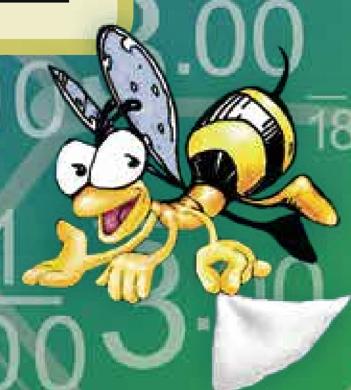
Natural Inquirer

Number 17

The Scientific Models in Adaptive Management Edition

What's Inside



Natural Inquirer

Scientific Models in Adaptive Management Edition • Number 17 • 2014

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Contents

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These resources can be found with the "Scientific Models in Adaptive Management" journal and on the "Educational Resources" pages:

- Note to Educators
- Lesson Plan
- Reflection Section Answer Guide
- National Education Standards (specific to each article), including:
  - National Science Education Standards
  - National Curriculum Standards for Social Studies
  - Common Core State Standards
  - Next Generation Science Standards

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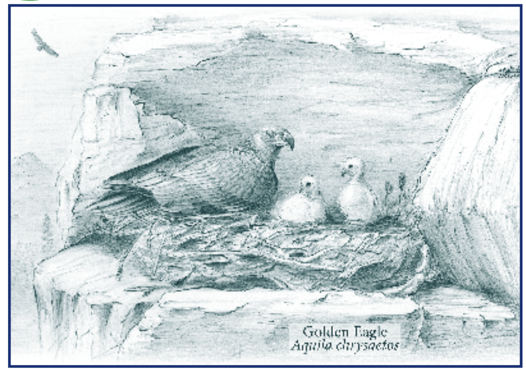

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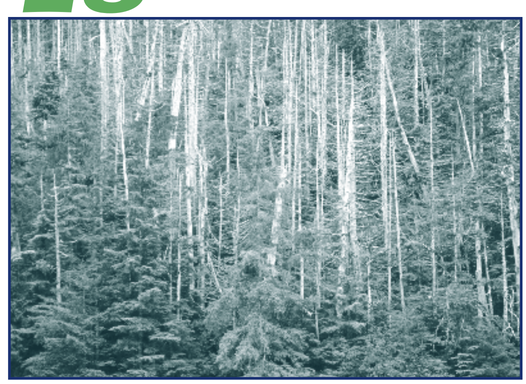


Editorial Review Boards

Natural Inquirer **editorial review boards hard at work.**

Editorial Review Boards' Comments

I learned how to use adaptive management.

Maybe they could include more fun facts to keep more interest.

I learned how quickly our environment can change.

I learned not to use too much of the ecosystem services provided.

I learned about the importance of adaptive management and how managers can help preserve nature. I also learned that anyone can get involved.

I learned that many cedars are dying and we need to help them.

Condense the article.

It looks pretty good. You could put the cover photo courtesy on the inside of the cover.

Exchange the word "illustration" for the figure number.

The compass rose needs to be a little sharper.

I think the article is perfectly fine in my opinion.

About Natural Inquirer

Scientists report their research in journals, which are special booklets that enable scientists to share information with one another. This journal, *Natural Inquirer*, was created so that scientists can share their research with you and with other middle school students. This journal presents the research of scientists with the U.S. Geological Survey and the Forest Service. The U.S. Geological Survey is an agency of the U.S. Department of the Interior. The Forest Service is an agency of the U.S. Department of Agriculture. If you want to know more about the U.S. Geological Survey or the Forest Service, you can read about them on the inside back cover of this journal, or you can visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org. Information is also available at http://www.fs.fed.us and http://www.usgs.gov.

All of the research in *Natural Inquirer* is concerned with nature, such as trees, forests, animals, insects, outdoor activities, and water. First, you will "meet the scientists" who conducted the research. Then, you will read something special about science and about the natural environment. You will also read about a specific research project, which is written in the format that scientists use when they publish their research in journals. Then, YOU will become the scientist when you conduct the FACTivity associated with each article. Don't forget to look at the glossary and the special sections highlighted in each article. Be sure to try the Word Search and Photo Challenge on pages 61 and 62!

At the end of each section of the article, you will find a few questions to help you think about what you have read. Your teacher may use these questions in a class discussion.

Who Are Scientists?

Scientists are people who collect and evaluate information about a wide range of topics. Some scientists study the natural environment. To be a successful scientist, you must:

- **Be curious**—Are you interested in learning?
- **Be enthusiastic**—Are you excited about a particular topic?
- **Be careful**—Are you accurate in everything you do?
- **Be open-minded**—Are you willing to listen to new ideas?
- **Question everything**—Do you think about what you read and observe?

Welcome

to the Scientific Models in Adaptive Management edition of *Natural Inquirer*!

In this journal, you will learn about two important processes used to improve the condition of our natural environment. One of these processes, scientific modeling, involves a variety of techniques that help scientists understand or predict things that they cannot actually observe. You will learn about scientific modeling as you read the articles in this journal. Scientific modeling is used in medical, **marine**, space, and environmental science, among other fields. Scientific modeling helps scientists understand how things work now and how they might work in the future. Adaptive management, the second process, is improved by scientific modeling. In this journal, you will learn how scientific modeling helps environmental managers adapt to a changing environment.

Glossary words appear in **bold** and are defined on page 8.

Adaptive Management

Adaptive management is a term used in **natural resource management**. Adaptive management is a process managers use to identify problems and take action. Adaptive management also involves using information and evaluating it. Using these processes, adaptive managers make decisions about future action. Adaptive management is a continual process of learning and adapting. Such management is a way to make the best decisions possible and take the best actions possible about natural resources. Adaptive management is about planning for and acting in an uncertain future.

Because managers must deal with an uncertain future, scientists often use models to help them predict what might happen in the future. Scientists also help managers collect information and evaluate the effect of managers' actions.

A model is a simple representation of a system. Models can be mathematical and include numbers and symbols, or they can be drawings, maps, or illustrations. Another type of model is a physical model, such as a model airplane. Managers often use models to practice adaptive management (**figures 1a-1d**).

Compare and contrast the models on page 5. What is similar about them? First, you may have noticed that all the models are described using a circle. Adaptive management does not have an end point. Adaptive management is like your own learning process. Both adaptive management and your learning process use past learning to try out new things. Other similarities you may have noticed in these adaptive management models include the following:

(a) A design phase in which plans are made.
(b) An **implementation** phase in which action is taken.
(c) An evaluation phase in which what happened following the action is **monitored** and assessed.

Based on these four models, write at least two questions you have about adaptive management. After you have read this journal, have your questions been answered? If not, do additional research to answer your questions.

Figures 1a-d. Four models used to describe and help practice adaptive management. Illustrations adapted from the originals by Stephanie Pfeiffer.

Figure 1a. U.S. Geological Survey model of adaptive management.

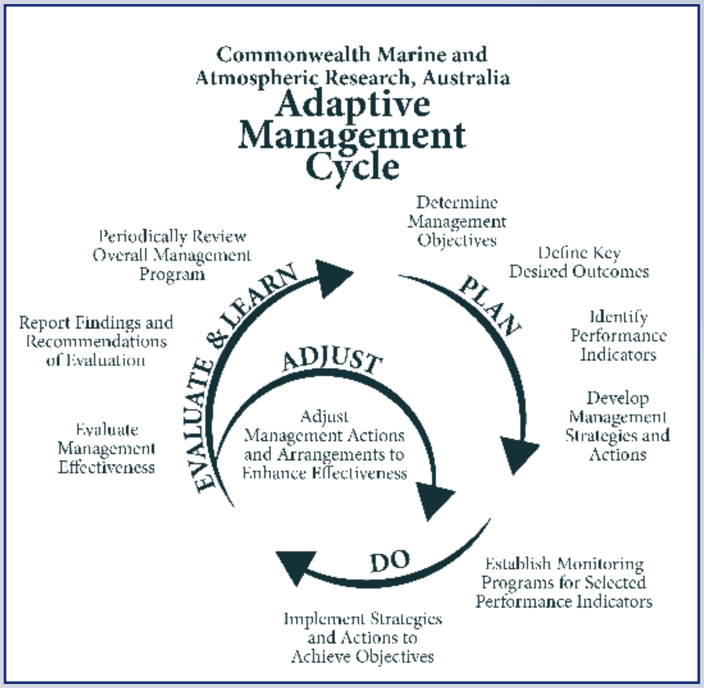


Figure 1c. Commonwealth Marine and Atmospheric Research model of adaptive management.

