DISCOVERY ENGINEERING IN BIOLOGY

Case Studies for Grades 6–12

REBECCA HITE • GINA CHILDERS
MEGAN ENNES • M. GAIL JONES

NSTApress
National Science Teaching Association

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This book is dedicated to all teachers and students who share a love of science and engineering.

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9

THE TRIUMPH OF THE PIKA

Understanding Environmental Impacts on Species

A Case Study Using the Discovery Engineering Process

Introduction

Climate change threatens the survival of many species, especially those that overheat in higher temperatures. This is particularly true of the pika (Figure 9.1, p. 180), an animal related to rabbits. This small, herbivorous (plant-eating) mammal lives in the mountains of the American West. Pika are known for being habitat specialists, meaning they can only survive in a narrow range of environmental conditions. (This is opposite from species that are generalists, which can survive in a wide range of environmental conditions.) Pika can easily overheat and are sensitive to changes in the environment. So, when a wildfire destroyed an entire forest, scientists were surprised to find that the pika population had survived. In uncovering the mystery of the pika's survival, the scientists learned valuable information about protecting wildlife in the face of climate change.

FIGURE 9.1

The American Pika

Lesson Objectives

By the end of this case study, you will be able to

- explore how species are impacted by human-influenced changes in the environment;
- examine and then model how change in the environment can alter species populations; and
- create an environmental assessment (EA) to evaluate the ecological impact of (proposed) human activity on a specific species in a specific location.

The Case

Read about research on the pika conducted by Dr. Johanna Varner and her colleagues. Their accidental observation of a wildfire while studying pika populations is helping to construct a better understanding of how wildfires affect species. This is extremely important, because scientists believe that wildfires will grow in both frequency and severity due to climate change. Once you are finished reading, answer the questions that follow.

In August 2011, ecologist Johanna Varner was conducting a field study on a pika population living in an Oregon gorge. Pika typically live in the mountains, not in gorges where the elevation is near sea level. Dr. Varner wanted to understand this unique population. They served as her experimental group. To have a basis of comparison, she also observed a second pika site at Mount Hood. This was her control group. Like most other pika, the Mount Hood population made dens in mountainside rock fields. As part of her observation, Dr. Varner installed temperature-recording devices in the pika's dens. In September, a sudden wildfire broke out at the Mount Hood site, seemingly ruining the experiment.

However, the wildfire led to a novel research opportunity. Natural disasters are on the rise, yet they remain hard to predict and, therefore, study. Science is based on careful and thoughtful design and observation, making investigating natural disasters as they are occurring very rare. But because Dr. Varner and her team already had an experiment set up at the wildfire site, they were in a unique position to study the disaster. And they realized that the wildfire could provide insight into the way such events affect wildlife. The researchers reconsidered their original plan and decided to focus their study on how the pika fared during the wildfire.

It soon became clear that the pika were still abundant at Mount Hood despite the fire. Dr. Varner and her team collected more data on the animals. They looked at the number of dens and the number of pika in each den, both before and after the fire. They also looked at temperature (or thermal) data from the temperature recorders, which had remained intact during the blaze. This gave them an idea of how hot the dens were before, during, and after the fire. They found the temperature in the dens did not rise above 64.4°F (18.5°C), although the fire outside exceeded 932°F (500°C). Varner and her research team found that the rock face provided a way to buffer the temperature, insulating the pika from the extreme heat. Also, the rock face provided a natural barrier to prevent the fire from moving throughout the forest, acting as a fire break. Another factor that allowed for pika survival is that, although these animals are habitat specialists, they are dietary generalists, meaning they can eat a variety of plants to survive. After a fire, the first plants that grow are mosses, which the pika are able to eat.

The results of Dr. Varner's study highlight the importance of maintaining natural features (like rock faces for pika dens) to provide refuges for sensitive species during natural disasters like wildfires. Also, it is important to maintain local, indigenous wildlife, so that after such events animal and plant species may rebound.

Recognize, Recall, and Reflect

1. In Dr. Varner's experiment, which pika population was the experimental group? Why? Which pika population was the control? Why?
2. Pika are described as habitat specialists, yet dietary generalists. What does this mean?
3. What were two recommendations made by the researchers to help sensitive species after natural disasters?

