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 Support Materials

Disruptions in Ecosystems

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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 Phenomena and Storylines

How are humans affecting the environment?

Phenomenon: Living and non-living components of ecosystems are affected by humans.

Phenomenon for Chapter	Driving Question for Chapter	Guiding Question for Activity	Activities	PE	Storyline/Flow
Chapter 1 **Humans can affect the relationships among organisms in an environment.**	What happens when a predator comes back into an environment? Chapter Examples: re-introduction of wolves in Yellowstone and Adirondacks	How do living things interact with living and non-living parts of the environment?	1.1	MS-LS2-2	People interact with the environment in many different ways. The ecosystem in Yellowstone National Park provides a good context for understanding these interactions.
		What effect did the reintroduction of wolves have on the food web in Yellowstone National Park?	1.2		Organisms within an ecosystem interact with each other through feeding relationships. These relationships can be modeled using a food web. The reintroduction of wolves in Yellowstone NP has an effect on the food web.
		How do organisms interact with each other?	1.3		Organisms can interact in many different ways, some of which are beneficial to one or both, and others which are harmful to one of both. This is true in all ecosystems.
		What effects do living and non-living factors have on populations?	1.4		A population of organisms is affected by interactions with other organisms as well as interactions with abiotic factors such as temperature, precipitation, space, soil, etc.
		How do biotic and abiotic factors affect patterns of interaction among organisms	1.5		Populations of organisms can fluctuate in size as the biotic and abiotic factors in the environment change. Sometimes these fluctuations are predictable, but sometimes they are not.
		Should wolves be reintroduced into the northeastern United States?	1.6		The reintroduction of wolves—a biotic component of the ecosystem—is likely to have an impact on the other parts of the ecosystem. This impact may be considered positive or negative depending on one's perspective.

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How are humans affecting the environment? (Continued)

Phenomenon for Chapter	Driving Question for Chapter	Guiding Question for Activity	Activities	PE	Storyline/Flow
Chapter 2 **Natural disasters can affect the transfer of energy and the cycling of matter in ecosystems.**	What happens in the environment when things die? Chapter Examples: fires, lava, hurricanes, flood, drought	How do organisms get matter and energy?	2.1	MS-LS2-3	All organisms need food because it provides the matter and energy to survive and grow. There are different ways that organisms can get food.
		How do life and death affect the movement of matter and energy in ecosystems?	2.2		Food webs can be used to explore how energy and matter flow throughout an ecosystem.
		How does matter move between biotic and abiotic parts of an ecosystem?	2.3		Matter cycles from the abiotic parts of the ecosystem to the biotic parts via plants. Matter flows from plants through animals and/or decomposers, and from animals through decomposers. Decomposers then cycle matter back into the abiotic parts of the environment.
		How does energy flow in an ecosystem?	2.4		Energy flows from the sun to plants, and then through the different levels of the food web. At each level, the majority of the energy is transformed into thermal energy that transfers to the abiotic parts of the environment. This energy cannot be used by living organisms to survive and grow.
		How does a disruption affect the flow of energy and cycling of matter in an ecosystem?	2.5		The specific effect that a disruption has on an ecosystem depends on which relationships are disrupted. In all cases, nearly the entire food web is affected because of the interconnections of the feeding relationships.
		How can a model be used to represent and make predictions about an ecosystem?	2.6		Models can help us predict what will happen in an ecosystem if there is a disruption. We can model any ecosystem, including local environments.

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How are humans affecting the environment? (Continued)

Phenomenon for Chapter	Driving Question for Chapter	Guiding Question for Activity	Activities	PE	Storyline/Flow
Chapter 3 **Human use of natural resources can affect populations and ecosystems.**	How do peoples' use of natural resources affect ecosystems? Chapter Examples: overfishing, dead zones	What factors should you consider when purchasing fish to eat?	3.1	MS-LS2-1	People rely on natural resources, including fish, for food. There are many reasons for choosing which fish to consume, including the effect of fisheries on the natural population.
		Can fishing limits prevent the overuse of an ecosystem?	3.2		We can use models to study the effects of different fishing practices. These models can help us predict if setting a limit on the number of fish caught has an effect on the wild fish population.
		What effect have humans had on the health of fisheries?	3.3		Data have been collected on three real fisheries with different histories, and with different regulations. We can examine if these differences have an effect on the wild populations and the health of the fishery.
		How do humans affect the size of dead zones?	3.4		Humans also affect the environment by introducing pollutants. The effects of these pollutants can occur far from the source.
		How do increases in the human population affect the resources available to organisms?	3.5		An increase in the size of the human population can affect the availability of natural resources that people rely on.

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How are humans affecting the environment? (Continued)

Phenomenon for Chapter	Driving Question for Chapter	Guiding Question for Activity	Activities	PE	Storyline/Flow
Chapter 4 **The introduction of a new organism can affect the stability of an ecosystem.**	How do new organisms affect the environment? Chapter Examples: introduction of zebra mussels in Hudson River, Quagga mussels in Great Lakes	How might the introduction of the zebra mussel affect the health of the Great Lakes and Hudson River ecosystems?	4.1	MS-LS2-4	The introduction of a new species to an ecosystem in which it has never been found may have an impact on the native species and the ecosystem. Zebras mussels in the Hudson River provide a context for understanding these impacts.
		What biotic and abiotic factors are affected when a new species is introduced to an ecosystem?	4.2		Scientists studying the Hudson River predicted the invasion of the zebra mussels and asked themselves which biotic and abiotic factors in the environment were might be affected. They began collecting data on these variables.
		How did the zebra mussel initially affect the health and biodiversity of the Hudson River ecosystem?	4.3		The initial impact of the introduction of the zebra mussels can be assessed by comparing data before and after the introduction to look for changes in different factors.
		What are the long-term effects of the zebra mussel invasion of the Hudson River?	4.4		The long term impact can be assessed by examining data that scientists continued to collect for over 20 years.
		Has the Quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?	4.5		There is another type of mussel that has been introduced to the Great Lakes. We can predict what kind of effect this has had on the ecosystem.

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How are humans affecting the environment? (Continued)

Phenomenon for Chapter	Driving Question for Chapter	Guiding Question for Activity	Activities	PE	Storyline/Flow
Chapter 5 **Humans are using more resources, causing the need for solutions.**	How can the effects of environmental problems be reduced? Chapter Examples: crop infestation, coral reefs, dead zones, invasive species, habitat destruction, deforesta-tion, pollution	What are some of the ways to deal with an insect problem?	5.1	MS-LS2-5	Humans are using more and more natural resources, and this can cause environmental problems. Finding solutions to these problems is complicated, and may lead to different problems.
		How can we balance human needs with those of the environment?	5.2		Every environmental decision has consequences, some of them immediate and some delayed. Balancing environmental needs with human needs can be difficult, both in the short and long terms.
		What factors should be considered when choosing or designing a solution to an environmental problem?	5.3		There are many factors that should be considered when designing a solution to an environmental problem. The solutions to environmental problems must be evaluated based on established criteria, and must abide by the constraints.
		How can we evaluate solutions to decide how well they might work?	5.4		Nearly all solutions to environmental problems have trade-offs. Sometimes solutions need to be revised based on new criteria and constraints.
		How can the negative impact of humans on coral reefs be reduced?	5.5		Coral reefs provide a context for understanding how to design and evaluate solutions to problems facing these endangered ecosystems.

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Teaching Strategies

Many teachers face the challenge of having students with a wide range of educational backgrounds, abilities, and needs in the same class. A variety of instructional approaches are needed to help all students succeed. This section describes strategies and tools for meeting the needs of diverse learners. It includes strategies for:

1) promoting acquisition and use of academic language, especially by English Learners,
2) fostering productive talk in the classroom and discourse between students,
3) supporting reading and comprehension,
4) scaffolding student writing, including peer review, and
5) supporting student skills in mathematics, especially in constructing and interpreting graphs.

1) Academic Language Development

This section provides strategies and tools for promoting the development of academic language. While these strategies are especially important for English Learners and students with special learning needs, they can be helpful for all students.

a) Academic Language Across the Unit

Following is a reference table showing where key academic terms and vocabulary are used across the unit, chapter by chapter. This reference table may be helpful to you as you help students develop a deeper understanding of these terms as they use them to explain scientific phenomena and concepts from one activity to the next.

Term	Chapter				
	1	2	3	4	5
Abiotic	X	X			
Algae	X				X
Analyze	X		X	X	
Biodiversity	X				X
Biotic	X	X			
Cause	X				X
Change	X				X
Characteristic				X	
Clarity					X
Commensalism	X				
Competition	X		X		X

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Teaching Strategies

Term	Chapter				
	1	2	3	4	5
Condition	X		X		
Constraints					X
Construct	X		X	X	
Consumer		X			
Coral					X
Criteria					X
Dead Zone					X
Decomposer		X			
Design					X
Develop	X		X	X	
Disruption	X	X	X	X	X
Drought	X				X
Dynamic				X	
Economic					X
Ecosystem	X	X			
Ecosystem service					X
Effect	X				X
Elaborate	X	X	X	X	X
Energy		X			
Engage	X	X	X	X	X
Environmental					X
Evaluate	X	X	X	X	X
Examine	X		X	X	
Explain	X	X	X	X	X
Explore	X	X	X	X	X
Factor	X		X	X	

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Teaching Strategies

Term	Chapter				
	1	2	3	4	5
Food chain	X	X			
Food web	X	X			
Habitat					X
Harvest					X
Impact	X			X	
Input			X		
Interaction	X	X	X	X	
Interpret			X	X	
Invasive species					X
Investigate	X		X	X	
Matter		X			
Model	X	X			
Monitor			X	X	
Mutualism	X				
Nutrients	X				X
Overharvesting					X
Parameter				X	
Parasitism	X				
Pattern	X				X
Photosynthesis		X			
Plankton					X
Polyp					X
Predator	X				X
Predict	X		X	X	
Prey	X			X	X
Problem	X				X

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Teaching Strategies

Term	Chapter				
	1	2	3	4	5
Producer		X			
Resource	X		X	X	
Respiration		X			
Social					X
Solution					X
Stability					X
Stable		X			
Substance	X	X			
Symbiosis	X				
Transformed		X			

b) Key Vocabulary

When words are formally defined in an activity, they appear in bold type in the Key Vocabulary list in the Teacher's Guide and in the Student Book. During informal and formal discussions listen for these words to see if students are applying them correctly. Encourage students to use these words when they speak in class and when answering the Analysis questions. Decide how you will support students' understanding of the vocabulary—perhaps with a student glossary or setting up a word wall in the classroom. Whenever appropriate, discuss familiar words with similar roots. For English Learners, and even native English speakers, explore how scientific meanings of words such as compete and host may be different from their everyday meanings. If you have many Spanish-speaking students, ask them to help point out roots of words or words that have the same or similar spelling and meaning in both English and Spanish.

Other relevant scientific words that are not considered key vocabulary for this unit aren't related to the primary learning goals, but you might need to clarify them for students. For example, in Chapter 1, you might need to explain that a species is a specific type of organism, such as a wolf or a coyote, without going into the complete definition of species.

c) Personal Vocabulary Log

A personal vocabulary log is a tool that students use to record and monitor their understanding of new words. Students try to determine the meanings of words they do not know, and keep track of these words in a personal vocabulary log. Following is a simple template that students can copy into their science notebooks.

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Word	Description of Meaning	Drawing or Diagram	Example

d) Supporting English Learners

You may wish to support English Learners by discussing the roots in some of the key vocabulary and other terms used frequently in this unit, including the following examples.

Interact/Interaction: Point out that the prefix "inter" generally means between or among, as in the word international. The root "act" has several meanings. In this case, it means to do something. In an interaction, two things have some action, or effect, on each other.

Carnivore/herbivore/omnivore: 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.

Biotic/abiotic: The root "bio-" means life, as in biology, or symbiosis. The prefix "a-" sometimes means not, as in apolitical. Thus biotic refers to living and abiotic refers to nonliving components of the ecosystem.

Symbiosis: The prefix "sym-" means together, or with, while "bio-" means life, so symbiosis means living closely together.

e) Word Walls

A Word Wall is a dedicated area of a room where words can be displayed so that they can be seen by all members of the class. The letters must be large enough so that they are easily visible from all parts of the classroom. Words can be added to the Word Wall as they are introduced in context. Once added, the words should remain in place so that students see them frequently and can refer to them. In the science classroom, Word Walls help reinforce vocabulary and understanding of scientific terms. This can help students to internalize science concepts. This strategy becomes more effective as students and teachers develop the habit of using the Word Wall to reference key terms. There are abundant resources, both online and in print, that describe the many different ways to use Word Walls interactively.

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Teaching Strategies

2) Productive Talk and Classroom Discourse

Effective collaboration is essential for scientists to develop an understanding of the natural world and for engineers to design solutions to problems. Middle school students benefit from scaffolds that make expectations explicit and that help them practice collaborating with peers. Below are strategies that promote productive talk and constructive discourse in the classroom. The first two are for use by students, directly, while the remaining strategies are for the teacher to use with students.

a) Communication Skills

Students may need additional tools to help them build effective communication skills. Student Sheet 1, "Developing Communication Skills" promotes positive and productive classroom discourse by suggesting how students might express disagreement, seek clarification or more information, or build on each other's ideas. The suggestions are in the form of sentence starters with which students initiate comments to each other.

b) Group Work

This unit assumes that students work in pairs and small groups (usually four students) to engage in the practices of science and engineering. Student Sheet 2, "Evaluating Group Interaction" allows students to self-assess their interactions when working in groups and provides an opportunity to discuss the criteria and expectations for successful group work. At the end of class, ask students to self-assess their work as a group by selecting the level that best describes their work together and to support their rating with descriptive evidence. This allows students to identify and discuss ways to improve their interactions as a group.

c) Discussion Starters

Generating and sustaining class discussions in which students engage in discourse with one another can be challenging. The following Teacher Discussion Starters are intended to be used by the teacher when facilitating a whole-class or group discussion in order to help students develop appropriate skills and habits:

- Ask students to rephrase or repeat what another student said.
  - Who can repeat what Andre just said or put it into their own words?
  - (After a partner talk) What did your partner say?

- Ask students to agree/disagree with another student and explain their reason.
  - Do you agree/disagree? (And why?)
  - What do people think about what Hannah said?
  - Does anyone want to respond to that idea?

- Ask students to add on to what another student said.
  - Who can add on to the idea that Omar is building?
  - Can anyone take that suggestion and push it a little further?

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- Ask students to explain what someone else means.
  - Who can explain what Bo means when she says that?
  - Who thinks they could explain why Diana came up with that answer?
  - Why do you think she said that?

d) Elicit, Probe, and Challenge Questions

Teacher questioning is an effective tool for eliciting students' initial thinking and preconceptions about an idea, probing their initial explanations for phenomena, and challenging them to develop refined explanations that account for all of the evidence and are based on sound scientific reasoning. Below are explanations of Elicit, Probe, and Challenge questions, including when to use them in the trajectory of student learning.

ELICIT QUESTIONS

Purpose: To elicit students' prior knowledge about and experiences with a concept, and their initial ideas and predictions relevant to the lesson. Elicit questions reveal a variety of different student ideas rather than one "right answer." The goal of Elicit questions is to learn about student thinking and ways of making sense, whether their ideas are scientifically accurate or not. Student responses often reveal misconceptions, which can help inform later instruction. Elicit questions also help engage students in the lesson, helping them see the connections between their own ideas of what they will study during the lesson. Students are also able to see that different people have different ideas. This sets up a "need" to find out which ideas are best.

When to use: At the start of a lesson (especially Engage activities at the start of each chapter) or the introduction of a new topic.

Student grouping: Multiple students, often the whole class or a group of students.

Language used: Phrase elicit questions in everyday language that will make sense to the students, even before they begin a unit of study. Avoid using scientific terminology with which students are not very familiar.

Examples:

- Right now, we are just getting out our ideas. For now, these are just our predictions about _____. Later, we will gather some evidence to see if we can support or challenge any of our predictions.
- As you listen to different ideas, think about which ideas you agree with and which you disagree with. Think about your reasons. Do you have evidence to support your idea?
- What do you think would happen to_____ if we changed _____?
- How do you think people affect ecosystems?
- Why do you think would happen if wolves were reintroduced to Yellowstone?
- What is the relationship between zebra mussels and phytoplankton?

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Teaching Strategies

PROBE QUESTIONS

Purpose: To get more information about a student's thinking and understanding around a topic. Probe questions are directed to one student who has already provided an answer or offered an idea. The teacher then follows up with this same student to probe their thinking. Sometimes a teacher asks a sequence of questions that probe the thinking of the same student before moving on. It is not designed to teach new ideas or to "lead" students to a correct answer. Probe questions help the teacher understand how a student is making sense of a topic, and they can reveal misconceptions. Probe questions help students by encouraging them to explore, share, and clarify their own ideas. This is an essential step in moving their ideas toward more scientific, evidence-based understandings.

When to use: Throughout the lesson, asked repeatedly.

Student grouping: Directed to an individual student who has already provided an answer or offered an idea during whole-class discussion, during small-group work, or as students work individually.

Language used: These questions should not introduce new language or new science ideas; the goal is to build on ideas already presented by the student.

Examples:

- Tell us more about that.
- Tell me more about how you think that happens.
- So you are saying [paraphrase student response]. Tell me how I'm getting it wrong.
- Explain more about what you mean by "it's the wrong environment."
- Why do you think that?
- What's your evidence?
- How did you arrive at that conclusion?
- Can you give us an example?

CHALLENGE QUESTIONS

Purpose: To help students challenge their thinking and develop a deeper understanding of the science ideas. Challenge questions push students to think further, to reconsider their thinking, to make a new connection, and/or to use new science vocabulary in a meaningful way. The goal is to get students thinking harder while also scaffolding or guiding their thinking towards more scientific understandings. Avoid questions or hints that lead students to the "right" answer without challenging them to really think. Such "leading" questions often come in a "fill-in-the-blank" or "yes/no" format, accompanied with hints so that students can frequently guess the right answer.

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When to use: Anytime during the lesson except when you are trying to elicit students' initial ideas and predictions about a science idea or concept.

Student grouping: Directed to an individual student who has already provided an answer or offered an idea during whole-class discussion, during small-group work, or as students work individually.

Examples:

- Add some of the new ideas we've been talking about to your explanation.
- Explain how that happens.
- Why does that happen?
- How does that relate to the ideas we've been studying?
- Does it always work that way?
- How does that idea relate to Sonia's example?

e) KWLs

One effective way of helping students track their growing understanding is with a three-column KWL chart. The letters KWL refer to the three sections of the strategy that ask, "What do I *Know*? What do I *Want to Know*? What did I *Learn*?" These charts are used throughout a chapter or across several activities, so be sure to create them in such a way that they can be revisited (e.g. create an electronic file to project, put it on poster paper on the wall, etc.). KWLs help students process and apply the information that they encounter in readings and investigations. In this activity you will develop the KWL as a class, and begin by filling in the first two columns. Ask students for answers for the first column, What do I Know? about the topic. Answers will vary depending on students' prior knowledge. If necessary, ask the students questions to point them in the right direction. Then move to the second column, What do I Want to Know? and have students suggest questions about what they want to know about these three ecosystems. They will fill in the third column, What did I Learn? as they continue through the unit.

f) Venn diagram

A Venn diagram is a tool for helping students compare and contrast ideas, and includes two or more overlapping circles in which words or phrases are written to help visually depict the similarities and differences between two or more things, concepts or categories. Each circle is labeled according to the subjects being compared. Students write information that is unique to the subject of each circle in the outer part of the appropriate circle. In the overlapping space they write the information or elements common to both subjects. A Venn diagram allows students to visually map characteristics that are both unique and shared among a set of concepts or things. The diagram is flexible and easily adjusted by adding additional circles to compare up to four ideas. Direct students to set up the diagram with the appropriate number of circles, one for each subject being compared. The circles must intersect so that there is an overlap for each category. Venn Diagrams may be completed as

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a class, in groups, in pairs, or by individual students. The completed diagram helps students compare and contrast things in both discussion and writing.

g) Walking Debate

A walking debate allows students to express their opinions about an issue by moving from one area of the room to another. Each area represents a certain side of an issue. Students select an area to stand in based on the side of an issue they agree with. The "sides" then discuss the issue and present their arguments to the other groups. Students can opt to change their location if the presentations given change their opinions about the issue.

In asking students to choose a position and stand in the corresponding area of the room, the Walking Debate requires students to physically commit to a position. This serves several purposes. First, it requires that students take a position. Secondly, students will more clearly see the distribution of thoughts, ideas, or opinions among their classmates. Walking Debate also allows students a way to practice identifying evidence and reasoning in a group setting, which is an important component of scientific argumentation.

Begin by identifying the question or issue that is being debated, and designate different parts of the classroom as representing certain points of view. For example, for the question "Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?" one area of the room would be designated as the "positive" area and another the "negative" area. Students walk to the area that best represents their point of view and talk within that group to come up with a convincing argument to bring people from other areas to their own area. The groups make their presentations, students ask questions of the other groups, and those who change their minds move to the area that represents their final position. Over the course of one activity, several activities, or a unit, the class may encounter more evidence related to the debate issue. If the first Walking Debate was successful, the teacher might give students a chance to repeat the debate and decide if they will change positions. It is helpful to have students keep a record of the evidence they will consider for the Walking Debate, especially when they are new to the strategy. Have students record their evidence on an index card to which they can easily refer during the debate. Students might do this in pairs when they are becoming familiar with the strategy.

3) Reading and Comprehension

Below are several strategies that are used in the unit to help students make sense of challenging science content. Sometimes these strategies are used by individual students, while at other times they are used in pairs or in groups of four.

a) Directed Activities Related to Text (DART)

Directed Activities Related to Text (DARTs) can help students to process and manipulate information they read. Examples of this strategy vary widely, from questions at the end of sections of text, to students marking text or looking at text structures, to students using information in text to complete charts, tables, or diagrams. They usually work best when students complete them in pairs or small groups. For example, a DART might be intended

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to help students define and provide examples of interactions between organisms. It can also be used to have them compare and contrast the interactions. Monitor students as they use DARTs, both to determine whether they are using the tool correctly and to assess and provide feedback on group collaboration.

b) Read, Think, and Take Note Literacy Strategy

Explain to students that they will use a literacy strategy that is based on the ways proficient readers think while reading and that they can use whenever they encounter challenging text. Review the guidelines shown in the student book for the "Read, Think, and Take Note" strategy and model the strategy on a passage of text by reading it aloud and giving examples of your thinking and the notes you would record.

Give students time to read the text while following the strategy. After they have finished reading, have them work in pairs, groups, or as a class to compare their notes, discuss what they wrote, and answer each other's questions. Look for additional occasions for students to apply this strategy when reading text. Provide support as needed when students use the strategy throughout the unit, but try to decrease the support and encourage more independence as they become more experienced with the strategy.

c) Stop to Think

"Stop to Think" questions are embedded in readings to focus students' attention on important ideas in the section of text they have just read. The questions may require students to identify the main idea of a previous paragraph or synthesize ideas presented in two or more preceding paragraphs. Because some questions require interpretation and application of knowledge, students will not always find answers by skimming and searching the text.

"Stop to Think" questions give students "think time" to summarize, interpret, or apply what they have just read. The suggested stopping points in the reading where the questions appear break the text into manageable chunks of information to summarize. Students may also use the questions to predict what might come next in the reading.

"Stop to Think" questions do not require a written response. Depending on the reading ability of students, it may be appropriate to have them stop and answer the questions with a partner, or in small groups. If the class is doing the reading together, at each "Stop to Think" question have the students share out their answers to the questions.

A small group or class discussion should be held after the reading is complete to give students a chance to process their answers and review the answers of other students. This allows students to read without the interruption of a written response, but to still process their interpretation of the reading and answers to the questions. After the discussion students can write notes or a short summary in their science notebook to refer back to later in the unit.

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Teaching Strategies

4) Writing

a) Science Notebooks

A science notebook is a useful tool for students and teachers in terms of student learning and classroom management. Keeping a science notebook helps students track data, record questions as they arise in investigations and discussions, and build science-writing skills. As a literacy tool, science notebooks allow for student reflection and facilitate student discourse. All activities in this unit are set up to encourage the use of science notebooks. Following are some suggestions of ways to set up a science notebook at the beginning of the course:

- The notebook should have sturdy covers, whether it is fixed-page composition-style, spiral-bound, or another type of notebook that will not lose pages easily.
- Students should make a title page and table of contents page. The table of contents must allow space for the activity titles and notebook page numbers for easy reference after students have completed activities.
- Have students number each page.
- Have students make entries in a specific format that is the same for every activity. For example:
  - Guiding Question (copied from Student Book)
  - Data (data tables, notes from readings, what they discussed as a group)
  - Analysis Items
- Post guidelines for notebook formatting, and follow this format when writing any assignments on the board or overhead.
- If students need to make corrections, they can neatly cross out the old information and insert the new information after it. This reflects how scientists maintain their own data records.
- Copy Student Sheets at a size that students can paste or tape into their notebooks. Have tape, glue sticks, or staplers available for students at all times. Whenever possible, have students write directly in their notebooks rather than on the Student Sheets.

b) Peer Review of Writing

A Writing Review is a peer-review activity that is especially useful in guiding students to write complete and coherent explanations, arguments, Analysis item responses, and procedures that others can understand. Student Sheet 3, "Writing Review," provides a structured way for students to review one another's written work. A reviewer student learns to recognize flaws in logic, gaps in information, or other writing problems that they may be prone to. The student being reviewed uses their peer's constructive comments to improve or revise their response. With successive Writing Review opportunities, students learn how to provide and accept constructive feedback to help each other improve their class work.

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c) The Explanation Tool

Student Sheet 4, "Explanation Tool," provides scaffolding for students as they learn to write scientific explanations. Students should use the first side of the tool as a note-taking space. They do not need to write in complete sentences until they reach the second side of the tool where they construct their complete scientific explanation. Students begin by filling in the Question before they obtain more evidence from the activity.

Decide whether to have students read and review any text, graphs, or other evidence as a class, in their groups, or individually. As students follow the bulleted steps for completing the first parts of the Explanation tool, you might need to clarify some terms. Students may already be familiar with the concept of evidence. Discuss their ideas about evidence and explain that evidence is factual information or data that supports or refutes a conclusion. Have students use the information in the student book to record evidence that addresses the question being considered.

Students are then asked to record what science concepts are connected to the evidence and might help answer the question. Encourage them to note any concepts they think might be relevant. As they develop their reasoning in the next section, they note how the concepts connect to the evidence. At this point they may find that some concepts are not appropriate for inclusion with their final scientific explanation.

The last box on the first side of the tool is where students state a claim. Define a scientific claim as a conclusion for a question or problem. Science focuses on claims that can be supported or refuted by using evidence and logical reasoning.

Ask students to respond to the initial question by stating a claim based on the evidence they have recorded and their scientific reasoning.

The last section of the tool guides students to construct a scientific explanation utilizing the previous components of the tool. The tool contains a series of five components that students should include to create a complete paragraph that provides a clear and logical explanation.

d) The Argument Tool

Student Sheet 5, "Argument Tool," provides scaffolding for students as they engage in argumentation. The first sets of boxes provide a space for students to think through and record their ideas before they move on to a formal scientific argument on the second page of the Tool. Students record the question they are are investigating, then two possible claims that could be argued. They then record under each claim what, if any, evidence supports that claim. Students then critique the quality and amount of the evidence. Students may need assistance when they first begin critiquing evidence.

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Students then use their ideas to construct a formal paragraph that clearly sets forth their argument. They also complete a short critique of one of the alternative claims. Students may need assistance when they first begin critiquing alternative claims (rebuttals). Model developing a simple critique of an alternative claim using the sentence starters provided in the tool. For example: Other people might claim that the zebra mussel has had a positive effect on the Hudson River ecosystem. I think the problem with this argument is that the only data that could be considered positive is increased water clarity. Everything else is negative.

5) Mathematics and Graphing

a) Creating Graphs

Being able to represent data graphically is essential for allowing scientists to detect patterns and construct cause and effect explanations. Two optional student handouts are provided to provide scaffolds for students as they construct graphs of their data: Student Sheet 6, "Bar Graphing Checklist," and Student Sheet 7, "Scatterplot and Line Graphing Checklist." At first, students may rely on these student sheets extensively as they gain practice.

b) Interpreting Graphs

Analyzing and interpreting graphs is an essential practice for scientists and engineers. Knowing how to identify patterns in the data on the graphs allows scientists and engineers to develop explanations for phenomena and solutions to problems. Student Sheet 8, "Interpreting Graphs," walks students through the process of determining if there is a pattern in the data, and if so, what type of pattern they see. The student sheet also provides sentence starters for students to interact with their partner, group, or class about the graphs.

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STUDENT SHEET 1 **Name** _____

Developing Communication Skills

Communicating	Sentence Starters
To better understand	One point that was not clear to me was . . . Are you saying that . . . Can you please clarify . . .
To share an idea	Another idea is to . . . What if we tried . . . I have an idea. We could try . . .
To disagree	I see your point, but what about . . . Another way of looking at it is . . . I'm still not convinced that . . .
To challenge	How did you reach the conclusion that . . . What makes you think that . . . How does it explain . . .
To look for feedback	What would help me improve . . . Does it make sense, what I said about . . .
To provide positive feedback	One strength of your idea is . . . Your idea is good because . . .
To provide constructive feedback	The argument would be stronger if . . . Another way to do it would be . . . What if you said it like this . . .

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STUDENT SHEET 2 **Name** _____

Evaluating Group Interaction

Procedure

Use the table below to rate your group's performance.
Give evidence for your scores by answering questions 1 and 2.

Group Interactions	Score
Group stays on task and manages time efficiently	
Group shares opportunities	

Give some examples of how you managed the task and time efficiently.

Give some examples of how your group shared opportunities to contribute to the activity. Your examples might include times when you or your group members: respected and treated others with courtesy; helped each other do the work; shared the work (not having one person do all of the work alone); or stayed open-minded and willing to compromise.

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STUDENT SHEET 3

Name _____

Writing Review

Use these questions to review someone else's writing. Answer the following questions after you have read or heard this person's answer twice.

Name of person whose writing you reviewed:

1. State the topic of the writing.

_____

_____

2. a. Are the facts clear and accurate?
b. If you answered "no," which facts need to be more clear or need correction?
c. If you answered "yes," which facts are presented clearly and accurately?

_____

_____

3. a. Do the facts support the writer's position?
b. If you answered "no," which facts do not support the writer's position?
c. If you answered "yes," which facts support the writer's position?

_____

_____

4. List any statements or ideas that the writer did not support with facts.

_____

_____

_____

5. Do you agree with the writer's conclusion? Explain why or why not.

_____

_____

_____

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STUDENT SHEET 4

Name _____

Explanation Tool

Question

What is the scientific question you are investigating?

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?

Scientific Reasoning

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

Claim

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

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Explanation Tool
Continued

Name _____

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

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Explanation Tool Rubric

Component	Level 3 Proficient	Level 2 Developing	Level 1 Emerging	Level 0 Not Evident
Claim	Claim answers the question, is accurate, and is complete. Completely describes the trend in the relationship between two variables.	Claim does answer the question but it is inaccurate or incomplete.	Claim does not answer the question.	Does not make a claim.
Evidence	Provides appropriate and sufficient evidence to support the claim.	Provides appropriate, but insufficient evidence to support the claim. May include some inappropriate evidence.	Evidence does not support the claim; only provides inappropriate evidence.	Does not provide evidence.
Science Concepts	Includes explanation of science concepts that link evidence to the claim (concepts are appropriate), and science concepts are sufficient (no omission of key concepts) and are clearly stated and accurate.	Includes explanation of some science concepts that link evidence to the claim, but are insufficient (one or more concepts that should have been included are not included) or some are inappropriate.	Restates evidence and does not include explanation of science concepts.	Does not include science concepts.
Scientific Reasoning	Includes logic statements that link the claim, evidence and science concepts (including words such as 'because…' 'therefore…') that clearly demonstrates logical reasoning.	Attempts to include a logic statement that links the evidence to the claim but does not adequately link the evidence to the claim.	Restates evidence or claim and does not include a logic statement that links the evidence to the claim.	Does not include scientific reasoning.

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STUDENT SHEET 5

Name _____

Argument Tool

Question
What is the question that you are investigating?

Claim A	**Claim B**
What is a claim you could argue?	What is a claim you could argue?
The evidence that supports this claim is . . .	**The evidence that supports this claim is . . .**

Scientific Reasoning: Evaluating the Evidence and Claim

Critique the quality and strength of the evidence that supports this claim.	Critique the quality and strength of the evidence that supports this claim.

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Argument Tool
Continued

Name _____

Constructing a Scientific Argument

Decide which claim you think is best supported by the evidence and scientific reasoning. Using the criteria below and the information in the boxes you have completed, write a scientific argument that includes:

- The scientific question
- Your claim (that is best supported by evidence and reasoning)
- Relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

Scientific Argument

Critique of the Rebuttal

Other people might claim _____ . I think the problem with this argument is _____.

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Argument Tool Rubric

Component	Level 3 Proficient	Level 2 Developing	Level 1 Beginning	Not Evident
Claim	Claim answers the question completely.	Claim partially answers the question.	Claim does not answer the question.	Does not make a claim.
Evidence	Provides appropriate evidence to support the claim.	Provides evidence that actually supports a different claim, but not the one selected or is missing some evidence.	Provides inappropriate evidence (evidence does not support the claim selected or a counter claim).	Does not provide evidence.
Scientific Reasoning	Appropriately uses relevant science concepts to thoroughly evaluate the evidence provided and support the selected claim.	Uses inappropriate science concepts to evaluate the evidence provided or is missing some science concepts.	Evaluates the evidence provided without mention of science concepts. For example, states evidence is good but does not explain why.	Does not evaluate the evidence.
Rebuttal	Student identifies an alternative claim AND Student provides a critique of the alternative claim (e.g. the alternative claim is not supported by evidence because . . ., the evidence that supports this alternative claim is not good because . . .	Student identifies an alternative claim AND Attempts to critique the alternative claim, but the critique is not accurate or is not specific (e.g. "that idea does not make sense," or "there's no evidence for that claim"	Student provides an alternative claim (it can be weak or not plausible) BUT Does not provide a critique or the critique does not make sense	Student does not identify an alternative claim or provide a critique.

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Name _____

Bar Graphing Checklist

- ☐ Determine whether a bar graph is the best way to represent the data.
- ☐ If so, draw the axes. Label them with the names and units of the data.
- ☐ Decide on a scale for each axis. Be sure there is enough space for all the data, but that it's not too crowded.
- ☐ Mark intervals on the graph, and label them clearly.
- ☐ Plot your data on the graph.
- ☐ Fill in the bars.
- ☐ Title your graph. The title should describe what the graph shows.

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STUDENT SHEET 7

Scatterplot and Line Graphing Checklist

- ☐ Determine whether a line graph or a scatterplot is the best way to represent the data.
- ☐ Draw the axes. Label them with the names and units of the data.
- ☐ Decide on a scale for each axis. Be sure there is enough space for all the data, but that it's not too crowded.
- ☐ Draw intervals on the graph, and label them clearly.
- ☐ Plot your data on the graph.
- ☐ For a scatterplot, leave the points unconnected.
- ☐ For a line graph, draw a smooth line or curve that follows the pattern indicated by the position of the points.
- ☐ Title your graph. The title should describe what the graph shows.
- ☐ If more than one data set has been plotted, include a key.

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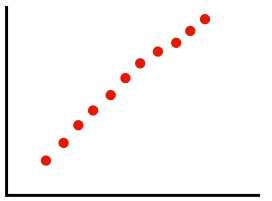
Name _____

Interpreting Graphs

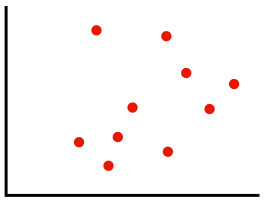
Determine the path that describes the data.

Is there a relationship?



There is a pattern.