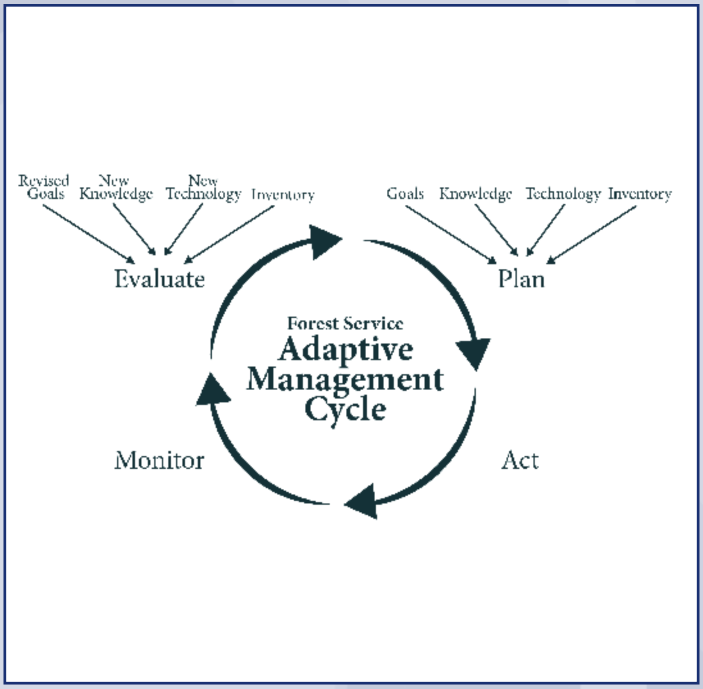


Figure 1b. Forest Service model of adaptive management.

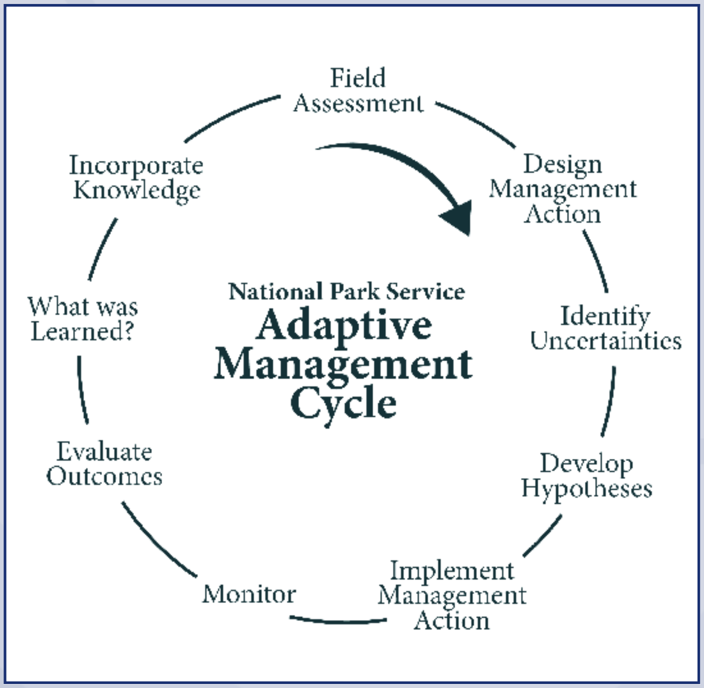


Figure 1d. National Park Service model of adaptive management.

All the models in **figure 1** either state or **imply** that learning through experience helps to make better decisions about management actions.

Examine the National Park Service model **(figure 1d)**. On the right-hand side, you see that adaptive management includes identifying uncertainties. Uncertainty involves being unsure about some things. We are uncertain, for example, about the **magnitude** of climate change. We may be uncertain whether an earthquake or flood will occur, or whether an insect pest will damage vegetation.

Other uncertainties involve human actions. We often do not know what humans will do in a situation. In adaptive management and the models that support it, identifying uncertainties is important.

Adaptive management is a tool that natural resource managers can use to improve the effectiveness of their management through learning. Using adaptive management, managers try something new. They evaluate and learn from the results, then make any necessary changes. After they make the changes, they evaluate again and learn from the results. Managers continue to make any necessary changes. This process continues without an endpoint.

During adaptive management, managers **monitor** and evaluate the results of actions. Monitoring and evaluating first involve identifying what one wants to know about a management action. Then, monitoring includes developing a research plan, followed by collecting, analyzing, and evaluating information. Often, scientists help managers with these parts of adaptive management.

In this journal, you will read about research that scientists have done that can help managers practice adaptive management. In each model in **figure 1**, identify where in the model scientists are most likely to work with managers.

Models

Ironically, one tool used for monitoring and evaluating is not shown in **figure 1**. This tool is the use of models to describe natural ecosystems. Sometimes these models also include human actions. In adaptive management, managers and scientists often use models like those in **figure 1** to describe systems. They also use maps and other illustrations to describe systems.

When working with managers doing adaptive management, scientists often use mathematical models to describe ecosystems. Mathematical models are equations. Mathematical models help scientists predict what might happen in the future (**figure 2**). The models enable predictions to be made by making **assumptions** about the identified uncertainties (See "When Zombies Attack!"). Using mathematical models, scientists help managers understand what might happen if they take various actions. After taking an action, managers monitor and evaluate the effects of that action. They compare the effects with the model's prediction. Where in **figures 1a-1d** would you place the use of models in adaptive management?

Using models in adaptive management helps managers make informed decisions when acting for an uncertain future. Adaptive management provides a way for natural resource managers to keep track of and learn from their actions. Learning is one of the most important elements in adaptive management. In this edition of *Natural Inquirer*, for example, you will read about Denali National Park in Alaska. Park managers at Denali have an important challenge that they face at the beginning of every hiking season. Managers want to open as many trails as possible to hikers. Managers also want to keep noise and disturbance away from nesting

Figure 2. Mathematical models of the average height of 18-year-olds based on their height at age 15. In this model, height at age 18 is uncertain. These models make assumptions about the number of inches boys and girls will grow from age 15 to 18. These assumptions are based on an average of the measured heights of many 15- to 18-year-olds.

$H_{B18} = H_{B15} + 6$

Where H_{B18} = height of boys in inches at age 18, H_{B15} = height of boys in inches at age 15

$H_{G18} = H_{G15} + 1.5$

Where H_{G18} = height of girls in inches at age 18, H_{G15} = height of girls in inches at age 15

If scientists assumed that boys would grow 7 inches between age 15 and 18, how would the first model change?

eagles. Managers, along with scientists, monitor the number and location of active eagle nests every year. They use this information in models. Based on monitoring and modeling results, managers continue to learn about the correct number of trails and which trails to open each year.

Many government agencies use adaptive management. Two of those agencies are the Forest Service and the U.S. Geological Survey (USGS). The Forest Service and the USGS developed this journal to describe their use of scientific models in adaptive management. You can read about these

WHEN ZOMBIES ATTACK!