Investigate and Explain

Climate change poses a threat to many species. To better understand how wildlife populations like the pika may be affected by future warming trends, scientists make models that depict various outcomes. Figure 9.2 includes four maps. The first one, labeled Map A, shows current pika populations and the amount of suitable habitats available to them. The pika are shown as black spots; the suitable habitats are shown in light gray. Each consecutive map shows the amount of suitable pika habitats at different levels of warming: Map B shows low warming, Map C shows medium warming, and Map D shows high warming. For these maps, the suitable habitats are shown in dark gray. Current suitable habitat areas still appear on these maps in light gray for comparison. After examining the data, answer the questions that follow.

1. Look at Map A. In which two states do most of the observed pika (black spots) live? Why are there suitable pika habitat areas (light-gray areas) that don't actually have any pika?
2. As temperatures increase from low (Map B), to medium (Map C), to high (Map D), what is the general trend of the American pika's habitat (dark-gray areas)?
3. Look at Map D. In this scenario, what state would have the largest habitat range for the pika? Why do you think that geographic location would be the last refuge for the pika in the highest temperatures?

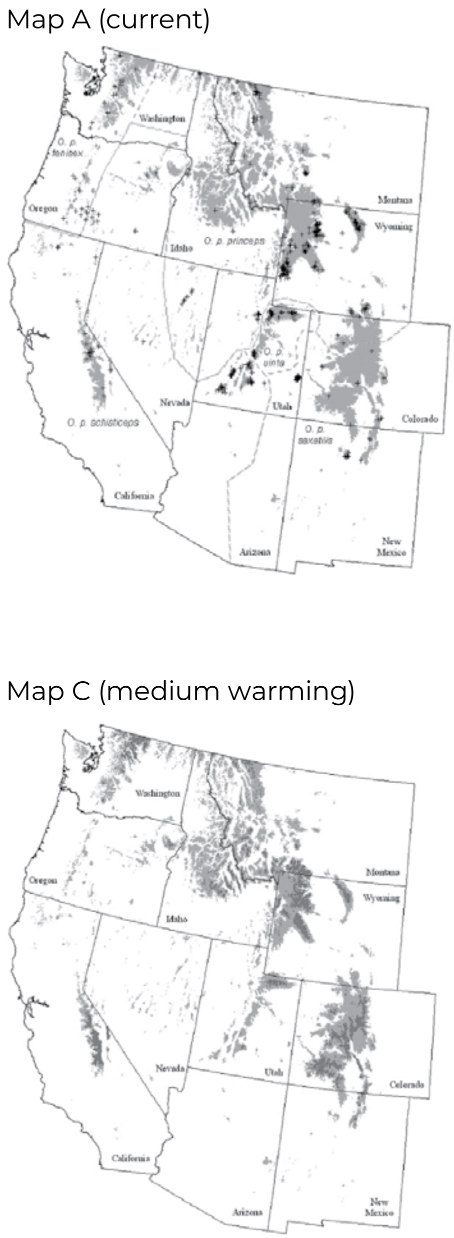
Activity

Imagine you work as a wildlife ecologist, researching how environmental changes can influence the entire population of a single species. You are studying one famous case that illustrates this phenomenon. In the second half of the 18th century, Europe was engaged in the Industrial Revolution, when factories began to dot the countryside. These factories churned out black dust (soot) that blanketed the nearby villages and forests, covering both trees and rocks.

Prior to the Industrial Revolution, the peppered moth population in England was mostly composed of a light-colored variety; a smaller number of the moths

FIGURE 9.2

Pika Habitats in Scenarios of Climate Change



+ Pika occurence
□ Current habitat
■ Habitat after warming

were a darker-colored (melanic) variety (Figure 9.3). The lighter moth's coloration worked as camouflage, allowing it to blend in with surroundings like trees and lichens in order to hide from predators such as birds. In the mid-1800s, several decades after the Industrial Revolution began, people noted that the light-colored moths had become fewer and fewer in number. Instead, people saw more of the darker variety resting on the trees and rocks.

FIGURE 9.3

Two Types of Peppered Moth

In the 1950s, Bernard Kettlewell conducted experiments to understand what had happened to these moths. He found that the change in the environment caused by the Industrial Revolution had influenced moth predation. During the Industrial Revolution, soot from factories darkened the forests. The darker surroundings caused the light-colored moths to stand out to predators. Because they were easier to hunt, light-colored moths often didn't live long enough to reproduce. Meanwhile, the darker-colored moths were able to camouflage themselves better in the now-dark environment, which allowed them to live longer, mate, and pass on their genes for dark color to their offspring. This, in turn, shifted the peppered moth populations from the lighter phenotype, or appearance, to the darker phenotype.