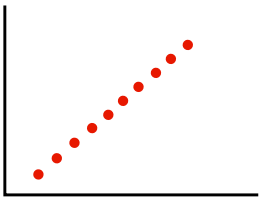
Relationship



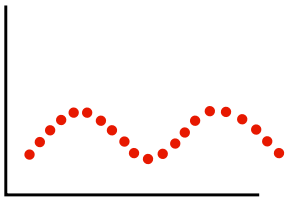
There is no pattern.

No relationship

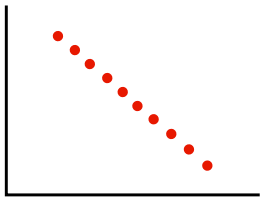
What is the general trend of the data?



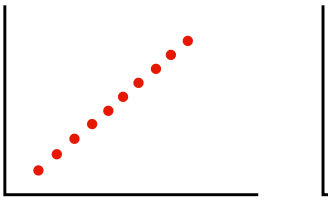
Positive: as x increases, y increases



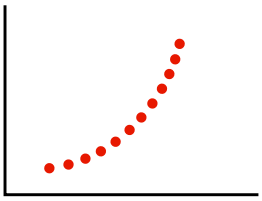
Cyclical: as x increases, y repetitively increases and decreases



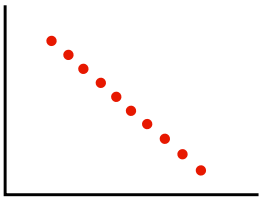
Negative: as x increases, y decreases



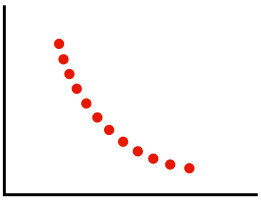
Linear: as x increases, y consistently increases (sometimes called "direct")



Non-linear: as x increases, y increases at a changing rate



Linear: as x increases, y consistently decreases



Non-linear: as x increases, y decreases at a changing rate (sometimes called "inverse")

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Name _____

Video Guide: Wolves in Yellowstone

	True	False
1. Wolves had disappeared from Yellowstone National Park and were brought back to the area by park rangers.		
2. Local cattle ranchers are concerned about wolves killing their cows.		
3. Wolves in Yellowstone stay inside of the park's boundaries.		
4. Some people moving into the area are building more houses and reducing open space.		
5. Wolves may eat cows, sheep, elk, and bison.		
6. The Yellowstone environment includes mountains, lakes, forests, and grasslands.		

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Name SAMPLE STUDENT RESPONSE

Video Guide: Wolves in Yellowstone

	True	False
1. Wolves had disappeared from Yellowstone National Park and were brought back to the area by park rangers.	X	
2. Local cattle ranchers are concerned about wolves killing their cows.	X	
3. Wolves in Yellowstone stay inside of the park's boundaries.		X
4. Some people moving into the area are building more houses and reducing open space.	X	
5. Wolves may eat cows, sheep, elk, and bison.	X	
6. The Yellowstone environment includes mountains, lakes, forests, and grasslands.	X	

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Name _____

Yellowstone Food Web Data

Animal	Diet
Beaver	Bark from trees such as willow, aspen, birch and maple; also plants such as pondweed and cattails
Bison	Low-growing grasses
Cowbird	Seeds, fruits, and insects, including ticks
Coyote	Small and large mammals, usually plant-eaters
Elk	All kinds of plants
Gray wolf	Large and small animals
Grizzly bear	Seeds, berries, grasses, fish, large mammals such as bison and elk
Snowshoe hare	Grasses and twigs from trees such as willow, aspen, and maple
Winter tick	Blood from large plant-eaters

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Name _____

Types of Interactions

Pattern of Interaction		My Group's Definition	Video Example	Revised Definition	Additional Examples
Predator–prey					
Competition					
Symbiosis	**Commensalism**				
	Mutualism				
	Parasitism				

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Name SAMPLE STUDENT RESPONSE

Types of Interactions

Pattern of Interaction		My Group's Definition	Video Example	Revised Definition	Additional Examples
Predator–prey		*One animal eats another*	*Hawk eats squirrel, wolf eats elk*	*Feeding relationship where one animal kills and the other is killed*	*Bear eats a fish*
Competition		*Two animals fight for the same food*	*Grizzly bears and wolves compete for elk*	*Two or more species require the same limited resources*	*European green crabs and native crabs compete for food*
Symbiosis	**Commensalism**	*One animal benefits and other does not*	*Bug hitchhiking on a person, remora fish on a shark*	*Helps one species and doesn't help or harm the other*	*Fox using a groundhog burrow*
	Mutualism	*Both animals benefit*	*Clownfish and anemone, people and digestive bacteria*	*Helps both species involved*	*Plover eating food from crocodile's mouth*
	Parasitism	*One animal benefits and the other is harmed*	*Ticks feed on cow, lice feed on fish*	*Benefits one species (parasite) and harms the other (host)*	*Tapeworm living in intestine of an animal*

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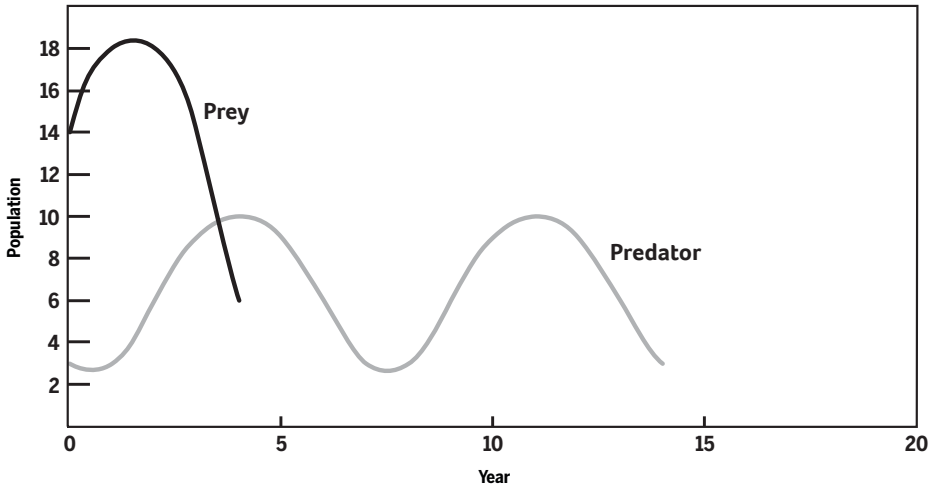
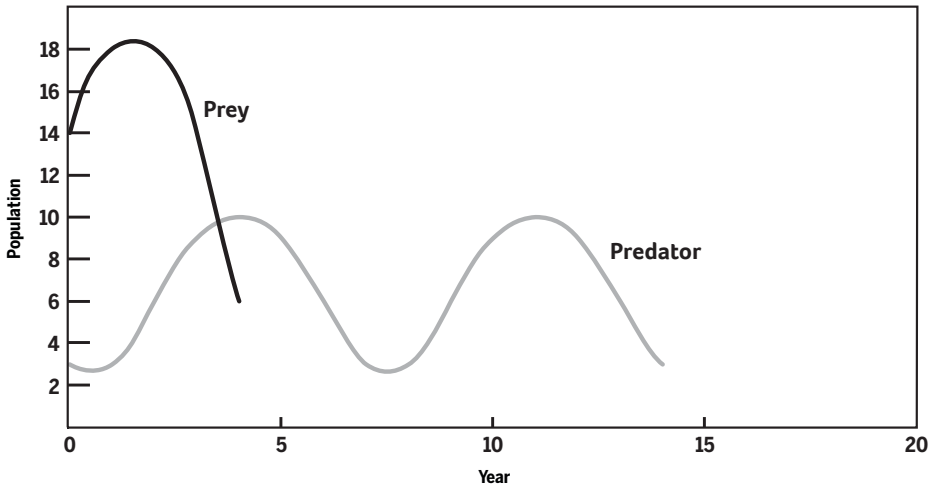
Name _____

Predicting Predator-Prey Interactions

Prediction: Predator and Prey Populations Over Time



Ecological Model: Predator and Prey Populations Over Time



Compare your prediction to the ecological model of predator-prey interactions. If your ideas changed, explain how they changed. If your ideas stayed the same, explain what you understand about predator-prey relationships.

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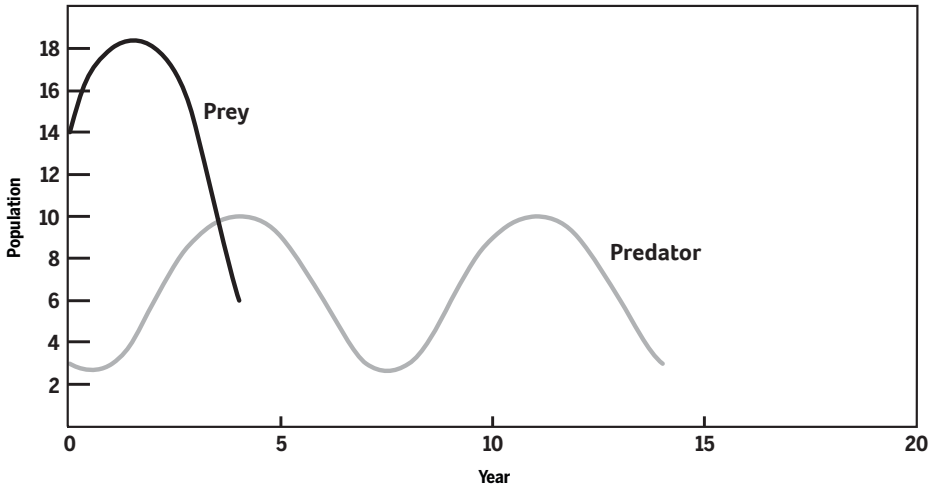
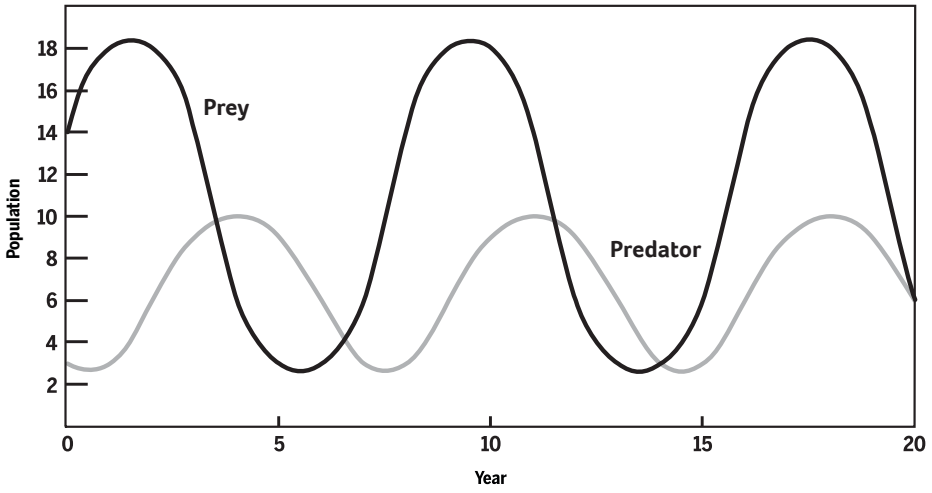
Name SAMPLE STUDENT RESPONSE

Predicting Predator-Prey Interactions

Prediction: Predator and Prey Populations Over Time



Ecological Model: Predator and Prey Populations Over Time



Compare your prediction to the ecological model of predator-prey interactions. If your ideas changed, explain how they changed. If your ideas stayed the same, explain what you understand about predator-prey relationships.

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Name _____

Graphing Rainfall and Fawn Survival Data

Title: _____

KEY
Rainfall (cm):

Fawn survival rate (fawns per 100 females):

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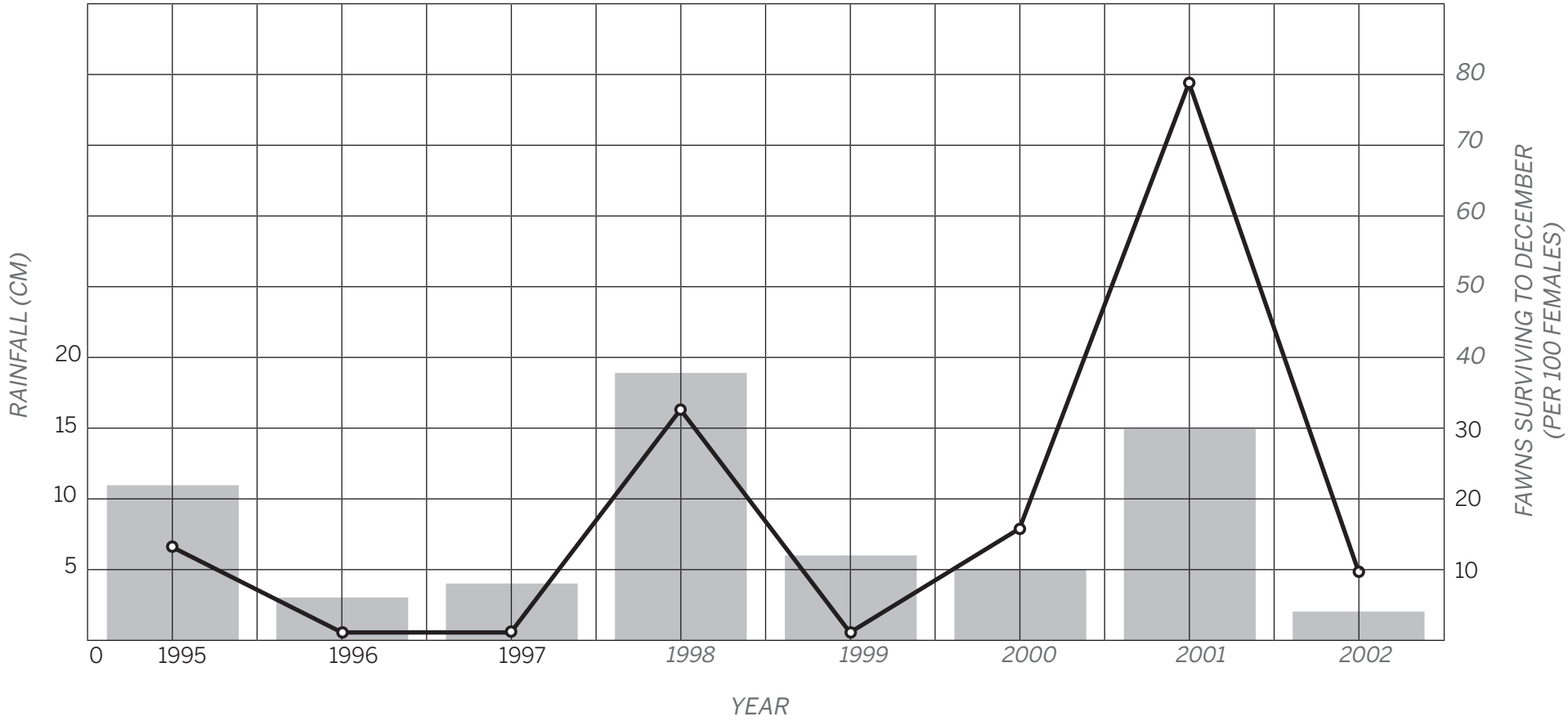
Name SAMPLE STUDENT RESPONSE

Graphing Rainfall and Fawn Survival Data

Title: *Rainfall vs. Fawn Survival, 1995-2002*



KEY

Rainfall (cm):

Fawn survival rate (fawns per 100 females):

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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 1.5

Explanation Tool

Question

What is the scientific question you are investigating?

Which graph best represents the pattern of interaction described in your scenario (Scenario 2)?

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?
Graphs A, D, and E are the only ones that show abiotic factors. *Only Graph A shows ups and downs every year with the time of year.*	*Water temperature is an abiotic factor.* *Abiotic interactions can affect populations.*

Scientific Reasoning

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

My reasoning is that the pattern every year shows that whenever the water temperature changes, the worm population changes in the opposite direction. So when the water temperature goes up, the worm population goes down and when the water temperature goes down, the worm population goes up. The information in the scenario said that the worm population increases in winter when the water temperature goes down. It also said that the population decreased in the summer when the water temperature went up. The pattern shown by Graph A therefore matches the information in Scenario 2.

Claim

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

Graph A best matches the interaction between an abiotic factor (water temperature) and a population (worms) that goes up in winter when water is cold and down in summer when water is warm.

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Explanation Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 1.5

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

The question is "Which graph best represents the pattern of interaction described in your scenario (Scenario 2)?"

My claim is that Graph A best matches the interaction between an abiotic factor (water temperature) and a population (worms) that goes up in winter when water is cold and down in summer when water is warm (Scenario 2). The evidence to support my claim is that Graphs A, D, and E are the only ones that show abiotic factors and that only Graph A shows ups and downs every year with the time of year. The science concept connected to the evidence is that abiotic factors can affect populations. The reasoning that links the evidence and science concepts to my claim is that the pattern every year shows that whenever the water temperature changes, the worm population changes in the opposite direction. So when the water temperature goes up, the worm population goes down and when the water temperature goes down, the worm population goes up. The information in the scenario said that the worm population increases in winter when the water temperature goes down. It also said that the population decreased in the summer when the water temperature went up. The pattern shown by Graph A therefore matches the information in Scenario 2.

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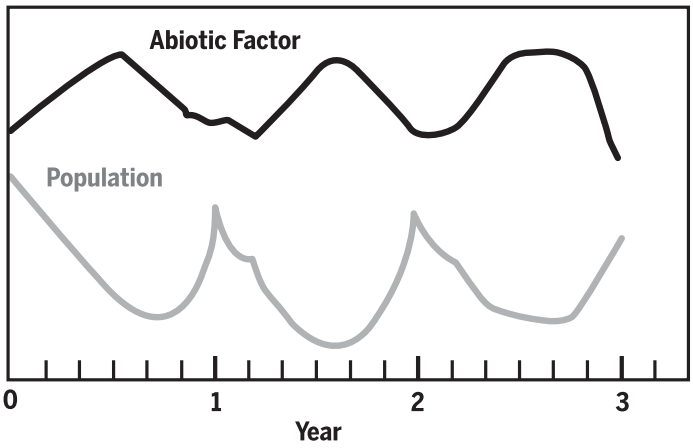
Name _____

Patterns of Interaction

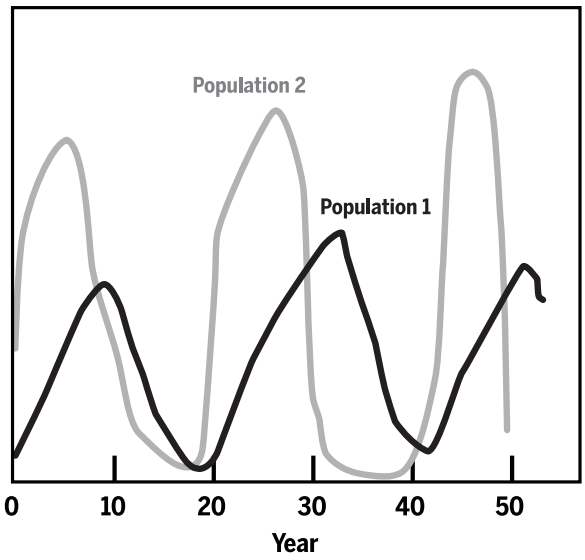
Graph A



Scenario: _____

_____

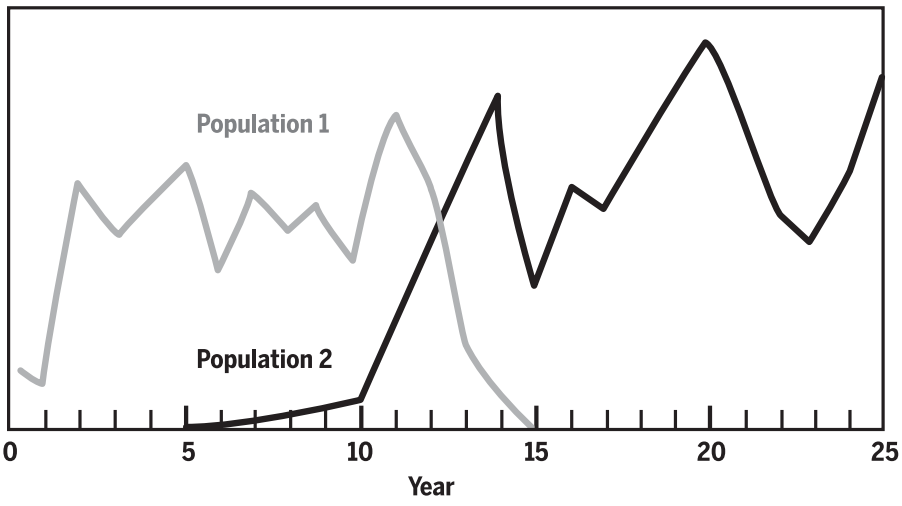
Graph B



Scenario: _____

_____

Graph C



Scenario: _____

_____

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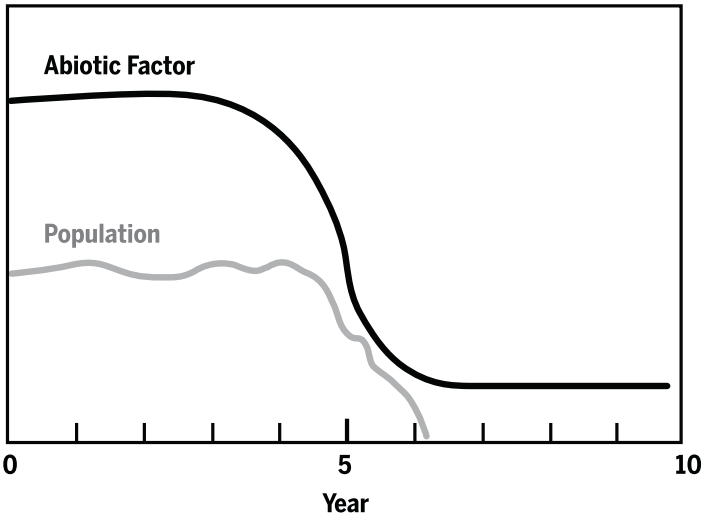
Patterns of Interactions

Continued

Name _____

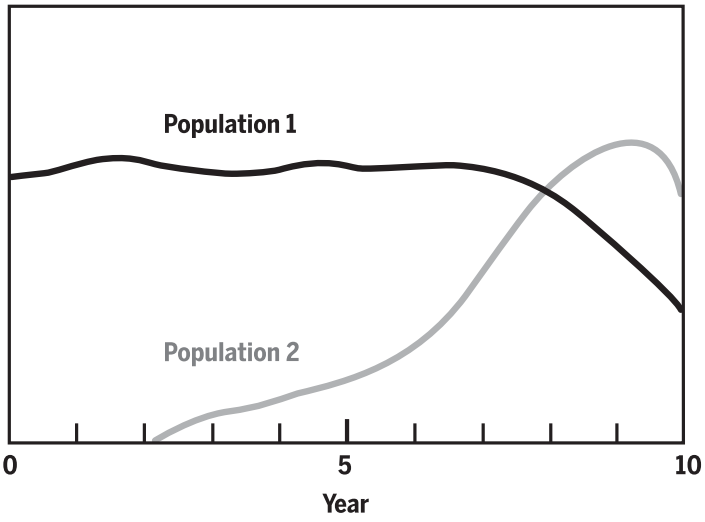
Graph D



Scenario: _____

_____

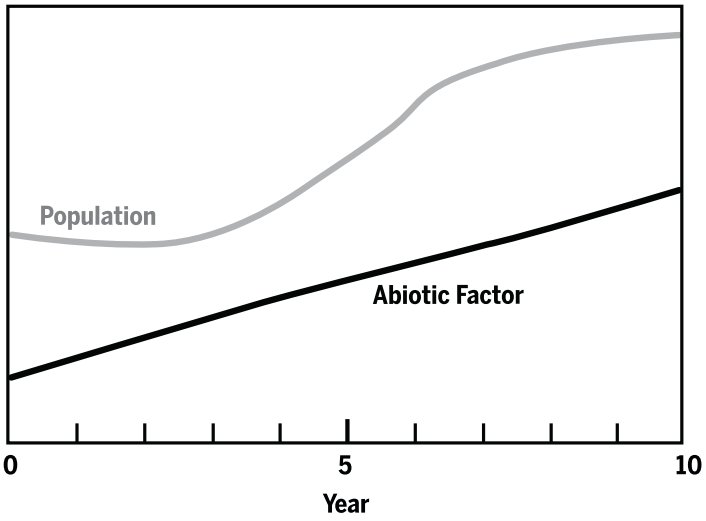
Graph E



Scenario: _____

_____

Graph F



Scenario: _____

_____

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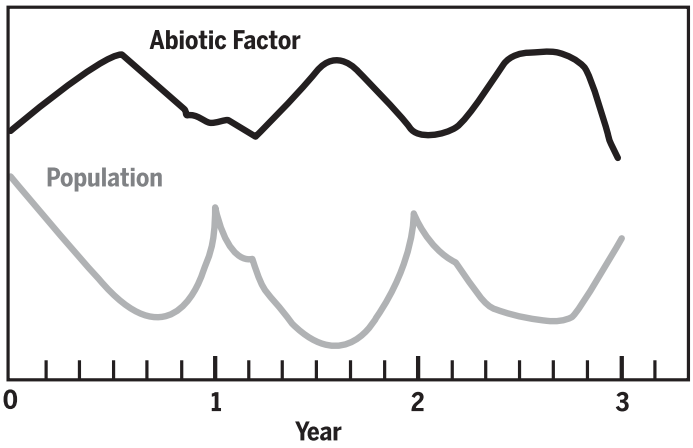
Name *SAMPLE STUDENT RESPONSE*

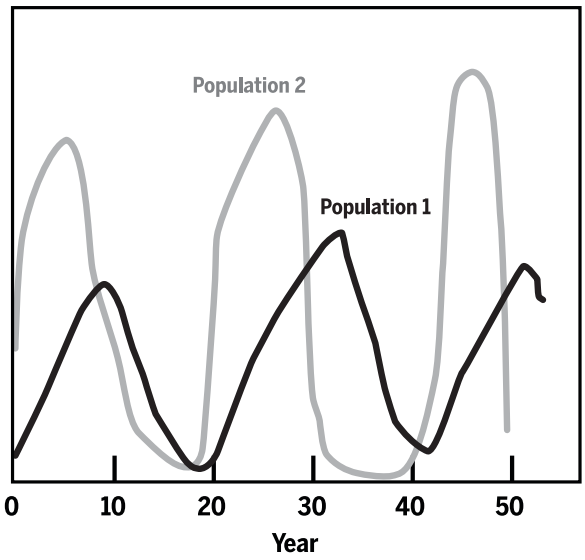
Patterns of Interaction

Graph A



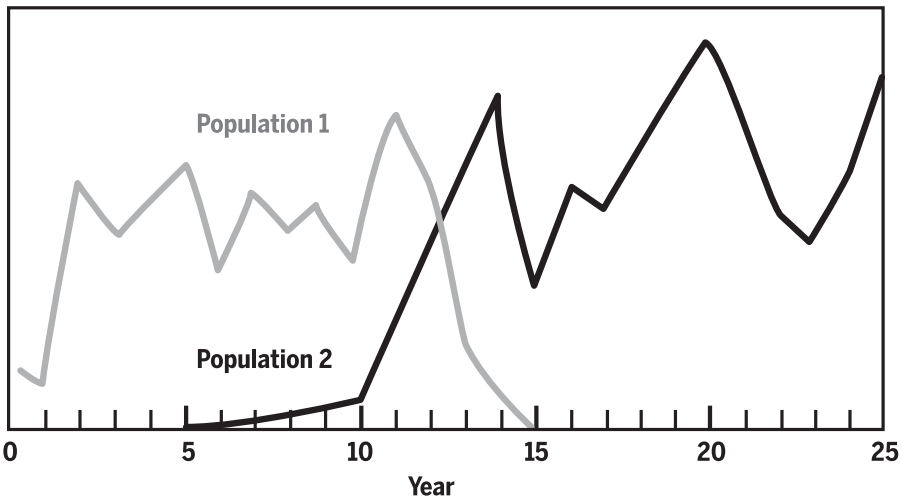
Scenario: *Marine Worms and Ocean Temperatures. The worm population went up when the water got cold and the population went down when the water got warm.*

Graph B



Scenario: *Canadian Lynx and Snowshoe Hare. The lynx population went down after the hare population went down, and the lynx population went up after the hare population went up. This is predator-prey. The lynx is the predator and the hare is the prey.*

Graph C



Scenario: *Freshwater Lake Fish. The yellow perch population went down after the rainbow smelt was introduced. The smelt ate the perch's food. This is competition.*

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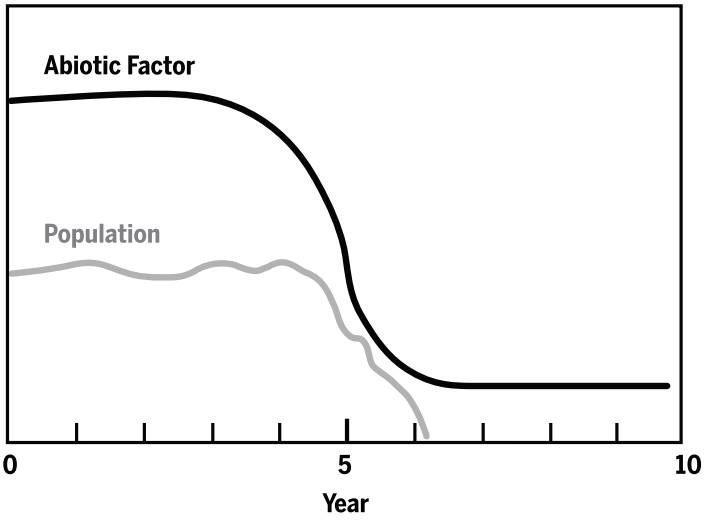
Patterns of Interactions
Continued

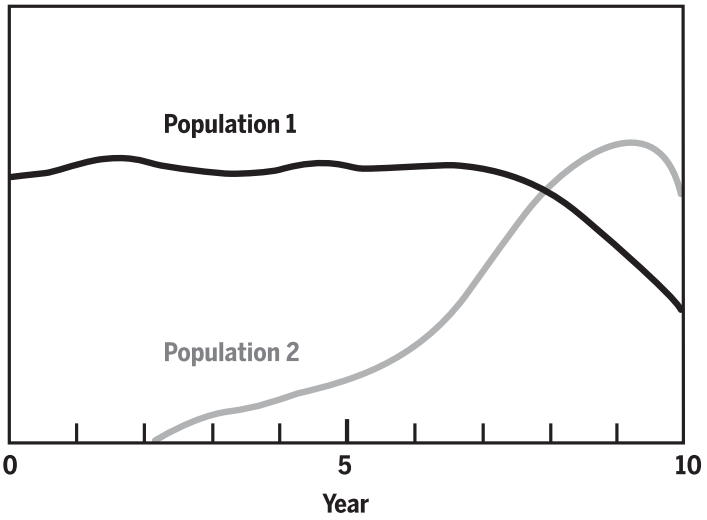
Name *SAMPLE STUDENT RESPONSE*

Graph D



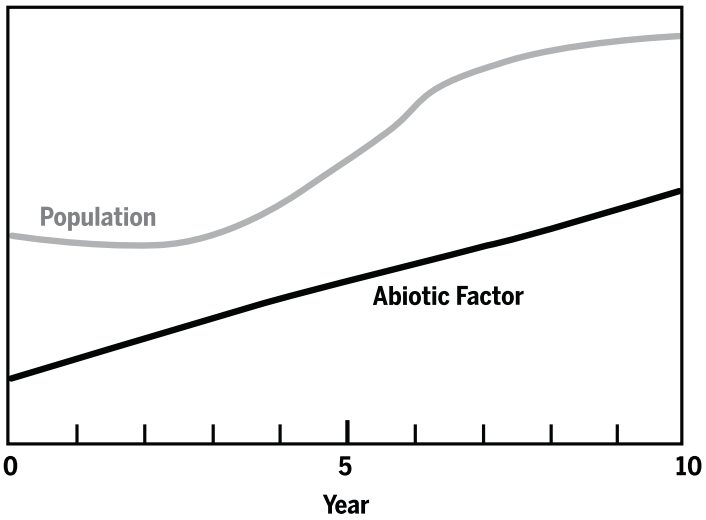
Scenario: *Oxygen and Fish Populations. When the level of oxygen went down, the fish population went down to zero. The fish population could not survive without enough oxygen.*

Graph E



Scenario: *Insects in Fields and Orchards. There were insect populations in fields and orchards. When a wasp was introduced, the insect populations went down. This is parasitism.*

Graph F



Scenario: *Phosphorus and Algae Growth. When phosphorus levels went up, the population of algae increased.*

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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 1.6

Explanation Tool

Question

What is the scientific question you are investigating?

What is the effect of large populations of deer on ecosystems?

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?
Studies show that overgrazing occurs when deer populations are large. *Large deer populations can cause bird populations to decrease.*	*Deer are primary consumers, and many deer will eat a lot of plants.* *Deer may compete with other organisms for resources.*

Scientific Reasoning

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

Deer are primary consumers, so they eat plants. Therefore there is competition between deer and other organisms that depend on plants. So when there are large populations of deer, populations of other organisms, such as plants and organisms that eat plants will decrease.

Evidence shows that overgrazing of plants occurs when deer populations are large and that large deer populations can cause bird populations to decrease.

Claim

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

A large population of deer can cause damage to ecosystems.

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Explanation Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 1.6

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

We are investigating the question: What is the effect of large populations of deer on ecosystems? My claim is that when a population of deer becomes too large, it can cause damage to an ecosystem. The evidence for this is based on studies showing that large deer populations cause overgrazing of plants and reduce the populations of some birds. These relationships are explained by the role of deer as primary consumers and by the concept of competition between organisms. These concepts lead me to reason that too many deer harm both the plants and other organisms that need the plants for food or shelter.

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Name _____

DART: Reading Support for Activity 1.6

1. As you read, determine if the following statements are true or false. If the statement is false, correct it so that it becomes true.

	True	False
a. Today, there are large populations of deer in the northeastern U.S. because they have few predators.		
b. Bears killed almost 6.5 million deer in 2013.		
c. Depending on what they eat, deer can help plants grow up to 3 kilometers from their original site.		
d. Large populations of deer in a small area result in a healthy forest with lots of plants.		
e. Each year, deer cost people a lot of money because they are kept as pets.		
f. People have proposed controlling the deer populations by letting them die of starvation.		

2. Look for an example of each of the following patterns of interaction in the reading. If there is no appropriate example, write "none."