Mathematical models and other types of models were used in the articles you will read in this journal. The following paragraph describes the development of a mathematical model. Because zombies are not real, the entire model was based on assumptions. The scientists who developed the model contributed the following paragraph.

Zombies are trendy in popular culture and entertainment. In this paragraph, we describe how we modeled a zombie attack. We used biological assumptions based on popular zombie movies. We first introduce a model for a zombie infection. We illustrate the outcome using numerical solutions. We then change the model to introduce a period during which humans are infected, but not infectious, before becoming undead. We then update the model to include the effects of a possible cure. We examine the effect of regular reductions in the number of zombies. Finally, we develop conditions under which all zombies are removed. We show that only quick, aggressive attacks against zombies can stave off the doomsday scenario: the collapsing of society as zombies overtake us all.

Munz, P.; Hudea, I.; Imad, J.; Smith, R.J. 2009. When zombies attack! Mathematical modeling of an outbreak of zombie infection. In Tchuenche, J.M.; Chiyaka, C., eds. Infectious disease modeling research progress. Ottawa, Ontario, Canada: University of Ottawa: 133–150. This abstract was edited slightly for a middle school audience and approved by P. Munz.

agencies on the inside back cover of this journal. The scientists from these agencies work with natural resource managers and help them with part of the adaptive management process.

USGS scientists work with many groups. These groups include natural resource managers, landowners, State and local governments, Native American tribes, and citizens. Citizens, for example, may be interested in outdoor recreation such as boating, hiking, and wildlife and bird watching. USGS uses adaptive management to involve different groups with different viewpoints and interests in the process. Where in **figure 1a** do you see this part of the adaptive management process?

The Forest Service uses adaptive management to improve the condition of the nation's forests and grasslands. Managing wildland fire by using adaptive management is also an important job of the Forest Service.

In this journal, you will learn how people use scientific modeling in adaptive management to understand and manage the decline in numbers of shorebirds and horseshoe crabs. You will learn how resource managers could use scientific modeling to save cedar trees in Alaska. You will also learn how using models in adaptive management can help managers protect **ecosystems** into the future. If zombie attacks were possible, you would understand the importance of preparing for an attack. Adaptive management is helping managers prepare for an uncertain natural resource future. In a changing world, this preparation is important for everyone.

Glossary

assumption (ə **səm(p)** shən): A temporary belief that can be tested.

ecosystem (**ē** kō sis təm): A system made up of an ecological community of living things. interacting with their environment, especially under natural conditions.

implementation (**im** plə men **tā** shən): The act of carrying out. Accomplishing.

imply (im **plī**): To express indirectly.

ironically (ī **rän** ik lī): Related to irony; an inconsistency between what is expected and what has happened.

magnitude (**mag** nə tüd): The size or quantity of.

marine (mə **rēn**): Of or relating to the sea.

monitor (**mä** nə tər): To watch or keep track of.

natural resource management (**na** chə rəl **rē** sȯrs **ma** nij mənt): The conduct of activities within natural areas to achieve goals.

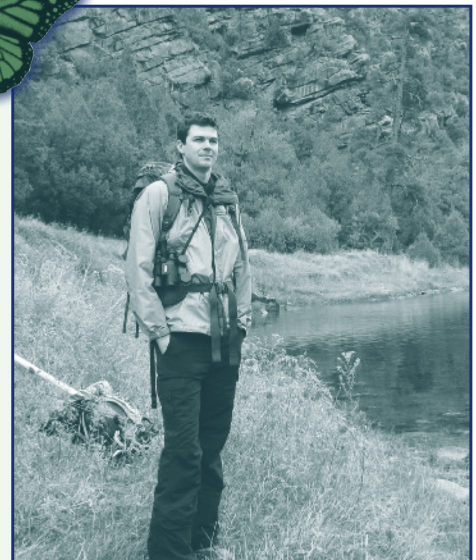
Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.

The Golden Egg

Using Adaptive Management To Regulate Hiking Near Golden Eagle Nests in Denali National Park

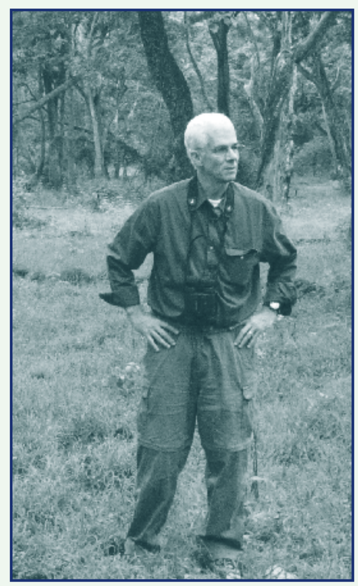
Photo courtesy of Kent Miller, National Park Service.

Meet the Scientists



▶ **Dr. Julien Martin**, Research Scientist: The most satisfying moments in my job involve finding solutions to problems related to **conservation**. In the case of the golden eagle study, for example, our goal was to help park managers **regulate** recreation activities near golden eagle territories. Such regulation would help ensure a healthy population of eagles in Denali National Park. It is a nice example of the use of scientific knowledge to help make smart decisions for conservation.

◀ **Dr. Carol McIntyre**, Avian Bioecologist: Studying birds that nest at northern latitudes is exciting and one of the most interesting parts of my career. I also enjoy studying bird **migration**, particularly using technology such as **telemetry** that enables us to track the movements and migratory behavior of birds. Another exciting part of science is **collaborating** with other scientists on projects. Working with a diverse group of scientists always makes the project more interesting.



▶ **Dr. Jim Nichols**, Population Ecologist: One of my more interesting experiences occurred while working on a project on a big lake in central Florida that required collecting alligator eggs. I worked with a group of scientists with several airboats (two scientists per airboat) and a helicopter. The operation worked like this: The helicopter would fly over the marshland and swampland surrounding the lake. Whenever the people in the helicopter spotted an alligator nest, they would hover over the nest. One of the airboats would speed over to the nearest shoreline (riding on an airboat is a lot of fun!). After arriving on the shore, the people from the boat would look around for an alligator "run" (a small ditch leading from the lake to the alligator nest, used by the female alligator to go to and from the lake). The people from the boat would then walk up the run to the nest. (This method was a lot easier than trying to walk through all the dense marsh vegetation.)

While working on a two-person airboat team, I began walking behind my partner up an alligator run to the nest. Suddenly, my partner began moving through the water without moving his legs—he looked exactly like he was surfing! He yelled something and jumped off to the side of the ditch. It turns out that he had accidentally stepped right on the female alligator in the run, and she moved very quickly, taking him with her for a short ride! It was an experience that I will never forget because it was exciting and no one was hurt. We completed our mission, which was to collect a nest full of eggs for the purpose of studying alligator hatching and growth.

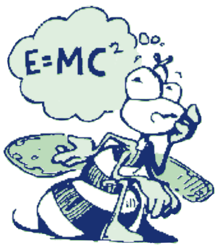
What Kinds of Scientists Did This Research?

avian bioecologist: This scientist studies the relationship of birds with each other and with the nonliving environment.

population ecologist: This scientist studies the populations of different species and how each population interacts with its environment.

research scientist: This scientist has expert knowledge of one or more sciences, especially a natural or physical science.

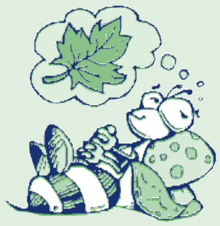
Thinking About Science



Sometimes in science no clear-cut answers exist for a problem. When no clear-cut answers are available, scientists need to find a way to solve their problem the best way they can. Often scientists will design models of what they think is happening and then test these models. These models come as close to reality as possible. Models, however, give scientists a point of reference. This point of reference enables scientists to come up with possible answers to questions they are trying to answer. In this study, scientists made models of what might happen to golden eagles and their nests in areas with hiking activity. Specifically, the scientists used models to examine whether hiking activity would affect nesting success of golden eagles.