To understand how this occurs, you will explore data on phenotypes of peppered moth populations in 19th-century England. You will conduct a two-part ecological investigation in which you explore the change in the physical appearance of peppered moths, and then create a model to examine how environmental changes can influence populations of species.

Part I

To begin your ecological study, you analyze data from 1860 (several decades after the start of the Industrial Revolution), which was collected during a random sampling of peppered moths from all over England. The summary of that data is in Table 9.1. After completing this part of the activity, answer the questions that follow.

(*Note:* These are mock statistics that reflect the type of frequency differences you might have found in areas of England affected by pollution from the Industrial Revolution. These are not data points that were actually collected.)

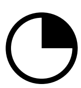
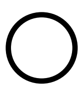
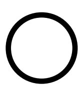
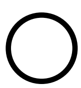
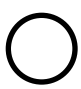
TABLE 9.1

Ecological Survey Data of Light and Dark Peppered Moths in 1860s England

Sampling Location #	Location in England	Distance to Closest Factory	Number of Light-Colored Moths Observed	Number of Dark-Colored Moths Observed	Total Number of Moths Observed
1	Northwest England and Ireland	8 km to 10 km	698	228	926
2	Northeast England and Scotland	More than 20 km	923	22	945
3	Central England	Less than 1 km	18	928	946
4	Southwest England	More than 10 km	840	92	932
5	Southeast England	2 km to 5 km	280	641	921

ACTIVITY QUESTIONS, PART I

1. You will now create a pie chart map of your data. Follow the steps below.
   a. Calculate the percentage of each moth per sampling area in the chart below. (The first one has been done for you.)
   b. Use the calculations to create a pie chart for each sampling area. (The first one has been done for you.)

Sampling Location #	Percent Light-Colored Moths	Percent Dark-Colored Moths	Pie Chart	Geographic Location
1	698/926 = 0.754 0.75 × 100 = 75%	228/926 = 0.246 0.25 × 100 = 25%		Northwest England and Ireland
2				
3				
4				
5				

c. Plot your data to the correct geographic area on this outline map of England.

2. In which regions are light-colored moths most prevalent? In which regions are dark-colored moths most prevalent? How does distance from a factory affect the prevalence of each moth variety?

Part II

Next, you will model how a sudden change in the environment can indirectly influence wildlife populations. Once you're done, answer the questions that follow.

MATERIALS

- ✓ 5 pieces of 8.5 × 11 in. construction paper, one of each color: green, black, yellow, white, and red
- ✓ 2 pieces of 8.5 × 11 in. patterned paper or fabric
- ✓ 1 bag of green, black, yellow, white, and red paper dots (at least 50 in all, 10 of each color)
- ✓ 1 pair of tweezers (to capture dots)

In this modeling activity, you will be a predator that is hunting paper dots for food. The dots are your prey, the sheets of paper are different environments. Follow these steps:

1. First, place down a piece of green construction paper (Trial 1).
2. Then, dump the dots from the bag onto the paper and spread them out.
3. Close your eyes. When you open them, quickly pick up the dot that stands out the most.
4. Once you have picked up your dot, put it back into the bag.
5. Repeat Steps 2 through 4 until about half (25 or so) of the dots are left.
6. Count up the number of dots that you snagged by color, recording the data in the Paper Dot Hunting Chart. Then, add up the data in each row.
7. Put all 50 of the dots back into the bag.
8. Repeat Steps 1 to 7 but with the next "environment," or sheet of paper (Trials 2 through 7).

Paper Dot Hunting Chart

Environment (Paper Color)	Prey A (Green Dots)	Prey B (Black Dots)	Prey C (Yellow Dots)	Prey D (White Dots)	Prey E (Red Dots)	Total Caught
Trial 1: Green						
Trial 2: Black						
Trial 3: Yellow						
Trial 4: White						
Trial 5: Red						
Trial 6: Pattern 1						
Trial 7: Pattern 2						

ACTIVITY QUESTIONS, PART II

1. In this modeling activity, what were the relationships between totals (frequencies) of prey (dot colors) to their environment (paper colors)?
   a. When was the prey the easiest to see?
   b. When was the prey most difficult to see?
   c. How does the environment affect the traits that are common in a population?

Apply and Analyze

Read this short article from Carolina Biological about using a technique called *mark-release-recapture* (MRR) to determine populations of freshwater turtles: *http://classroom.jc-schools.net/coleytech/climate/Carolina%20Tips.pdf*. After reading, answer the questions that follow.