Pattern of Interaction		Example
Predator-prey		
Competition		
Symbiosis	mutualism	
	commensalism	
	parasitism	

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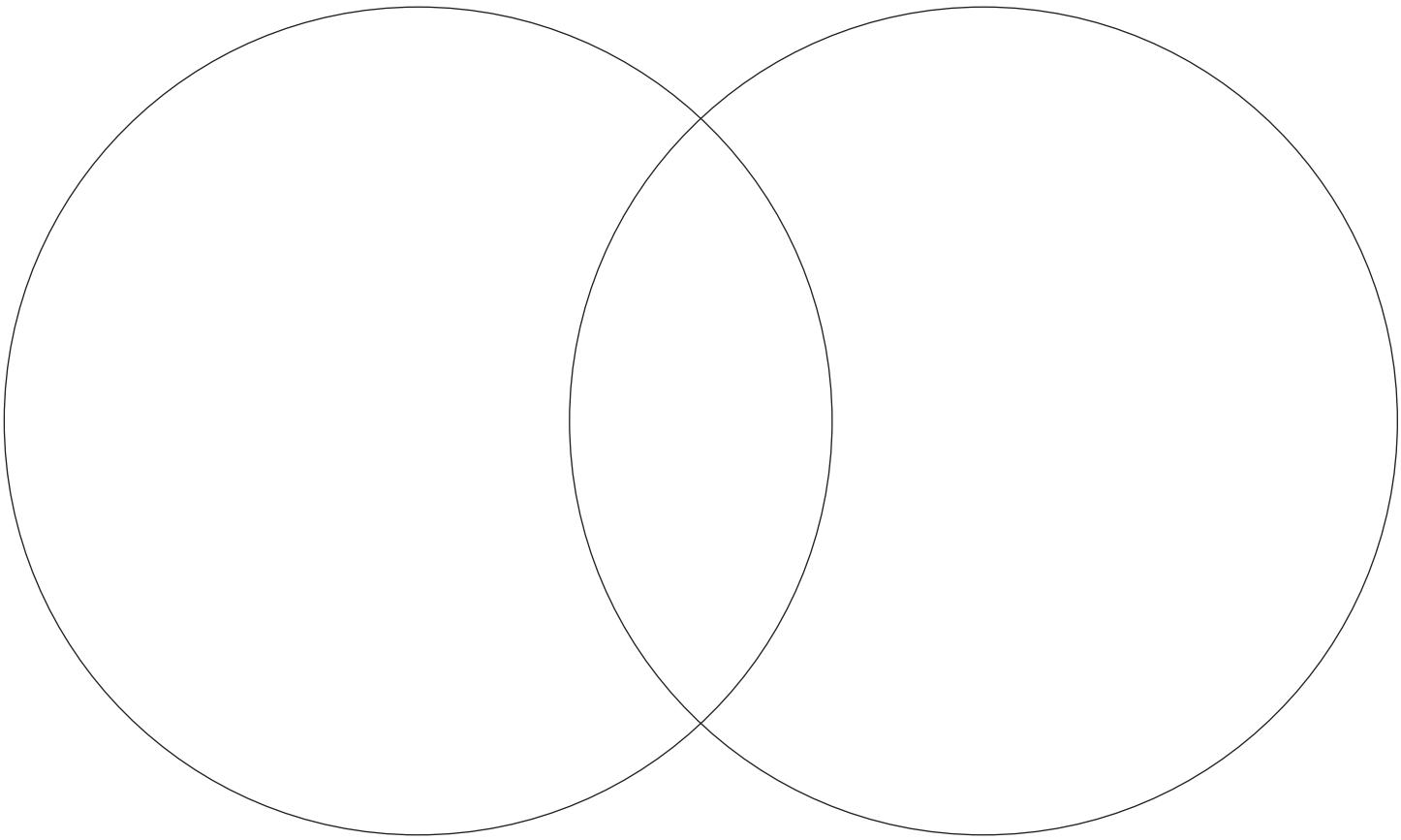
DART: Reading Support for Activity 1.6

Continued

Name _____

3. Fill in the Venn diagram shown below by identifying common organisms found in each ecosystem. Be sure to include plants as well as animals.



Adirondacks **Yellowstone**

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Name _____ SAMPLE STUDENT RESPONSE

DART: Reading Support for Activity 1.6

1. As you read, determine if the following statements are true or false. If the statement is false, correct it so that it becomes true.

	True	False
a. Today, there are large populations of deer in the northeastern U.S. because they have few predators.	X	
b. ~~Bears~~ *People* killed almost 6.5 million deer in 2013.		X
c. Depending on what they eat, deer can help plants grow up to 3 kilometers from their original site.	X	
d. Large populations of deer in a small area result in a ~~healthy~~ *overgrazed* forest with ~~lots of~~ *few* plants.		X
e. Each year, deer cost people a lot of money because they ~~are kept as pets.~~ *eat garden plants and crops, and are hit by cars.*		X
f. People have proposed controlling the deer populations by ~~letting them die of starvation.~~ *reintroducing wolves.*		X

2. Look for an example of each of the following patterns of interaction in the reading. If there is no appropriate example, write "none."

Pattern of Interaction		Example
Predator-prey		*Predators: bobcats, coyotes, black bears* *Prey: deer*
Competition		*Deer and songbirds; deer and people*
Symbiosis	mutualism	*Deer and Trillium plant*
	commensalism	*Songbirds and shrubs*
	parisatism	*Deer and blacklegged tick*

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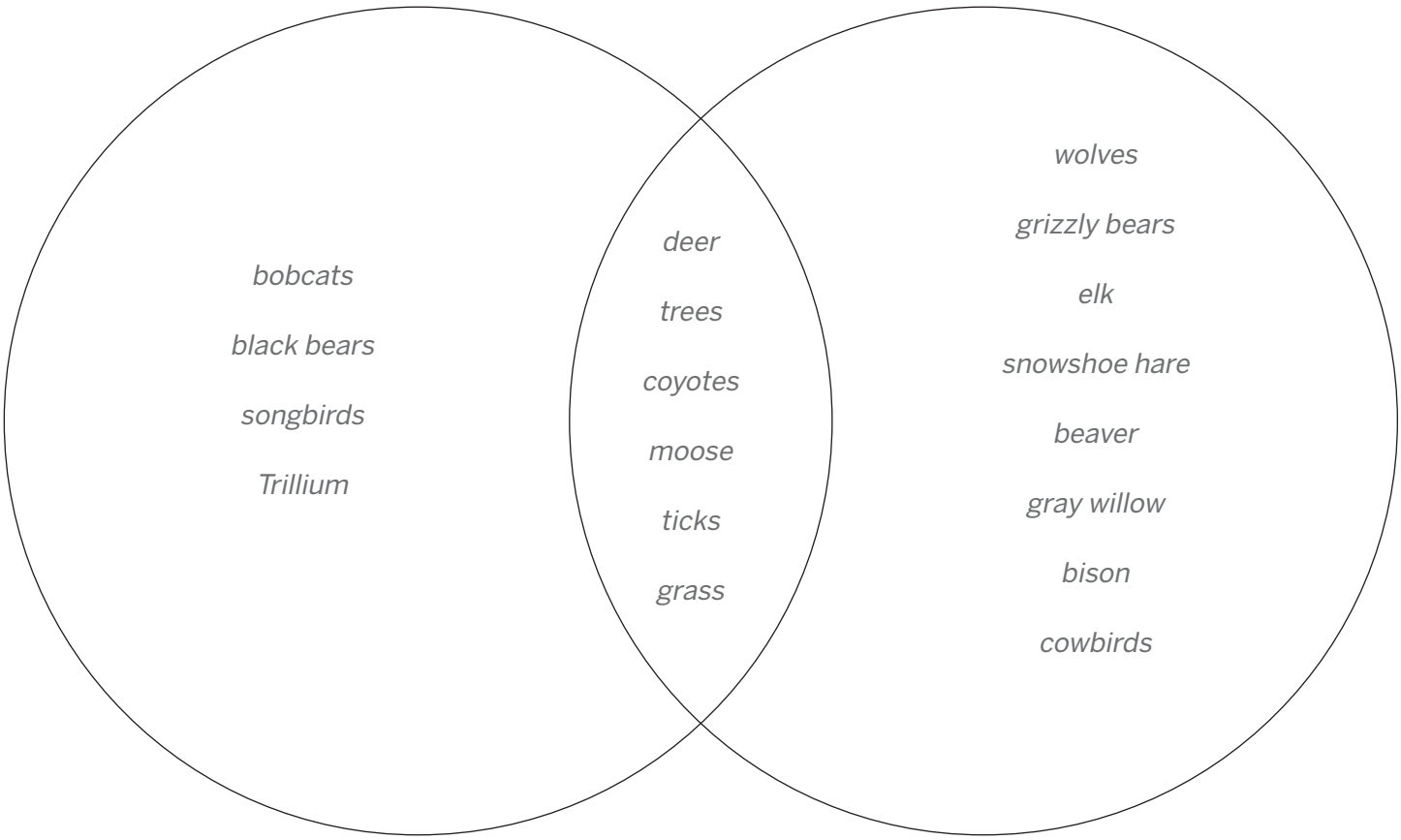
DART: Reading Support for Activity 1.6

Continued

Name SAMPLE STUDENT RESPONSE

3. Fill in the Venn diagram shown below by identifying common organisms found in each ecosystem. Be sure to include plants as well as animals.



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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.

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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.

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Name _____

Anticipation Guide: Matter and Energy in Ecosystems

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.

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Name SAMPLE STUDENT RESPONSE

Anticipation Guide: Matter and Energy in Ecosystems

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.

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Name _____

Making Sense of Scientific Findings

Finding	What it says	What it means
A. Building blocks of living things		
B. Van Helmont experiment		
C. Hydroponics		
D. Cellular respiration		

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Making Sense of Scientific Findings

Continued

Name _____

Finding	What it says	What it means
E. Photosynthesis		
F. Compost		
G. Decomposers		
H. Rotting food		

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Name _____ SAMPLE STUDENT RESPONSE

Making Sense of Scientific Findings

Finding	What it says	What it means
A. Building blocks of living things	*Plants and animals are made of substances that contain carbon.*	*Organisms need a source of carbon.*
B. Van Helmont experiment	*The mass of the soil did not change even though the tree gained 74 kg.*	*Plants don't get their matter from soil. They must get it from somewhere else.*
C. Hydroponics	*Plants can grow with only air, water and dissolved minerals. They do not require soil.*	*This confirms Finding B that plants don't get their matter from soil.*
D. Cellular respiration	*All organisms use oxygen to break down food and release carbon dioxide and water.*	*All organisms break down sugars (that contain carbon) and give off carbon dioxide and water to the environment.*

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Making Sense of Scientific Findings
Continued

Name *SAMPLE STUDENT RESPONSE*

Finding	What it says	What it means
E. Photosynthesis	*Plants use carbon dioxide and water to make their sugars (food) and release oxygen.*	*The carbon in sugars comes from the carbon dioxide in the air.*
F. Compost	*The food is being broken down and is warm.*	*Dead things and their waste give off heat when they break down.*
G. Decomposers	*Decomposers consume dead organisms and their wastes.*	*Decomposers are causing the breakdown of dead organisms and their waste.*
H. Rotting food	*Sterilized food doesn't rot/decompose.*	*Without decomposers dead organisms and their wastes would never break down.*

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Scoring Guide for Developing and Using Models

This scoring guide is used when students develop their own models or use established models to describe relationships and/or make predictions about scientific phenomena.

What to look for:

- Response accurately represents the phenomenon
- Response includes an explanation of relevant ideas and concepts represented by the model or a prediction based on the relationships between ideas and concepts represented by the model

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
The student's model completely and accurately represents the components, relationships, and mechanisms of the phenomenon AND the student uses it to develop a complete and correct explanation or prediction.	The student's model completely and accurately represents the components, relationships, and mechanisms of the phenomenon AND includes a mostly correct use of the model to create an explanation or prediction.	The student's model represents components of the phenomenon AND includes a partially correct representation of the relationships or mechanisms associated with the phenomenon.	The student's model represents components of the phenomenon BUT provides little or no evidence of the relationships or mechanisms associated with the phenomenon.	The student's response is missing, illegible, or irrelevant.

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Name _____

Forest Change Matter Captions for Activity 2.5

Matter: In this mature forest, matter is cycling constantly between the abiotic environment and the biotic environment. Plants conducting photo synthesis transfer carbon dioxide and water into the food chain when they make sugars. This matter moves up the chain. At every step, some of the matter is released back to the abiotic system when organisms respire. The rest goes back when dead organisms are broken down by decomposers.

Matter: The matter in the biotic part of the system (organisms) is released to the abiotic part of the system by the fire. The matter is released as carbon dioxide and water.

Matter: There is some matter in the biotic part of the ecosystem, in the burned bits of organisms, but the organisms are dead. Most matter has been transferred to the abiotic part of the system.

Matter: Some plants are growing. They are beginning to transfer some matter from the abiotic part of the system into the biotic part of the system.

Matter: Now that there are plants to provide food for the animals, there is more matter in the plants and animals in the biotic part of the system.

Matter: Matter is cycling between the abiotic part of the system and all levels of the food chain in the biotic part of the system.

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Name _____

Forest Change Description Captions for Activity 2.5

Description: 1. A fully grown forest has old trees and populations of animals.

Description: 2. The forest is burning.

Description: 3. The fire has stopped and the organisms are all dead or have left.

Description: 4. Some plants are beginning to grow.

Description: 5. Plants have grown and some plant-eating animals have returned to the forest.

Description: 6. The forest has mostly regrown. Animal populations have returned.

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Name _____

Forest Change Energy Captions for Activity 2.5

Energy: Plants transfer energy from the sun into the biotic system when they make sugars. Then the energy flows up the food chain. All organisms, including decomposers, release energy to the environment as heat. The heat can't be reused by plants.

Energy: The energy stored in the organisms is released by the fire as heat.

Energy: There is little energy left in the dead bits of the organisms that haven't completely burnt up.

Energy: The plants are also beginning to transform some energy from the sun into energy stored in sugars in the plants.

Energy: Now that there are plants to provide food for the animals, there is also more energy in the biotic (plants and animals) part of the system.

Energy: Energy from the sun is continually taken in by plants, transformed into chemical energy, moves up the food chain and to decomposers, and is released to the environment as heat.

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Name _____

Changes Due to Fire in a Forest Ecosystem

Forest Change	Caption
	Description: Matter: Energy:
	Description: Matter: Energy:
	Description: Matter: Energy:

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Changes Due to Fire in a Forest Ecosystem

Continued

Name _____

Forest Change	Caption
	Description: Matter: Energy:
	Description: Matter: Energy:
	Description: Matter: Energy:

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Name SAMPLE STUDENT RESPONSE

Changes Due to Fire in a Forest Ecosystem

Forest Change	Caption
	Description: *A fully grown forest.* Matter: *In this forest, matter is cycling constantly between the abiotic environment and the biotic environment. Plants conducting photosynthesis transfer carbon dioxide and water into the food chain when they make sugars. This matter moves up the chain. At every step, some of the matter is released back to the abiotic system when organisms respire. The rest goes back when dead organisms are broken down by decomposers.* Energy: *Plants transfer energy from the sun into the biotic system when they make sugars. Then the energy flows up the food chain. All organisms, including decomposers, release energy to the environment as heat. The heat can't be reused by plants.*
	Description: *The forest is burning.* Matter: *The matter in the biotic organisms is released to the abiotic part of the system by the fire, which releases carbon dioxide and water.* Energy: *The energy stored in the organisms is released by the fire as heat.*
	Description: *The fire has stopped and remaining organisms are all dead.* Matter: *There is some matter in the biotic part of the ecosystem, and in the burned bits of organisms, but the organisms are dead and most matter has been released to the abiotic part of the system.* Energy: *There is little energy left in the dead bits of the organisms that haven't completely burnt up.*

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Changes Due to Fire in a Forest Ecosystem

Continued

Name SAMPLE STUDENT RESPONSE

Forest Change	Caption
	Description: *Some plants are beginning to grow.* Matter: *The plants are beginning to transfer some matter from the abiotic part of the system into the biotic part of the system.* Energy: *The plants are also beginning to transform some energy from the sun into energy stored in sugars in the plants.*
	Description: *More organisms are present in the ecosystem, including some animals.* Matter: *Now that there are plants to provide food for the animals, there is more matter in the plants and animals in the biotic part of the system.* Energy: *Now that there are plants to provide food for the animals, there is also more energy in the biotic (plants and animals) part of the system.*
	Description: *The forest has mostly regrown and animal populations have also returned.* Matter: *Matter is cycling between the biotic and abiotic systems.* Energy: *Energy from the sun is continually taken in by plants, transformed into chemical energy, moves up the food chain and to decomposers, and is released to the environment as heat*

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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.

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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.

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Name _____

Populations Over Time

Game A: What's your fishing limit? _____

Round #	Starting # of Fish in Blue Bay		# of Fish You Caught		$ You Earned ($1 per extra orange fish caught, $2 per yellow fish)
	Orange	Yellow	Orange	Yellow	
1					$
2					$
3					$
4					$
Total					$

End Result (what's going on in Blue Bay):

_____

_____

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Populations Over Time
Continued

Name _____

Game B: What's your fishing limit? _____

Round #	Starting # of Fish in Blue Bay		# of Fish You Caught		$ You Earned ($1 per extra orange fish caught, $2 per yellow fish)
	Orange	Yellow	Orange	Yellow	
1					$
2					$
3					$
4					$
Total					$

End Result (what's going on in Blue Bay):

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Populations Over Time

Continued

Name _____

Game C: What's your fishing limit? _____

Round #	Starting # of Fish in Blue Bay		# of Fish You Caught		$ You Earned ($1 per extra orange fish caught, $2 per yellow fish)	Ecosystem Conditions
	Orange	Yellow	Orange	Yellow		
1					$	
2					$	
3					$	
4					$	
Total					$	

End Result (what's going on in Blue Bay):

_____

_____

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Name *SAMPLE STUDENT RESPONSE*

Populations Over Time

Game A: What's your fishing limit? *No Limit*

Round #	Starting # of Fish in Blue Bay		# of Fish You Caught		$ You Earned ($1 per extra orange fish caught, $2 per yellow fish)
	Orange	Yellow	Orange	Yellow	
1	*25*	*5*	*3*	*2*	$ *3*
2	*44*	*10*	*3*	*0*	$ *3*
3	—	—	—	—	$ *None*
4	—	—	—	—	$ *None*
Total					$ *6*

End Result (what's going on in Blue Bay):

There are no more fish.

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Populations Over Time
Continued

Name *SAMPLE STUDENT RESPONSE*

Game B: What's your fishing limit? *3 orange fish*

Round #	Starting # of Fish in Blue Bay		# of Fish You Caught		$ You Earned ($1 per extra orange fish caught, $2 per yellow fish)
	Orange	Yellow	Orange	Yellow	
1	*25*	*5*	*1*	*0*	$ *0*
2	*28*	*10*	*2*	*0*	$ *0*
3	*34*	*20*	*3*	*0*	$ *1*
4	*44*	*40*	*3*	*0*	$ *1*
Total			*9*	*0*	$ *2*

End Result (what's going on in Blue Bay):

Blue Bay is filled with fish, and we earned money.

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Populations Over Time
Continued

Name *SAMPLE STUDENT RESPONSE*

Game C: What's your fishing limit? *3 orange fish*

Round #	Starting # of Fish in Blue Bay		# of Fish You Caught		$ You Earned ($1 per extra orange fish caught, $2 per yellow fish)	Ecosystem Conditions
	Orange	Yellow	Orange	Yellow		
1	*25*	*5*	*3*	*0*	**$** *1*	*Normal Conditions*
2	*28*	*10*	*2*	*0*	**$** *0*	*Plankton Die Off*
3	*20*	*15*	*3*	*0*	**$** *1*	*Habitat Loss*
4	*5*	*20*	*1*	*0*	**$** *0*	
Total			*9*	*0*	**$** *2*	

End Result (what's going on in Blue Bay):

We had very few orange fish left in Round 4 and orange fish left at the end. The yellow fish population increased.

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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 3.3

Argument Tool

Question

What is the question that you are investigating?

Was the Pacific halibut fishery healthy in 2014?

Claim A	**Claim B**
What is a claim you could argue? *The Pacific halibut fishery was healthy in 2014.*	What is a claim you could argue? *The Pacific halibut fishery was not healthy in 2014.*
The evidence that supports this claim is . . . *- amount of fish caught each year is monitored by scientists so that they population stays about the same* *- catch limits go up and down, but change depending on how the population is doing* *- catch has gone up and down but always stayed within 1000-3500 thousands of kg*	**The evidence that supports this claim is . . .** *- the average mass of both female and male halibut is much lower in 2014 than in 1975 and 1995* *- females average about 15kg in 2014, but were about 33kg average in 1975 and 20kg in 1996* *- males average about 13kg in 1975, but were about 13kg average in 1975 and about 8kg in 1995.* *-average mass of both males and females has decreased over time*

Scientific Reasoning: Evaluating the Evidence and Claim

Critique the quality and strength of the evidence that supports this claim. *This evidence is strong in terms of the population size, if the statements about fishing limits are accurate and they are being adjusted each year to keep the population stable. This evidence does not support the claim in terms of individual organisms.*	Critique the quality and strength of the evidence that supports this claim. *This evidence is strong in terms of individual organisms, if smaller average mass is a sign that the population is less healthy. It does not support the claim in terms of population size.*

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Argument Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 3.3

Constructing a Scientific Argument

Decide which claim you think is best supported by the evidence and scientific reasoning. Using the criteria below and the information in the boxes you have completed, write a scientific argument that includes:

- The scientific question
- Your claim (that is best supported by evidence and reasoning)
- Relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

Scientific Argument

Was the Pacific halibut fishery healthy in 2014?

Sample "Yes" Answer:
The Pacific halibut fishery was healthy in 2014. The data shows that over time the population numbers are fairly stable. The average mass of the individual organisms is decreasing, but we do not have any data about how average mass of individual fish affects the population. If the changes in catch limits keep the population stable, it indicates that the fish are not being overfished and that the fishery is healthy, otherwise the population size would have decreased.

Sample "No" Answer:
The Pacific halibut fishery was not healthy in 2014. The data shows that the average mass of both male and female halibut has decreased over time and is much lower in 2014 than in 1975 and 1995. If the population was healthy, the average mass of the fish would not have decreased. Population size (numbers) is not the only thing that indicates a healthy fish population.

Critique of the Rebuttal

Other people might claim _____ . I think the problem with this argument is _____.

Sample "Yes" Critique: Other people might claim that the Pacific halibut fishery was not healthy in 2014 because the average mass of the fish is declining. However, we have no evidence indicating if this is good or bad, or if it matters at all.

Sample "No" Critique: Other people might claim that the Pacific halibut fishery was healthy in 2014 because the number of fish in the population stayed steady. However, that is not the only evidence of a healthy fish population. The average mass of the individual fish is another important indicator of fishery health.

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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 3.4

Explanation Tool

Question

What is the scientific question you are investigating?

Why does total nitrogen in the Gulf of Mexico correlate to water flow from the Mississippi Basin?

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 graph shows that generally when water flow is increased the nitrogen input is also increased *- there are lots of farms in the Mississippi Basin* *- the streams and rivers in the Mississippi watershed empty into the Gulf of Mexico*	*- cause and effect* *- extra fertilizer in farms can be washed away into streams and rivers*

Scientific Reasoning

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

- if there is more water flowing from more farms that will cause more nitrogen to be washed from the Basin into the Gulf

Claim

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

An increase in water flow in the Mississippi Basin will lead to an increase in nitrogen flowing into the Gulf of Mexico.

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Explanation Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 3.4

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

Why does total nitrogen in the Gulf of Mexico correlate to water flow from the Mississippi Basin?

An increase in water flow in the Mississippi Basin will cause an increase in nitrogen flowing into the Gulf of Mexico. Data shows that in most years when there is increased water flow in the Basin there is higher nitrogen input into the Gulf. There are many farms surrounding the rivers and streams in the Basin, and excess fertilizer used on those farms can be washed into the waterways causing an increase in nitrogen. An increase in water flow will cause an increase in nitrogen input because it is washing away more fertilizer.

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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 3.5

Argument Tool

Question

What is the question that you are investigating?

Is an increase in the human population in the Chesapeake Bay area affecting the number of oysters in the Bay?

Claim A	**Claim B**
What is a claim you could argue? *The increase in human population is affecting the number of oysters.*	What is a claim you could argue? *The increase in human population is not affecting the number of oysters.*
The evidence that supports this claim is . . . – *there is more nitrogen run-off with more people because there are more farms to grow more food* – *larger dead zones occur after more nitrogen run-off (in 2003-2005 the nitrogen run off went from about 75,000 to 250,000 metric tons of nitrogen run off and the dead zone went from about 5 km^2 to 7 km^2 in 2006)* – *oyster harvests usually decrease when dead zones increase (2004-2007 were some of the smallest oyster harvests in the last 25 years)*	**The evidence that supports this claim is . . .** – *humans are catching a lot fewer oysters now than in previous decades (close to 20,000 metric tons in 1953, but only about 2,000 metric tons in 2013)*

Scientific Reasoning: Evaluating the Evidence and Claim

Critique the quality and strength of the evidence that supports this claim. *This evidence is strong and there is a lot of evidence.*	Critique the quality and strength of the evidence that supports this claim. *This evidence is not strong because the lower oyster catch could just be because there are fewer oysters because they have been overfished. We have no evidence that the lower catch means more oysters are being left in the Bay.*

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Argument Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 3.5

Constructing a Scientific Argument

Decide which claim you think is best supported by the evidence and scientific reasoning. Using the criteria below and the information in the boxes you have completed, write a scientific argument that includes:

- The scientific question
- Your claim (that is best supported by evidence and reasoning)
- Relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

Scientific Argument

Is an increase in the human population in the Chesapeake Bay area affecting the number of oysters in the Bay?

The increase in the human population in the Chesapeake Bay area is affecting the number of oysters in the Bay. An increase in the human population means that there need to be more farms to grow food for more people. If there are more farms then there is more nitrogen run-off, which leads to larger dead zones. When the dead zones increase, the oyster harvests decrease, likely because there are fewer oysters to catch. Overall, this means that more people in the area leads to fewer oysters.

Critique of the Rebuttal

Other people might claim _____ . I think the problem with this argument is _____.

Other people might claim that the increase in human population in the Chesapeake Bay area does not affect the number of oysters in the Bay. I think the problem with this argument is that the only data that might support this is that fewer oysters are being caught than in previous decades, but that could just be because the oysters have been overfished by humans.

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Name _____

Ecosystems Comparison

Ecosystem	Description*	Biotic Factors	Abiotic Factors	Effects of Zebra Mussels	Other Notes
Great Lakes					
Hudson River					

* Is it salt or fresh water? An ocean, a river, or a lake? Does the water flow one direction, many directions, or remain mostly still?

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Name SAMPLE STUDENT RESPONSE

Ecosystems Comparison

Ecosystem	Description*	Biotic Factors	Abiotic Factors	Effects of Zebra Mussels	Other Notes
Great Lakes	*Fresh water, connected lakes, biggest in the world*	*Plankton* *Fresh water mollusks* *Fish*	*Fresh water*	*Plankton populations dropped* *Blue-green algae increased* *Fish populations dropped* *Botulism bacteria increased* *Blocked pipes*	
Hudson River	*River through NY state, connects to Great Lakes, mixes with ocean at the end. Estuary water is cloudy.*	*Phytoplankton* *Zooplankton* *Fresh water mollusks* *Bacteria* *Fish (pelagic and littoral)*	*Fresh water, and mixed salt/fresh water* *More sunlight after zebra mussels*	*Phytoplankton fell 80-90%* *Zooplankton fell 50%* *Fish populations dropped* *Visibility went up, more plants* *Dissolved oxygen dropped* *Blocked pipes*	

* Is it salt or fresh water? An ocean, a river, or a lake? Does the water flow one direction, many directions, or remain mostly still?

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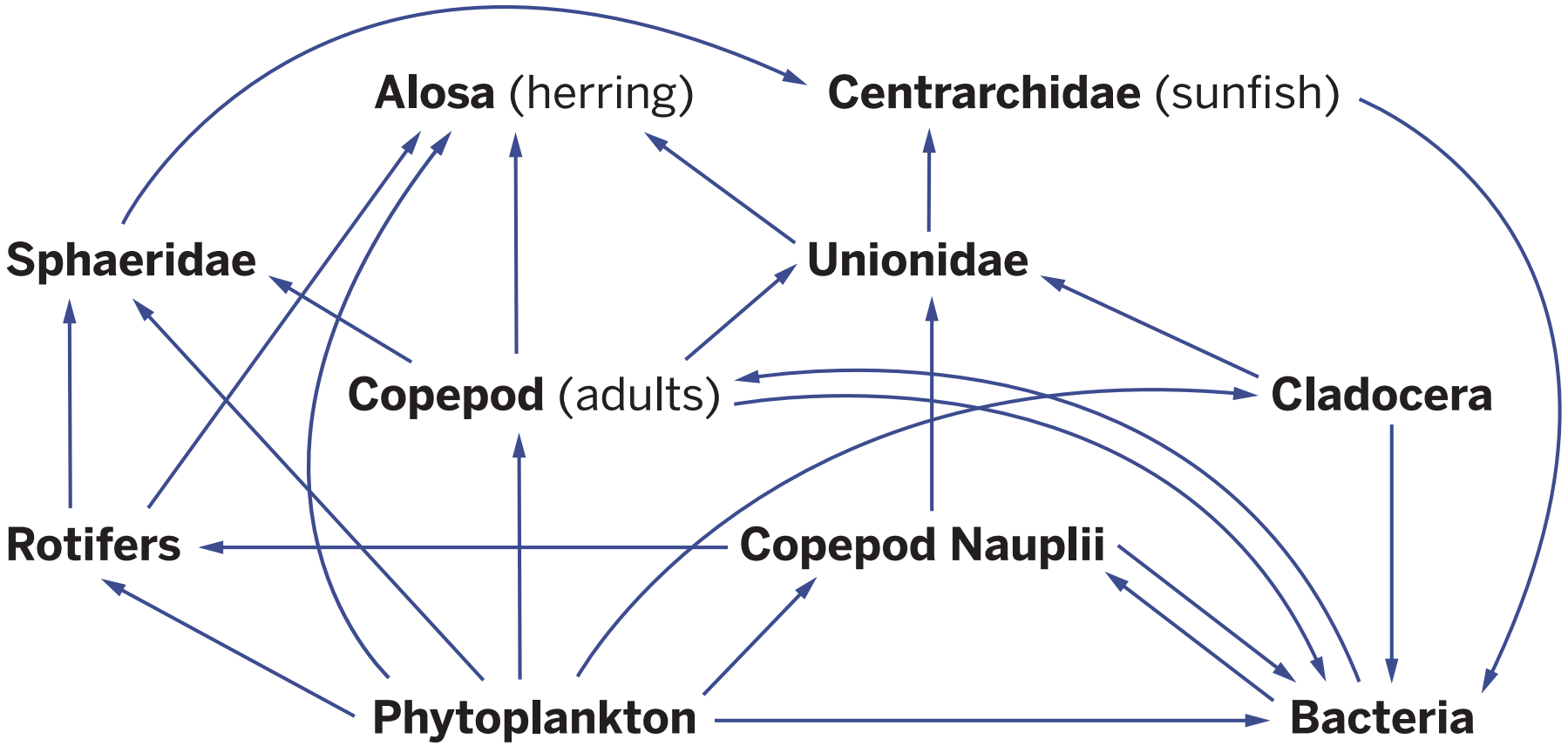
Name _____

Hudson River Food Web before Zebra Mussels



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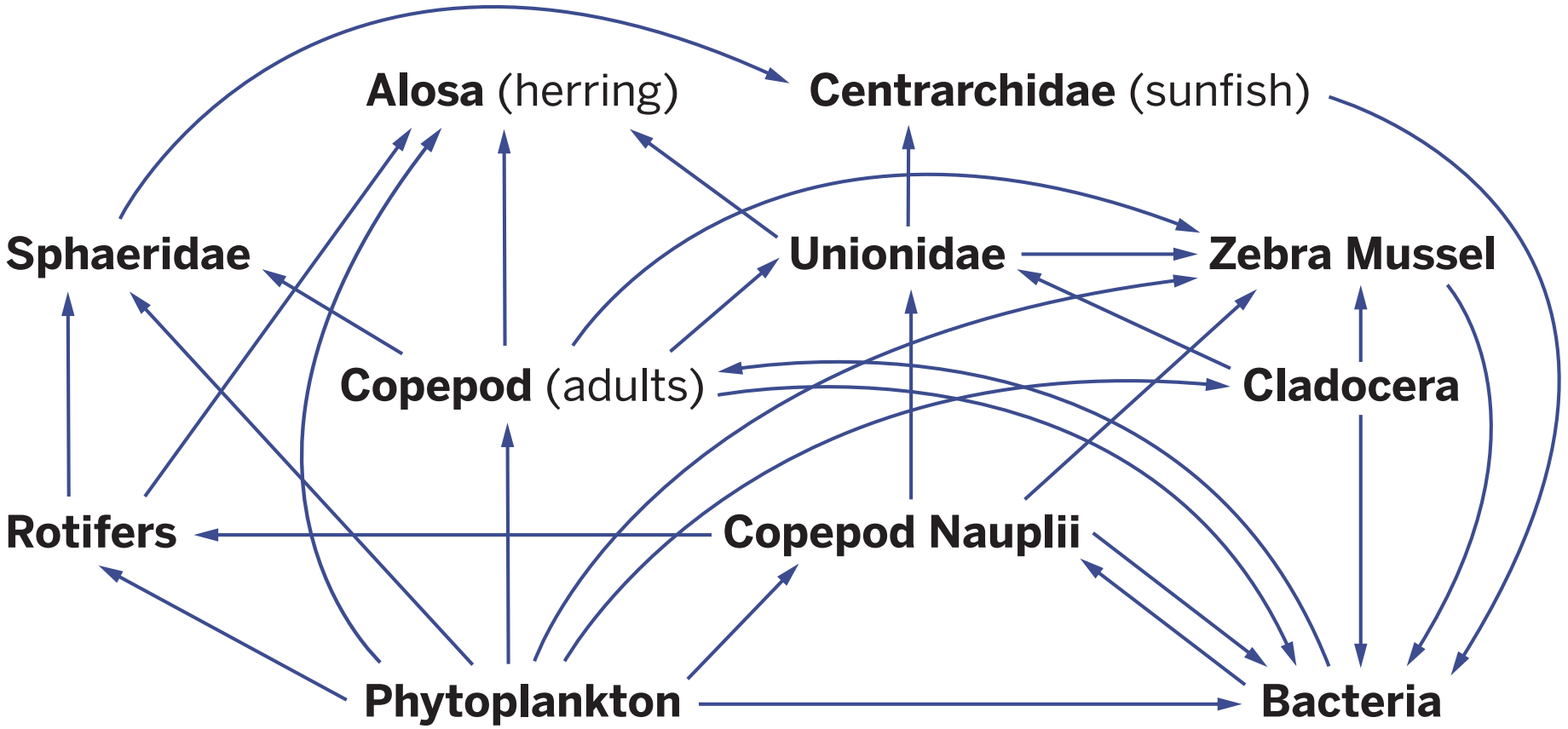
Name _____

Hudson River Food Web after Zebra Mussels



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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 4.4

Argument Tool

Question

What is the question that you are investigating?

Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?

Claim A	**Claim B**
What is a claim you could argue? *The zebra mussel had a positive effect on the Hudson River ecosystem.*	What is a claim you could argue? *The zebra mussel had a negative effect on the Hudson River ecosystem.*
The evidence that supports this claim is . . . *- rotifer (zooplankton) population decreased when the zebra mussels first arrived, but is now increasing as zebra mussel population decreases* *- 2000-2013 the population average for rotifers went from 161/L to 186/L, zebra mussel population went from 1300/m^2 to 1085/ m^2.*	**The evidence that supports this claim is . . .** *- rotifer (zooplankton) population is much smaller than it was before the zebra mussels arrived. (was 1,000-2,000/L, after zebra mussel less than 200/L.* *- open water fish was 10.35 million before the zebra mussels. 5.24 million after* *-number of open water fish has continued to fall, now 3.34 million.*

Scientific Reasoning: Evaluating the Evidence and Claim

Critique the quality and strength of the evidence that supports this claim. *Even though the rotifer population is a little higher, it has not gone up enough to show that the ecosystem has recovered or that the zebra mussel has had a positive effect. The number of open water fish has not recovered.*	Critique the quality and strength of the evidence that supports this claim. *The rotifer population had decreased significantly, and this means that other planktoneaters like fish and native mussels do not have as much food. The number of open water fish has continued to go down even when the zebra mussel population has been reduced.*

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Argument Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 4.4

Constructing a Scientific Argument

Decide which claim you think is best supported by the evidence and scientific reasoning. Using the criteria below and the information in the boxes you have completed, write a scientific argument that includes:

- The scientific question
- Your claim (that is best supported by evidence and reasoning)
- Relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

Scientific Argument

Has the zebra mussel had a positive or negative effect on the Hudson River ecosystem?

