" literacy strategy with the class. This strategy is explained in Section 3 of Teaching Strategies. After groups have finished reading, ask them to share some of the notes that they wrote. Use these notes to frame a summary of the reading, writing the various threats on a board or chart paper. The main problems identified in the reading are: fishing – overfishing and destructive fishing techniques; pollution – including excess nutrients and increased sediments; tourism – direct damage from physical contact, indirect damage from pollution and development. If needed, clarify the difference between food and nutrients since nutrients are mentioned at the end of the reading. The effects of climate change, such as increasing ocean temperatures and acidity, are mentioned in the reading. These should be included in the list of threats but steer groups away from choosing these problems since they have not been considered previously in the unit and are extremely complex. This may be a topic students could investigate over the course of the year.

3. **Groups choose and summarize a threat.** (10 minutes)

   a. Allow time for groups to choose a threat.

   Some of the threats will be more familiar to students than others (e.g.: overfishing). Circulate among the groups and discuss why they chose that particular threat. As you do so, check for understanding. You might want to remind the class about the importance of using systematic processes as they develop and evaluate solutions

b. Have students write a summary of the threat they have chosen.

Step 3 of the procedure asks groups to write a paragraph to summarize the threat. Group responses will vary depending on the threat that they chose. A sample response is shown below:

The threat that my group chose is the effect of overfishing on the coral reef. Many organisms live in and around coral reefs, so fishers like to fish around them. If a species is overfished it disrupts the food web for the ecosystem. Some species in the ecosystem will decrease and others will increase. If a species like the crown-of-thorns sea star increases, it can cause damage to the coral reef. Coral reefs are important for their biodiversity and because they provide ecosystem services. Over a quarter of the world's coral reefs have been destroyed over the last 50 years, so we should protect the coral reefs we have left.

This is a good point to break the activity if needed.

4. Groups use a systematic approach to design a solution to stop or reduce the threat. (40 minutes)

a. Remind students of the steps they have used in designing and evaluating solutions.

> **Assessment – PE– MS-ESS3-3**
> Step 4 asks groups to design a method to stop or reduce the threat. This is related to Performance Expectation MS-ESS3-3, "Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment."

Remind students of Steps 1 to 4 on Handout 5.3-2.

1. Describe the problem.
   (Already done in Procedure step 3)
2. Describe the needs that the solution is to address.
3. Identify the constraints that the solution must meet.
4. Identify the criteria that apply to the solution.

Point out that this time they are not provided with solutions to choose from or to adapt. Groups will have to design their own solutions that best meet the criteria and constraints they identify.

Check to see if groups addressed the required aspects of the solution and that they used a systematic process. A sample response is provided below:

The threat is overfishing coral reefs, which has already changed the food web, and caused the number and average size of fish to decrease.

Our solution is designed to protect the biodiversity of the reef, keep the food web in balance, and provide employment for fishers and food and income for their families.

The constraints for our solution are a) no organisms can be added to the coral reef ecosystem, and b) families of fishers will not have to leave the area.

The criteria that we will use are:

1. *The number of fish should increase as close to before the overfishing began as possible. (Environmental)*
2. *The biodiversity of the reef should be the same as before overfishing. (Environmental)*
3. *Ecosystem services will be similar. (Social and Economic)*
4. *The income of local families should stay the same or close to the same. (Social and Economic)*

Our solution would be to set fishing limits for all species found in and around the reef and to employ fishers to monitor the number, types, and sizes of fish. The fishing limits would be set each year and would include limits on the number and size of fish caught. If the population gets too low, we might have to set the fishing limit to zero until that population recovered.

Our solution meets the environmental criteria because it would prevent the removal of any part of the food web and restore balance to the ecosystem. Overfishing a predator, prey, or producer could cause a large disruption to the reef (cause and effect).

Our solution also works from an economic and social perspective. Since fishing will still be allowed (unless a population's numbers becomes too low), fishers will still be able to earn a living. The fishers could also be employed to monitor the health of the coral reef.

When the overfishing is stopped the ecosystem should recover, so there is no need to add fish or other organisms to increase the numbers. It is also unlikely that fishers' families would have to move. Fishing would still be allowed, so they would still have a source of income. Also, there would be new jobs because people would be hired to monitor the ecosystem and to check that the fishing limits were being followed.

Evidence that our solution was working would be no reduction in the size of the healthy reef and no reduction in the number and types of species found there. Other evidence would be an increase in the number and the size of the fish caught. Ecosystem services, such as tourism, should not decrease. We would not want local families to lose any income because of the fishing restrictions. There should be no families moving away due to lack of jobs or money.

This is an appropriate place to break session two of this activity.

Follow-Up

5. **Groups present their solutions to the class.** (40 minutes)

> **Assessment – PE– MS-LS2-5 and ESS3-4**
> Step 6 provides an opportunity for students to address a blend of Performance Expectations MS-LS2-5 ("Evaluate competing design solutions for maintaining biodiversity and ecosystem services") and MS-ESS3-4 ("Construct an argument supported by evidence for how increases in human population impact earth's systems.") Although Step 6 suggests an oral argument, if a written response was submitted it could be assessed against WHST6-8.1.

a. Explain that Step 6 represents the culminating assessment for the chapter.