1. Imagine you were conducting an MRR study of the Mexican spider monkey, a critically endangered species. (According to the International Union for Conservation of Nature, a critically endangered species is defined as having an extreme risk of extinction in the wild.) You are able to mark 75 monkeys (categorized as Marked, or M) and release them back into their habitat. When you return, you capture 75 monkeys and note that 45 are recaptures (categorized as Recaptures, or R) and 30 are not marked (categorized as Unmarked, or U). Using this equation ($X = [(U + R)/R]M$),

what is the total number (X) of monkeys you estimate to be in the wild population? Show your work: X = _____________

2. The Mexican spider monkey is one of five subspecies of the Geoffroy's spider monkey species. The other subspecies are the Nicaraguan spider monkey, the hooded spider monkey, the ornate spider monkey, and the Yucatán spider monkey. It is important during MRR studies that the correct species or subspecies is captured, marked, recaptured, and counted. What are three ways you would ensure that you and your research team are marking and recapturing the correct monkeys?

   1. ____
   2. ____
   3. ____

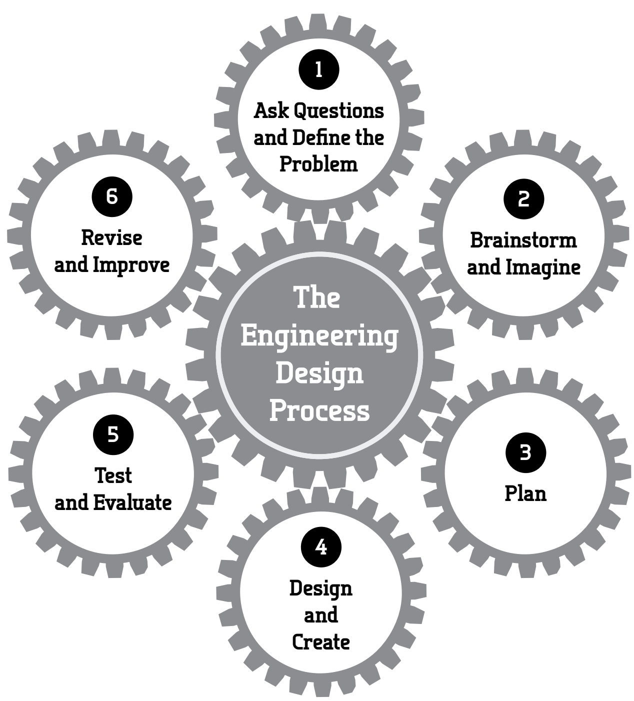
Design Challenge

The case study in this lesson illustrates how scientific observations can lead to potential solutions to problems. Observations and discoveries often spark innovations, especially in the field of engineering. Engineering is the application of scientific understanding through creativity, imagination, and the designing and building of new materials to address and solve problems in the real world. You will be asked to take the science you have learned in this case and design a process or product to address a real-world issue.

Engineers use the engineering design process (Figure 9.4) as steps to address a real-world problem. Environmental engineers provide information for environmental assessments (EAs). Now, you will use the engineering design process to create your own EA. In this case, you are asking questions (Step 1) about species that are threatened or endangered by climate change or other environmental changes. You will then learn about the components of an EA and brainstorm

FIGURE 9.4

The Engineering Design Process



(Step 2) a topic for your own EA—a proposed activity in your community that may affect threatened or endangered local species. After gathering research, you will make a plan (Step 3) for your EA. Then, you will create (Step 4) your EA. Afterward, a peer will evaluate (Step 5) your EA and provide feedback. Finally, you will consider improvements (Step 6) to your EA based on the feedback.

1. Ask Questions

The pika is just one animal species that is threatened by climate change and other environmental issues. What are some other plants and animals that are threatened or endangered? What actions and activities are harming them?

2. Brainstorm and Imagine

An EA outlines the positive and negative environmental effects of a proposed action (usually, an action taken to benefit people). The EA is supposed to (1) demonstrate the need for a human action, (2) consider how that human action would impact the environment, and (3) develop ways to mitigate (or reduce) unintended impacts to endangered or threatened animal or plant species. Examples of proposed actions may include the following:

- Industry: siting and constructing a new factory, farm, business, etc.
- Energy: siting and constructing a new energy source (wind farm, nuclear power plant, etc.)
- Transportation Infrastructure: siting and constructing a new road, bridge, railroad, airport, etc.
- Development: siting and developing land for a subdivision, park, nature refuge, etc.