Glossary words are **bold** and are defined on page 18.

Thinking About the Environment



National parks attract many visitors throughout the year. These visitors come to see the beauty of the parks and take part in educational and recreational activities at the parks (**figure 1**). The number of people who visit a park can have an effect on the park in many ways. The effects of recreational activities such as hiking and biking, for example, are a concern for some parks. Some effects of these types of activities may be easy to see. Land erosion from too much foot or bike traffic in an area is one example. Other consequences of people hiking and biking in a park may not be as easy to see. The stress caused to animals by hiking and biking and changes in animal behavior because of the presence of humans are two examples of this kind of effect.

Figure 1. National parks provide many opportunities to enjoy the outdoors. Photo courtesy of Tim Rains, National Park Service.

National parks have multiple purposes that are mandated by the Organic Act of 1916. Managers of national parks, therefore, need to protect the environment, plants, and animals. Managers must also ensure that people, including future generations, can enjoy their visits to the park.

What Is the Organic Act?

President Woodrow Wilson signed the Organic Act of 1916, which created the National Park Service. The National Park Service's mission was clearly stated. The National Park Service's mission is to "…. conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." To read the entire Organic Act, visit http://www.cr.nps.gov/history/online_books/anps/anps_1i.htm.

Introduction

Denali National Park in Alaska has one of the largest reported golden eagle nesting populations (**figures 2a and 2b**). The golden eagle is one of North America's largest birds of prey. These birds are very fast. They can dive from the air to catch their prey at speeds up to 150 miles per hour (241.4 kilometers per hour)! Golden eagles typically eat small animals such as rabbits, hares, and squirrels, but they have been known to attack larger prey. Pairs of golden eagles maintain large territories. Some of these territories can be up to 60 square miles in size. (Complete the number crunch to see how big this territory is.) Golden eagles are legally protected to help the population survive. Three Federal laws protect the golden eagle (**figure 3**).

Because the golden eagle population is fragile, park managers want to protect nesting eagles from disturbance caused by hikers in the park. Managers also want hikers to have a good experience in the park. Park managers were not sure how much hiking activities would affect nesting golden eagles in Denali National Park (**figure 4a and 4b**). They asked scientists to help them study this question.

The scientists and managers formed a team to develop a way to make decisions about hiking in Denali National Park. The managers identified management **objectives** for protecting eagles while providing opportunities for hikers. The scientists knew a great deal about golden eagles and developed models to help make the best decisions for eagles and hikers. The models the scientists developed looked at how eagles might respond to hiking.

The question the scientists and managers wanted to answer with this research was: How much does hiking need to be restricted to maintain golden eagle populations at desired levels?

Figure 2a. Golden eagles are large birds of prey. Photo courtesy of Terry Sohl.

Figure 2b. A golden eagle nest. Illustration by Stephanie Pfeiffer.

Name of the law	How the law protects golden eagles
The Bald and Golden Eagle Protection Act of 1962	This act prohibits anyone, without a permit issued by the U.S. Secretary of the Interior, from "taking" bald eagles, including their parts, nests, or eggs. The act provides criminal penalties for persons who "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or any manner, any bald eagle ... [or any golden eagle], alive or dead, or any part, nest, or egg thereof."
The Migratory Bird Treaty of 1918	This treaty established a Federal **prohibition**, unless permitted by regulations, to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird, included in the terms of this Convention . . . for the protection of migratory birds . . . or any part, nest, or egg of any such bird." (16 United States Code 703)
The Lacey Act of 1900	This act protects both plants and wildlife by prohibiting trade of illegally transported, sold, or taken plants and wildlife.

Figure 3. Three laws protect the golden eagle.

▲ **Figure 4a**. Denali National Park is located in Alaska. Map by Lindsay Gnann.

◀ **Figure 4b**. Denali National Park has a variety of rugged terrain. Photo courtesy of Tim Rains, National Park Service.

Number Crunches

- How many acres are in 60 square miles? (Hint: 1 square mile = 640 acres.) A football field in the United States is approximately 1 acre in size, so about how many football fields would be in 60 square miles?
- How many square kilometers are in 60 square miles? (Hint: 1 square mile = 2.59 square kilometers)

What Is Adaptive Management?

Have you ever heard that experience is the best teacher? This idea is the foundation of adaptive management. Adaptive management is a way for land managers to deal with an unknown future and to learn from trying new things. When land managers try something new, the outcome is evaluated. Based on the evaluation, the managers try another approach to improve their management. The process continues, with managers continuing to learn and adapt.

Scientists often help managers by designing and implementing the evaluation process. As you can see, scientists are involved in some parts of the adaptive management process. Land managers, however, treat the entire adaptive management process as an experiment. What occurs when you do an experiment? Hopefully, you learn from your experience!

Number Crunch

- How many years ago was the National Park Service established? How many decades?

Reflection Section

- In your own words and in the form of a question, state the problem the scientists were trying to solve.
- Why do you think scientists were trying to maximize hiking and protection of the golden eagle nests?

Methods

To identify the best way to manage hiking and still protect nesting golden eagles, the scientists used a formal decisionmaking framework as part of adaptive management (see page 4 for more information about adaptive management). First, the scientists had to gather information about the potential problem.

Since 1988, at least 93 eagle territory sites have been **monitored** in Denali. The scientists focused on 25 territories that they believed would be most affected by hiking. Golden eagle territories are areas of land in which eagles hunt and live. The scientists had to find out two main things. One thing they needed to know was the number of occupied and unoccupied eagle territories. The second thing they needed to know was the number of territories where golden eagles laid eggs and did not lay eggs (**figure 5**).

After scientists had this information, they created three mathematical models to help them understand the effect of hiking on golden eagle nests. Each model made an **assumption** that the scientists could test (**figure 6**). This process is similar to making a hypothesis and testing it. (For information about making assumptions in models, read "When Zombies Attack" on page 7.)

The scientists believed the population of golden eagles also depended on another important factor. This factor was the availability

Figure 5. Golden eagle nests are large and often found in high places. In this photo, a golden eagle is preparing to land at its nest. Photo courtesy of Kent Miller, National Park Service.

Model number	What the model assumed
1	Assumed no effect of hiking on whether the eagles lived and reproduced in the territory.
2	Assumed a moderate effect of hiking on whether the eagles lived and reproduced in the territory.
3	Assumed a large negative effect of hiking on whether the eagles lived and reproduced in the territory.

Figure 6. The models helped scientists study what may happen with different limits on hiking.

Figure 7. The snowshoe hare is adapted to cold climates. What is one adaptation you see? Photo courtesy of Jake Frank, National Park Service.

of snowshoe hares for food. Snowshoe hares are a primary prey for golden eagles in Denali (**figure 7**). The scientists believed that more eagles would nest when hares were plentiful. This information is important for understanding eagle nesting behavior.

Scientists do not know the exact population size of snowshoe hares from year to year. This lack of information is a source of uncertainty when trying to develop models of eagle nesting. The scientists have a hare **index** to help them estimate the population size. This index does not give scientists exact numbers, but it does tell scientists when hares are in high and low phases of their population cycle.

The scientists used computer software to predict how different amounts of hiking would affect eagle nesting each year. Specifically, the scientists used the three models and the information they gathered about eagle reproduction and prey abundance to develop the software.

Adaptive Management in Your Life

Do you have bird boxes in your schoolyard? If you do not, pretend that you do. Your class has decided to use adaptive management to improve the situation for nesting birds. First, you must identify the problem and your objective. Let's say that no bird has ever nested in any of the bird boxes. A lack of nesting birds is the problem. Your objective is to have three successful bird boxes. A successful bird box is one in which eggs are laid and hatched, and baby birds are able to leave the nest and fly away (**figure 8**).