My claim is that the zebra mussel has had a negative effect on the Hudson River ecosystem. The evidence that supports this claim is that the rotifer (zooplankton) population is much smaller than it was before the zebra mussels arrived. There used to be 1,000-2,000/L and after the zebra mussel arrived it dropped to less than 200/L. Even though the rotifer population has increased a little since 2000 (from 161/L to 186/L) the population is still much smaller than it used to be. The number of open water fish was 10.35 million before the zebra mussels arrived. It fell to 5.24 million after the zebra mussels arrived. Between 2000 and 2013 the number of open water fish has continued to fall and is now at 3.34 million even though the zebra mussel population has decreased during this time. My scientific reasoning is that the decrease in the rotifer population means that all predators that eat zooplankton, such as native fish and mussels, will therefore have less to eat and their populations will decline. Therefore, this is the claim that fits best with all of the data on zebra mussels and rotifer populations.

Critique of the Rebuttal

Other people might claim _____ . I think the problem with this argument is _____.

Other people might claim that the zebra mussel has had a positive effect on the Hudson River ecosystem. I think the problem with this argument is that there is more evidence of negative effects, like the rotifer population decreasing, than there is evidence of positive effects, like the fact that the rotifer population is starting to increase a little bit.

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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 4.4

Explanation Tool

Question

What is the scientific question you are investigating?

What is the long-term effect of zebra mussels on the factor you chose? (rotifers)

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?
- 1990 to 2000 zebra mussel increased from zero to about 1300/m^2 *- average rotifer population went from 409/L to 161/L.* *- 2000 to 2013, zebra mussel population decreased slightly to an average of 1085/m^2* *- average rotifer population increased slightly to an average of 186/L.*	*This is a predator/prey relationship. Zebra mussels are the predators and rotifers are the prey.*

Scientific Reasoning

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

Normally as the population of predators increases the population of prey will decrease, and as the predator population decreases the prey population increases. The evidence shows this happening with zebra mussels and rotifers.

Claim

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

If the zebra mussel population increases, the rotifer population decreases, but if the zebra mussel population decreases the rotifer population will increase.

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Explanation Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 4.4

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 is the long-term effect of zebra mussels on the factor you chose? (rotifers)

My claim is that if the zebra mussel increases, the rotifer population decreases, but if the zebra mussel decreases the rotifer population will increase. The evidence that supports my claim is that the patterns in the graph show that as the population average of zebra mussels increased (1990-2000), the population average of rotifers decreased. However, when the population of zebra mussels decreased (2000-2013), the rotifer population increased. Because zebra mussels are predators that prey on rotifers, a larger zebra mussel population will eat more rotifers, causing a decrease in the rotifer population. The reverse will happen if the predator population (zebra mussels) decreases: the prey population (rotifers) will increase. This is what normally happens in predator-prey relationships: when a predator population increases, it causes the prey population to decrease, and vice versa. This is an example of a cause and effect relationship.

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Name _____ *SAMPLE STUDENT RESPONSE*

Activity 4.5

Argument Tool

Question

What is the question that you are investigating?

Has the Quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?

Claim A	**Claim B**
What is a claim you could argue? *The Quagga mussel has had a positive effect on the Lake Michigan ecosystem.*	What is a claim you could argue? *The Quagga mussel has had a negative effect on the Lake Michigan ecosystem.*
The evidence that supports this claim is . . . *- water clarity from 16.4 ft average in the 1980's to 28.4 ft average in the 2000's* *- zebra mussels from a high average population in 2000 of up to 100,000 m^2 to 0 in 2010*	**The evidence that supports this claim is . . .** *- Diporeia (zooplankton) from 20,000/m^2 in 1994 to less than 3,000/ m^2 in 2010* *- Many fish (trout, salmon, Whitefish, etc) eat diporeia*

Scientific Reasoning: Evaluating the Evidence and Claim

Critique the quality and strength of the evidence that supports this claim.	Critique the quality and strength of the evidence that supports this claim.
An increase in water clarity might mean more plants would grow, but we have no data on this. Even though zebra mussels have decreased, that has not lead to an increase in plankton because the Quagga mussels are eating the diporeia (even more than the zebra mussels were).	*The plankton levels have decreased even more than when the zebra mussels invaded, and there are many fish that depend on this plankton for food. Also, the population of diporeia has continually decreased and not shown any signs of increasing. The fish populations have probably decreased due to the Quagga mussels as well.*

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Argument Tool
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 4.5

Constructing a Scientific Argument

Decide which claim you think is best supported by the evidence and scientific reasoning. Using the criteria below and the information in the boxes you have completed, write a scientific argument that includes:

- The scientific question
- Your claim (that is best supported by evidence and reasoning)
- Relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

Scientific Argument

Has the Quagga mussel had a positive or negative effect on the Lake Michigan ecosystem?

My claim is that the Quagga mussel has had a negative effect on the Lake Michigan ecosystem. The evidence that supports this claim is that the diporeia population is much lower than it was before the Quagga mussels were introduced from 20,000/m^2 in 1994 to less than 3000/m^2 in 2010, even lower than when the zebra mussel population was at its highest. The diporeia are important prey for many predators such as trout and salmon. My scientific reasoning is that the decrease in the diporeia population means that all predators that eat the diporeia, including salmon and trout, will therefore have less to eat and their populations will decline. Therefore, this is the claim that fits best with all of the data on Quagga mussels and their effect on the Lake Michigan ecosystem.

Critique of the Rebuttal

Other people might claim _____ . I think the problem with this argument is _____.

Other people might claim that the Quagga mussel has had a positive effect on the Lake Michigan ecosystem because the water is clearer and there are fewer zebra mussels. I think the problem with this argument is that there are more negative than positive effects from the Quagga mussel, like the decrease in Diporeia which many fish depend on for food.

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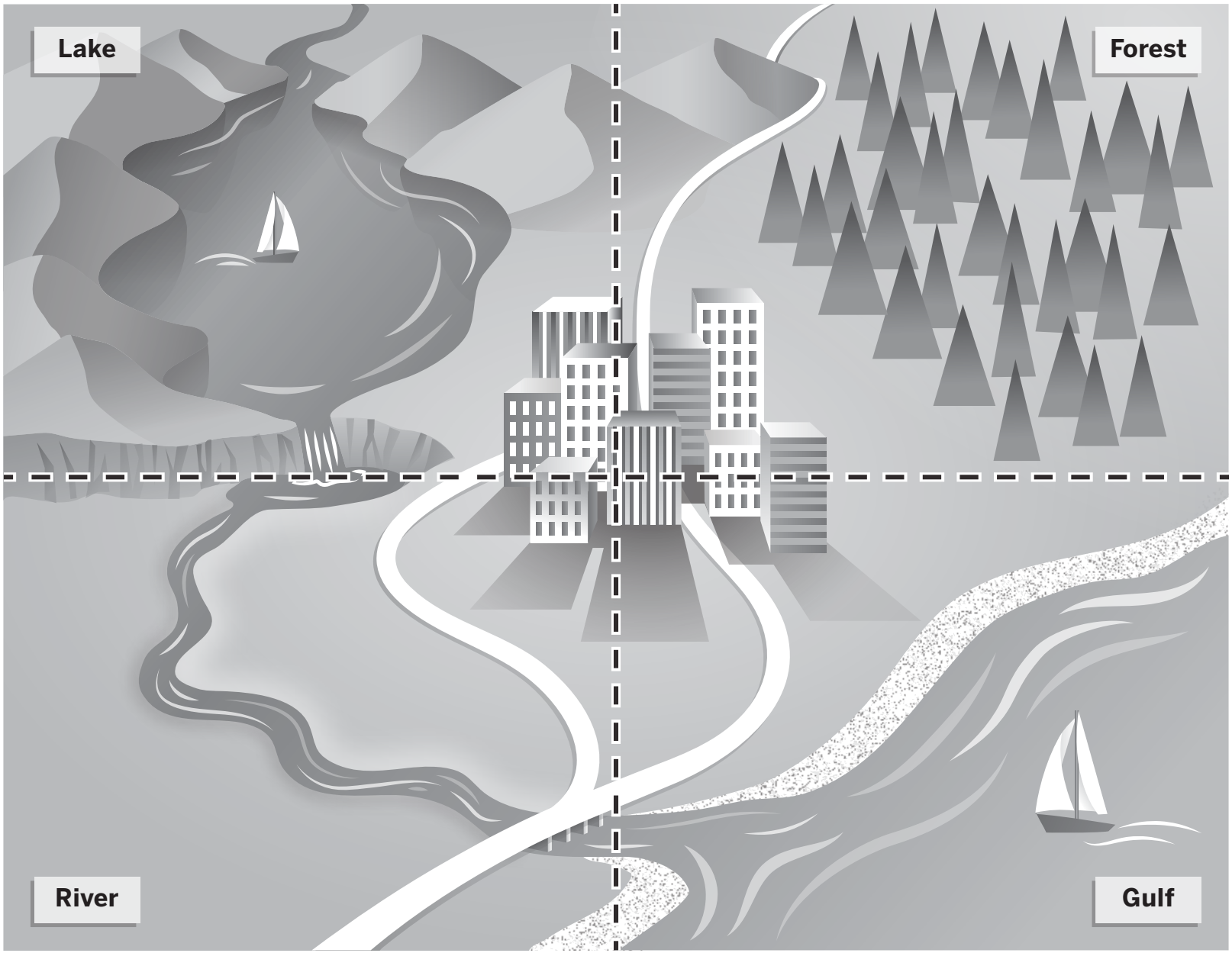
Map

Name _____



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Name _____

Control Methods

A) Chemical control

A pesticide would be sprayed on the plants and the soil. The pesticide is very effective at killing any beetles that it touches. It is also poisonous to many other insects and some animals. The effectiveness of the pesticide decreases rapidly over time. The insecticide would have to be reapplied frequently over a two-month period.

Advantages	Disadvantages

B) Relocate the farm

Holly, her parents, and her two younger brothers would move to a new location several hundred miles away. This would involve selling the farm and leaving her school and friends behind. It is uncertain if the farm could be sold for enough money to buy another farm in the new location. If not, then Holly's parents would have to find different jobs.

Advantages	Disadvantages

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Control Methods
Continued

Name _____

C) Biological control

Toads will be used to control the beetles. The toads eat many types of small organisms, such as frogs, lizards, snakes, mice, snails, and insects. They have been used successfully to control insect pests in several other countries. The toads are not native to the area. Thirty toads will be brought to the farm and released in the fields.

Advantages	Disadvantages

D) Physical removal

All of the fields would be burned. This would kill all of the crops but would also kill the insects, including the grubs that live in the soil. The fields would be left bare for one year. Workers would be hired to monitor the fields and trap and remove any of the beetles that were found there. After one year, the crops would be replanted. Workers would continue to monitor the fields for the beetles until the crops could be harvested later in the year.

Advantages	Disadvantages

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Name _____ SAMPLE STUDENT RESPONSE

Control Methods

A) Chemical control

A pesticide would be sprayed on the plants and the soil. The pesticide is very effective at killing any beetles that it touches. It is also poisonous to many other insects and some small animals. The effectiveness of the pesticide decreases rapidly over time. The insecticide would have to be reapplied frequently over a two-month period.

Advantages	Disadvantages
Kills insects that it touches. *It is easy to use.*	*Poisons other insects and small animals.* *Doesn't last long and has to be reapplied frequently.* *Could kill the crops.* *Could make people sick.*

B) Relocate the farm

Holly, her parents, and her two younger brothers would move to a new location several hundred miles away. This would involve selling the farm and leaving her school and friends behind. It is uncertain if the farm could be sold for enough money to buy another farm in the new location. If not, then Holly's parents would have to find different jobs.

Advantages	Disadvantages
They would be away from the insects. *Will get some money by selling the farm.*	*Move away from school and friends.* *Might not have enough money to buy a new farm.* *Parents may have to get new jobs.* *Will have to make new friends.*

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Control Methods
Continued

Name *SAMPLE STUDENT RESPONSE*

C) Biological control

Toads will be used to control the beetles. The toads eat many types of small organisms, such as frogs, lizards, snakes, mice, snails, and insects. They have been used successfully to control insect pests in several other countries. The toads are not native to the area. Thirty toads will be brought to the farm and released in the fields.

Advantages	Disadvantages
The toads will eat the insects. *This won't hurt the crops or the environment.* *The toads can protect the crops from other small animals that could attack the crops.* *It has worked in other countries.*	*They are not native to the area.* *Something may kill the toads.* *The toads might run away.* *The toads might not be able to adapt.* *The toads eat more than insects.*

D) Physical removal

All of the fields would be burned. This would kill all of the crops but would also kill the insects, including the grubs that live in the soil. The fields would be left bare for one year. Workers would be hired to monitor the fields and trap and remove any of the beetles that were found there. After one year, the crops would be replanted. Workers would continue to monitor the fields for the beetles until the crops could be harvested later in the year.

Advantages	Disadvantages
It would kill the insects. *The crops would be replanted without any insects.*	*It would kill the crops and maybe some animals.* *It takes a long time.* *Holly's family would not have crops (to eat and sell) for at least one year.* *Sounds like it would cost a lot of money.* *The fire could get out of control.* *The smoke from the fire causes pollution.*

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Name _____

Score Sheet

Area managed (circle one): Lake River Forest Gulf

Round	Turn	Event	Environmental points	Money points	Happiness points	Total points
Start	0		10	10	10	30
Round 1	1					
	2					
	3					
	4					
Carry the score on to the next round						
Round 2	1					
	2					
	3					
	4					
Carry the score on to the next round						
Round 3	1					
	2					
	3					
	4					

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Name *SAMPLE STUDENT RESPONSE*

Score Sheet

Area managed (circle one): (Lake) River Forest Gulf

Round	Turn	Event	Environmental points	Money points	Happiness points	Total points
Start	0		10	10	10	30
Round 1	1	*Add a farm – Yes*	*9*	*11*	*11*	*31*
	2	*Add an industrial complex – Yes*	*8*	*12*	*12*	*32*
	3	*Hunting - No*	*10*	*11*	*11*	*32*
	4	*Build a housing development - Yes*	*9*	*12*	*12*	*33*
Carry the score on to the next round						
Round 2	1	*Build a dam - No*	*10*	*10*	*11*	*31*
	2	*Add a new type of fish - No*	*12*	*8*	*9*	*29*
	3	*Build a bypass - Yes*	*11*	*8*	*8*	*27*
	4	*Build a resort - Yes*	*11*	*9*	*9*	*29*
Carry the score on to the next round						
Round 3	1	*Private foundation*	*13*	*10*	*10*	*33*
	2	*Non-native species*	*13*	*10*	*10*	*33*
	3	*Economic conditions*	*13*	*10*	*9*	*32*
	4	*Flooding*	*12*	*8*	*7*	*27*

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Name _____

Analyzing the Insect Solutions

Solution to Insect Problem	Economic Impact	Social Impact	Environmental Impact
A. Chemical Control			
B. Relocate the Farm			
C. Biological Control			
D. Physical Removal			

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Name _____ SAMPLE STUDENT RESPONSE

Analyzing the Insect Solutions

Solution to Insect Problem	Economic Impact	Social Impact	Environmental Impact
A. Chemical Control	*Might be expensive because it has to be reapplied frequently over a 2 month period.*	*Might make people sick.*	*Kills other insects and small animals.* *Might harm the crops.*
B. Relocate the Farm	*Might lose money when selling the farm, moving, and buying a new home.*	*Move away from friends and school.* *Parents may have to find new jobs if they can't find another farm.*	*The insects will still be there.* *A new farm may replace a natural area.*
C. Biological Control	*Might be expensive if the toads become invasive and spread.*	*Small pets can be harmed by the toads.*	*The toad will affect the food web of the ecosystem.* *The toad could become an invasive species.*
D. Physical Removal	*Expensive because there would be no crops for a year and many workers would have to be hired.*	*Might have to find new jobs until the crops grew again.*	*Pollution from the smoke when the crops are burned.* *It will kill some native organisms.*

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Name _____

Designing a Solution

1. Describe the problem.	
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.

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Designing a Solution

Continued

Name _____

5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

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Name *SAMPLE STUDENT RESPONSE*

Designing a Solution

1. Describe the problem.

Insects are damaging the sugar cane crop.

2. Describe the needs that the solution is to address.

The insects that are damaging the crops should be stopped from doing any more damage.

[Note: Students may add more needs, such as the family needs to earn more money to make up for the lost crops, etc.]

3. Identify the constraints that the solution must meet.

Student responses will vary. An example is given below.

All of the insects must be killed.

4. Identify the criteria that apply to the solution.

Student responses will vary. An example is given below.

Social: The solution should be quick.

Environmental and economic: The solution should preserve as much of the crop as possible.

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Designing a Solution
Continued

Name *SAMPLE STUDENT RESPONSE*

5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

We believe that chemical control is the solution that best meets our criteria and constraint.

The chemicals should kill all of the insects, which means it meets our constraint.

It does not require removing or burning any of the sugar cane. Therefore it meets one of the criteria. It also seems quicker than the other solutions, which means it is best at meeting the other criterion.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

We recommend using chemical control but we would also employ people to check the fields so that we would know when the insects were all gone. We would then know when to stop spraying the chemical on the crops. We could also employ the people to check the fields every now and again, to make sure that the insects didn't come back. It would cost extra money to employ the people but we might save money by stopping using the chemical sooner. We would also continue to have crops to sell.

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Name _____

Possible Solutions

Environmental Problem 1 – Potential Solutions

A. Employ divers to find the crown-of-thorns starfish and inject them with a fluid that kills them. ($150,000)

B. Create a protected area around the reef where no fishing is allowed. ($200,000)

C. Ask people to monitor and report the numbers of the starfish. ($200,000)

D. Introduce a new predator that eats the eggs and the young starfish. ($150,000)

E. Employ fishers to remove the crown-of-thorn starfish and move them to other areas. ($150,000)

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Possible Solutions

Environmental Problem 2 – Potential Solutions

A. Enforce policing of the protected area and apply heavy fines for misuse. ($150,000)

B. Move the people in the village to a new area far away from the lake. ($200,000)

C. Offer more educational opportunities to teach the villagers new skills. ($100,000)

D. Help the villagers to change their crops to ones that need less space to grow. ($200,000)

E. Employ the villagers to clean the sediment from the lake. ($150,000)

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Possible Solutions

Environmental Problem 3 – Potential Solutions

A. Increase the frequency of monitoring the lake and nearby rivers for the presence of zebra mussels. ($200,000)

B. Ban all boats from lakes and rivers within 25 miles of Yellowstone National Park. ($100,000)

C. Require all boat owners to inspect their boats and certify that they are clear of zebra mussels before entering the park. ($100,000)

D. Introduce a zebra mussel predator into Yellowstone Lake so that if the mussel arrives, it will be eaten. ($150,000)

E. Apply a low-dosage of chemicals to the lake to prevent zebra mussel colonies from becoming established. ($150,000)

F. Educate the people who live in and around the park to recognize zebra mussels and how to prevent their spread. ($100,000)

G. Have mandatory inspection points on all roads that lead to the park. All boats would be sprayed with chemicals at the inspection points. ($100,000)

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Possible Solutions

Environmental Problem 4 – Potential Solutions

A. Ban the harvesting of oysters until the oyster population has recovered to what it was 100 years ago. ($200,000)

B. Introduce a larger, fast-growing oyster from Asia that can filter the waters and can also be harvested and sold. ($200,000)

C. Ban the use of substances such as fertilizer in communities close to the rivers and streams that drain into the bay. ($150,000)

D. Install filtering systems that reduce the nutrients in runoff at the mouths of the rivers and streams that drain into the bay. ($350,000)

E. Retrain the people who rely on the oyster fishery to catch and sell other organisms, such as crabs, instead. ($150,000)

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Name _____ *SAMPLE STUDENT RESPONSE*

Designing a Solution

Activity 5.4
Environmental Problem 1

1. Describe the problem.

Overfishing of predators of crown-of-thorns starfish is causing damage to the coral reef, especially to slow growing coral.

2. Describe the needs that the solution is to address.

Protect the reef.
Maintain the biodiversity of the reef.
(Students may also suggest - Protect ecosystem services.)

3. Identify the constraints that the solution must meet.

Total budget cannot be more than $500,000.

4. Identify the criteria that apply to the solution.

1. Remove as many crown-of-thorns starfish as possible. (Environmental and economic)

2. Maintain ecosystem services as much as possible. (Economic and social)

3. Maintain the biodiversity of the coral reef. (Environmental)

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Designing a Solution
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 5.4
Environmental Problem 1

5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solutions A, D, and E would probably remove the most crown-of-thorns starfish, which means they are a good match for criterion 1. However, solution D would affect the biodiversity of the coral reef by introducing a new species therefore it does not work well with criterion 3.

Solution B affects ecosystem services in a negative way so it does not meet criterion 2 well.

I would use a combination of solutions C and E. This would remove the crown-of-thorns starfish, and provide a way of monitoring their numbers. It also provides more jobs for people in the area. The total cost would be $350,000 which means that it meets the constraint.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

Solutions C and E reduce the number of crown-of-thorns starfish but they don't solve the problem of overfishing of its predators. I would use the remaining $150,000 to monitor fishing in the area and educate people not to catch the predators of the crown-of-thorns starfish.

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Name _____ *SAMPLE STUDENT RESPONSE*

Designing a Solution

Activity 5.4
Environmental Problem 2

1. Describe the problem.

The forest is a protected area but is being used by local people. Sometimes the trees are cut down by local people. This is negatively affecting the forest and the lake.

2. Describe the needs that the solution is to address.

Protect the forest. Protect the quality of the water in the lake. Protect the biodiversity in the forest and the lake. (Students may also suggest – Help the local people with food and jobs.)

3. Identify the constraints that the solution must meet.

Total budget cannot be more than $500,000.

4. Identify the criteria that apply to the solution.

1. The biodiversity of the forest and the lake should be maintained. (Environmental)

2. The quality of the lake water should be as high as possible. (Environmental and social)

3. The food supply for the villagers should be improved. (Social and economic)

4. Protect as much of the forest as possible. (Environmental)

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Designing a Solution
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 5.4
Environmental Problem 2

5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solutions A, C, and D would probably preserve the most forest and protect biodiversity (criteria 1 and 4).

Solution E best meets criterion 2 by increasing the water quality of the lake.

Solutions C and D might help the villagers grow more food or have more money to buy food (criterion 3).

I would use a combination of solutions C, D, and E. This allows the villagers to stay in the area, grow more crops on existing land, and provide employment while improving the water quality of the lake. It also teaches new skills that can help with providing money for the villagers. The total cost would be $450,000 which meets the constraint.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

I would spend the remaining money on educating the villagers on the importance of protecting the forest and how doing so benefits the village and the environment.

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Name SAMPLE STUDENT RESPONSE

Designing a Solution

Activity 5.4
Environmental Problem 3

1. Describe the problem.

Zebra mussels are an invasive species that affect biodiversity and ecosystem services. They have spread across the US and are now in states near Yellowstone.

2. Describe the needs that the solution is to address.

Prevent zebra mussels from becoming an invasive species in Yellowstone Lake.

3. Identify the constraints that the solution must meet.

Total budget cannot be more than $500,000.

4. Identify the criteria that apply to the solution.

1. The biodiversity of the lake should be maintained. (Environmental)

2. Ecosystem services, such as boating and fishing, should be disrupted as little as possible. (Economic and social)

3. There should be the least chance of introducing any invasive species into the lake. (Environmental)

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Designing a Solution
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 5.4
Environmental Problem 3

5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solutions D and E do not meet criterion 1 very well as they will probably affect the food web of the lake. This will affect the biodiversity of the lake. Solution D also increases the chance of introducing an invasive species into the lake, which is against criterion 3.

Solution B does not fit well with criterion 2 as it has a negative effect on ecosystem services.

I suggest using a combination of solutions A, C, and F. If people are educated on what to look for they will do a better job of inspecting their boats and in monitoring the lake and river for zebra mussels. I did not choose solution G because I wanted to avoid adding chemicals to the environment as the chemicals could affect the organisms in and around the lake. My solutions would cost $400,000 which falls within the budget limit.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

The main problem with solution C is that some boat owners may not carry out the inspections or not do them well. I would improve the solution by spending the money that is left over by making the boat inspections mandatory. I would also have the inspections checked and certified by an official who was trained on the zebra mussel problem.

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Name _____ *SAMPLE STUDENT RESPONSE*

Designing a Solution

Activity 5.4
Environmental Problem 4

1. Describe the problem.

The number of oysters in Chesapeake Bay has fallen to very low levels.

2. Describe the needs that the solution is to address.

Improve the quality of the water in Chesapeake Bay. Restore the biodiversity of the bay. Decrease the number of dead zones. Increase the oyster harvest in the bay.

3. Identify the constraints that the solution must meet.

Total budget cannot be more than $500,000.

4. Identify the criteria that apply to the solution.

1. Reduce the number of dead zones as much as possible. (Environmental)

2. Decrease the nutrient-carrying runoff into the bay as much as possible. (Environmental)

3. Improve the water quality as much as possible. (Environmental, economic, and social)

4. Improve ecosystem services as much as possible. (Economic and social)

5. Improve the biodiversity of the bay. (Environmental)

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Designing a Solution
Continued

Name *SAMPLE STUDENT RESPONSE*

Activity 5.4
Environmental Problem 4

5. Which of the proposed solutions, or combinations of solutions, best meets the criteria and constraints? Make sure to provide your reasoning.

Solution A might meet criterion 3 because as the number of oysters increases, the water in the bay will be more filtered.

Solution B helps with criteria 3 and 4 as the new oysters would increase the oyster harvest and help filter more water. It doesn't address the other criteria and it will affect the food web which would probably not work with criterion 5.

Solution E would help with criterion 4 as it will provide more employment but it doesn't solve the other problems with the bay.

I would choose solutions C and D because they would help to reduce the runoff that is carrying nutrients into the bay. This would decrease the dead zones and would help more organisms to survive. This meets criteria 1, 2, and 5. The total cost would be $500,000 which is the maximum budget.

6. How could the solution be improved? (You may adjust the criteria and the solutions)

I would improve the solution by not having a total ban on fertilizers in communities with rivers and streams that drain into the bay. I would make those communities reduce the use of fertilizer. The new filtering systems should be able to clean nutrients from the runoff. This will help the bay. I would use the money that was saved to retrain some people on using other organisms instead of oysters in their businesses.

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Scoring Guide for Designing Solutions

This scoring guide is used when students design solutions.

What to look for:

- Response includes a complete design relevant to the problem to be solved
- Response includes evidence of how well the design meets criteria within the defined constraints
- Response indicates how scientific ideas and concepts relate to the successful design

Level	Description
Level 4 Advanced	The student's design: • meets all of the criteria within the defined constraints, AND • uses relevant scientific concepts to explain why any revisions were made to optimize the design AND (or 'uses relevant scientific concepts to explain why this is an optimal solution') • has further improved on any pre-existing design
Level 3 Proficient	The student's design: • meets all of the criteria within the defined constraints, AND • explains the relevant scientific concepts.
Level 2 Developing	The student's design: • meets all of the criteria but exceeds the defined constraints OR • meets some of the criteria within the defined constraints.
Level 1 Beginning	The student's design does not meet any of the criteria.
Level 0 Not Evident	The student proposes no design or an irrelevant design.
x	The student had no opportunity to respond.

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Types of Interactions

Predator-prey interactions, competition, and symbiosis are all interactions between living organisms. A **predator-prey** interaction involves a feeding relationship between two animals. The **predator** is the animal that kills and consumes another animal, called the **prey**. In the photo above the bear is the predator and the fish is the prey.

Competition can occur when two or more species require the same limited resources. Competition can cause one or both populations to go down. For example, in 1989 green crabs from Europe ended up in the San Francisco Bay. These crabs started eating up the clams in the Bay. Local yellow shore crabs now found it very hard to find clams to eat. Since 1989, the yellow shore crab population has gone down 90% in some areas.

Symbiosis includes mutualism, commensalism, and parasitism. These interactions are defined and illustrated on the next page. Many symbiotic relationships have evolved over time. These established interactions do not usually change population sizes. However, if either population were to be affected by living or non-living factors, the other population might be affected in turn.

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Type of Symbiosis

Mutualism helps both species involved.

The Nile crocodile allows the Egyptian plover to enter its open mouth. The plover benefits by eating small bits of food left on the crocodile's teeth. The crocodile benefits by having its mouth cleaned, reducing the chance of infection.

Commensalism helps one species, while neither helping nor harming the other.

Groundhogs (woodchucks) are the major hole-digging mammal of North America. Their abandoned burrows are used for shelter by foxes, opossums, raccoons, and skunks.

Parasitism benefits one species (the parasite), which lives in or on the other (the host). The host is usually harmed.

Tapeworms can live in the intestines of animals. They obtain nutrients from food passing through the intestines and harm the host by depriving them of needed nutrients.

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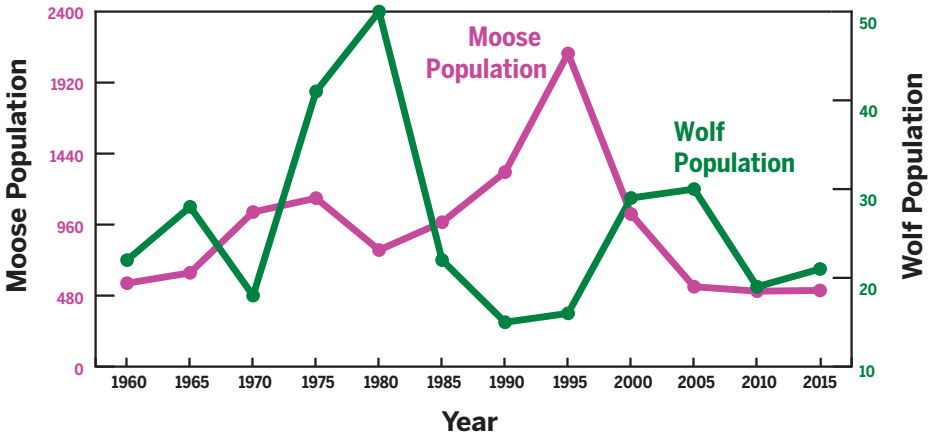
Wolves and Moose on Isle Royale

One of the longest studies of predator-prey interactions is that of the wolves and moose on Isle Royale, Michigan. Isle Royale is an isolated island in Lake Superior. Wolves are the only large predators on the island. Moose eat plants. Isle Royale and smaller nearby islands are part of Isle Royale National Park.

Figure 3.
Wolf and Moose Populations in Isle Royale National Park 1960-2015



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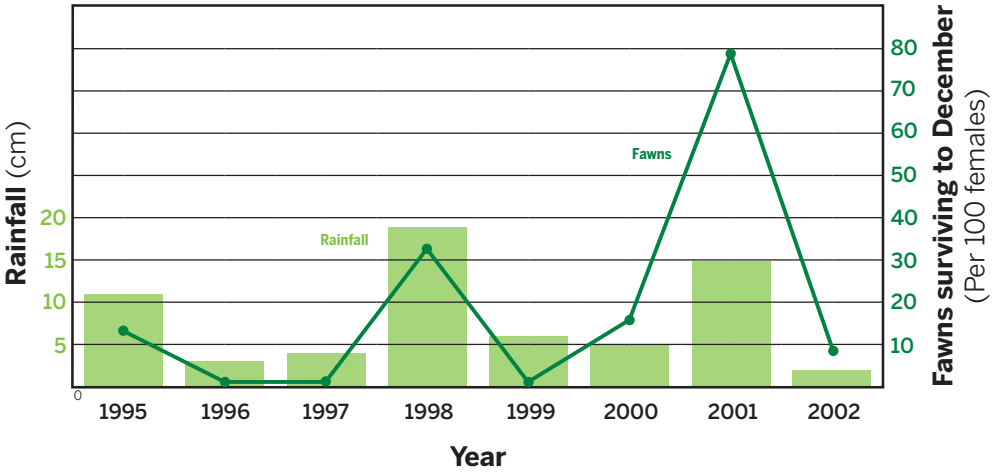
Sonoran Pronghorn

One endangered species found in the Arizona desert ecosystem is the Sonoran pronghorn, the fastest land mammal in North America. They eat a variety of desert plants. Droughts have been increasingly frequent in the western United States, even in desert ecosystems. Young pronghorns, called fawns, are especially sensitive to drought conditions.

Figure 4.
Rainfall vs. Fawn Survival 1995-2002



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Populations of Deer

In this chapter, you have closely examined the Greater Yellowstone ecosystem. People often think of the animals in this ecosystem as living only in the western U.S. At one time, many of these animals existed in large numbers in other parts of the U.S. For example, bears, wolves, elk, and moose were found across the northern states. Today, black bears and moose can still be found in upstate New York and other northeastern states.

One species that thrives in much of the U.S. is deer. White-tailed deer in particular have been successful in the absence of predators. You may have heard of white-tailed deer because it is a host animal for the blacklegged tick, also known as the deer tick. This tick sometimes carries Lyme disease, which can be transmitted to humans when they are bitten by an infected tick. Lyme disease is a growing problem, especially in the Northeast and upper Midwest.

The white-tailed deer population was estimated to be over 30 million a few hundred years ago. Deer, as well as the wolves that ate

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them, were hunted almost to extinction in the early part of the 20th century. Deer populations recovered when wildlife protections were put into place and predator populations remained low. Today, large deer populations mean that hunters can apply for licenses to kill deer during certain times of the year.

Figure 2.

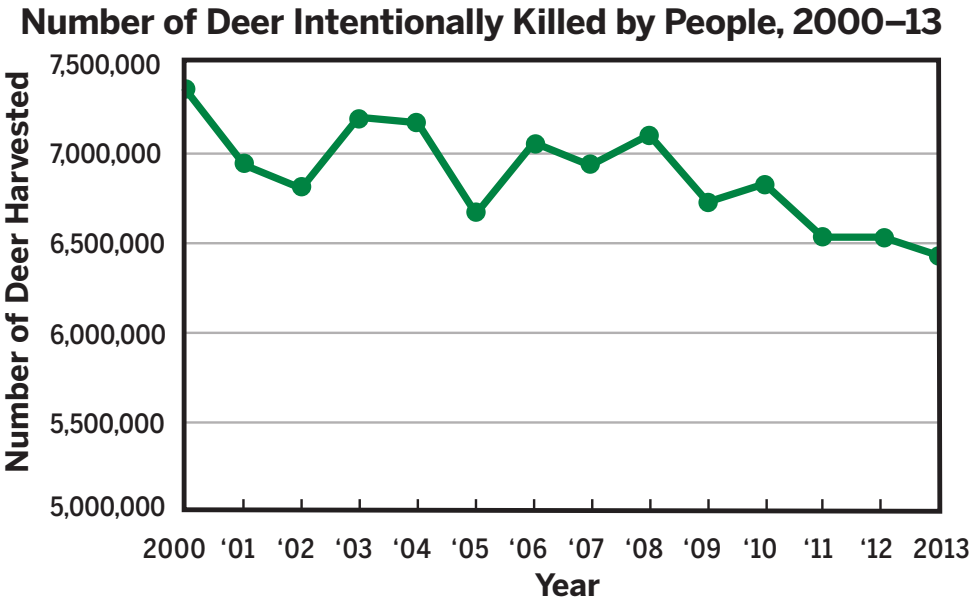

Figure 2 shows that the number of deer killed in 2000 was over 7 million, which dropped to just under 6.5 million in 2013. This represents a 12.6% drop in killed deer.

Deer Within an Ecosystem

Today, white-tailed deer are found throughout North America, from Canada to Mexico. In the northeast, bobcats, coyotes, and black bears eat deer, usually scavenging dead deer. Bobcats and coyotes also hunt them in the winter when the deer are tired and slowed by deep snow. However, these interactions are not enough to reduce deer populations.

Trillium

White-tailed deer usually live at the forest edge, and are often found in fields and grasslands during summer months. They eat plant leaves, twigs, buds, nuts, and fruits and vegetables. They do not eat grass. The deer scatter seeds in their droppings, spreading certain plant species like *Trillium* (at left) up to 3 kilometers from their original site.