Think about something your town, city, or county might need to do in order to grow or recover economically or environmentally. Which of the examples listed above are the most relevant in your local context? Conduct some research on your town, city, and county websites to find out what the needs are in your community. Discuss your thoughts and ideas with your classmates.

Choose one action that your city, town, or county might take in order to meet a need. Look at the Environmental Assessment Components section. Think about what information you'll need to create your EA. Keep this in mind (and refer back to the EA description) as you conduct research on your chosen action in Step 3.

Environmental Assessment Components

EAs contain the following five parts: introduction, purpose, need, alternatives, and environmental impacts.

1. **Introduction.** The introduction should include a brief, one-paragraph description of the project background. Include a summary of the need for human action.
2. **Purpose.** The purpose is a statement of the proposed human action and two to three of its objectives. The purpose should be general in nature, whereas objectives are more specific to the actual location of the project. For example, a purpose could be to "put a new park in town." One objective could then be to "find what lots are available for that park."
3. **Need.** Identifying and explaining the need is critical in an EA. The need is the specific problem the project is intended to address. The need should be specific and stated as a problem, not a solution. The need should be described in a manner that allows for multiple ways of addressing the problem. The need should not be defined by the proposed action.
    - Example 1: The need is not "to build a dam" but rather "to control flooding and prevent future flood damages and losses."
    - Example 2: The need is not "to build a 300-foot communications tower" but rather "to improve public safety and interoperable communications among first responders during an emergency event."
4. **Alternatives.** There should be some discussion of various alternatives to justify the EA.
    - No Action Alternative: This is what will happen if no action is taken or this proposed idea does not happen.
    - Action Alternatives: If this course of action is not taken, what are other courses of action? If the proposed project cannot happen, how else could the need be met?
5. **Affected Environment and Potential Impacts on a Single Animal or Plant Species.** In this section, describe the physical setting where the action will take place and give information on the existing environment for a species of concern. Then, discuss how that species may be affected by the proposed action and alternatives.

(Continued)

- Potential effects to the environment (e.g., ecosystem, climate)
- Describe how that environmental change may have potential impacts to your chosen plant and/or animal species (e.g., impacts on threatened or endangered status, habitat, food resources)

Example of an EA Topic

Texas is a very large state. With a land area of 268,597 square miles and almost 30 million people, transporting people from town to town is a serious need. Several times a week, more than 50,000 Texans travel back and forth between Houston and Dallas/Fort Worth. A high-speed rail system could help connect people from the southern part of the state (Houston) to northern parts of the state (Dallas/Fort Worth) in 90 minutes, helping to reduce road traffic and conserving gasoline and productive time lost to commuting.

However, where to locate the rail is important, as the 240-mile route may impact ecosystems and wildlife. Therefore, an ecological study was conducted to determine how wildlife may be affected. One concern is for the whooping crane, an endangered bird that migrates along the proposed high-speed rail route. The rail system may take away needed habitat and resources for the crane, driving it toward extinction. Therefore, the rail will avoid locating near or along major bodies of water (salt marshes and wetlands) where whooping cranes live and travel.

Alternatives are too costly (air travel) or take too long (automobile). High-speed rail also produces less carbon dioxide (CO_2) than airplanes and cars. It will also reduce cars on the road, which could reduce deaths by motor vehicles. If there is no action, Texans will lose jobs and economic gains.

3. Create a Plan

Conduct research on your chosen action in order to gather the information you will need to write your EA. Then create a plan for your EA. In your plan, make sure to (1) identify the community you want to work with, (2) describe one need of that community (either in industry, energy, transportation, or development), (3) identify the action that could be taken to meet that need, and (4) summarize the effects of that action on the environment. Use the Create a Plan graphic organizer (p. 193) for guidance.

4. Design and Create

Write your EA in these five parts: introduction, purpose, need, alternatives, and environmental impacts. Remember to reflect on the following questions:

- How does this action potentially affect the environment?
- What is an endangered or threatened species that would be affected?
- What are alternatives to this action?
- What happens if no action is taken?

5. Test and Evaluate

Share your EA with a peer for feedback. Ask for an evaluation of your work and consider ways your EA could be clearer. Have you made the best case for your EA?

6. Revise and Improve

Revise and make improvements to your EA based on feedback from your classmate. What are some ways you can use the input to refine your plan? You may choose to accept all or only some of the feedback. Be sure to justify your reasoning for using or not taking suggestions.

Create a Plan

What is the community you chose?