Your class does research in the media center. You decide that the bird boxes are placed too close to the playground. You move the bird boxes away from the playground. After 2 weeks, you observe and record bird activity. One pair of adult birds is observed carrying nesting material to one of the nests. After evaluating your results, your class does more research. You discover that one of the unsuccessful bird box holes is too small. You cut a bigger hole, wait 2 more weeks, and observe and record any nesting activity. A pair of birds is observed at the second bird box. After evaluating the results of your bird-box management, your class does more research. You discover that nesting birds like to have an open space in the front of the bird box. The last unsuccessful bird box faces a large bush. What steps will you take next?

Figure 8. Bird boxes provide habitat for nesting birds. Photo by Babs McDonald.

Reflection Section

- Why do you think the scientists chose to study only 25 territories instead of all 93 territories?
- Why do you think scientists used three different models in their study?

Findings

Under model 2, closing some of the hiking areas had a small effect on golden eagle nesting (**figure 9**). Under model 3, however, closing fewer areas to hiking had a large negative effect on golden eagle nesting. The scientists found that more areas need to be closed to hiking as the number of unoccupied nests increased. The scientists also found that more areas need to be closed to hiking when fewer snowshoe hares were found in the area.

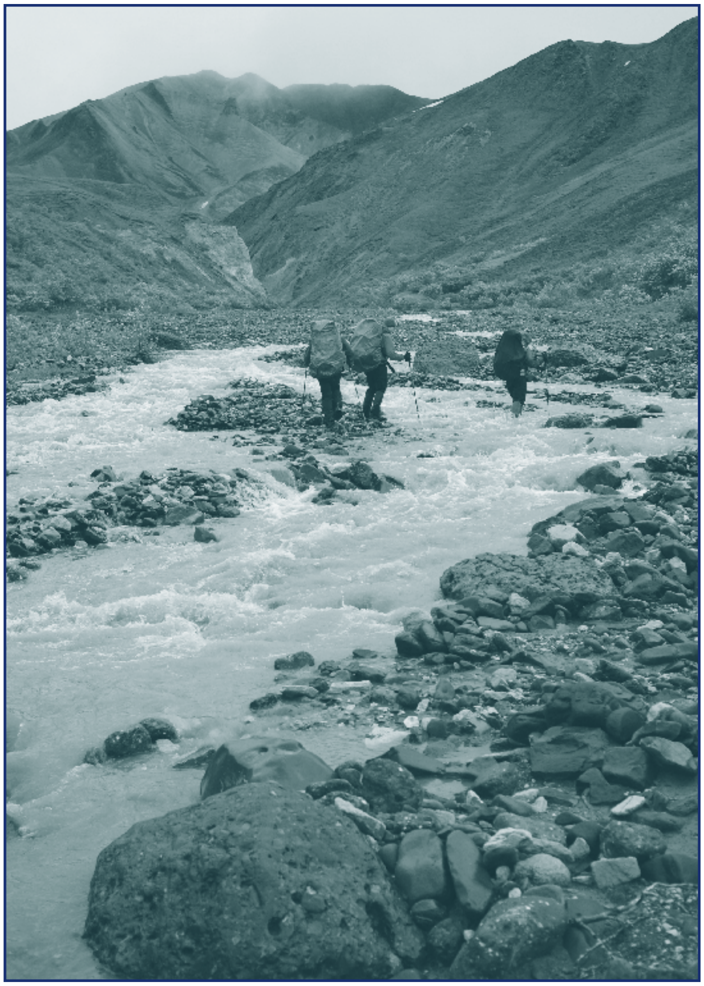


Figure 9. Hikers in Denali National Park. Photo courtesy of the National Park Service.

You Are the Adaptive Manager!

In this article, you are learning about research and evaluation as a part of the adaptive management process. One important feature of adaptive management is its focus on an uncertain future. Scientists help managers by doing research. Scientists provide information that can be used to predict what might happen in the future. Pretend you are the land manager of the area being studied in this research. How would you use the findings of this study? What management action would you take? After taking the action, what would you ask the scientists to monitor?

Reflection Section

- Why do you think that when snowshoe hare abundance is low, more hiking areas need to be closed?
- Based on the findings you read, do you think hiking has any effect on golden eagle nesting? Why or why not?

Discussion

The scientists said that it was important to consider the things in the models about which they were uncertain. This step is necessary before making any decisions about which model is best to use. For example, accurately accounting for the number of snowshoe hares may change model outcomes. The scientists believe that even with the limitations of these models, using the models to make management decisions is better than waiting to make decisions until more data are available.

Reflection Section

- Do you think that making management decisions based on the models in the paper is better than waiting until more data are available? Why or why not?
- Do you think scientists and managers need to take this much effort to protect golden eagles? Why or why not? (Hint: Review figure 3).

Adapted from Martin, J.; Fackler, P.L.; Nichols, J.D.; Runge, M.C.; McIntyre, C.L.; Lubow, B.L.; McCluskie, M.C.; Schmutz, J.A. 2011. An adaptive-management framework for optimal control of hiking near golden eagle nests in Denali National Park. Conservation Biology. 25(2): 316–323.

Glossary

assumption (ə **səm(p)** shən): A fact or statement taken for granted.

collaboration (kə **lab** ə **rə** shən): The act of working with others.

conservation (**kän(t)** sər **vā** shən): A careful preservation and protection of something.

index (**in** deks): A number (as a ratio) derived from a series of observations and used as an indicator or measure.

mandate (**man** dāt): To officially require something.

migration (mī **grā** shən): Passing, usually periodically, from one region or climate to another for feeding or breeding.

monitor (**mä** nə tər): To watch, keep track of, or check usually for a special purpose.

objective (əb **jek** tiv): An aim or goal.

prohibition (prō ə **bi** shən): An order forbidding something.

regulate (**re** gyə lāt): (1) To control according to a system. (2) To bring under control of law or some authority.

telemetry (tə **le** mə trē): The process of transmitting data by telemeter (tə le mə tər). A telemeter is a device that allows measurements to be made at a distance.

Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.

Note to Educators: If you are a Project Learning Tree trained educator, you may use "A Forest of Many Uses."

The article title "Golden Egg" is an allusion to Aesop's Fables classic "The Goose with the Golden Egg." "The Goose with the Golden Egg" is a tale about a man who becomes too greedy and ends up with nothing. To see the text, visit http://www.bartleby.com/17/1/57.html and http://www.umass.edu/aesop/content.php?n=14&i=1.