Before each group presents their solution to the class, remind students that the various solutions are to be evaluated against the criteria and constraints. If necessary, remind students that the criteria will address environmental, economic, and social needs and that trade-offs should be described.

b. Remind students of the process of scientific argumentation.

Students are not required to submit a written response to Step 6, but look for students' ability to construct an oral argument. Review the process of argumentation and provide the Argument Tool to help students structure their responses as needed. Encourage students to include the effect of increasing human population in their response. Although empirical data may not be available students could reference the evidence that groups identify in the last bullet point in Step 4. A sample response is provided below:

The question that I am arguing is which of the presented solutions is best at reducing human impact on the coral reef. My claim is that the solution that involved setting limits and monitoring fishing in and around the reefs is the best solution. The evidence that would support my claim is that in this solution the size of the reef would not decrease and the number and types of organisms found there would also not decrease. The income for people who fish there would stay the same.

My reasoning is based on the solution meeting environmental, economic, and social needs. This solution meets environmental needs because it would maintain a stable reef ecosystem. The solution also meets economic and social needs because it will not require any fishers to lose their jobs. As the human population increases, there will be extra stress on the reef because there will be more demand for fish and probably more tourists visiting the reef. Even though there will be limits on some types of fishing, the fishery will be healthier in the long run. There is also the possibility for the fishers to earn extra income by helping to monitor the health of the reef. They could also watch for people using destructive fishing techniques, like using explosives. By keeping the reef healthy, the money from increased tourism can help the families in the area. I did not choose any of the other solutions because I thought that they mainly addressed the environmental aspects of sustainability. Although they may have helped the reef, they would have caused problems with jobs and the stability of families who made a living from the reef.

c. Allow groups to present their solutions to the class.

Where possible, groups should use presentation software, posters, or other tools to enhance the presentations. Draw students' attention to Procedure Step 6 and encourage members of the class to provide feedback on each solution and presentation. Provide time for groups to revise their solutions based on feedback from the class.

6. Revisit the guiding question. (10 minutes)

a. Use the Guiding Question as a focus for a discussion on human impact on the environment.

Begin the discussion by focusing on human impact on coral reefs. Expand the discussion to include examples of human impact seen throughout the unit. Conclude the discussion by encouraging students to share other examples of human impact that they have encountered or heard of. Remind students to apply their understanding of the crosscutting concepts of stability and change and cause and effect as they state their opinions and positions.

b. Use Analysis question 1 to relate the discussion to the nature of science.

Students have already encountered the concept that "scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes." They should understand that solving environmental problems that are caused by human actions is difficult. From discussion of this question they should realize that it becomes even more difficult when multiple communities and countries are involved.

Activity 5.5

Suggested Answers To Analysis

1. **Some of the causes of threats to the health of coral reefs are local and some are global. How does the challenge of designing and applying a sustainable solution differ when the cause is a worldwide problem, such as climate change?**

   Science can describe the consequences of actions but society does not always take decisions based on science alone. A sustainable solution has to address economic and social needs too. With a global threat the needs of many people and communities would have to be considered. There are many differences between communities and also between countries. These include money available, needs, politics, values, and many others. A global solution would need the agreement and action of all countries. This would be very difficult to achieve.

Activity 5.5

Evaluate: Coral Reefs

Materials and Advance Preparation

For each student

- ☐ 1 Handout 5.3-2, “Designing Solutions” (optional)

Teaching Suggestions

Getting Started

1. **Facilitate a class discussion about coral reefs.** (10 minutes)

   a. Remind the class about the environmental problems they studied in the previous activity.

Doing the Activity

2. **Groups complete the reading on threats to coral reefs using a literacy strategy.** (15 minutes)

   a. Assist students as needed with the coral reef reading.

3. **Groups choose and summarize a threat.** (10 minutes)

   a. Allow time for groups to choose a threat.

   b. Have students write a summary of the threat they have chosen.

4. **(Assessment) Groups use a systematic approach to design a solution to stop or reduce the threat.** (40 minutes)

   a. Remind students of the steps they have used in designing and evaluating solutions.

Follow-Up

5. **(Assessment) Groups present their solutions to the class.** (40 minutes)

   a. Explain that Step 6 represents the culminating assessment for the chapter.

   b. Remind students of the process of scientific argumentation.

   c. Allow groups to present their solutions to the class.

6. **Revisit the guiding question.** (10 minutes)

   a. Use the Guiding Question as a focus for a discussion on human impact on the environment.

   b. Use Analysis question 1 to relate the discussion to the nature of science.

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Disruptions in Ecosystems

Ecosystem Interactions, Energy, & Dynamics


CHAPTER 1

Wolves in Yellowstone


CHAPTER 2

Ecosystem Models


CHAPTER 3

Interactions between Populations & Resources


CHAPTER 4

Zebra Mussels


CHAPTER 5

Designing Solutions

Middle School Unit aligned with the Next Generation Science Standards

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