____

____

____

Describe one need of this community. Then summarize an action that could be taken to address this need.

Industry Need	Energy Need	Transportation Need	Development Need

Action to Meet Need	Action to Meet Need	Action to Meet Need	Action to Meet Need

Summarize the environmental effects of your chosen action.

____

____

____

TEACHER NOTES

THE TRIUMPH OF THE PIKA

UNDERSTANDING ENVIRONMENTAL IMPACTS ON SPECIES

A Case Study Using the Discovery Engineering Process

Lesson Overview

In this lesson, students explore the impact of environmental change on wildlife. The case study focuses on the pika, a mammal related to the rabbit. Although pika are very sensitive to heat, a group of them were able to survive a wildfire. A team of ecologists who happened to be using the animals as a control group in an experiment were able to figure out that they survived by using available natural resources as a buffer against the fire. Students will use data and maps to understand how environmental changes (including climate change) impact endangered and threatened species. They will also create a model to illustrate the effects of environmental change, using data on peppered moths from 19th-century England. Last, students will create environmental assessments (EAs) to evaluate an action taken in their community to meet a human need. In their EAs, they will evaluate the potential impacts of the action on local endangered or threatened species.

Lesson Objectives

By the end of this case study, students will be able to

- explore how species are impacted by human-influenced changes in the environment;
- examine and then model how change in the environment can alter species populations; and
- create an EA to evaluate the ecological impact of (proposed) human activity on a specific species in a specific location.

Use of the Case

Due to the nature of these case studies, teachers may elect to use any section of each case for their instructional needs. They are sequenced in order (scaffolded) so students think more deeply about the science involved in the case and develop an understanding of engineering in the context of science.

Curriculum Connections

Lesson Integration

This lesson may be taught during a unit on ecology and population dynamics for beginner biology courses. This lesson fits well into topics related to natural selection and human impacts on the environment.

Related Next Generation Science Standards

PERFORMANCE EXPECTATIONS

- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity

SCIENCE AND ENGINEERING PRACTICES

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying out Investigations
- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Engaging in Argument From Evidence

CROSSCUTTING CONCEPTS

- Cause and Effect
- Systems and System Models
- Stability and Change

Related National Academy of Engineering Grand Challenges

- Restore and Improve Urban Infrastructure
- Develop Carbon Sequestration Methods
- Engineer the Tools of Scientific Discovery

Lesson Preparation

Before starting the lesson, it is helpful for students to have some understanding of human impacts on the environment, climate, and natural selection. Review the concepts of a controlled experiment and ecological succession before beginning the lesson so students can understand how scientists support what they know about climate change. Also review how to interpret data from maps and analyze layered data.

You will need to make copies of the entire student section for the class. Students will need internet access at various points in the lesson. Alternatively, you can project videos or print and distribute copies of online content for the class. Look at the Teaching Organizer (Table 9.2) for suggestions on how to organize the lesson.

For the Activity section, we suggest using green, black, yellow, white, and red construction paper. For the patterned pieces of paper or fabric, choose ones that have many of the same colors as the construction paper. Students can work in pairs. Each group will need five sheets of construction paper (one of each color), two patterned sheets of paper or fabric, and one bag of green, black, yellow, white, and red dots. Use a hole punch to create the dots. Groups will need 10 dots of each color. So for a class of 30 in which you would have 15 groups of two, punch out 150 dots per color. Place 10 dots of each color into a resealable bag for each group.

Materials

Per group

- ✓ 5 pieces of 8.5 × 11 in. construction paper, one of each color: green, black, yellow, white, and red
- ✓ 2 pieces of 8.5 × 11 in. patterned paper or fabric
- ✓ 1 bag of green, black, yellow, white, and red paper dots (at least 50 in all, 10 of each color)
- ✓ 1 pair of tweezers (to capture dots)

Time Needed

Up to 115 minutes

TABLE 9.2

Teaching Organizer

Section	Time Suggested	Materials Needed	Additional Considerations
The Case	10 minutes	Student pages	Activity done individually in class or as homework prior to class
Investigate and Explain	10 minutes	Student pages	Activity done individually or in pairs
Activity	20 minutes	Student pages; 5 pieces of 8.5 × 11 in. construction paper (one of each color: green, black, yellow, white, and red); 2 pieces of 8.5 × 11 in. patterned paper or fabric; 1 bag of green, black, yellow, white, and red paper dots (at least 50 in all, 10 of each color); 1 pair of tweezers (to capture dots)	Activity done individually or in pairs
Apply and Analyze	10–15 minutes	Student pages, internet access	Individual activity
Design Challenge	45–60 minutes	Student pages, internet access	Small-group activity