Web Resources

Denali National Park
http://www.nps.gov/dena/index.htm

A Brief History of the National Park Service
http://www.cr.nps.gov/history/online_books/kieley/index.htm

National Geographic's Golden Eagle page
http://animals.nationalgeographic.com/animals/birds/golden-eagle/

Cornell's Lab of Ornithology—Golden Eagle page
http://www.allaboutbirds.org/guide/Golden_Eagle/id

Photo Gallery of Denali National Park
http://www.flickr.com/photos/denalinps/

Photo Gallery of Denali National Park
http://www.nps.gov/dena/photosmultimedia/photogallery.htm

FACTivity

Time Needed

One class period

Materials

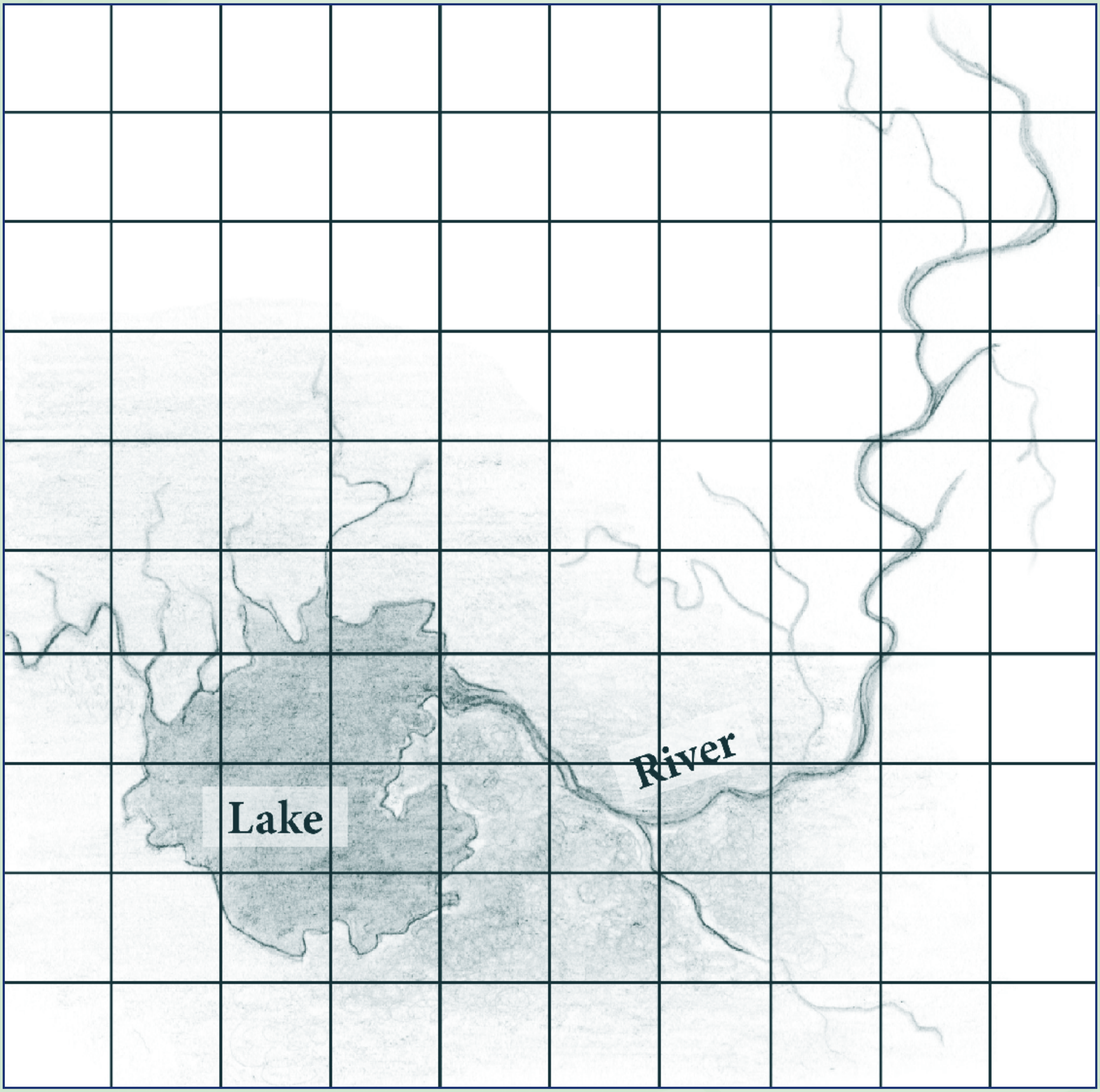
- Graph paper for each group of students (see graph paper provided on p. 20)
- Highlighters/colored pencils
- Pencils

In this FACTivity, you will become a park manager and examine where to place trails in a fictional park according to the location of eagles' nests.

Methods

1. Your teacher will divide the class into small groups of three to four students. Your teacher will also provide each group with two pieces of graph paper. Use one piece of graph paper for your draft and one piece of graph paper for presenting your final product.
2. The graph represents the area in the park. First, plot and label these points on your graph:
    - Waterfall (7, 5)
    - Park Welcome Center (1, 1)
    - Mountain Peak (2, 8)
3. Next, plot two eagle territories. Place the territories wherever you choose; however, take into account the following things:
    - Each block represents 10 square miles.
    - Golden eagles maintain an area up to 60 square miles in size. Therefore, you should give each eagle 60 square miles. You may give the eagle the land any way you choose as long as you give the eagle 60 square miles total for each nesting site.
    - You will use highlighters or colored pencils to color in the 60 square miles allotted to each eagle.
4. Next, place the following items on your grid.
    - Potential scenic area 1: (9, 10)
    - Potential scenic area 2: (6, 3)
    - Potential scenic area 3: (1, 8)

    Decide whether to use these potential areas as scenic areas for hikers based on the needs of the visitors and the eagles.
5. Decide how you will place two trails through the park. The trails should not interfere with the eagles' nests. Draw the trails on the map and then write a paragraph for each trail describing highlights of the trail and how the trail protects the eagles' nesting sites. Use complete sentences, correct spelling, and proper punctuation.
6. After your student group and all the others present their trail maps to the class, hold a class discussion about challenges that were encountered creating the trails and how this activity is similar and different from what would happen in an actual park. The following list has some questions to help start the discussion. (Note: These questions could also be used as part of an assessment.)
    - How difficult did you find it to fit two eagle territories into the park?
    - In the real world, you would not be able to assign the territories because the eagles only choose a site they like. How would this difference make things more challenging for someone who is managing the park?
    - Were you able to make use of all possible scenic areas? Why or why not?



10 square miles

Each square in the grid is equal to 10 square miles.

Photo by Babs McDonald.

At Your Service

Developing Models To Help Natural Resource Managers Make Better Decisions

Meet the Scientists

◀ **Dr. Colin Beier**, Ecologist: My favorite science experience was the first time I visited Chichagof (**chə** chug ôf) Island in southeast Alaska. We left Juneau and flew across the islands and ocean channels in a four-seat floatplane, circled, and landed in a beautiful green-water cove. We spent the next 2 weeks camping and doing fieldwork. We were studying why Alaska's yellow-cedar trees were dying across southeast Alaska and collecting samples from the cedar trees to measure their rings.

While doing fieldwork, we encountered several big coastal brown bears. We had one very close call with a mother and her cubs. It was scary at the time, but also an amazing experience. I was deep in the ancient rainforest surrounded by two of my favorite things—huge trees and huge bears.

▶ **Dr. Trista Patterson**, Ecological Economist: My favorite science experience is kind of "the darkness before the dawn." So many times I've been hashing over a difficult problem for weeks, months, years… and then one day some missing piece falls into place. Usually when this experience occurs, I am not in my office or in front of a computer. I am hiking with a colleague or having a conversation about something totally different and unexpected with someone I've just met!

For more information about Dr. Patterson, download her scientist card at http://www.naturalinquirer.org/scientists-v-92.html (Set 8). Photo courtesy of Doug Demarest.

◀ **Dr. Terry Chapin**, Ecosystem Ecologist: My favorite science experience has been talking with Alaskan Native hunters. Alaskan Native people depend on hunting and fishing for food and for their cultural connections to the land and sea. These men and women know how climate change is affecting Alaskan ecology more directly than does any scientist. I've learned from them that the ice is thinner and more dangerous for winter travel. I've learned that new birds and fish are appearing, and the ones on which they have depended in the past are changing in behavior and health. These changes affect all aspects of their lives. These Alaskan Natives, however, have good ideas about how they and the ecosystems on which they depend can adapt to change.