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White-tailed deer eat about 3% of their body weight per day, which can be 1–5 kilograms (2–10 pounds) of plant material a day. When large numbers of deer are concentrated in an area, their feeding can affect the local ecosystem, reducing the diversity of plants and small animals. As you can see in the photos below the healthy forest (on the left) has new plant growth on the forest floor as well as on the lower layers of the forest. The forest on the right shows signs of overgrazing. Numerous studies have shown that this can occur when large numbers of herbivores such as deer are feeding in one area.

The healthy forest at left has typical plant life on the forest floor. The overgrazed forest at right lacks young trees, shrub, and other plants typical of a healthy forest.

Deer can also affect the number of songbirds in a forest. Some songbird populations eat or nest in the same trees and shrubs that are consumed by deer. One study found that bird counts across the U.S. showed that high populations of deer correlated with declining populations of certain songbird species.

People and Deer

Hungry deer are not restricted to wild ecosystems. Urban and suburban areas with high deer populations routinely have problems with deer eating flowers, vegetables, shrubs, and other neighborhood plants. It is estimated that they cause about $250 million in damage to these environments, as well as another $100 million in damage to cropland.

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By far the greatest damage results from collisions between deer and cars. On average, over one million such collisions occur each year. This can sometimes result in human injury or death as well as the death of the deer. Damage to cars involved in deer collisions is estimated to be 1-4 billion dollars a year.

Controlling Deer Populations

Hunting is one way to control deer populations. White-tailed deer are one of the most commonly hunted species in the U.S., with approximately six million deer killed each year. In most cases, the dead animals are used for food.

In addition to hunting to reduce deer populations, some people have proposed reintroducing wolves into areas such as the Adirondacks in upstate New York. The Adirondacks are a mountainous area inside Adirondack Park, the largest preserve in the lower 48 states and considerably larger than Yellowstone National Park.

The park contains mountains, lakes, rivers, forests, and many types of plants and animals. The park covers about 6 million acres, of which 45% is protected public land. Much of the private land is used for agriculture, forestry, and open space. There are 105 towns and villages within the park, and over 60 million people live within a day's drive of the park.

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Scientific Findings

A. Living things are made mostly of substances, like proteins, carbohydrates, and fats, that contain carbon.

Substances in organisms	Main building blocks in the substance
Carbohydrates	carbon, hydrogen, oxygen
Proteins	carbon, hydrogen, oxygen, nitrogen, sulfur
Fats	carbon, hydrogen, oxygen

B. A scientist named Van Helmont weighed some soil and planted a willow tree in the soil. Over five years, the willow tree gained 74 kg (164 pounds). The soil lost only 0.05 kg (0.025 lb).

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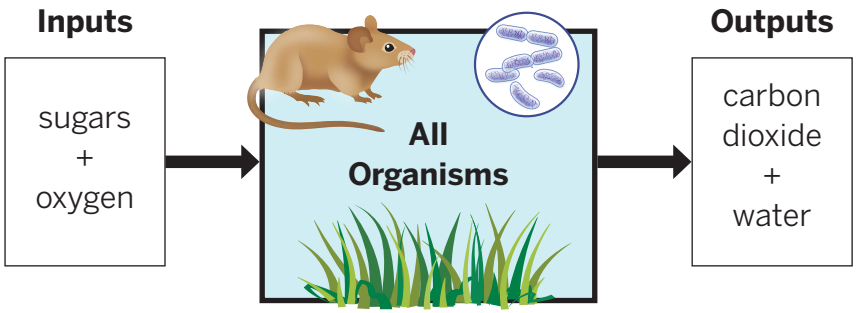
C. Plants can be grown in the presence of sunlight with only air plus water containing some dissolved minerals.

These plants are growing without soil.

D. All organisms—including plants, animals, and bacteria—conduct a process called cellular respiration. They must do this all the time in order to use the energy stored in food. In this process, the organisms take in oxygen and use it to break down sugars and other substances in food. They give off carbon dioxide and water.

Cellular Respiration



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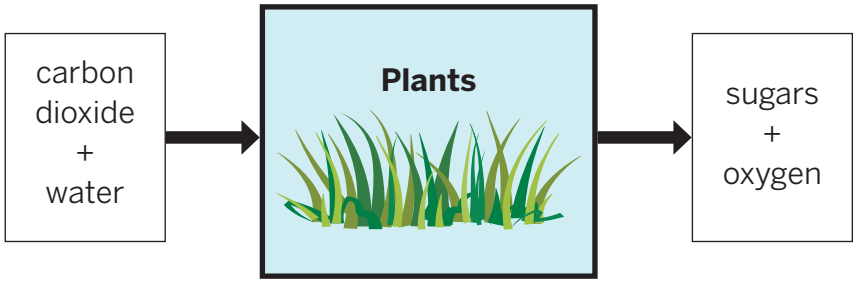
E. Plants conduct photosynthesis to make their own food. When they do this, they use carbon dioxide and water as the source of matter they need to make sugars. Plants that live on land get water from the soil, and carbon dioxide from the air. Plants that live in water use carbon dioxide that is dissolved in the water.

Photosynthesis



F. Following your teacher's instructions, examine the contents of the compost bag that was set up in Activity 2.1. Record your findings in your science notebook.

G. Decomposers get food by consuming dead animals and plants. For example, scientists have shown that compost piles are full of many kinds of bacteria that break down the organisms and release heat.

Left: A compost pile. Right: Bacteria viewed through a powerful microscope.

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H. Dead organisms and their wastes will only rot if decomposers are present. For example, if food is sterilized to kill all decomposers it will not rot.

The berries on the left were treated to kill decomposers.

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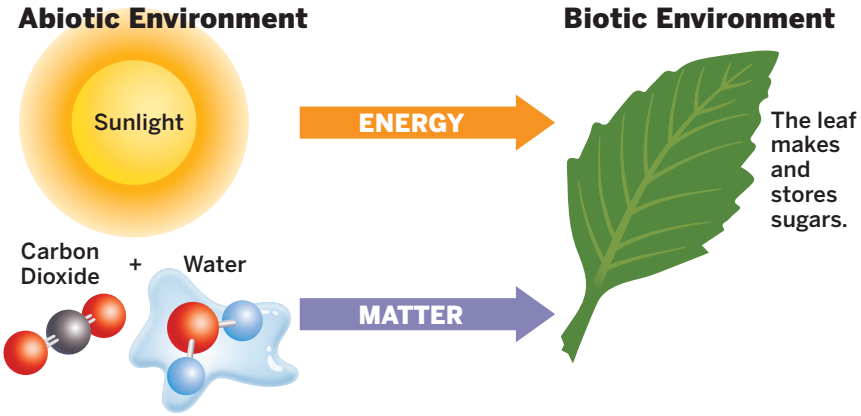
Photosynthesis

Plants need sunlight in order to make food. Plants are able to transform the energy in sunlight into chemical energy in sugars through photosynthesis. Without light energy from the Sun, the plants would be unable to make their own food in the form of sugars. For a while, they would use the food they have stored, but eventually they would die. This is because the food that plants make provides the chemical energy for their life processes.



The energy that flows from the Sun and is transformed by plants is in fact the source of energy for nearly all life on Earth, whether on land or in water. If all the plants died, the organisms in the rest of the food web that rely on them for food would die too. This is because the chemical energy stored in the food of plants is the only source of energy for plant-eating animals.

While all organisms require water and other substances, such as minerals (plants and animals) and vitamins (animals), these substances do not provide energy for organisms. Only substances that contain carbon (carbohydrates, proteins, and fats) can provide the kind of chemical energy useful to living organisms. They use this energy to move, grow, and carry out all of their activities.

Chemical energy only flows from the producers to the consumers and decomposers. It cannot flow to lower levels of the food chain. At each level of a food chain, organisms use some of their energy for their own maintenance and growth. When these organisms are eaten, chemical energy stored in the organisms moves to the next level. Plants never get energy from animals. Even Venus fly traps, which capture insects caught in their leaves, get only other kinds of nutrients from those animals, not energy.

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Three Fisheries

Pacific Halibut: A Healthy Fishery

The Pacific halibut fishery is known for maintaining a healthy population of Pacific halibut. The fishery is carefully monitored, and each year scientists make new recommendations on where and how many fish can be caught. The entire fishery adopts these limits, and they are carefully enforced.

Pacific Halibut

Red Snapper: On the Rebound

The red snapper has been fished in the Gulf of Mexico since at least the 1840's. As fishing technology has improved, more and more snapper have been caught. By the 1990's, up to 15 million pounds of red snapper were being caught in the Gulf of Mexico each year. The snapper population was being severely overfished. In 2007 fishers and the government worked together to set new regulations for the fishery. They used scientific studies of the snapper population levels to determine the number of fish each fisher is allowed to catch during the year. The limits are evaluated every year and changed as needed.

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Red Snapper

Orange Roughy: Is It Too Late?

The orange roughy was not fished for many years. They live on the bottom of the ocean, in very deep waters, and for a long time were rarely caught. That all changed with modern fishing techniques and equipment allowing fishers to find and catch fish more effectively, even deep on the bottom of the ocean. Because orange roughy tend to sit in groups on the ocean floor, they were easy targets for fishers. To make matters worse, orange roughy grow and reproduce very slowly: they don't even start to reproduce until they are 20 years old! There were no limits on orange roughy catches until the mid-1990's, and only in some areas where the orange roughy is fished.

Orange Roughy

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Name _____

An Unwelcome Newcomer

Invasion of the Zebra Mussels

The zebra mussel is a small freshwater animal with two shells like a clam. It is named for its striped shell. This tiny creature may look harmless, but it can cause big problems. The zebra mussel is not native to North America but arrived in this part of the world about thirty years ago.

Zebra mussels cling to any hard surface—including native mussels and other animals with shells. This can cause these animals to die because they can't eat. Zebra mussels are filter feeders. They pump water through their gills and strain out microscopic animals and plants called plankton. Zebra mussels can quickly clear the plankton from huge bodies of water, leaving little food for the native mussels and other animals.

Zebra mussels can also cause millions of dollars in damage. The mussels clog water pipes to businesses and power plants. They damage boats, docks, and other structures.

The Great Lakes Invasion

The Great Lakes are a system of connected freshwater lakes and waterways in northeastern North America, between Canada and the United States. It is the largest group of freshwater lakes on Earth, and holds about 20% of the world's fresh water. In many places, if

The Great Lakes include Lakes Superior, Michigan, Huron, St. Clair, Erie, and Ontario.

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Zebra mussels

you stand on the shore of one of the Great Lakes you cannot see to the other side. Zebra mussels were first discovered in a small lake in the Great Lakes system, Lake St. Clair, in 1988. Scientists believe the mussel was introduced by one of the large ships that travel across the Atlantic Ocean carrying cargo between countries. Soon scientists were finding zebra mussels in other areas of the Great Lakes systems and rivers connected to the Great Lakes, such as the Mississippi and Ohio Rivers. Even today, scientists continue to find new zebra mussel invasions in ecosystems as far away from the Great Lakes as Texas and California.

How do these mussels spread so quickly? A single female can produce up to one million eggs each year. The young mussels float along water currents and eventually attach themselves to hard surfaces like rocks on the riverbeds and the bottom of boats. They form dense colonies, with as many as 10,000 mussels in a single square foot.

The Hudson River Invasion

The Hudson River flows south through New York State, from the mountains to New York City. Because the river is connected to the Great Lakes, scientists predicted it would not be long before the zebra mussel would arrive in the Hudson.

The Hudson River's ecosystem is very different from the Great Lakes. Lake water settles into layers, with cool water near the bottom and warm, clear water above. In the Hudson River water flows from the mountains to the Atlantic Ocean. The last 150 miles of the Hudson River is significantly affected by water from the Atlantic Ocean. The salt water from the ocean mixes with fresh water from the river. The tides from the ocean mix the water from top to bottom. This area of mixed salt and fresh water is called an estuary. In the estuary, tides also stir up material from the riverbed, making the water cloudy. Little sunlight can pass through the water. Less sunlight means fewer plants and phytoplankton.

Scientists wondered how zebra mussels might affect the ecosystems of the Great Lakes and the Hudson River. They also wondered if different biotic and abiotic factors in the ecosystems might lead to different effects from the zebra mussels. Soon they would find out.

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Zebra Mussels Invade

What Makes a Good Invader?

There are many characteristics of the zebra mussel that help them thrive in North American lakes and rivers. Zebra mussels can reproduce when they are less than a year old. Just one female can lay up to 1 million eggs every year. Zebra mussels will eat most types of plankton and will attach to nearly any hard surface. They can grow in water as cold as 3°C and as warm as 30°C.

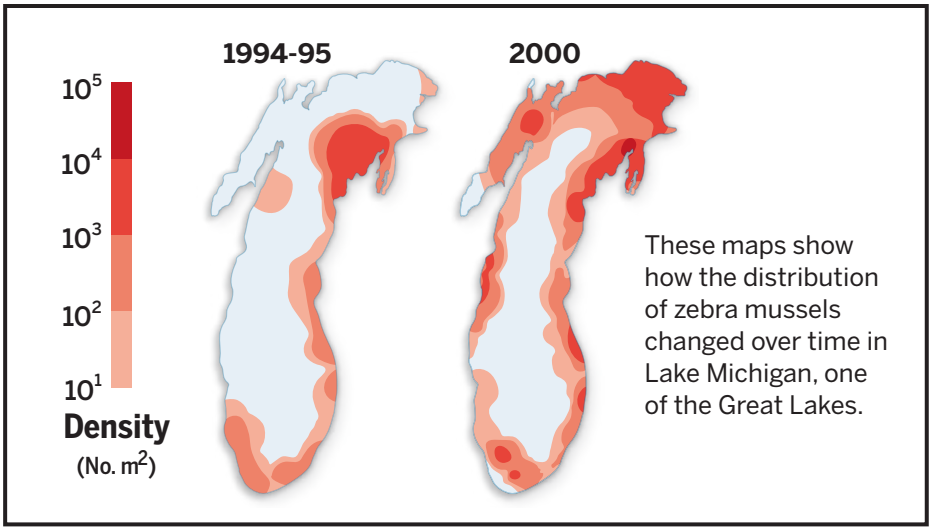
Zebra mussels are sensitive to several abiotic factors, which limit their spread. They can only live in fresh water or water that has very little salt (less than 0.4%). They cannot survive in water with low oxygen levels. They also are not found in water that moves faster than about two meters per second, so you won't find them in fast-moving streams or rivers. They will only reproduce if the water is 14-16°C or warmer.

Stop to Think

What characteristics of zebra mussels make them likely to live in a variety of river ecosystems?

In the Hudson River and Great Lakes, the conditions for a zebra mussel invasion were just right. There were lots of plankton for the zebra mussels to eat, many hard surfaces for the mussels to attach to, and in spring and summer the temperatures were just right for zebra mussels to reproduce. This means that once the zebra mussels were introduced, it was easy for them to spread out.

Lake Michigan Zebra Mussel Density



These maps show how the distribution of zebra mussels changed over time in Lake Michigan, one of the Great Lakes.

Stop to Think

What do the patterns in the data on the map tell you about the density of zebra mussels in Lake Michigan between 1994-95 and 2000?

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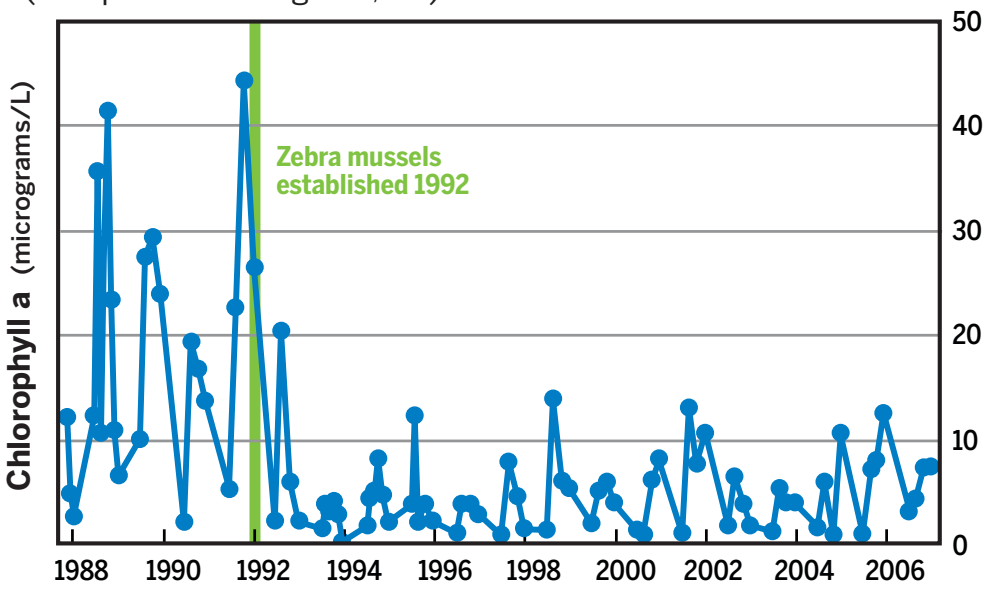
Changes Caused by Zebra Mussels

By 1992, there were so many zebra mussels in the Hudson River that scientists estimate they were filtering a volume of water equal to all of the water in the estuary every 1-4 days during the summer. In the years right after their arrival, phytoplankton fell by 80-90 percent. Zooplankton (which eat phytoplankton) declined by half.

The plankton populations in the Great Lakes also dropped dramatically. Some research showed the zebra mussels were rejecting certain types of harmful blue-green algae as food. This meant the blue-green algae population increased, while other plankton decreased, causing changes in the biodiversity and the food availability for other filter feeders.

Hudson River Chlorophyll Levels Over Time

(Sampled from Kingston, NY)



In both locations the populations of native mussels, also filter feeders, shrank dramatically. Native mussels could not compete with the zebra mussels, and their populations dropped as the plankton populations dropped. In the Hudson, native mussel populations fell from more than one billion to almost none. Many fish species also eat plankton. With the decline in plankton populations, there were fewer—and smaller—fish in the open river as well as the open lakes. The biodiversity of the Hudson was changing.

Stop to Think

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?

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But some populations in the Hudson River increased—likely due to the change in the river's water clarity. With far less phytoplankton, the water got clearer. During the summer, visibility went from 3-4 to 4-8 feet from the surface. Since sunlight reached deeper into the water, rooted aquatic plants increased by up to 40 percent. Populations of fish living in these shallow weeds increased, and they were also found further upriver than before the invasion. Another surprising result was that dissolved oxygen in the river fell by about 15 percent. Scientists think the enormous zebra mussel populations were consuming a lot of oxygen very quickly. At the same time, the mussels were removing the phytoplankton that produce oxygen.

In the Great Lakes, most of the species that increased after the zebra mussel invasion were considered "nuisance" or even harmful species, like the blue-green algae. The zebra mussel increase also seemed to cause an increase in the bacteria that produces botulism toxin, and more than 52,000 waterbird deaths due to botulism toxin occurred between 2002 and 2006.

Stop to Think

What are some of the biotic and abiotic factors that were affected by the zebra mussels in the Great Lakes and Hudson River?

Effect on Ecosystem Services

The organisms living in the Hudson River and the Great Lakes are not the only organisms depending on those ecosystems. Humans depend on, and benefit from, these two ecosystems in many ways. When humans benefit from an ecosystem, scientists call these benefits ecosystem services. For example, a lake might provide people with drinking water, fish to eat, and a place to go sailing and relax. All of these benefits are **ecosystem services**. When scientists study the effect of a non-native species, like the zebra mussel, they study how it affects the ecosystem in all ways, including how it affects ecosystem services.

In both the Great Lakes and the Hudson River, the zebra mussels have affected many ecosystem services. One effect has been on power plants and water treatment facilities built on the shores of large lakes and rivers. These facilities have large pipes to take in and release water. The zebra mussels attach to the pipes and other equipment. The number of mussels that attach to the pipes is so great that the pipes become clogged, causing large increases in maintenance and repair costs. Another effect is that the blue-green algae that increased after the zebra mussel invasion releases harmful toxins into the water in the Great Lakes, causing beaches to be closed and preventing

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The Hudson River provides many ecosystem services to the nearby communities, including a place for recreation.

people from going swimming. Also, several fisheries, including the Lake Whitefish, have declined dramatically due to the zebra mussel invasion, causing people to lose income and jobs. However, some fisheries on the Hudson River that rely on littoral fish have increased.

Stop to Think

Why might people be concerned about the effects of zebra mussels on ecosystem services?

Questions about long-term impact

Once scientists had a clear picture of the invasion's immediate impact, they started to wonder about long-term effects the zebra mussels might cause in these two ecosystems. Would the systems continue to change, or would they recover? Would native species eventually tolerate or even feed on the zebra mussel? Perhaps another species might arrive that would change the effects of the invasion? Should people try to control the zebra mussel invasion or see if the ecosystem would eventually stabilize? Only continued studies would allow scientists to determine how the zebra mussel might change these ecosystems in the long term.

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Long Term Changes

In 2005, 14 years after the first sighting of zebra mussels in the Hudson River, Cary Institute scientists noticed an unexpected change in the river: zooplankton had returned to the same levels as before the invasion. The scientists also observed a change in the zebra mussels they were collecting from the river. Scientists group zebra mussels by three sizes: small (less than 10 mm), medium (10–20 mm), and large (more than 20 mm). While there were still many zebra mussels in the Hudson River, they were on average much smaller. Populations of the largest—or oldest— mussels were in decline. Zebra mussels can live six or seven years, but now it seemed that most were dying after only one or two years. If there were fewer older and larger zebra mussels, it made sense that there was more zooplankton. That's because large zebra mussels feed on bigger food particles like zooplankton. Smaller zebra mussels can eat only smaller particles like phytoplankton and bacteria.

Stop to Think

What effect do you think the smaller and younger zebra mussel population might have on the rest of the food web?

These changes started to affect the rest of the food web. As zooplankton increased, so did native mussels and clams. Scientists anticipated some fish species would increase too as their food supply increased. Scientists didn't know all the factors that caused the decline in large zebra mussels, but they did know blue crabs were starting to eat the zebra mussels.

Over time, blue crabs have developed a taste for zebra mussels and are one significant factor in the decrease of zebra mussels.

By monitoring several aspects of the Hudson River over many years, Cary Institute scientists are beginning to answer their original question: How might a zebra mussel invasion affect the Hudson River ecosystem? Early on during the invasion, zebra mussels thrived and had a huge impact on the ecosystem's food web—just as scientists had predicted. However, about 20 years later the number of zebra mussels has greatly declined. Parts of the ecosystem, such as the number of zooplankton, native mussels, and clams, have started to increase. But is this the end of the story? Or have we just seen the first two stages of an invasion that might have three, four, or more stages?

As their data sets grow, the scientists are able to track changes in the river—whether from pollution, weather, invasive species, or human activity—and to pose new questions. This broad approach puts scientists in a unique position to investigate future changes to the Hudson River ecosystem.

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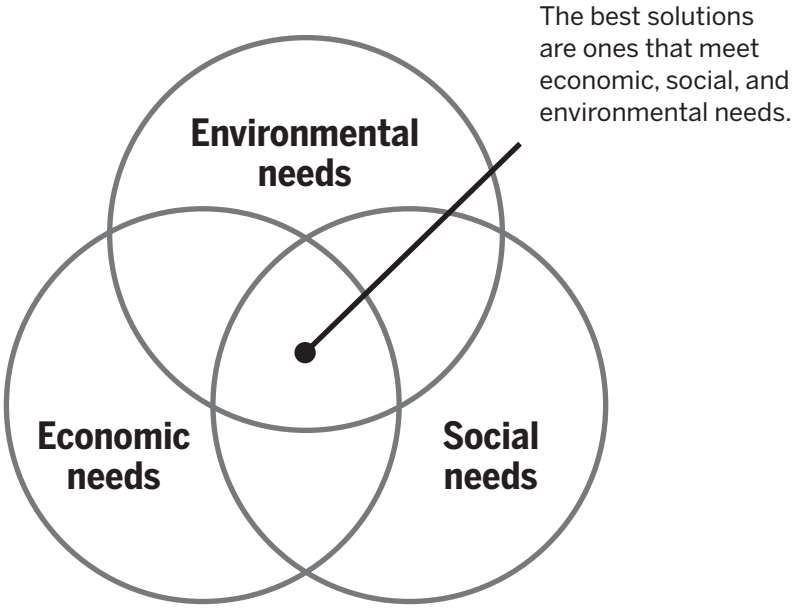
Designing a solution to an environmental problem

Engineers design solutions to problems. However, the aim of engineering is not just to design a solution, but to design the best solution. Before designing a solution, engineers will identify criteria and constraints. **Criteria** are the desired features of the solution. **Constraints** are limits that apply to solving the problem. A solution can have many criteria and constraints. This can make designing the solution complicated.

As you saw in the previous activity, it can be difficult to satisfy the needs of people and those of the environment. When considering criteria related to people, it is useful to look at the social and economic impacts. **Economic** impacts are often related to money. They can be positive, such as earning more money. They can also be negative, such as reduced income or higher costs for people in an area. **Social** impacts are often related to the quality of life. They can include factors such as the health and safety of residents, the standard of living, and opportunities for work and leisure. An important social consideration is whether a solution is fair to different groups of people. One way of analyzing solutions to environmental problems is to consider how well they meet economic, social, and environmental needs.



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Environmental Problem 1

Coral reefs are very important to the health of the oceans as they are home to almost 25% of all marine organisms. They are also important to communities as they provide protection from erosion from storms. They provide ecosystem services such as food, recreation, and employment. One threat to coral reefs is the crown-of-thorns sea star, a large starfish that preys on hard coral. It is native to coral reefs in the Indian and Pacific Ocean regions. Some coral species grow quickly and others grow slowly. When the crown-of-thorns feeds on the faster growing coral it provides an opportunity for the slower growing species to establish itself. This increases the biodiversity of the coral reef. During the warmer months each female can produce millions of eggs. Predators of the adult crown-of-thorns include several species of fish. In some coral reefs, overfishing of these predators has led to large increases in the numbers of crown-of-thorns starfish. When this occurs, much more of the reef is eaten by the starfish. In some cases up to 90% of a reef can be destroyed by the crown-of-thorns starfish.

A crown-of-thorns starfish (bottom left) on a reef.

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Environmental Problem 2

In a corner of an island in Southeast Asia, there is a village next to a lake. Near to the lake is a large area containing mountains and forest. Although not a national park, the land in this area is protected from development. Most of the people in the village are farmers. There are few employment and educational opportunities. Most people have little money. The lake is used for drinking water and for electrical power generation for the region. The fish in the lake are an important and inexpensive food source for families in the region. Recently, villagers have been going into the protected area to hunt animals and cut down some of the trees. The wood from the trees can be used for fuel and can be sold. Some of the farmers in the village have also cut down trees in the protected area so that they can expand their farms to grow more food. All of these actions have led to a decrease in the biodiversity of the forest. The removal of the trees has also led to increased erosion of the soil in the forest. The soil is being washed into the lake which is increasing the sediment there. This is affecting the food web of the lake and also the quality of the drinking water.

The area in front of the picture used to be a forest until the trees were cut down and removed.

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Environmental Problem 3

Yellowstone Lake is the largest body of water in Yellowstone National Park. It is a very large (350 km^2) freshwater lake with an average depth of 42 m. More than 140 rivers and streams flow into Yellowstone Lake. The Yellowstone River is the largest outflow of water from the lake, eventually reaching the Missouri River. At the present time, no zebra mussels have been spotted in Yellowstone Lake but they have reached neighboring states. Scientists are concerned that one day they might arrive in Yellowstone.

Zebra mussels are an invasive species that first appeared in the Great Lakes in the 1980's. Ever since then they have been spreading around the country. They spread easily partly because each female can lay millions of eggs. Young mussels float along the water currents. Eventually they attach themselves to hard surfaces like rocks and the bottom of boats. Colonies can become very dense with as many as 10,000 mussels per square foot. Zebra mussels also cling to native mussels and other shelled animals. These animals die because they can't feed. Zebra mussels disrupt ecosystems by eating microscopic animals and plankton. This reduces the food available for the native invertebrates and small fish. They also disrupt ecosystem services by clogging water pipes to businesses and power plants. They damage boats, docks, buoys, and other structures.

Yellowstone Lake in northwestern Wyoming.

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Environmental Problem 4

Chesapeake Bay is the largest estuary in the country. Over 100,000 rivers and streams from six states, including New York, drain into the bay. Over 16 million people live close to these streams and rivers. It used to be the world's largest oyster-producing region. However, this century the oyster harvest is only about 1% of what it was 100 years ago. The reasons for this large decline include destruction of habitat, overharvesting, disease, and reduction in water quality. The decrease in oysters has had a major effect on the environment and the local economy. Without large numbers of oysters, the water in the bay is not filtered well. The water quality is made worse by runoff into the streams and rivers that feed into the bay. The runoff is rich in nutrients. This has increased algae growth in the bay. When the algae die, they sink to the bottom of the bay where bacteria decompose them. The presence of large numbers of bacteria reduces the oxygen content of the water, causing dead zones. Very few organisms can survive in these zones. Some of the organisms that are mobile, such as crabs and fish, can move out of the dead zone. Other organisms that cannot move as freely, such as oysters, are more likely to die in dead zones.

An oyster catch in Chesapeake Bay.

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Threats to Coral Reefs

Coral reefs are made up of millions of tiny invertebrate animals called polyps. The polyps rely on algae for their survival. The algae live inside the tissues of the polyps and are producers, capturing the energy of the sun. Most polyps use chemicals in the sea-water to make a hard structure around them in which they live. It is these hard cases that make up coral reefs. Healthy coral reefs are full of color and life with many organisms making their homes in or near the reef.

A healthy coral reef.

Coral reefs are also easily damaged and are under threat in many parts of the world. On a global level, climate change is causing some parts of the ocean to be warmer. It is also causing some parts of the ocean to become more acidic. These increases in temperature and acidity can damage or even kill the coral reefs. These global threats can be very difficult to address, because they require so many people all over the world to work together.

On a local level there are also a number of threats to coral reefs. These threats can often be addressed by the people living in the communities near the coral reefs. The large number and types of fish that live in coral reefs makes them places that appeal to fishermen. However, overfishing can cause the number of fish to go down. It can also cause the average size of the fish that are caught to decrease, as fish are caught at a younger age. In order to catch enough fish to

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feed their families and to sell, some people turn to destructive fishing techniques. One such technique is dynamite fishing, where explosives are thrown into the water. Both the explosion and the shockwaves kill or stun the fish in the blast area. This allows the fishermen to collect a large number of fish in a short period of time. The explosion also causes great damage to the coral in the reef. In the end this reduces the amount of coral and the number of fish and other organisms in the area. Even when non-destructive fishing techniques are used, reefs can be harmed. If one or more species is overfished, the food web can become unbalanced. You read about one example of this in the last activity, with the crown-of-thorns sea star.

An unhealthy coral reef.

The beauty of coral reefs makes them an attractive destination for many people. The presence of tourists is important to the local economy as it benefits businesses, such as tour companies, hotels, and restaurants. Unfortunately, tourism can also cause problems for the reef ecosystem. When swimmers and divers stand on or even touch a reef, the coral can be damaged. This is even more of a problem when boats drop their anchors onto the reef. Boats can also cause pollution with the gasoline and oil that they use. Development of the coast causes an indirect threat to reefs that are nearby. As roads, hotels, and other buildings are constructed, debris and sediment can wash into the ocean and smother the reef. Sediment can also reduce the clarity of the water, which affects the ability of the algae to capture the energy of the sun. Nutrients from substances such as fertilizer can be washed from coastal developments into the ocean. This can cause weed-like algae to grow quickly and overgrow a reef. An increase in the nutrients in the water also allows more of the young crown-of-thorns sea stars to survive and become adults.