Vocabulary

- camouflage
- climate change
- control group
- dens
- ecologist
- endangered
- environmental assessment
- experimental group
- extinct
- dietary generalists
- dietary specialists
- habitat specialists
- habitat generalists
- herbivorous
- indigenous
- insulated
- introduced
- invasive
- mammal
- mark-release-recapture
- melanic (melanin)
- phenotype
- pika
- population
- species
- wildlife

Extensions

- The Activity section can be expanded to further explore population dynamics. Tell students that when they "prey" on their dots, the dots that "survive" can go on to "reproduce." After each round in a trial, students can add three more dots of the same colors that have survived to represent the offspring with the same traits as the surviving parent. You can elect to have students time their rounds with a stopwatch to keep up the pace of the activity.
- The Apply and Analyze section can be extended by modeling population size estimation (*www.learner.org/jnorth/tm/monarch/EstimateMRR.html*). This activity requires minimal materials, and students will garner a better understanding of the MRR method.
- The Design Challenge can be extended into an environmental impact assessment, or EIA (*https://link.springer.com/referenceworkentry/10.1007%2F1-4020-4494-1_117*). The EIA expands upon an EA with more information into the mitigation strategies discussed in the EA.

Assessment

Use the Teacher Answer Key to check the answers to section questions. You can evaluate the students' EAs to assess the Design Challenge. Their EAs should be divided into five parts: introduction, purpose, need, alternatives, and environmental impacts. The students should include all the information requested in the Environmental Assessment Components template on page 190. In their EAs, students should identify an action that might be taken in their community to address a human need. They should include research on how that specific action may impact a threatened or endangered species within an environmental context. During the Design Challenge, students should also be able to provide constructive peer reviews on classmates' EAs and incorporate the feedback of others into their own EAs.

Teacher Answer Key

Recognize, Recall, and Reflect

1. **In Dr. Varner's experiment, which pika population was the experimental group? Why? Which pika population was the control? Why?**

   Experimental Group: Pika living in the gorge. Pika normally only live in the mountains, so it is strange to find a pika population at sea level. Control Group: Pika living on Mount Hood. This is because Pika normally only live in the mountains, so it is a "normal" group for comparison.

2. **Pika are described as habitat specialists, yet dietary generalists. What does this mean?**

   Pika can only live in a narrow range of environmental conditions (i.e., only in mountain areas, cool temperatures). This makes them habitat specialists. However, they can eat a wide variety of plants, making them dietary generalists.

3. **What were two recommendations made by the researchers to help sensitive species after natural disasters?**

   First recommendation: Maintain natural features like rock faces to provide refuges for sensitive species during natural disasters like wildfires. Second recommendation: Maintain local, indigenous wildlife so that after a natural disaster, animal and plant species may rebound.

Investigate and Explain

1. **Look at Map A. In which two states do most of the observed pika (black spots) live? Why are there suitable pika habitat areas (light-gray areas) that don't actually have any pika?**

   Utah and Wyoming. The black spots represent locations where pika populations have been observed in the wild. Habitat areas are places that could support the pika, but that does not mean pika actually live there.

2. **What is the general trend of the American pika's habitat (dark-gray areas) as temperature increases from low (Map B), to medium (Map C), to high (Map D)?**

   As temperature increases, the habitats available for the pika decrease.

3. **As temperatures increase from low (Map B), to medium (Map C), to high (Map D), what is the general trend of the American pika's habitat (dark-gray areas)?**

   California. Student answers may vary. They could hypothesize that California has more protected areas or rock faces that provide thermal buffers (mentioned in the case study) to protect the pika. California also has stricter government regulations that may help protect vulnerable species.