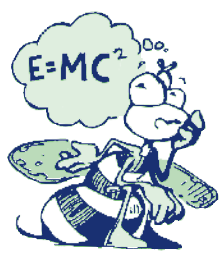
What Kinds of Scientists Did This Research?

ecological economist: This scientist studies the relationships between human **economies** and natural ecosystems.

ecologist: This scientist studies the relationships of living things with each other and with the nonliving environment.

ecosystem ecologist: This scientist studies the physical and biological characteristics of an ecosystem and how these characteristics interact with each other.

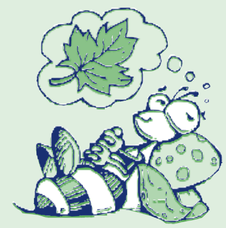
Thinking About Science



How do the words "adaptive management" relate to science? If you read the introduction to this journal, you already know something about adaptive management. Adaptive management is treating decisions as experiments and learning from successes and failures. Managing adaptively means being willing to change actions and try something new. Natural resource managers are the professionals who practice adaptive management. These managers, however, rely on scientists to create models, design ways to **monitor** natural resources, and evaluate results so that the managers' decisions are based on scientific information.

To be successful, adaptive management relies on a team of professionals. This team involves scientists and managers working together. In this article, you will learn how a team of scientists created models to help managers improve their decisionmaking. For more information about models, read "Welcome to the Scientific Models in Adaptive Management edition of the *Natural Inquirer*!" on page 4.

Thinking About the Environment



Although many things about the natural environment are uncertain, one thing is certain: the environment will continue to change. Human activities have caused environmental change to happen faster in recent decades. With change comes uncertainty—we are not always sure what will happen. One way that natural resource managers prepare for change is by using adaptive management. Managers use adaptive management so they can make the best decisions possible about protecting and using the environment.

Some environmental changes occur naturally. Volcanoes, floods, and earthquakes are natural events that create sudden change. Human activities can also create rapid change, as when a forest is cut down to build a shopping mall (**figure 1**). Some human-caused changes occur over longer periods of time. Climate change, for example, is one change that is creating uncertainty about the future. In this research, you will learn how scientists use information to help managers prepare to make good decisions, in spite of change and uncertainty.

Figure 1. Sometimes, humans cause rapid environmental change. Photo by Babs McDonald.

Introduction

Natural resource managers often face a **dilemma**. When a natural area provides a lot of ecosystem services, many people want to use the services in that area. This use can disturb ecosystems. Humans can disturb ecosystems when one service is used at the expense of another service. An example of this tradeoff is using an area to produce food. When land is used to produce food, wildlife habitat is lost. Too much disturbance can, in time, reduce the amount of all ecosystem services provided. This reduction occurs because the natural area becomes **degraded.** After an ecosystem is degraded, people cannot benefit from its many services. A degraded ecosystem can take many years to recover.

This dilemma of too much use might happen to many natural areas at the same time. When many areas need attention, natural resource managers must have a way to determine which areas need the most attention. Natural resource managers have limited time and money but must work in large areas that cover many hundreds or thousands of hectares. Managers need a way, therefore, to identify **priorities** for natural resource management.

The scientists in this study developed a process to help managers identify management priorities. The managers needed a process that is useful as conditions change over time. As conditions change over time, the managers wanted to adapt their management priorities to fit the changing conditions.

Glossary words are **bold** and are defined on page 30.

Reflection Section

- What was the problem the scientists were trying to solve?
- Identify one area of your life in which you have to set priorities.
- What is one similarity between your need to set priorities and the managers' need to set priorities?

What Are Ecosystem Services?

Ecosystem services are the variety of benefits that ecosystems provide to people. These services include, for example, clean air, clean water, pollination, food, control of climate change, wildlife habitat, outdoor recreation, soil **erosion** control, building products, and scenery (**figure 2**). As you can see, a lot of different kinds of ecosystem services can be identified. For more information, download or order the *Natural Inquirer* "Ecosystem Services" edition at http://www.naturalinquirer.org.

Figure 2. Name two ecosystem services being provided by this ecosystem. Photo by Babs McDonald.

What Is Adaptive Management?

Have you ever heard that experience is the best teacher? This idea is the foundation of adaptive management. Adaptive management is a way for land managers to deal with an unknown future and to learn from trying new things. When land managers try something new, the outcome is evaluated. Based on the evaluation, the managers try another approach to improve their management. The process continues, and managers continue to learn and adapt.

Scientists often help managers by designing and implementing the evaluation process. As you can see, scientists are involved in some parts of the adaptive management process. Land managers, however, treat the entire adaptive management process as an experiment. What occurs when you do an experiment? Hopefully, you learn from your experience!

Methods

The scientists first developed an illustration (**figure 3**). This illustration is a model that shows the relationship between ecosystem services and human use of natural resources.

The scientists and managers then created models of what might happen as more or fewer natural resources are used (**figure 4**).

The scientists studied the ecosystems of southeastern Alaska (**figures 5 and 6**). They collected existing information about the ecosystems from different sources. The information described southeastern Alaska's land characteristics.

The scientists were interested in the following characteristics: (1) physical land characteristics, (2) human use, and (3) disturbance caused by human activities.

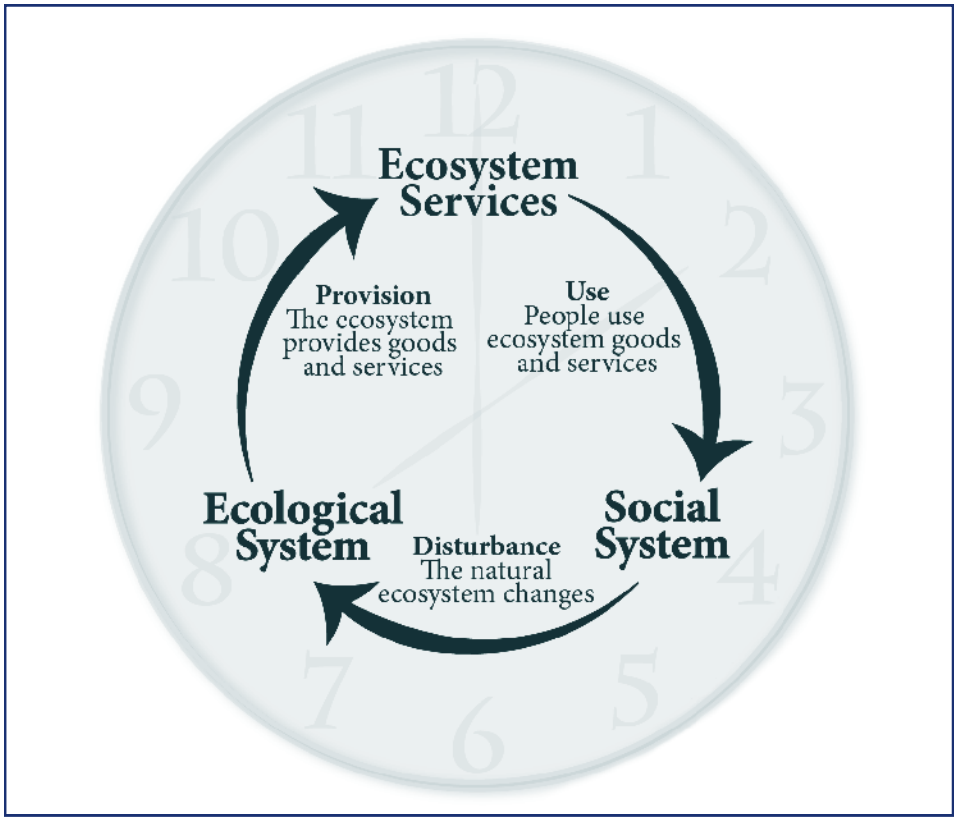


Figure 3. Ecosystem services, human use, and ecosystem **disturbance** are related to each other. Pretend this model is sitting inside a clock face. In this model, an ecosystem is shown at 8 o'clock. At 10 o'clock, the model shows that the ecosystem provides ecosystem services. At 2 o'clock, the model shows that people use ecosystem services (the social system). At 6 o'clock, the model shows that too much human use may result in disturbance to the ecosystem. The scientists included changes that result from natural resource management as a disturbance. They considered management a disturbance because management modifies the natural ecosystem. Illustration by Stephanie Pfeiffer.