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Yellowstone Food Web

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Activity 1.2

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Yellowstone Food Web

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Yellowstone Food Web

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Activity 1.2

grizzly bear

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coyote

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snowshoe hare

© Troy Smith

bison

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beaver

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Activity 1.2

Courtesy of the Maine Medical Center Research Institute

winter tick

cowbird

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aspen tree

© Theodore Clutter/Science Source

grasses

© Leslie Timmona

pine seeds

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Yellowstone Food Web

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Activity 1.2

gray wolf

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gray wolf

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Yellowstone Food Web

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Activity 2.2


badger
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Activity 2.2


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bald eagle


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CHANGE CARDS

Forest

A

Activity 2.5

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CHANGE CARDS

Forest

C

Activity 2.5

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CHANGE CARDS

Forest

B

Activity 2.5

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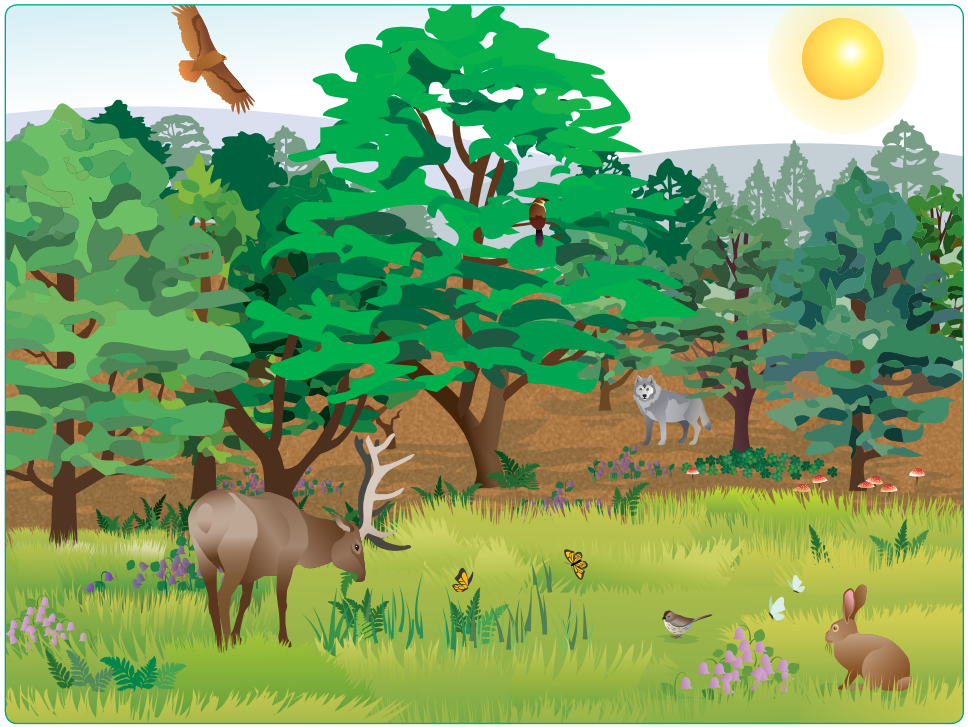
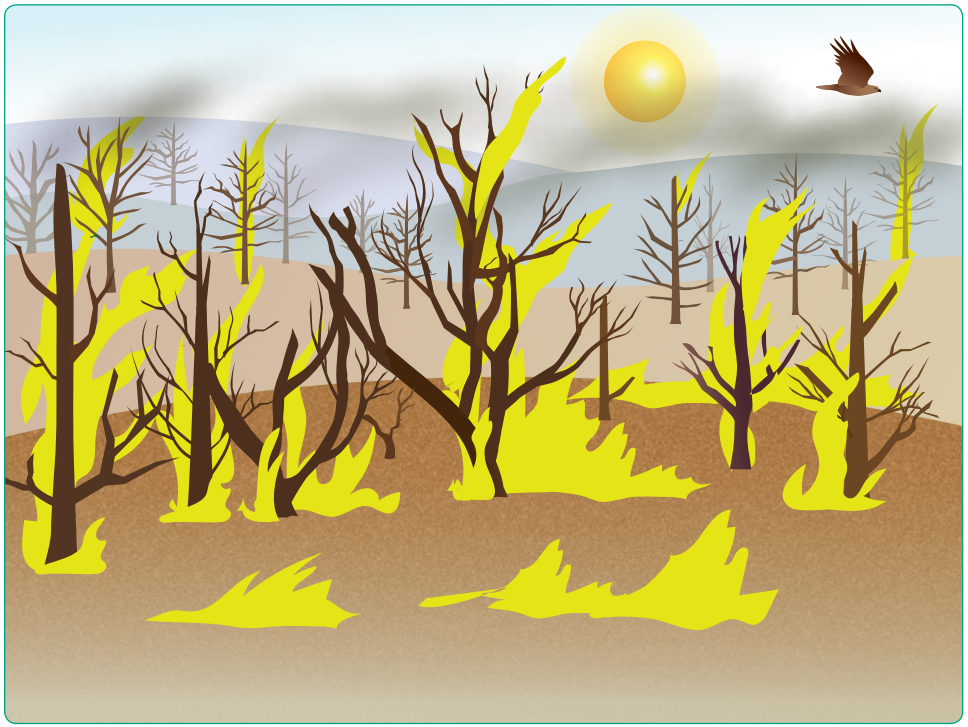
CHANGE CARDS

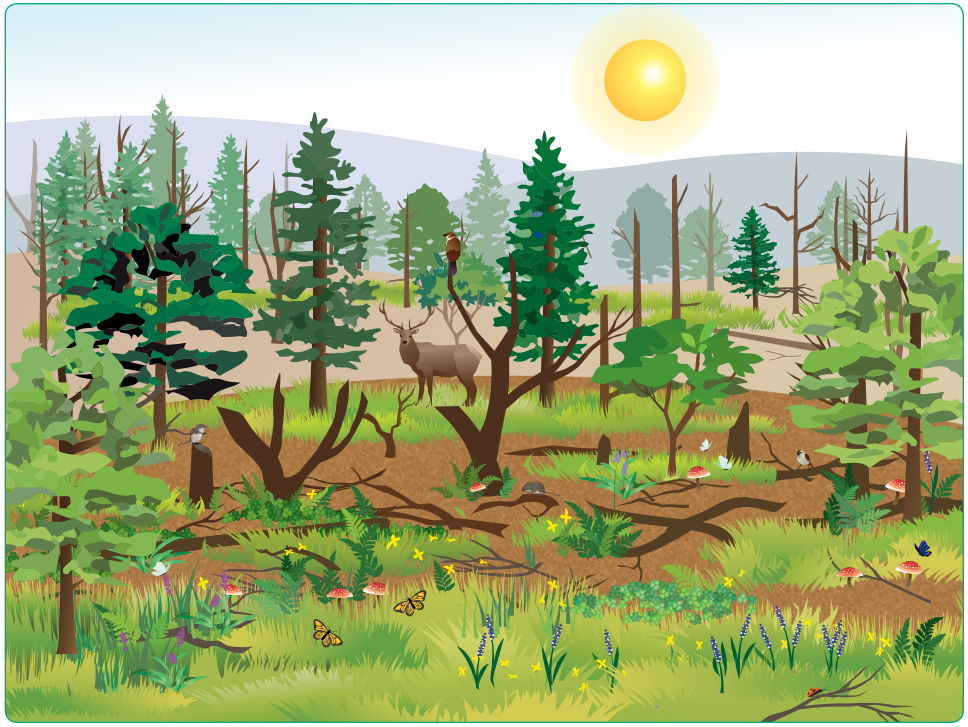
Forest

D

Activity 2.5







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CHANGE CARDS

Forest

Activity 2.5

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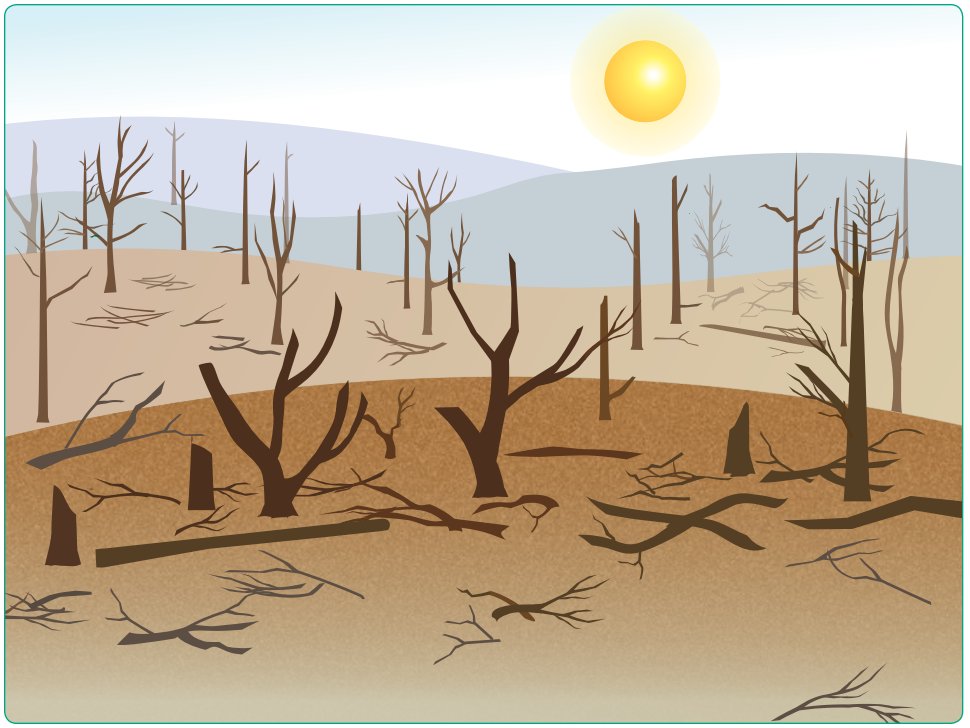
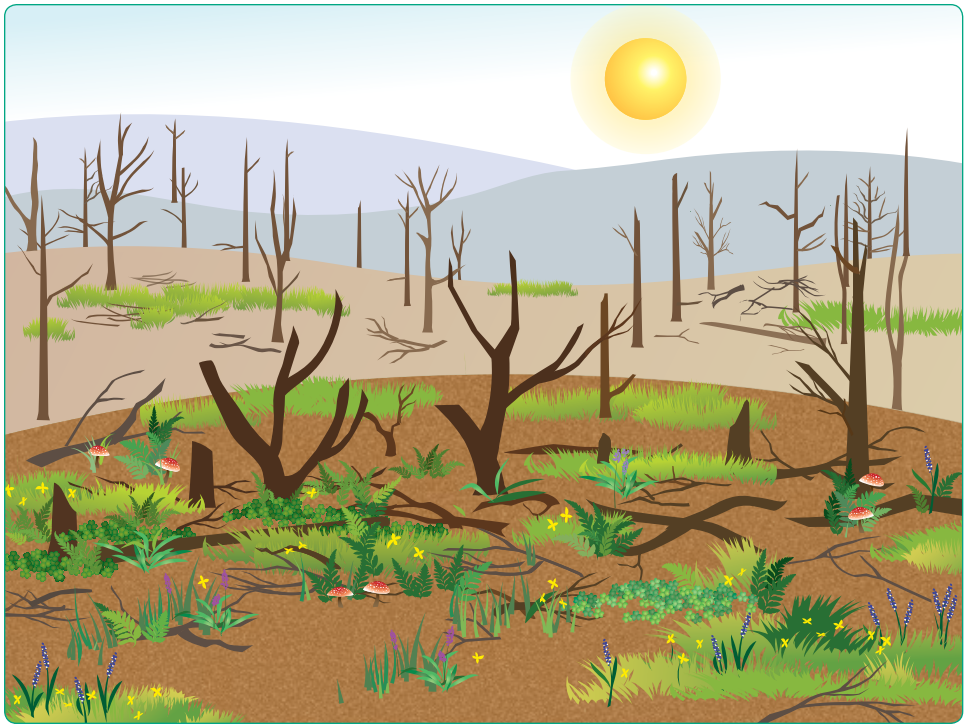
CHANGE CARDS

Forest

Activity 2.5





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CHARACTER CARD

Game

Activity 3.2

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CHARACTER CARD

Game

Activity 3.2

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CHARACTER CARD

Game

Activity 3.2

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CHARACTER CARD

Game

Activity 3.2

You captain an ocean trawler,
which has no fishing limits.

Catch as many fish as you want to.

You captain an ocean trawler,
which has no fishing limits.

Catch as many fish as you want to.

You captain an ocean trawler,
which has no fishing limits.

Catch as many fish as you want to.

You captain an ocean trawler,
which has no fishing limits.

Catch as many fish as you want to.

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CHARACTER CARD

Game

Activity 3.2

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CHARACTER CARD

Game

B

Activity 3.2

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CHARACTER CARD

Game

B

Activity 3.2

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CHARACTER CARD

Game

B

Activity 3.2

You are a line fisher (you catch with a long line with multiple hooks).

You may catch up to 3 fish, but only 1 yellow fish, each round.

You are a line fisher (you catch with a long line with multiple hooks).

You may catch up to 3 fish, but only 1 yellow fish, each round.

You are a line fisher (you catch with a long line with multiple hooks).

You may catch up to 3 fish, but only 1 yellow fish, each round.

You are a line fisher (you catch with a long line with multiple hooks).

You may catch up to 3 fish, but only 1 yellow fish, each round.

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Ecosystem Disruptions Card

Activity 3.2

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Ecosystem Disruptions Card

Activity 3.2

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Ecosystem Disruptions Card

Activity 3.2

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Ecosystem Disruptions Card

Activity 3.2

Habitat loss occurs, so there is not enough space for all fish to lay eggs. At the end of this round instead of doubling the amount of fish only add one new fish for every two surviving fish.

Ecosystem conditions are normal. Play this round following the regular rules.

Unusually warm weather causes Bay water temperature increases, and fish eggs die off. At the end of this round instead of doubling the amount of fish only add one new fish for every three surviving fish.

Plankton die off occurs, not enough food for all fish to reproduce. At the end of this round instead of doubling the amount of fish only add one new fish for every two surviving fish.

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Hudson River Ecosystem

1

Activity 4.1

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Hudson River Ecosystem

3

Activity 4.1

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Hudson River Ecosystem

2

Activity 4.1

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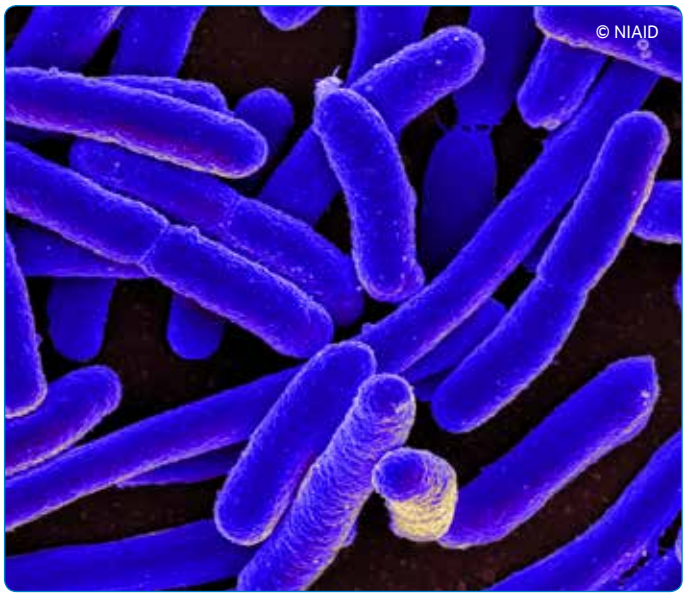
Hudson River Ecosystem

4

Activity 4.1

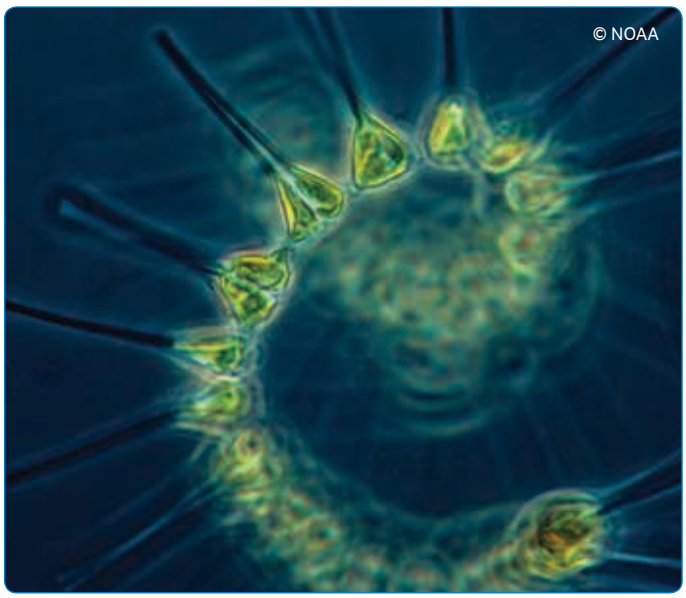


Bacteria

Bacteria are decomposers. They help break down the remains of dead animals and plants, making the nutrients available for other organisms.

Rotifers

Rotifers are a type of zooplankton that eat bacteria, phytoplankton and sometimes zooplankton like small copepods.



Phytoplankton

Phytoplankton are producers. They use chlorophyll to capture light energy in chemical bonds of carbon molecules.

Copepod nauplii

Copepod nauplii are young copepods, they are small zooplankton that eat phytoplankton and bacteria.

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Hudson River Ecosystem

5

Activity 4.1

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Hudson River Ecosystem

7

Activity 4.1

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Hudson River Ecosystem

6

Activity 4.1

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Hudson River Ecosystem

8

Activity 4.1

Copepod (adults)

Copepods are zooplankton that eat phytoplankton, bacteria, and small zooplankton.

Unionidae

Unionidae are native mussels in the Hudson River. They are filter feeders and eat all types of plankton.

Cladocera

Cladocera are zooplankton that eat phytoplankton, bacteria, dead organisms and small zooplankton.

Sphaeriidae

Sphaeriidae are native clams in the Hudson River. They are filter feeders and eat all types of plankton.

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Hudson River Ecosystem

9

Activity 4.1

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Hudson River Ecosystem

10

Activity 4.1

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Alosa (herring)

Alosa live in open water and they feed on all types of plankton.

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Centrarchidae (sunfish)

Centrarchidae live near the shore in shallow “weed beds” where they feed on insect larvae, crustaceans, small fish and small clams.

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Hudson River Ecosystem

11

Activity 4.1

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Hudson River Ecosystem

11

Activity 4.1

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Hudson River Ecosystem

11

Activity 4.1

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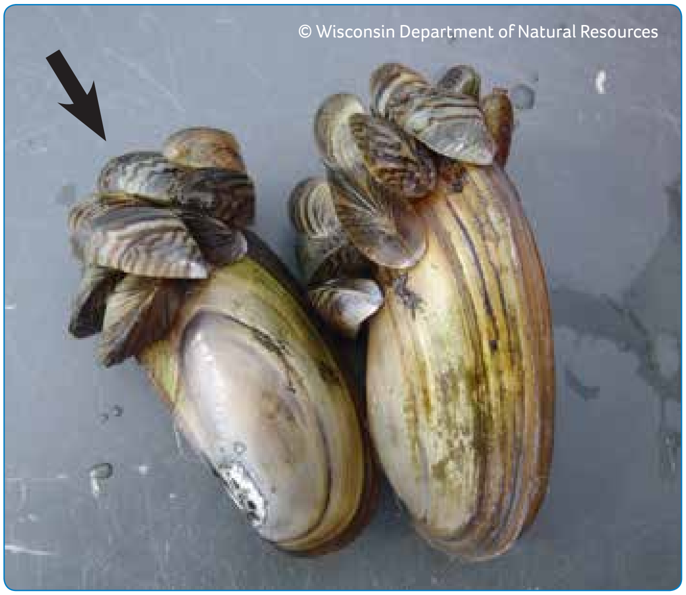
Hudson River Ecosystem

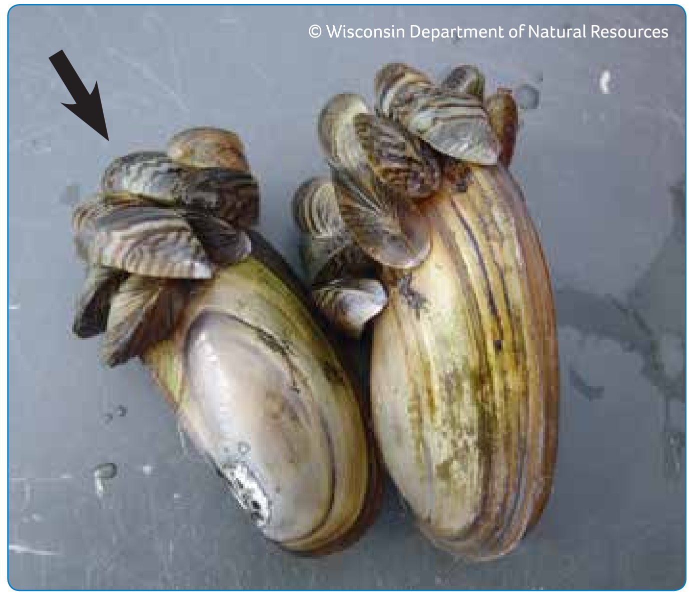
11

Activity 4.1



Zebra Mussel

These small clams are filter feeders, eating small plankton and plant and animal fragments.



Zebra Mussel

These small clams are filter feeders, eating small plankton and plant and animal fragments.

Zebra Mussel

These small clams are filter feeders, eating small plankton and plant and animal fragments.

Zebra Mussel

These small clams are filter feeders, eating small plankton and plant and animal fragments.

AMERICAN MUSEUM OF NATURAL HISTORY

EVENT CARDS

ROUND

1

Activity 5.2

AMERICAN MUSEUM OF NATURAL HISTORY

EVENT CARDS

ROUND

1

Activity 5.2

Action

There is a proposal to establish a large farm near the river. As a group, you must decide whether to approve the proposal.

Consequence

If you decide to allow the new farm:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the River area	Subtract two points	Add two points	Add two points
The manager of the Gulf area	Subtract two points	Add two points	Add two points
All others	Subtract one point	Add one point	Add one point

If you decide not to allow the farm:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
All	Add one point	Subtract one point	Subtract one point

Action

There is a proposal to build a much-needed housing development. As a group, you must decide whether to approve the proposal and, if so, where it should be built.

Consequence

If you decide to allow the new housing development:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the area where the develop-ment is built	Subtract two points	Add two points	Add two points
All others	Subtract one point	Add one point	Add one point

If you decide not to allow the new housing development:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
All	Add one point	Subtract one point	Subtract two points

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EVENT CARDS

ROUND

1

Activity 5.2

American Museum of Natural History | The Lawrence Hall of Science, University of California, Berkeley

EVENT CARDS

ROUND

1

Activity 5.2

Action

There is a proposal to build a road that by-passes the town and reduces traffic congestion. The road will begin near the river before passing through the gulf near to the city and on up through the forest. As a group, you must decide whether to approve the proposal.

Consequence

If you decide to allow the new road:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	No change	Add one point	Add two points
All others	Subtract two points	Add one point	Add two points

If you decide not to allow the new road:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
All	Add one point	Subtract one point	Subtract one point

Action

There is a proposal to build a small industrial complex. As a group, you must decide whether to approve the proposal and, if so, where it should be built.

Consequence

If you decide to allow the new industrial complex:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the area where the develop-ment is built	Subtract two points	Add two points	Add one point
All others	Subtract one point	Add one point	Add one point

If you decide not to allow the new industrial complex:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
All	Add one point	Subtract two points	Subtract one point

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EVENT CARDS

ROUND

1

Activity 5.2

American Museum of Natural History | The Lawrence Hall of Science, University of California, Berkeley

EVENT CARDS

ROUND

1

Activity 5.2

Action

There is a proposal to temporarily ban all hunting in the Forest area. As a group, you must decide whether to approve the proposal.

Consequence

If you decide to ban hunting:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Forest area	Add three points	Subtract two points	Subtract two points
All others	Add two points	Subtract one point	Subtract one point

If you decide not to ban hunting:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Forest area	Subtract two points	No change	No change
All others	Subtract one point	No change	No change

Action

There is a proposal to temporarily suspend all fishing in the lake as fish populations reach historically low levels. As a group, you must decide whether to approve the proposal.

Consequence

If you decide to suspend fishing:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Add three points	Subtract two points	Subtract two points
The manager of the River area	Add two points	Subtract two points	Subtract one point
All others	Add one point	Subtract one point	Subtract one point

If you decide to allow fishing:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Subtract two points	Add two points	Add one point
The manager of the River area	Subtract two points	Add two points	Add one point
All others	Subtract one point	Add one point	Add one point

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EVENT CARDS

ROUND

2

Activity 5.2

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EVENT CARDS

ROUND

2

Activity 5.2

Action

There is a proposal to build a dam where the lake meets the river. The dam would generate additional electricity for the region, which is important in supporting the growing population. However, the dam would reduce the flow of water into the river. It would also allow the flow of water to be controlled. Your community's support will be crucial in order for the dam to be built. As a group, you must decide whether to support the proposal.

Consequence

If you decide to build the dam:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Subtract two points	Add one point	Add one point
The manager of the River area	Subtract two points	Add one point	Add one point
The manager of the Gulf area	Subtract two points	Add one point	Add one point
The manager of the Forest area	No change	Add one point	Add one point

If you decide not to build the dam:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
All managers	Add one point	Subtract two points	Subtract one point

Action

There is a proposal to introduce a new species of fish into the lake. This species is much larger than the existing species of fish. Those who support this proposal think that it will attract people who enjoy fishing, therefore increasing area tourism. Those who oppose the introduction are concerned about how it will affect the ecosystem, especially the other fish in the lake. As a group, you must decide whether to approve the proposal.

Consequence

If you decide to allow the introduction of the fish:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Subtract two points	Add two points	Add two points
The manager of the River area	Subtract one point	Add one point	Add one point
All others	Subtract one point	Add one point	No change

If you decide not to introduce the fish:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Add two points	Subtract two points	Subtract two points
The manager of the River area	Add one point	Subtract one point	Subtract one point
All others	No change	Subtract one point	No change

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EVENT CARDS

ROUND

2

Activity 5.2

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EVENT CARDS

ROUND

2

Activity 5.2

Action

The increasing population of the region means that several new schools must be built. The Forest and Gulf area will each have a new elementary school, while the River area will be the site of a large middle and high school campus.

Consequence

If you decide to build the schools:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the River area	Subtract two points	No change	Add two points
The managers of the Forest and Gulf areas	Subtract one point	No change	Add two points
The manager of the Lake area	No change	No change	Add two points

If you decide not to build the schools:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the River area	Add one point	No change	Subtract two points
The managers of the Forest and Gulf areas	Add one point	No change	Subtract two points
The manager of the Lake area	No change	No change	Subtract two points

Action

There is a proposal to build a large resort in the Gulf area that will boost tourism.

Consequence

If you decide to build the resort:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Gulf area	Subtract two points	Add two points	Add one point
All others	No change	Add one point	Add one point

If you decide not to support the proposal and the resort is not built:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Gulf area	Add one point	Subtract two points	Subtract one point
All others	Add one point	Subtract one point	No change

If your group cannot agree whether the resort should be built:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
All managers	No change	Subtract one point	Subtract two points

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EVENT CARDS

ROUND

2

Activity 5.2

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EVENT CARDS

ROUND

3

Activity 5.2

Action

There is a prolonged period of heavy rain which causes flooding.

Consequence

If you built the dam in Round 2:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Subtract one point	Subtract one point	Subtract one point
The manager of the River area	Subtract one point	Subtract one point	Subtract one point
The manager of the Gulf area	Subtract one point	Subtract one point	Subtract one point
The manager of the Forest area	No change	Subtract one point	Subtract one point

If you did not build the dam in Round 2:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Subtract one point	Subtract two points	Subtract two points
The manager of the River area	Subtract two points	Subtract two points	Subtract two points
The manager of the Gulf area	Subtract two points	Subtract two points	Subtract two points
The manager of the Forest area	No change	Subtract one point	Subtract one point

Action

The increasing population of the region has meant that there is more traffic on the roads. This can cause more congestion and pollution in communities close to the road.

Consequence

If you built a by-pass road in Round 1:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	No change	No change	No change
All others	Subtract two points	No change	No change

If you did not build a by-pass road in Round 1:

Who is affected	Environmental Points change	Money Points change	Happiness Points change
The manager of the Lake area	Subtract one point	No change	Subtract one point
All others	Subtract one point	No change	Subtract one point

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EVENT CARDS

ROUND

Activity 5.2

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EVENT CARDS

ROUND

3

Activity 5.2

Action

Slowly but surely, various nonnative species have entered the region. The effect that these species have on your area depends partly on how healthy your environment is.

Consequence

Who is affected	Environmental Points change	Money Points change	Happiness Points change
If you have 10 or more environmental points	No change	No change	No change
If you have between 6 and 9 environmental points	Subtract one point	Subtract one point	Subtract one point
If you have 5 or less environmental points	Subtract two points	Subtract two points	Subtract two points

Action

A private foundation has offered to provide the funds needed to create a conservation area in the most economically disadvantaged area in the region.

Consequence

Who is affected	Environmental Points change	Money Points change	Happiness Points change
If you have |the lowest number of money points*	Add two points	Add one point	Add one point
All others	No change	No change	No change

*If two or more members of your group are tied for the lowest number of money points, you must agree as a group where the conservation area will be located.

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EVENT CARDS

ROUND 3

Activity 5.2

Action

Economic conditions in the state have deteriorated quite badly. Many families are relocating to find work. The effect that these economic problems have on your area depends on the total of your money and happiness points

Consequence

Who is affected	Environmental Points change	Money Points change	Happiness Points change
If you have a total of 16 or more money and happiness points	No change	No change	Subtract one point
If you have a total of 10 to 15 money and happiness points	No change	Subtract two points	Subtract two points
If you have a total of 9 or less money and happiness points	No change	Subtract three points	Subtract three points

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Insect Solution

CARD

Activity 5.3

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Insect Solution

CARD

Activity 5.3

American Museum of Natural History | The Lawrence Hall of Science, University of California, Berkeley

Insect Solution

CARD

Activity 5.3

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Insect Solution

CARD

Activity 5.3

Constraint:

The family does not have to move away from the farm.

Criteria:

1. Has the least negative environmental impact
2. Does not take a long time

Constraint:

The family does not have to move away from the farm.

Criteria:

1. Has the least negative environmental impact
2. Does not take a long time

Constraint:

The family does not have to move away from the farm.

Criteria:

1. Has the least negative environmental impact
2. Does not take a long time

Constraint:

The family does not have to move away from the farm.

Criteria:

1. Has the least negative environmental impact
2. Does not take a long time

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Insect Solution

CARD

B

Activity 5.3

American Museum of Natural History | The Lawrence Hall of Science, University of California, Berkeley

Insect Solution

CARD

B

Activity 5.3

American Museum of Natural History | The Lawrence Hall of Science, University of California, Berkeley

Insect Solution

CARD

B

Activity 5.3

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Insect Solution

CARD

B

Activity 5.3

Constraint:
There should be no use of chemicals.

Criteria:
1. Has the least negative social impact
2. Keeps as much of the crops as possible

Constraint:
There should be no use of chemicals.

Criteria:
1. Has the least negative social impact
2. Keeps as much of the crops as possible

Constraint:
There should be no use of chemicals.

Criteria:
1. Has the least negative social impact
2. Keeps as much of the crops as possible

Constraint:
There should be no use of chemicals.

Criteria:
1. Has the least negative social impact
2. Keeps as much of the crops as possible

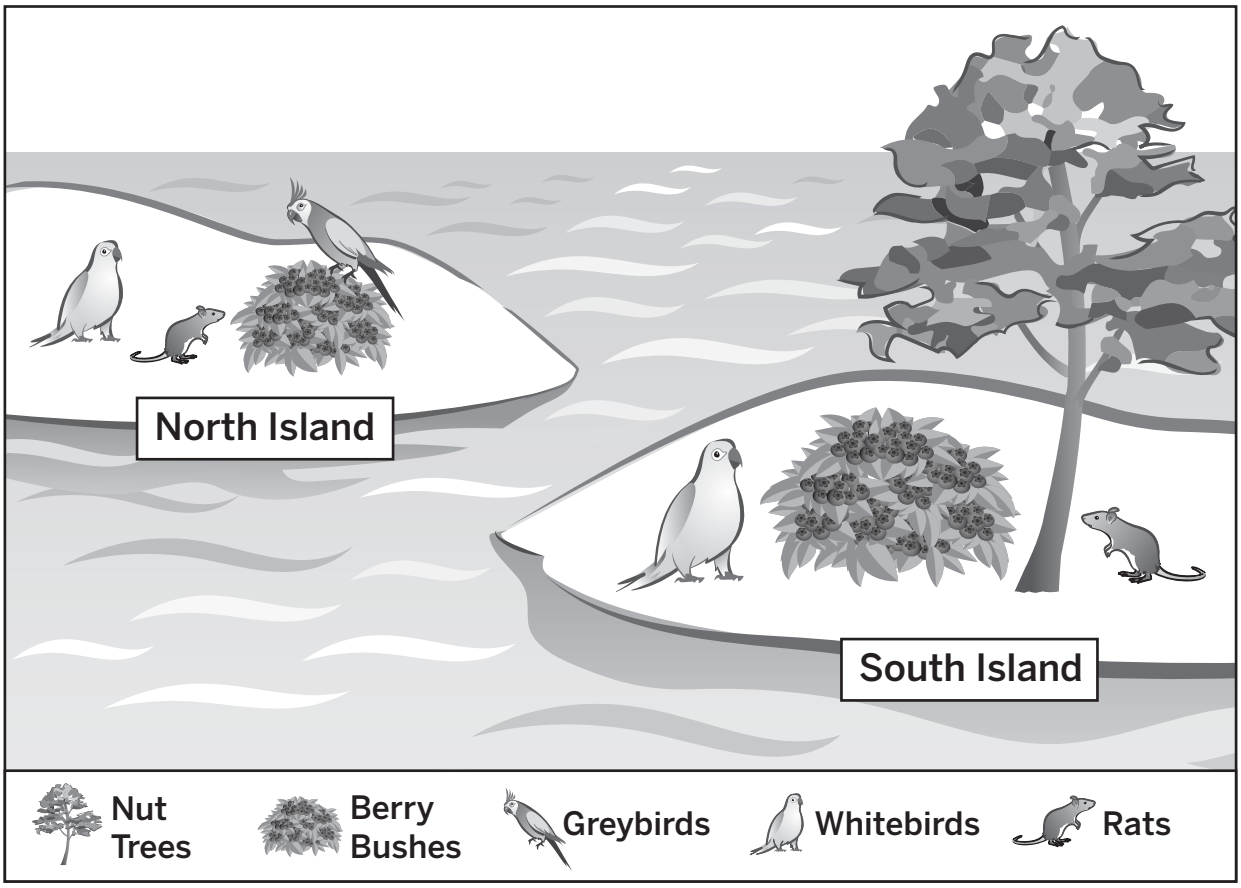
Name _____

Chapter 1 Assessment

1. Graybirds and whitebirds live on North Island. Both types of birds eat the berries of the berry bush. The seeds of the berry bush grow best after the berries are eaten by birds and dropped elsewhere around the island.

Whitebirds are also found on nearby South Island. The whitebirds on South Island eat berries and the nuts of the nut tree.

Rats are found on both islands. The rats eat berries and bird eggs.



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Chapter 1 Assessment

page 2

Name _____

1a. Identify examples of competition, predator-prey, and mutualism between species on each island.

North Island	South Island
Example of competition: Why is this an example of competition?	Example of competition: Why is this an example of competition?
Example of predator-prey: Why is this an example of predator-prey?	Example of predator-prey: Why is this an example of predator-prey?
Example of mutualism: Why is this an example of mutualism?	Example of mutualism: Why is this an example of mutualism?

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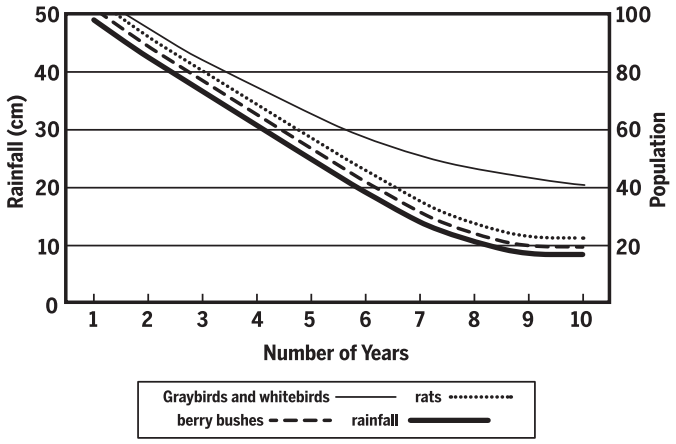
Chapter 1 Assessment

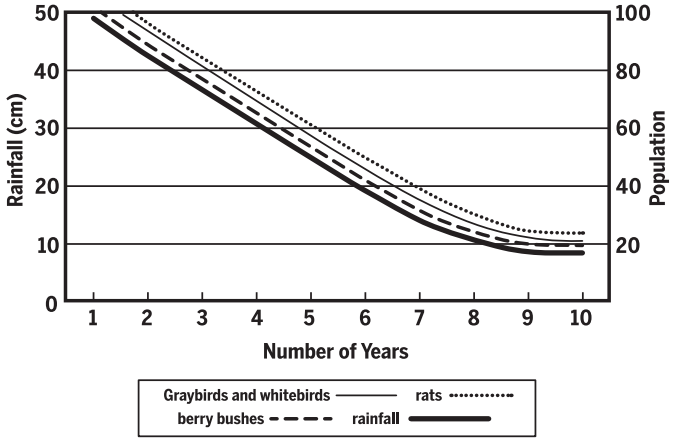
page 3

Name _____

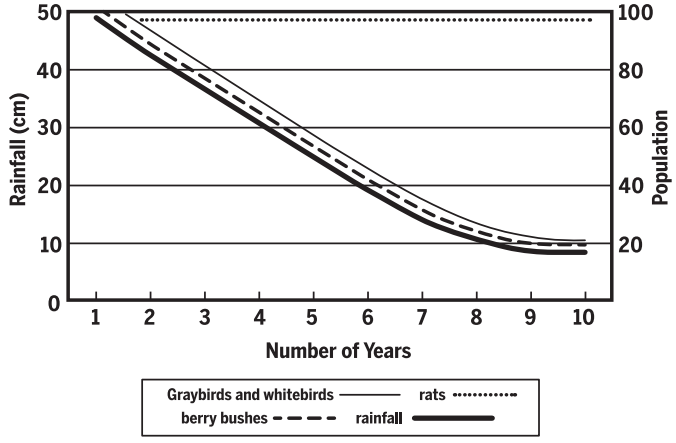
1b. Berry bushes need lots of rainfall. Make an X in the box next to the graph below that best predicts what would happen to the populations on the **North Island** during a 10-year period of decreasing rain. Using the space to the right of the other two graphs, explain why these graphs are not the best predictions of what would happen during the period of decreasing rain. You do not need to write anything next to the graph you chose as the best prediction.



A. ☐



B. ☐



C. ☐

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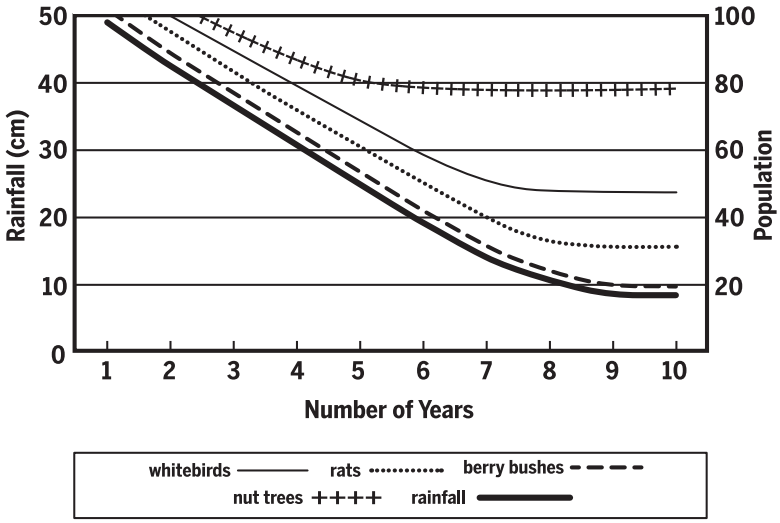
Chapter 1 Assessment

page 4

Name _____

1c. The graph below shows how the populations on the South Island changed during the same 10-year period of decreasing rain. Nut trees do not need a lot of rain. Construct a complete scientific explanation that answers the question, "Why did the population of whitebirds decrease to about half of what it was before?"