Activity Questions, Part I

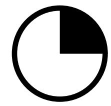
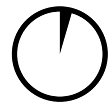
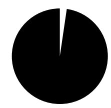
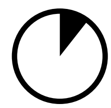
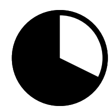
1. **Visualize the data so you can begin to draw conclusions. Create a pie chart using the outline of England. The first location has been done for you.**

   a. **Calculate the percentage of each moth per sampling area.**

   b. **Use the calculations to create a pie chart for each sampling area.**

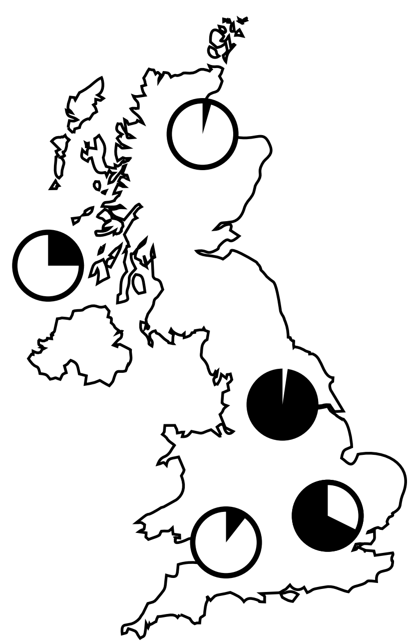
   c. **Plot your data to the correct geographic area on the map of England provided.**

      The key to the chart and map are shown on the following page.

Sampling Location #	Percent Light-Colored moths	Percent Dark-Colored Moths	Pie Chart	Geographic Location
1	*698/926 = 0.754* *0.75 × 100 = 75%*	*228/926 = 0.246* *0.25 × 100 = 25%*		*Northwest England and Ireland*
2	*923/945 = 0.977* *0.98 × 100 = 98%*	*22/945 = 0.023* *0.02 × 100 = 2%*		*Northeast England and Scotland*
3	*18/946 = 0.019* *0.02 × 100 = 2%*	*928/946 = 0.981* *0.98 × 100 = 98%*		*Central England*
4	*840/932 = 0.901* *0.90 × 100 = 90%*	*92/932 = 0.098* *0.10 × 100 = 10%*		*Southwest England*
5	*280/921 = 0.304* *0.30 × 100 = 30%*	*641/921 = 0.695* *0.70 × 100 = 70%*		*Southeast England*

2. **In which regions are light-colored moths most prevalent? In which regions are dark-colored moths most prevalent? How does distance from a factory affect the prevalence of each moth variety?**

   Student answers may vary but should relate these concepts from the data: The melanic moth phenotype is most prevalent in Central and Southeastern England. The prevalence of melanic moths increases with proximity to a factory.



Activity Questions, Part II

1. **In this modeling activity, what were the relationships between totals (frequencies) of prey (dot colors) to their environment (paper colors)?**

   Students' answers may vary but should relate the following concepts from the data.

   a. **When was the prey the easiest to see?**

      When the color of the prey contrasted with the environment, meaning the prey was not camouflaged.

   b. **When was the prey most difficult to see?**

      When the color of the prey was the same as the environment, meaning the prey was camouflaged.

   c. **How does the environment affect the traits that are common in a population?**

      Individuals in the population that are most noticeable to predators (not camouflaged to the environment) are eaten. Those that are eaten do not reproduce and pass on their traits (demonstrated as phenotypes) to the next generation. Therefore, the population's traits will shift to those that can survive predation (and reproduce) by being best to the environment adapted (camouflaged, and therefore able to avoid predators).

Apply and Analyze

1. **Imagine you were conducting an MRR study of the Mexican spider monkey, a critically endangered species. (According to the International Union for Conservation of Nature, a critically endangered species is defined as having an extreme risk of extinction in the wild. You are able to mark 75 monkeys (categorized as Marked, or M) and release them back into their habitat. When you return, you capture 75 monkeys and note that 45 are recaptures (categorized as Recaptures, or R) and 30 are not marked (categorized as Unmarked, or U). Using this equation ($X = [(U + R)/R]M$), what is the total number (X) of monkeys you estimate to be in the wild population? Show your work:**

   $X = 125 = [(30 + 45)/45]75)$

2. **The Mexican spider monkey is one of five subspecies of the Geoffroy's spider monkey species. The other subspecies are the Nicaraguan spider monkey, the hooded spider monkey, the ornate spider monkey, and the Yucatán spider monkey. It is important that during MRR studies that the correct species or subspecies is being captured, marked, recaptured, and counted.**

What are three ways you would ensure that you and your research team are marking and recapturing the correct monkeys?

Students' answers may vary but should be aligned to methods delineated in the article to reduce human sampling error in ecological fieldwork. Here are some examples:

- *Making a close examination of field marks to ensure the animal is the correct subspecies*
- *Ensuring that the MMR occurs in the exact habitat of the subspecies*
- *Using appropriate trapping techniques*
- *Differentiating between adults and juveniles*
- *Accounting for male and female sex differences*

Resources and References

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Note: Page references in **boldface** indicate information contained in figures or tables.

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