Your explanation should include the following:

- The scientific question
- Your claim
- The relevant evidence that supports your claim
- The science concepts that support the evidence
- Your scientific reasoning that links the evidence and science concepts to the claim

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Chapter 1 Assessment Student Checklist

1a. ☐ Describes 6 relationships

1b. ☐ An X is in one of the boxes

☐ There is an explanation next to one of the incorrect graphs

☐ There is an explanation next to the other incorrect graph

1c. ☐ Claim

☐ Evidence (numbers or trends from graph)

☐ Science Concept

☐ Reasoning

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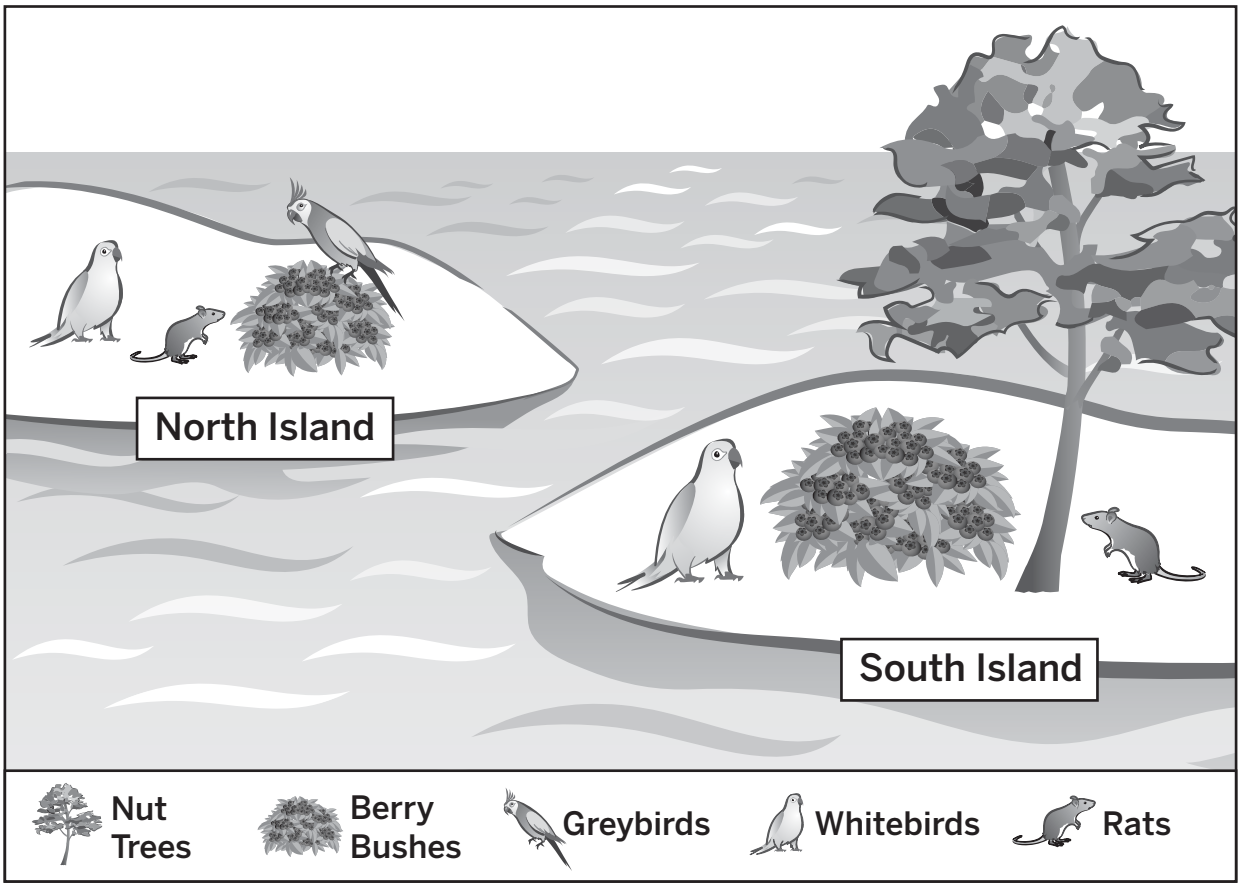
Name SAMPLE STUDENT RESPONSE

Chapter 1 Assessment

1. Graybirds and whitebirds live on North Island. Both types of birds eat the berries of the berry bush. The seeds of the berry bush grow best after the berries are eaten by birds and dropped elsewhere around the island.

Whitebirds are also found on nearby South Island. The whitebirds on South Island eat berries and the nuts of the nut tree.

Rats are found on both islands. The rats eat berries and bird eggs.



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Chapter 1 Assessment

page 2

Name *SAMPLE STUDENT RESPONSE*

1a. Identify examples of competition, predator-prey, and mutualism between species on each island.

North Island	South Island
Example of competition: *Competition between the two kinds of birds and between the birds and the rats for berries.* Why is this an example of competition?	Example of competition: *Rats and whitebirds compete for berries* Why is this an example of competition?
Example of predator-prey: *A predator-prey interaction between the rats and the birds (or, rats are predators, bird eggs are their prey)* Why is this an example of predator-prey?	Example of predator-prey: *Rats are predators of the whitebird eggs (or rats are predators, bird eggs are their prey)* Why is this an example of predator-prey?
Example of mutualism: *A mutually beneficial interaction (or mutualism) between the birds and the berries* Why is this an example of mutualism?	Example of mutualism: *The whitebirds and berries have a mutually beneficial interaction (mutualism)* Why is this an example of mutualism?

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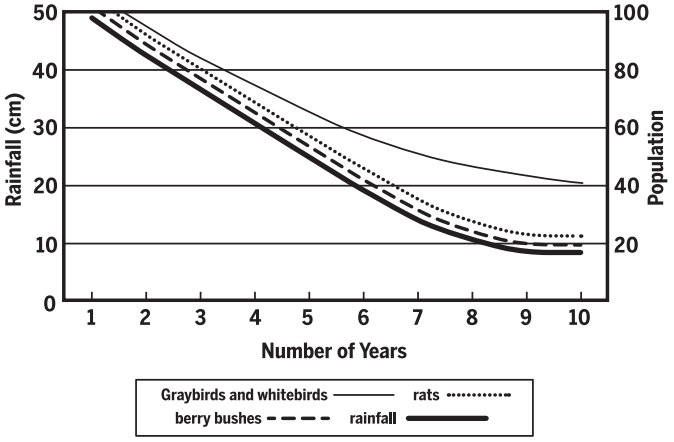
Chapter 1 Assessment

page 3

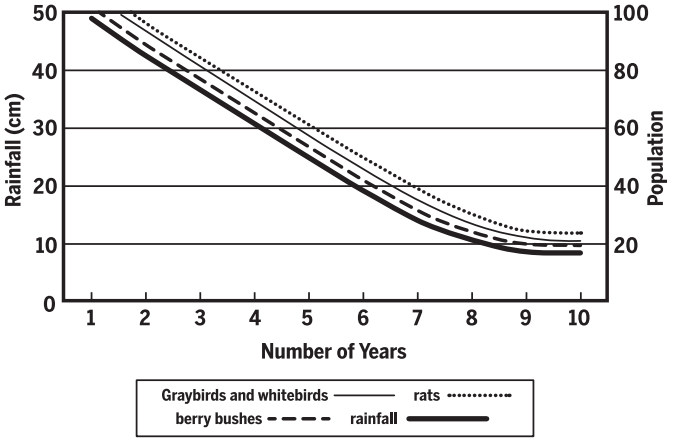
Name SAMPLE STUDENT RESPONSE

1b. Berry bushes need lots of rainfall. Make an X in the box next to the graph below that best predicts what would happen to the populations on the **North Island** during a 10-year period of decreasing rain. Using the space to the right of the other two graphs, explain why these graphs are not the best predictions of what would happen during the period of decreasing rain. You do not need to write anything next to the graph you chose as the best prediction.

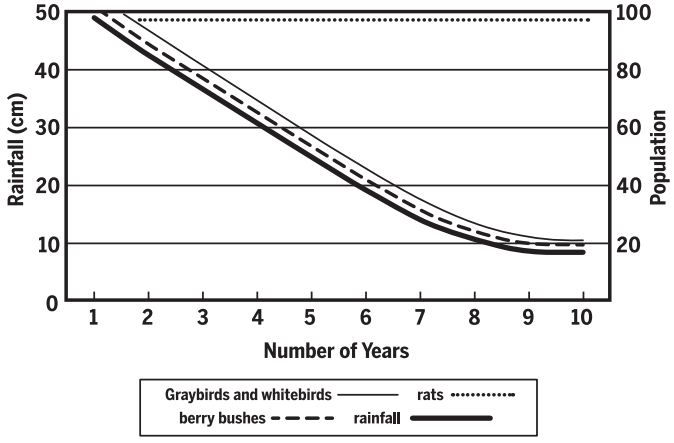


A. ☐

A can't be correct because the birds should follow the same pattern as the rats and bushes, since birds also eat berries.



B. ☒



C. ☐

C can't be correct because rats would decrease as the birds decreased, since rats eat bird eggs

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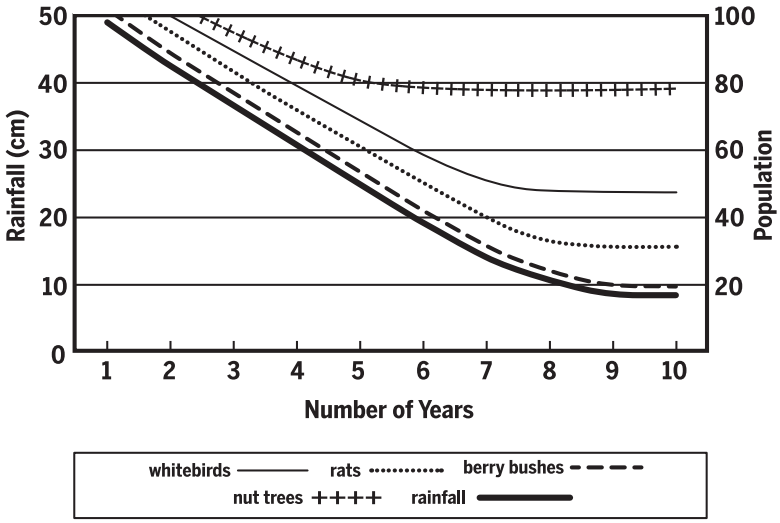
Chapter 1 Assessment

page 4

Name SAMPLE STUDENT RESPONSE

1c. The graph below shows how the populations on the South Island changed during the same 10-year period of decreasing rain. Nut trees do not need a lot of rain. Construct a complete scientific explanation that answers the question, "Why did the population of whitebirds decrease to about half of what it was before?"



Your explanation should include the following:

- The scientific question
- Your claim
- The relevant evidence that supports your claim
- The science concepts that support the evidence
- Your scientific reasoning that links the evidence and science concepts to the claim

The question my explanation answers is, "Why did the population of whitebirds decrease to about half of what it was before?" My claim is that the whitebird population decreases to half of what it was for three reasons: 1) there aren't as many berries for them to eat and 2) the rats eat more Whitebird eggs because there are fewer berries available. (3) Then it stays about the same and stops dropping because the whitebirds are able to eat nut trees. The evidence that supports my claim is the big drop in the berry populations, less of a drop in the rat population, and small drop of the nut tree population. The concept of the food web helps me figure out what is going on. Since the rats need to eat berries or bird eggs, their population will go down as the berries drop, and the ones left will eat more bird eggs. There won't be enough bird eggs for all the rats, so their population drops. The birds can eat nuts, and the evidence shows the nut tree population has dropped some, so I reason the birds are surviving on nuts. Even though the rats are hungry for bird eggs, there aren't so many rats any more, so I reason there aren't enough to eat all the birds.

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Scoring guide for Chapter 1 Assessment

Note: The rubrics below are drafts. They are intended as guides for assessing whether your students are achieving learning goals. We encourage you to use a scoring system that works in your classroom context and that is appropriate for the level of your students. So, for example, students may be able to earn a "full credit" score for a "Level 2: Developing" response.

1a. Identify examples of competition, predator-prey, and mutualism between species on each island.

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Describes all 6 relationships accurately: <u>On the North Island:</u> ● A **predator-prey** relationship between the rats and the graybird and whitebird (eggs) ● Mutualism between the birds and the berries ● Competition between the two kinds of birds ***and*** between the birds and the rats for berries. <u>On South Island:</u> ● Rats are **predators** of the whitebird (eggs) ● **Competition** between rats and whitebirds for berries ● **Mutualism** between the whitebirds and berries	Describes at least 4 relationships correctly	Describes at least 2 relationships correctly	Describes at least 1 relationship correctly	Does not describe the relationship between the species on the islands

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1b. Make an X in the box next to the graph below that best predicts what would happen to the populations on the North Island during a 10-year period of decreasing rain."

Explain why the other two graphs are not the best predictions of what would happen during the period of decreasing rain.

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Selects Graph B Explains that A can't be correct because the birds should follow the same pattern as the rats and bushes, since birds also eat berries. Explains that C can't be correct because rats would decrease as the birds decreased, since rats eat bird eggs	Selects Graph B Partially explains what is wrong with Graphs A and C	Selects Graph A Partially explains what is wrong with Graph C	Selects Graph C **OR** Selects any graph but does not explain anything	Student does not select a Graph or provide an explanation

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Scoring guide for Chapter 1 Assessment

1c. The graph below shows how the populations on South Island changed during the same 10-year period of decreasing rain. Nut trees do not need a lot of rain. Construct a complete scientific explanation focused on the question, "Why did the population of whitebirds decrease to about half of what is was before?"

	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Claim	Student advances a claim about what caused the whitebirds to decrease to about half of what they were initially. The claim must contain all of the following ideas: **1.** There aren't as many berries for birds to eat **2.** Rats eat more Whitebird eggs because there are fewer berries available [or, rats eat more bird eggs] **3.** The whitebirds can also eat nuts, so their population does not crash to zero	Student advances a claim about what caused the whitebirds to decrease. The claim must include one or two of the following ideas: **1.** There aren't as many berries for birds to eat **2.** Rats eat more bird eggs **3.** The whitebirds can also eat nuts, so their population does not crash to zero.	Student advances a partially correct claim about either fewer berries or more rats or availability of nuts.	Student advances a claim that does not relate to fewer berries (less food) or more rats (more predators) or availability of nuts.	Student does not advance a claim
Evidence	Student offers evidence to support all parts of the claim: **1.** The berries decrease a lot on the graph **2.** Rats decrease quite a lot on the graph **3.** Nuts decrease somewhat on the graph	Student offers clear but incomplete evidence to support the claim they offered. *E.g.* The berries decrease on the graph (supports the claim that there are fewer berries)	Student identifies evidence from the graph, but it is unclear or does not completely support the claim	Student offers ideas taken from the prompt that may partially support their claim (e.g. "the animals } eat berries and nuts")	Student does not offer evidence

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Scoring guide for Chapter 1 Assessment

	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Science Concepts	The concept of the **food web** helps me figure out what is going on and/or **Competition** and/or **Predator-prey relationship** and/or **Case and effect** and/or **Patterns**	Student describes the scientific concept but does not use the specific terminology. (*e.g.* the concept is that animals are connected in the ecosystem – some animals eat plants, other eat other animals and when they eat the same thing they are fighting for that thing)	Student describes the scientific concept vaguely, without using specific terminology (e.g. the concept is that everything is connected)	Student describes an unrelated scientific concept (e.g. the concept that relates is mutualism)	Student does not include science concepts
Scientific Reasoning	Student clearly demonstrates logical reasoning: *e.g.* **Since** the rats need to eat berries or bird eggs, their population will go down as the berries drop. The rats that are left will eat more bird eggs. There won't be enough bird eggs for all the rats, **so** their population drops. The birds can eat nuts, and the evidence shows the nut tree population has dropped some, **so** the birds are surviving on nuts. Even though the rats are hungry for bird eggs, there aren't so many rats any more, so there aren't enough to eat all the birds.	Student attempts to link claim and evidence (*e.g.* **because** the berries went down **then** the rats must have eaten more bird eggs because they needed more food)	Student does not adequately link claim to evidence (*e.g.* since everything is connected, the berries will affect the whitebirds)	Does not include logic statements (*e.g.* simply restates claim or evidence)	Does not include scientific reasoning

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Chapter 2 Assessment

1. The tables below lists organisms in a grassland ecosystem.

- In the box on the next page, **draw a model of this ecosystem** that shows the cycling of matter.
- Use arrows to show how **matter** moves between organisms in the ecosystem.
- Write a caption below your model that explains how matter cycles in the ecosystem.

Biotic components for your model:

Make a check mark if it is in your model	Organism	What It Eats
	Grass	Makes its own food
	Grasshoppers	Grass
	Garter snakes	Grasshoppers
	Eagles	Garter snakes
	Decomposers (mold/bacteria/fungi)	Dead and decaying organisms

Abiotic components for your model:

Make a check mark if it is in your model	Component
	CO_2 (carbon dioxide) in air
	H_2O (water)
	Soil

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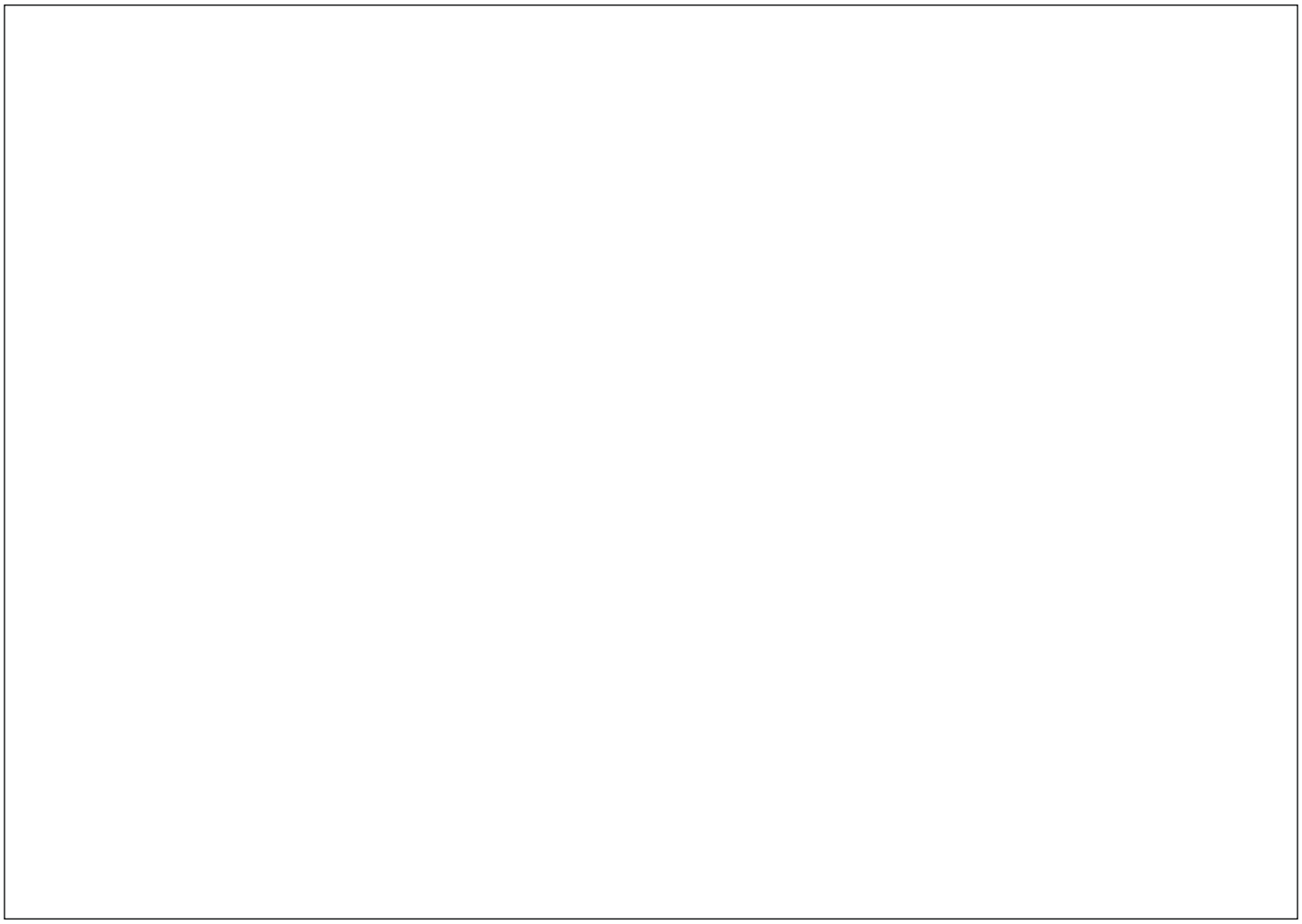
Name _____

Ecosystem Model (Version B)



Caption:

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Chapter 2 Assessment

page 3

Name _____

2. Suppose there was a large volcanic eruption and a thick cloud of ash blocked most sunlight from reaching the ecosystem for several months. Use the model you made in Part 1 to construct an explanation for what would happen in the ecosystem.

Construct a complete scientific explanation that answers the question, "How would an ash cloud from a volcano affect the *cycling of matter* in the ecosystem?"

Your explanation should include the following:

- The scientific question
- Your claim
- The relevant evidence that supports your claim (use evidence from your model)
- The science concepts that support the evidence
- Your scientific reasoning that links the evidence and science concepts to the claim

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Name _____

Chapter 2 Assessment Student Checklist

1.

- ☐ Model includes all biotic components listed.
- ☐ Model includes all abiotic components listed.
- ☐ Arrows show the movement (cycling) of matter.
- ☐ Caption explains how matter cycles through the ecosystem.

2.

- ☐ Claim
- ☐ Evidence (cite specific relationships in the ecosystem model)
- ☐ Science Concept(s)
- ☐ Reasoning

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Name SAMPLE STUDENT RESPONSE

Chapter 2 Assessment

1. The tables below lists organisms in a grassland ecosystem.

- In the box on the next page, **draw a model of this ecosystem** that shows the cycling of matter.
- Use arrows to show how **matter** moves between organisms in the ecosystem.
- Write a caption below your model that explains how matter cycles in the ecosystem.

Biotic components for your model:

Make a check mark if it is in your model	Organism	What It Eats
	Grass	Makes its own food
	Grasshoppers	Grass
	Garter snakes	Grasshoppers
	Eagles	Garter snakes
	Decomposers (mold/bacteria/fungi)	Dead and decaying organisms

Abiotic components for your model:

Make a check mark if it is in your model	Component
	CO_2 (carbon dioxide) in air
	H_2O (water)
	Soil
	Sun

*[The answers for questions 1 are shown on the **model page**.]*

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Chapter 2 Assessment

page 3

Name _____

2. Suppose there were a large volcanic eruption and a thick cloud of ash blocked most sunlight from reaching the ecosystem for several months. Use the model you made in the first three questions to construct an explanation for what would happen in the ecosystem.

Construct a complete scientific explanation that answers the question, "How would an ash cloud from a volcano affect organisms and the transfer of matter and energy in the ecosystem?"

Your explanation should include the following:

- The scientific question
- Your claim
- The relevant evidence that supports your claim (use evidence from your model)
- The science concepts that support the evidence
- Your scientific reasoning that links the evidence and science concepts to the claim

The scientific question is, "How would an ash cloud from a volcano affect organisms and the transfer of matter and energy in the ecosystem?" An ash cloud from a volcano would make many organisms in the ecosystem die. The energy that flows through the ecosystem comes from the sun. Plants use light from the sun to make glucose, and then herbivores eat the plants for the energy. But if the light from the sun is completely blocked, then plants cannot photosynthesize and will die. The herbivores (rabbits and grasshoppers) would lose their food source. If the herbivores die, then the consumers (rabbits, snakes and eagles) would die as well, because they would not have any food. By blocking the sun, the ash cloud stops the flow of energy and transfer of matter into the biotic component of the ecosystem.

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Scoring guide for Chapter 2 Assessment

Note: The rubrics below are drafts. They are intended as *guides* for assessing whether your students are achieving learning goals. We encourage you to use a scoring system that works in your classroom context and that is appropriate for the level of your students. So, for example, students may be able to earn a "full credit" score for a "Level 2: Developing" response.

1. Using the information in the tables

- Draw a model of the ecosystem that shows the cycling of matter.
- Use arrows to show how matter moves between organisms in the ecosystem.
- Write a caption below your model that explains how matter cycles in the ecosystem.

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Model includes grass, grasshoppers, garter snakes, eagle Model includes decomposers Model includes CO_2, H_2O, and soil Arrows show matter: ● Cycling from grass to lower level consumers to top-level consumers ● From each level, being transferred to decomposers ● Being cycled back to the non-living environment ● Being cycled from non-living environment back into producers *The caption students write should be used to interpret the model. You may rely on the caption to clarify the intentions of the arrows in the model.	Model includes all components. Student uses arrows to show the transfer of matter. Arrows show matter: ● Cycling from grass to lower level consumers to top-level consumers ● Shows matter being transferred to decomposers (but may not be from all levels of the food web) ● Being cycled back to the non-living environment ● Being cycled from non-living environment back into producers	Model includes most components. Student uses arrows to show the transfer of matter. Arrows show matter: ● Cycling from grass to lower level consumers to top-level consumers ● Student attempts to show a cycle, but the cycle is not clear and the caption does not explain it.	Model includes some components. Student uses arrows to show the transfer of matter Arrows show matter: ● Being cycled from producers to lower level consumers to top-level consumers. ● Arrows do not depict a cycle. The caption does not explain that matter cycles.	Student does not attempt to show the transfer of matter

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2. Suppose there was a large volcanic eruption and a thick cloud of ash blocked most sunlight from reaching the ecosystem for several months. Use the model you made in Part 1 to construct an explanation for what would happen in the ecosystem.

Construct a complete scientific explanation that answers the question, "How would an ash cloud from a volcano affect the cycling of matter in the ecosystem?"

Your explanation should include the following:

- The scientific question
- Your claim
- The relevant evidence that supports your claim (use evidence from your model)
- The science concepts that support the evidence
- Your scientific reasoning that links the evidence and science concepts to the claim

	Level 4: Proficient	Level 3: Advancing	Level 2: Developing	Level 1: Emerging	Level 0: Not evident
Claim	n/a	Student advances a claim that answers the question (e.g. an ash cloud would cause organisms in the ecosystem to die)	Student advances a claim that partially answers the question (e.g. the ash cloud would be bad for the ecosystem)	Student advances a claim that does not relate to how an ash cloud from a volcano would affect the organisms in an ecosystem	Student does not advance a claim.
Evidence	Student states specific evidence from their model to support their claim.	Student states evidence from their model, but the evidence may be general or not well described.	Student states general evidence, not specifically from their model, to support their claim.	Student states information from the prompt to support their claim.	Student does not state evidence.
Science Concepts	Student discusses **cycling of matter** generally or specific processes that are involved in the cycling of matter (e.g. photosynthesis)	Student discusses cycling of matter or other related scientific concepts	Student describes scientific concepts vaguely without using specific terminology	Student describes an unrelated scientific concept	Student does not include science concepts
Scientific Reasoning	Student clearly demonstrates logical reasoning	Student attempts to link claim and evidence	Student does not adequately link claim to evidence	Does not include logic statements (e.g. simply restates claim or evidence)	Student does not include scientific reasoning

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Chapter 3 Assessment

1. The table below shows the population of deer in a grassland ecosystem over a period of fifteen years. Use the information below and the table to help you answer the questions that follow.

- At the end of Year 4, 80% of the grassland is converted to farmland and fenced to keep the deer out.
- People do not hunt the deer.
- In Year 11, there is a very harsh winter and the deer have very little access to food.

Year	Deer Population	Average Mass (kg)	Number of deer births	% malnourished (severely underweight) deer
1	100	30	30	5
2	110	31	25	3
3	97	29	30	4
4	105	31	15	3
5	83	29	5	46
6	57	27	7	32
7	56	23	6	25
8	58	20	8	18
9	55	19	7	15
10	58	20	5	10
11	35	15	3	72
12	40	18	4	43
13	45	20	7	26
14	48	21	7	10
15	53	21	8	7

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Chapter 3 Assessment

page 2

Name _____

1a. Use the data to describe the effect of the grassland being converted to farmland in Year 4 on the deer population.

1b. Use the data to describe the effect of the harsh winter in Year 11 on the deer population.

2a. Construct a scientific argument that argues the question:
"Should the farmland be converted back to grassland?"

Your argument should include the following:

- The scientific question
- Your claim (which is best supported by evidence and reasoning)
- The relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

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Chapter 3 Assessment

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Name _____

2b. Imagine that you have a classmate who disagrees with your claim. What claim might your classmate make?

2c. What is the problem with your classmate's claim or the argument based on that claim?

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Name _____

Chapter 3 Assessment Student Checklist

1a. ☐ I have included **data from the table** that shows what happens to the deer population after Year 4

1b. ☐ I have included **data from the table** that shows what happens to the deer population after Year 11

2a. ☐ Claim

☐ Evidence (numbers or trends from graphs or tables)

☐ Reasoning

2b. ☐ I have written a claim that is different than my initial claim

2c. ☐ I have pointed out a problem with the hypothetical classmate's claim or argument

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Name SAMPLE STUDENT RESPONSE

Chapter 3 Assessment

1. The table below shows the population of deer in a grassland ecosystem over a period of fifteen years. Use the information below and the table to help you answer the questions that follow.

- At the end of Year 4, 80% of the grassland is converted to farmland and fenced to keep the deer out.
- People do not hunt the deer.
- In Year 11, there is a very harsh winter and the deer have very little access to food.

Year	Deer Population	Average Mass (kg)	Number of deer births	% malnourished (severely underweight) deer
1	100	30	30	5
2	110	31	25	3
3	97	29	30	4
4	105	31	15	3
5	83	29	5	46
6	57	27	7	32
7	56	23	6	25
8	58	20	8	18
9	55	19	7	15
10	58	20	5	10
11	35	15	3	72
12	40	18	4	43
13	45	20	7	26
14	48	21	7	10
15	53	21	8	7

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Chapter 3 Assessment
page 2

Name *SAMPLE STUDENT RESPONSE*

1a. Use the data to describe the effect of the grassland being converted to farmland in Year 4 on the deer population.

The population decreases. It goes from 105 in Year 4 to 83 in Year 5 and then to 57 in Year 6 and then stays relatively stable until Year 10.

1b. Use the data to describe the effect of the harsh winter in Year 11 on the deer population.

The population decreases. It goes from 58 in Year 10 to 35 in Year 11.

2a. Construct a scientific argument that argues the question:
"Should the farmland be converted back to grassland?"

Your argument should include the following:

- The scientific question
- Your claim (which is best supported by evidence and reasoning)
- The relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

The question my argument answers is, "Should the farmland be converted back to grassland?" My claim is that the farmland should be converted back to grassland. The evidence that supports my claim is that after the grassland was converted to farmland and fenced in Year 4 there was an increase in malnourished deer from 3% to 46%. The average mass of deer fell steadily from 31 kg in Year 4 to 15 kg in Year 11 . After this year the number of deer births also dropped from 15 to 5 and stayed below 8 for the rest of the years when data was collected. The overall population decreased from around 100 in years 1-4 to around 40-50 in Years 6-15. This evidence all shows that the conversion of grassland to farmland has had a negative effect on the deer population, because it has restricted their access to resources.

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Chapter 3 Assessment

page 3

Name *SAMPLE STUDENT RESPONSE*

2b. Imagine that you have a classmate who disagrees with your claim. What claim might your classmate make?

The classmate would say the farmland should not be converted back to grassland because humans need to farm to have food. Without farmland, humans might not have enough food.

2c. What is the problem with your classmate's claim or the argument based on that claim?

The problem with this argument is that if the deer population dies out, then the whole ecosystem might collapse because the organisms that eat deer would suffer, and the plants that deer eat would become too numerous. Farmland is important, but if an entire ecosystem collapses, then this could even put the farmland at risk because the environment would change.

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Scoring guide for Chapter 3 Assessment

Note: The rubrics below are drafts. They are intended as *guides* for assessing whether your students are achieving learning goals. We encourage you to use a scoring system that works in your classroom context and that is appropriate for the level of your students. So, for example, students may be able to earn a "full credit" score for a "Level 2: Developing" response.

1a. Use the data to describe the effect of the grassland being converted to farmland in Year 4 on the deer population.

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Student states that the population decreases **AND** Provides sufficient data from the table to support their answer (*e.g.* "the population decreases: it goes from 105 in year 4 to 83 in year 5 and then to 57 in Year 6 and then stays relatively stable until year 10")	Student states that the population decreases or that the population is negatively affected **AND** Provides some data from the data table to support their answer	Student states that the population is affected, but is not specific about the relationship	Student offers an idea related to the data table but does not address the question of what happens to the deer population.	Student does not discuss the deer population

1b. Use the data to describe the effect of the harsh winter in Year 11 on the deer population.

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Student states that the population decreases **AND** Provides sufficient data from the table to support their answer (*e.g.* "the population decreases: it goes from 58 in year 10 to 35 in year 11.")	Student states that the population decreases or that the population is negatively affected **AND** Provides some data from the data table to support their answer	Student states that the population is affected, but is not specific about the relationship	Student offers an idea related to the data table but does not address the question of what happens to the deer population	Student does not discuss the deer population

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Scoring guide for Chapter 3 Assessment

2a. Construct a scientific argument that argues the question "Should the farmland be converted back to grassland?"

Component	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Claim	Claim completely answers the question *e.g.* "The farmland should be converted back to grassland" or "The farmland should not be converted back to grassland"	Claim partially answers the question *e.g.* "Things should stay the way they are"	Claim does not answer the question. *e.g.* "More grasslands would help the deer"	Does not make a claim

Component	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Evidence	Provides appropriate evidence to support the claim. *e.g.* To support conversion back to grassland: "The evidence that supports my claim is that after the grassland was converted to farmland and fenced in Year 4 there was an increase in malnourished deer from 3% to 46%. After this year the number of deer births also dropped from 15 to 5 and stayed below 8 for the rest of the years when data was collected. The overall population decreased from around 100 in Years 1-4 to around 40-50 in Years 6-15."	Provides appropriate evidence to support the claim. **May include some inappropriate evidence.**	Provides evidence that actually supports a different claim, but not the one selected.	Provides inappropriate evidence (evidence does not support the claim selected or a counter claim).	Does not provide evidence

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	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Scientific Reasoning	Appropriately uses relevant science concepts to thoroughly evaluate the evidence provided and support the selected claim. Relevant science concepts can include disciplinary core ideas (e.g. food web, resources, competition) or crosscutting concepts (cause and effect or patterns). *e.g.* a student connecting the claim that farmlands should be converted back to grassland to evidence: "This evidence all shows that the conversion of grassland to farmland has had a negative effect on the deer population, because it has restricted their access to resources (food)."	Uses science concepts to evaluate the evidence provided to support the selected claim. May include some additional or inappropriate evidence and/or science concepts.	Uses inappropriate science concepts to evaluate the evidence provided.	Evaluates the evidence provided without mention of science concepts. For example, states evidence is good but does not explain why.	Does not evaluate the evidence.

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2b.

	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Counter-claim	N/A	Student writes a claim for the classmate that is not the same as the student's original claim.	Student attempts to write a claim that is not the same as the student's original claim, but the claim is either not clear or is not a true counter-claim	Student offers something other than a counter-claim	Student does not offer a counter-claim

2c.

	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Critique	Student identifies a problem with the claim, the evidence that would support that claim, or the reasoning connecting claim and evidence and offers full justification	Student identifies a problem with the counter-claim, the evidence that would support that claim, or the reasoning, but the critique or the justification is not clear	Student attempts to identify a problem with the counter-claim, but the critique is a surface-level critique without any justification	Student attempts to identify a problem with the counter-claim, but is not successful in identifying a problem or providing justification	Student does not offer a critique

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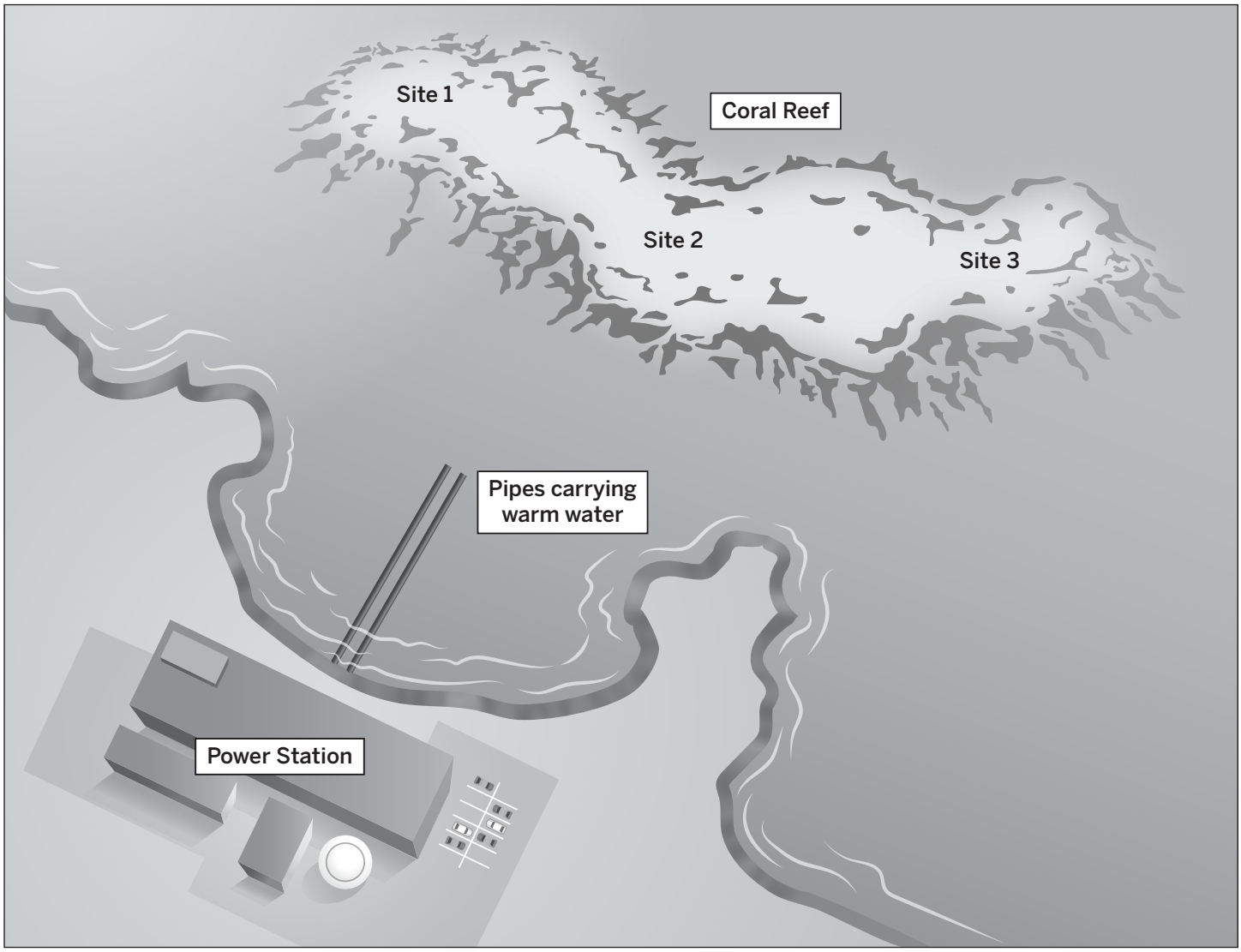
Name _____

Chapter 4 Assessment

1. There is a large coral reef off the coast of an island. Many organisms find food and live in and around the coral reef. The local energy company has built a new power station to meet the energy needs of the growing island population. The power station produces warm water that must be released. Pipes have been built to release warm, clean water into the ocean and 1 kilometer from the edge of the reef.

Algae are an invasive species that can be found near the reef. They use sunlight to make food. When large amounts of algae grow together they can form algal mats. These mats can float on the surface of the water. The mats can block sunlight from reaching the coral reef. Like the algae, coral needs sunlight to grow.

The data tables on pages 2 and 3 show data about water temperature and reef populations in the years following the construction of the power station.



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Chapter 4 Assessment

page 2

Name _____

Data from Site 1

Year	Water Temperature (°C)	Size of Coral Reef (square meters)	Size of Algal Mats (square meters)	Total Number of Species living at Site 1 (not including algae)	Estimated Number of Organisms living at Site 1 (not including algae)
1	28	98	0	21	1,200
2	28	97	0	21	1,200
3	31	81	10	19	1,100
4	32	75	15	18	1,000
5	32	71	17	18	900

Data from Site 2

Year	Water Temperature (°C)	Size of Coral Reef (square meters)	Size of Algal Mats (square meters)	Total Number of Species living at Site 2 (not including algae)	Estimated Number of Organisms living at Site 2 (not including algae)
1	28	100	0	20	1,300
2	28	101	0	20	1,300
3	31	83	10	19	1,200
4	31	78	15	18	1,100
5	32	71	20	17	1,000

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Chapter 4 Assessment

page 3

Name _____

Data from Site 3

Year	Water Temperature (°C)	Size of Coral Reef (square meters)	Size of Algal Mats (square meters)	Total Number of Species living at Site 3 (not including algae)	Estimated Number of Organisms living at Site 3 (not including algae)
1	28	99	0	22	1,250
2	28	99	0	22	1,300
3	29	98	0	22	1,250
4	28	98	0	22	1,300
5	29	98	0	22	1,250

1. Describe the changes that occurred at the three coral reef sites.

	Describe the changes (if any)
Site 1	
Site 2	
Site 3	

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Chapter 4 Assessment

page 4

Name _____

2a. Construct a scientific argument that answers the question:

"Did the power station cause large changes in the populations of organisms living on the coral reef?"

Your argument should include the following:

- The scientific question
- Your claim (which is best supported by evidence and reasoning)
- The relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

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2b. Imagine that you have a classmate who disagrees with your claim. What claim might your classmate make?

2c. What is the problem with your classmate's claim or the argument based on that claim?

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Chapter 4 Assessment Student Checklist

1. ☐ I have described changes to site 1

☐ I have described changes to site 2

☐ I have described changes to site 3

2. ☐ Claim

☐ Evidence (numbers or trends from graphs or tables)

☐ Reasoning

2b. ☐ I have written a claim that is different than my initial claim

2c. ☐ I have pointed out a problem with the hypothetical classmate's claim or argument

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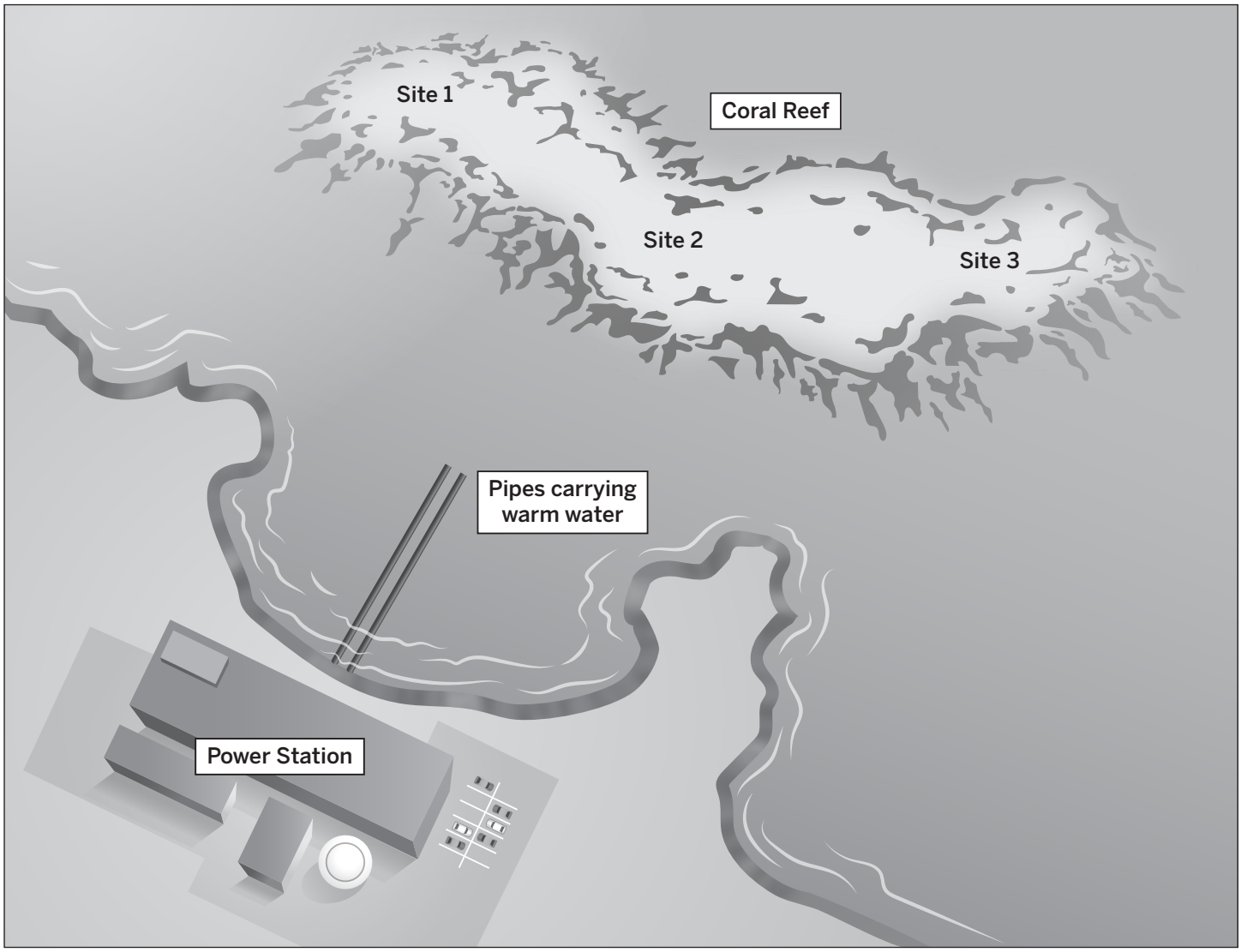
Name SAMPLE STUDENT RESPONSE

Chapter 4 Assessment

1. There is a large coral reef off the coast of an island. Many organisms find food and live in and around the coral reef. The local energy company has built a new power station to meet the energy needs of the growing island population. The power station produces warm water that must be released. Pipes have been built to release warm, clean water into the ocean and 1 kilometer from the edge of the reef.

Algae are an invasive species that can be found near the reef. They use sunlight to make food. When large amounts of algae grow together they can form algal mats. These mats can float on the surface of the water. The mats can block sunlight from reaching the coral reef. Like the algae, coral needs sunlight to grow.

The data tables on pages 2 and 3 show data about water temperature and reef populations in the years following the construction of the power station.



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page 2

Name SAMPLE STUDENT RESPONSE

Data from Site 1

Year	Water Temperature (°C)	Size of Coral Reef (square meters)	Size of Algal Mats (square meters)	Total Number of Species living at Site 1 (not including algae)	Estimated Number of Organisms living at Site 1 (not including algae)
1	28	98	0	21	1,200
2	28	97	0	21	1,200
3	31	81	10	19	1,100
4	32	75	15	18	1,000
5	32	71	17	18	900

Data from Site 2

Year	Water Temperature (°C)	Size of Coral Reef (square meters)	Size of Algal Mats (square meters)	Total Number of Species living at Site 2 (not including algae)	Estimated Number of Organisms living at Site 2 (not including algae)
1	28	100	0	20	1,300
2	28	101	0	20	1,300
3	31	83	10	19	1,200
4	31	78	15	18	1,100
5	32	71	20	17	1,000

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Chapter 4 Assessment

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Name *SAMPLE STUDENT RESPONSE*

Data from Site 3

Year	Water Temperature (°C)	Size of Coral Reef (square meters)	Size of Algal Mats (square meters)	Total Number of Species living at Site 3 (not including algae)	Estimated Number of Organisms living at Site 3 (not including algae)
1	28	99	0	22	1,250
2	28	99	0	22	1,300
3	29	98	0	22	1,250
4	28	98	0	22	1,300
5	29	98	0	22	1,250

1. Describe the changes that occurred at the three coral reef sites.

	Describe the changes (if any)
Site 1	*Site 1 experienced an increase in water temperature from 28 to 32 degrees C in those five years. During this time, the size of the coral reef decreased from 98 to 71 square meters. The algal mats increased from zero to 18 square meters. The number of species decreased from 21 to 18 and the estimated number of organisms decreased from 1,200 to 900.*
Site 2	*Site 2 experienced an increase in water temperature from 28 to 32 degrees C in those five years. During this time the size of the coral reef decreased by almost 30 meters, the size of the algal mats increased from zero to 20 square meters. The number of species decreased from 20 to 17 species and the estimated number of organisms deceased from 1,300 to 1,000.*
Site 3	*At Site 3 the change in temperature was not dramatic—it went between 28 and 29 degrees C during the five years. The coral reef did not significantly decrease in size and there was no growth of algal mats. The total number of species and organisms stayed constant.*

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Name *SAMPLE STUDENT RESPONSE*

2. Construct a scientific argument that answers the question:
"Did the power station cause large changes in the populations of organisms living on the coral reef?"

Your argument should include the following:
- The scientific question
- Your claim (which is best supported by evidence and reasoning)
- The relevant evidence that supports your claim
- Scientific reasoning that critiques the evidence and evaluates your claim

The question we are arguing is "Did the power station cause large changes in the populations of organisms living on the coral reef?" My claim is that the power station did cause large changes to populations in an ecosystem. The evidence that supports this claim comes from the coral reef sites that experienced a small change in water temperature. In those places (sites 1 and 2) the water temperature rose by 4° C. At site 3 the water temperature stayed about the same, just going up and down by 1° C. At sites 1 and 2, when the water temperature went up the size of the coral reefs went down by almost 30 square meters. The number of species and number of organisms also went down. At site 3 there was no real change in any of these numbers. Also, at sites 1 and 2 algal mats grew when the temperature went up. No algal mats grew at site 3.

My scientific reasoning is that the rise in water temperature caused the algal mats to grow. I know that algal mats and coral both need sunlight. The algal mats and coral are competing for sunlight. The algal mats have an advantage because they can block the sunlight from reaching the coral. Without enough sunlight the coral cannot grow as well. This would explain why the size of the coral reef decreases as the size of the algal mats increases. Having less coral will cause increased competition for food and space. This can cause the total population of organisms in and around the reef to be reduced. If organisms are competing for food and space, it is possible that some types of organisms will not survive or will be forced away from the reef. This can cause the total number of species to go down.

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Name *SAMPLE STUDENT RESPONSE*

2b. Imagine that you have a classmate who disagrees with your claim. What claim might your classmate make?

The power station did not cause large changes in the populations of organisms living on the coral reefs. Something else could have caused the changes besides the power station.

2c. What is the problem with your classmate's claim or the argument based on that claim?

The problem with this argument is that the main change on the coral reef was the power station and both sites that had a temperature changes had numbers of species that went down. The site that did not have a temperature change, did not have different numbers of species. This mean that the change in temperature was very likely the cause, and the change in temperature was a result of the power station.

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Scoring guide for Chapter 4 Assessment

1a. Describe the changes that occurred at the three coral reef sites.

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Student accurately describes all of the changes that occurred at Sites 1, 2 & 3, and includes specific references to the data tables: ● Sites 1 and 2 experienced an increase in water temperature from 28 to 32° C between years 3 and 5. ● During this time the size of the coral reef decreased by almost 30 square meters. ● Both of these sites with warm water saw a decrease in the number and types of organisms living there. ● Site 3 had no major change in water temperature. The size of the reef stayed the same at this site. The number of species and number of organisms stayed pretty constant at Site 3.	Student accurately describes *most* of the changes that occurred at Sites 1, 2, & 3: ● Sites 1 and 2 experienced an increase in water temperature. During this time the size of the coral reef decreased **OR** Both of these sites with warm water saw a decrease in the number and types of organisms living there. ● Site 3 had no change or extremely small changes.	Student vaguely or incompletely described the changes that occurred at the Sites. *e.g.* "The water temperature went up and the coral reefs went down"	Student minimally describes the changes at the Sites. *e.g.* "The water temperature changed"	Student does not describe the changes that occurred at the coral reef sites

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2. Construct an argument that answers the question, "Did the power station cause large changes to the populations of organisms living on the coral reef?

	Level 4: Proficient	Level 3: Advancing	Level 2: Developing	Level 1: Emerging	Level 0: Not evident
Claim	N/A	Claim answers the question completely. *e.g.* "The power stations caused large changes to the populations of organisms living on the reef" OR "The power station did not cause large changes to the populations of organisms living on the reef"	Claim partially answers the question.	Claim does not answer the question.	Does not make a claim.
Evidence	Provides appropriate evidence to support the claim. *e.g.* "The wastewater from the power station increased the temperature of the water surrounding the coral reef, especially at sites 1 and 2. At sites 1 and 2, when the water temperature went up, the size of the algal mats grew and the size of the coral reefs went down by almost 30 square meters. The number of species and number of organisms also went down." Or, for the alternative claim: "At Site 3, where there were only very small variation in temperature (e.g. an increase from 28 degrees Celsius to 29 degrees Celsius), there were no significant changes in the size of algal mats or the total number of species living at that site (it stayed at 22)."	Provides appropriate evidence to support the claim. May include some inappropriate evidence.	Provides evidence that actually supports a different claim, but not the one selected.	Provides inappropriate evidence (evidence does not support the claim selected or a counter claim).	Does not provide evidence.

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	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Scientific Reasoning	Appropriately uses relevant science concepts to thoroughly evaluate the evidence provided and support the selected claim. Relevant science concepts can include disciplinary core ideas (e.g. competition, interdependent relationships, food webs) or crosscutting concepts (e.g. stability and change, cause and effect, and/or patterns). e.g. "The reason why small changes in temperature caused by the power station caused such big changes in populations is because of competition for resources. The small change in water temperature made the algae grow just a little bit faster. However, the increased amount of algae made a big difference for the coral and other marine species, because the algae were very successful competitors for light and nutrients. Without light, the coral could not grow. And without coral, other marine species did not have a habitat."	Uses science concepts to evaluate the evidence provided to support the selected claim. May include some additional or inappropriate evidence and/or science concepts.	Uses inappropriate science concepts to evaluate the evidence provided.	Evaluates the evidence provided without mention of science concepts. For example, states evidence is good but does not explain why.	Does not evaluate the evidence.

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2b. Imagine that you have a classmate who disagrees with your claim. What claim might your classmate make?

	Level 4: Proficient	Level 3: Advancing	Level 2: Developing	Level 1: Emerging	Level 0: Not evident
Counter-claim	N/A	Writes a claim for the classmate that is not the same as the student's original claim.	Attempts to write a claim that is not the same as the student's original claim, but the claim is either not clear or is not a true counter-claim	Student offers something other than a counter-claim	Student does not offer a counter-claim

2c. What is the problem with your classmate's claim or the argument based on that claim?

	Level 4: Proficient	Level 3: Advancing	Level 2: Developing	Level 1: Emerging	Level 0: Not evident
Critique	Identifies a problem with the claim, the evidence that would support that claim, or the reasoning connecting claim and evidence and offers full justification	Student identifies a problem with the counter-claim, the evidence that would support that claim, or the reasoning, but the critique or the justification is not clear	Student attempts to identify a problem with the counter-claim, but the critique is a surface level critique without any justification	Student attempts to identify a problem with the counter-claim, but is not successful in identifying a problem or providing justification	Student does not offer a critique

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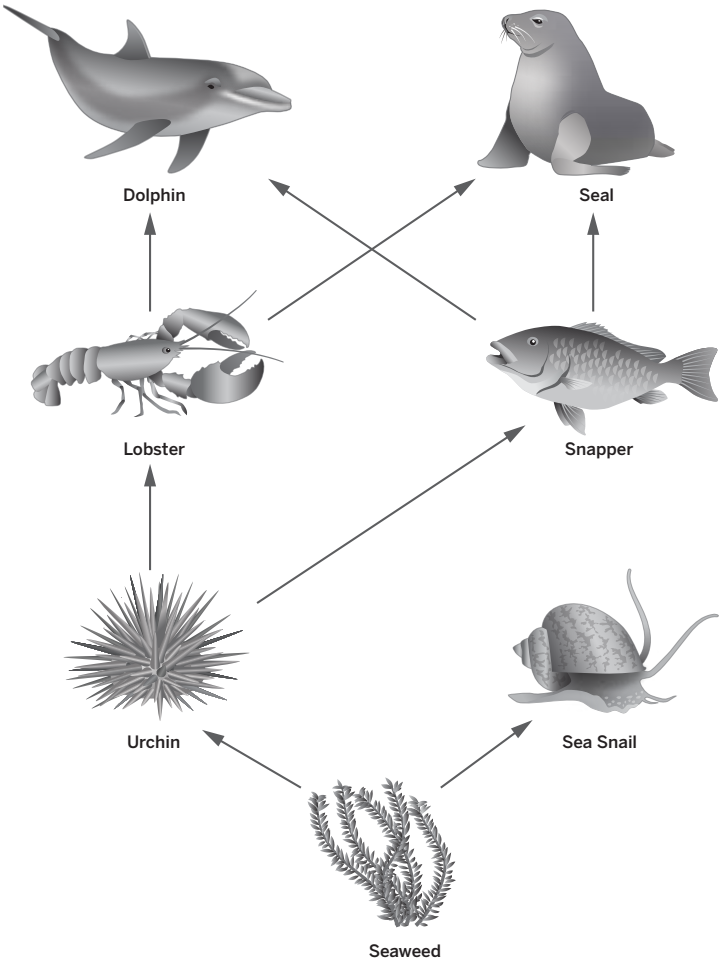
Name _____

Chapter 5 Assessment

1. Seaside City has been a popular vacation spot for the past 25 years. Each year more tourists visit and more people come to live there. A wide range of organisms can be found in the sea near the city. The following food web shows you the feeding relationships between some of these organisms. Seaweed also provides a safe environment for many types of organisms not shown on the food web below.

Visitors love to watch the seals and dolphins. Both tourists and residents enjoy eating lobster or snapper at local restaurants. However, the increasing human population has led to increased demand for lobster and snapper. The table below provides data about the sea near Seaside City. The data indicate that both species have become overfished.

Seaside City Food Web



Year	Number of species in the sea near Seaside City	Number of lobsters per 10 square meters	Number of snappers per 10 square meters	Number of sea urchins per 10 square meters	Percentage of the sea with seaweed
1990	325	5	5	10	50
1995	324	3	3	15	40
2000	320	2	2	20	30
2005	315	1	1	25	25
2010	305	1	0.5	30	20
2015	285	0.5	0.5	35	15

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Name _____

a. In 2015 the people of Seaside City decided that the changes in this ecosystem were a problem. Two solutions were proposed. A short list of criteria and constraints were also developed by Seaside City. You were selected as one of the team of scientists and engineers to examine the solutions.

Read the proposed solutions and **construct an argument that answers the question, "Which is the best proposed solution, based on the criteria, and why?"**

Proposed Solution A

The sea near Seaside City would become a protected area, where no fishing is allowed. The area would extend 5 km (about 3 miles) out to sea and around the city. The cost of creating the protected area would be 1.5 millions dollars. Scientists estimate that it will take at least 20 years for the numbers of lobsters and snappers to recover to the 1990 levels. It is estimated that 250 fishing jobs would be lost. However, it is believed that tourism will increase by 20% because of the protected area. As the number of tourists increases, new hotels could be built, creating more jobs. New businesses, such as boat trips for tourists and scuba diving, could also be developed. It is estimated that at least 100 new jobs would be created over the next 5 years. Scientists expect that the number of species in the protected area will take about 30 years to recover to the level that it was in the year 2000.

Proposed Solution B

Five hundred lobsters and one thousand snappers will be brought from other parts of the country. The cost of introducing the species would be $200,000. They will be added to the ocean near Seaside City. They are different, but related, species from the lobsters and snappers that are found near Seaside City. The introduced species are larger and grow more quickly than the existing species. Sales tax will be increased by 1% to cover the cost of the bringing in the new lobsters and snappers. Divers will be used to catch and remove at least fifty percent of the sea urchins. There will not be a total ban on fishing, but fishing boats will only be allowed to fish during one week each month. It is estimated that 50 fishing jobs would be lost. It is expected to take about 10 years for the area to recover to the level that it was in the year 2005. Tourism is expected to remain the same during that time.

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Chapter 5 Assessment

page 3

Name _____

Constraint: The solution must cost less than 2 million dollars.

Criteria:

1. Best recovery of the biodiversity of the ecosystem.

2. Lowest chance of introducing species that may become invasive.

3. Smallest number of job losses.

4. Shortest time for the ecosystem to recover.

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Name _____

b. Design your own solution. Explain why your solution is better than the solutions proposed by Seaside City.

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Name _____

Chapter 5 Assessment Student Checklist

1a. ☐ Claim

☐ Evidence (numbers or trends from proposed solutions)

☐ Reasoning

1b. ☐ New solution is proposed (needs to be different than initial solutions)

☐ Explains why solution is better than previous solution

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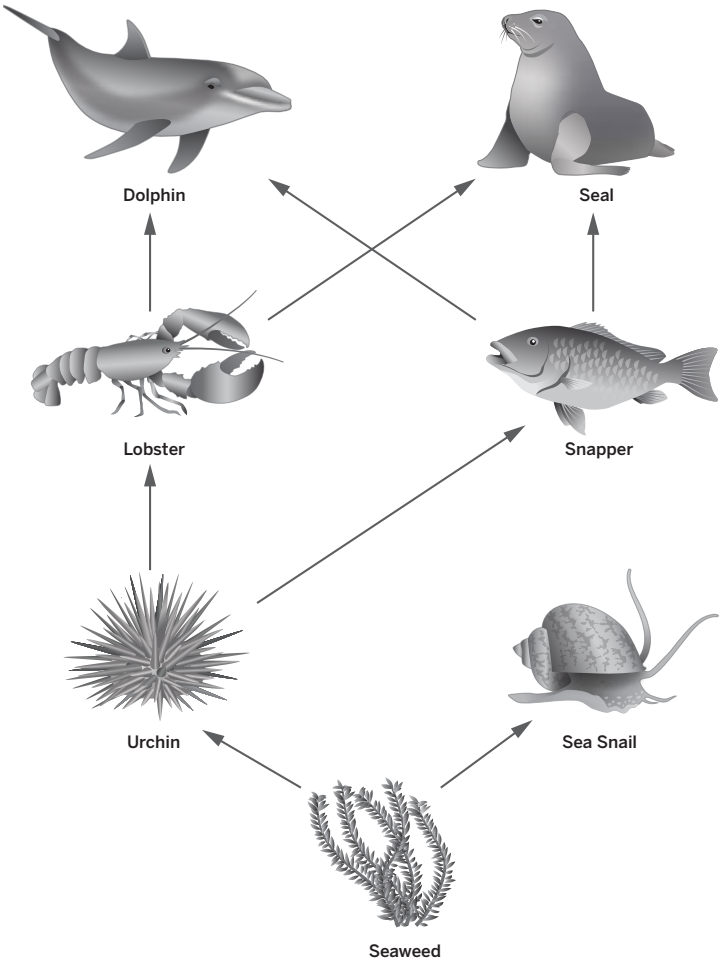
Name _____ SAMPLE STUDENT RESPONSE

Chapter 5 Assessment

1. Seaside City has been a popular vacation spot for the past 25 years. Each year more tourists visit and more people come to live there. A wide range of organisms can be found in the sea near the city. The following food web shows you the feeding relationships between some of these organisms. Seaweed also provides a safe environment for many types of organisms not shown on the food web below.

Visitors love to watch the seals and dolphins. Both tourists and residents enjoy eating lobster or snapper at local restaurants. However, the increasing human population has led to increased demand for lobster and snapper. The table below provides data about the sea near Seaside City. The data indicate that both species have become overfished.

Seaside City Food Web



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1990	325	5	5	10	50
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2000	320	2	2	20	30
2005	315	1	1	25	25
2010	305	1	0.5	30	20
2015	285	0.5	0.5	35	15

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Name SAMPLE STUDENT RESPONSE

a. In 2015 the people of Seaside City decided that the changes in this ecosystem were a problem. Two solutions were proposed. A short list of criteria and constraints were also developed by Seaside City. You were selected as one of the team of scientists and engineers to examine the solutions.

Read the proposed solutions and **construct an argument that answers the question, "Which is the best proposed solution, based on the criteria, and why?"**

Proposed Solution A

The sea near Seaside City would become a protected area, where no fishing is allowed. The area would extend 5 km (about 3 miles) out to sea and around the city. The cost of creating the protected area would be 1.5 millions dollars. Scientists estimate that it will take at least 20 years for the numbers of lobsters and snappers to recover to the 1990 levels. It is estimated that 250 fishing jobs would be lost. However, it is believed that tourism will increase by 20% because of the protected area. As the number of tourists increases, new hotels could be built, creating more jobs. New businesses, such as boat trips for tourists and scuba diving, could also be developed. It is estimated that at least 100 new jobs would be created over the next 5 years. Scientists expect that the number of species in the protected area will take about 30 years to recover to the level that it was in the year 2000.

Proposed Solution B

Five hundred lobsters and one thousand snappers will be brought from other parts of the country. The cost of introducing the species would be $200,000. They will be added to the ocean near Seaside City. They are different, but related, species from the lobsters and snappers that are found near Seaside City. The introduced species are larger and grow more quickly than the existing species. Sales tax will be increased by 1% to cover the cost of the bringing in the new lobsters and snappers. Divers will be used to catch and remove at least fifty percent of the sea urchins. There will not be a total ban on fishing, but fishing boats will only be allowed to fish during one week each month. It is estimated that 50 fishing jobs would be lost. It is expected to take about 10 years for the area to recover to the level that it was in the year 2005. Tourism is expected to remain the same during that time.

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Chapter 5 Assessment

page 3

Name SAMPLE STUDENT RESPONSE

Constraint: The solution must cost less than 2 million dollars.

Criteria:
1. Best recovery of the biodiversity of the ecosystem.
2. Lowest chance of introducing species that may become invasive.
3. Smallest number of job losses.
4. Shortest time for the ecosystem to recover.

I believe that proposal A is the best solution. Both proposals fall within the constraint of costing less than $2,000,000. Proposal A meets criteria 1 and 2 better than Proposal B. However, Proposal B meets criteria 3 and 4 better than Proposal A. Proposal A creates a protected area where no fishing is allowed. This is a good environmental solution and would allow the ecosystem to recover more fully than Proposal B, although it would take about 30 years to do so. Proposal B is a quicker solution as it involves importing 500 lobsters and 1,000 snappers. I think this could be a problem as these organisms are not native to the area and could affect populations of native species. They might even become invasive. It is therefore possible that the ecosystem will not recover well and may undergo more changes. This is why I believe that Proposal A is a better solution than Proposal B. The biggest problem with Proposal A is that more jobs will be lost than with Proposal B. It is estimated that 250 fishing jobs would be lost and 100 new jobs created because of increased tourism. This means that there would a loss of about 150 jobs compared to an estimated job loss of 50 fishing jobs with Proposal B. This would cause increased negative social and economic consequences compared to Proposal B. However, I believe that if the ecosystem changed because of the introduction of non-native species under Proposal B, there is a risk that there could be more job losses in future years. Therefore, I believe Proposal A is still the better choice.

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Name *SAMPLE STUDENT RESPONSE*

b. Design your own solution. Explain why your solution is better than the solutions proposed by Seaside City.

I think it is most important that the area fully recovers. I don't think it matters if it takes longer for it to recover, so I would remove criterion 4. I also think that criterion 1 is more important than 3. So I don't think the best solution has to be the one that has the fewest job losses.

I would modify Proposal A by making the protected area a little smaller and allowing limited fishing just outside the area. However, I would put limits on the amount of fish and lobsters that they can catch. Having the protected area will attract more tourists and this will create more jobs. Allowing limited fishing will reduce the number of fishing jobs that are lost. By maintaining ecosystem services such as tourism and fishing, this solution is better than Solution A from an economic and social perspective. This is also better than Solution B from an environmental perspective because it does not introduce any non-native species.

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Scoring guide for Chapter 5 Assessment

Note: The rubrics below are drafts. They are intended as guides for assessing whether your students are achieving learning goals. We encourage you to use a scoring system that works in your classroom context and that is appropriate for the level of your students. So, for example, students may be able to earn a "full credit" score for a "Level 2: Developing" response.

a. Construct an argument that answers the question, "Which is the best proposed solution, based on the criteria, and why?"

	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Claim	N/A	Claim completely answers the question *e.g.* "Proposal B best meets the criteria" OR "Proposal A best meets the criteria"	Claim partially answers the question	Claim does not answer the question	Does not make a claim
Evidence	Provides appropriate evidence to support the claim. *e.g.* Proposal B will remove at least 50% of the sea urchins using divers. 500 lobsters and 1,000 snappers will also be brought to the area from a different part of the country. These will eat more of the sea urchins. In addition fishing will be limited to one week per month. These measures will help the area to recover more quickly than in Proposal A. Also, proposal B produces less disruption to ecosystem services and 100 fewer people would lose their jobs than in Proposal A.	Provides appropriate evidence to support the claim. **May include some inappropriate evidence.**	Provides evidence that actually supports a different claim, but not the one selected.	Provides inappropriate evidence (evidence does not support the claim selected or a counter claim).	Does not provide evidence.

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	Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
Scientific Reasoning	Appropriately uses relevant science concepts to thoroughly evaluate the evidence provided and support the selected claim. Relevant science concepts can include disciplinary core ideas (e.g. ecosystem resilience and recovery, tradeoffs, biodiversity) or crosscutting concepts (e.g. stability and change). *e.g.* The better proposal will be the one that allows the ecosystem to recover without too much disruption to humans. The best balance of these factors is Proposal B. There is a possibility that the lobsters and snappers could be invasive, but the benefits outweigh the costs.	Uses science concepts to evaluate the evidence provided to support the selected claim. May include some additional or inappropriate evidence and/or science concepts.	Uses inappropriate science concepts to evaluate the evidence provided.	Evaluates the evidence provided without mention of science concepts. For example, states evidence is good but does not explain why.	Does not evaluate the evidence.

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b. Design your own solution. Explain why your solution is better than the solutions proposed by Seaside City."

Level 4: Advanced	Level 3: Proficient	Level 2: Developing	Level 1: Beginning	Level 0: Not evident
New solution has clear benefits over Proposal A or Proposal B *e.g.* I would modify Proposal A by making the protected area a little smaller and allowing limited fishing just outside the area. However, I would put limits on the amount of fish and lobsters that they can catch. Having the protected area will attract more tourists and this will create more jobs. Allowing limited fishing will reduce the number of fishing jobs that are lost. By maintaining ecosystem services such as tourism and fishing, this solution is better than Solution A from an economic and social perspective. This is also better than Solution B from an environmental perspective because it does not introduce any non-native species. I think it is most important that the area fully recovers. I don't think it matters if it takes longer for it to recover, so I would remove criterion 4. I also think that criterion 1 is more important than 3. So I don't think the best solution has to be the one that has the fewest job losses.	A new solution is proposed, but the benefits over Proposal A or Proposal are not clear	Student attempts to provide a new solution	Student restates a previous solution	Student does not provide a solution

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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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American Museum of Natural History

The Lawrence Hall of Science
University of California, Berkeley