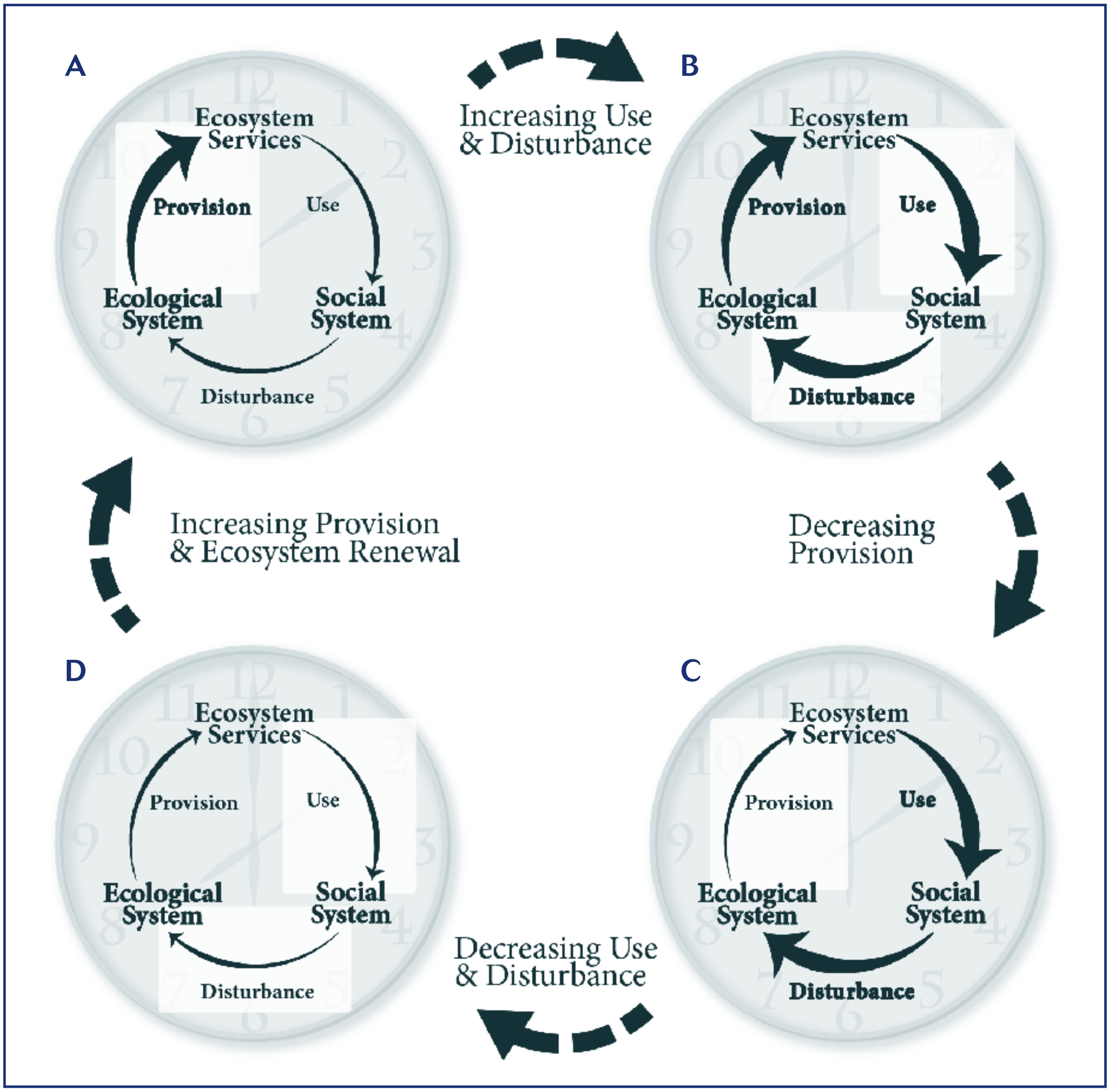


Figure 4. This illustration is a model representing what can happen to ecosystems when people use natural resources. Arrow thickness represents the **magnitude** of ecosystem **provision**, use, and disturbance. Illustration by Stephanie Pfeiffer.

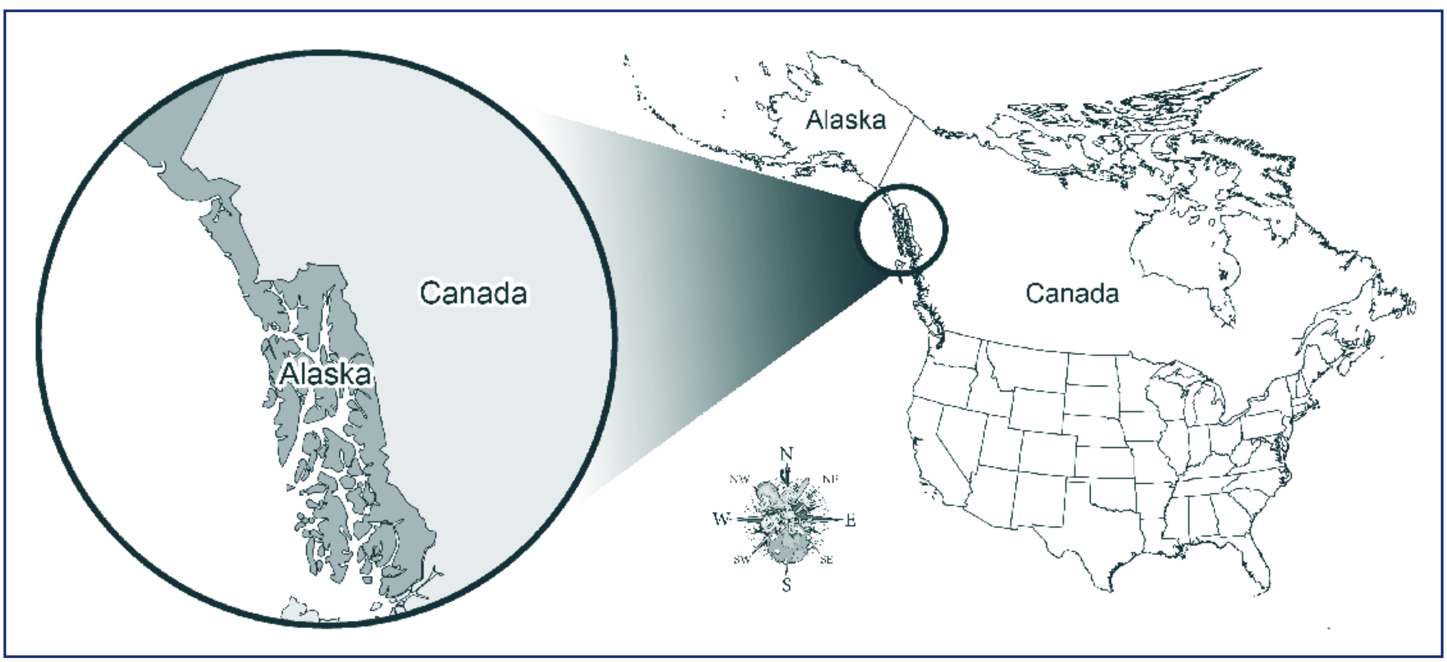


Figure 5. The scientists studied southeastern Alaska. Map by Lindsay Gnann.

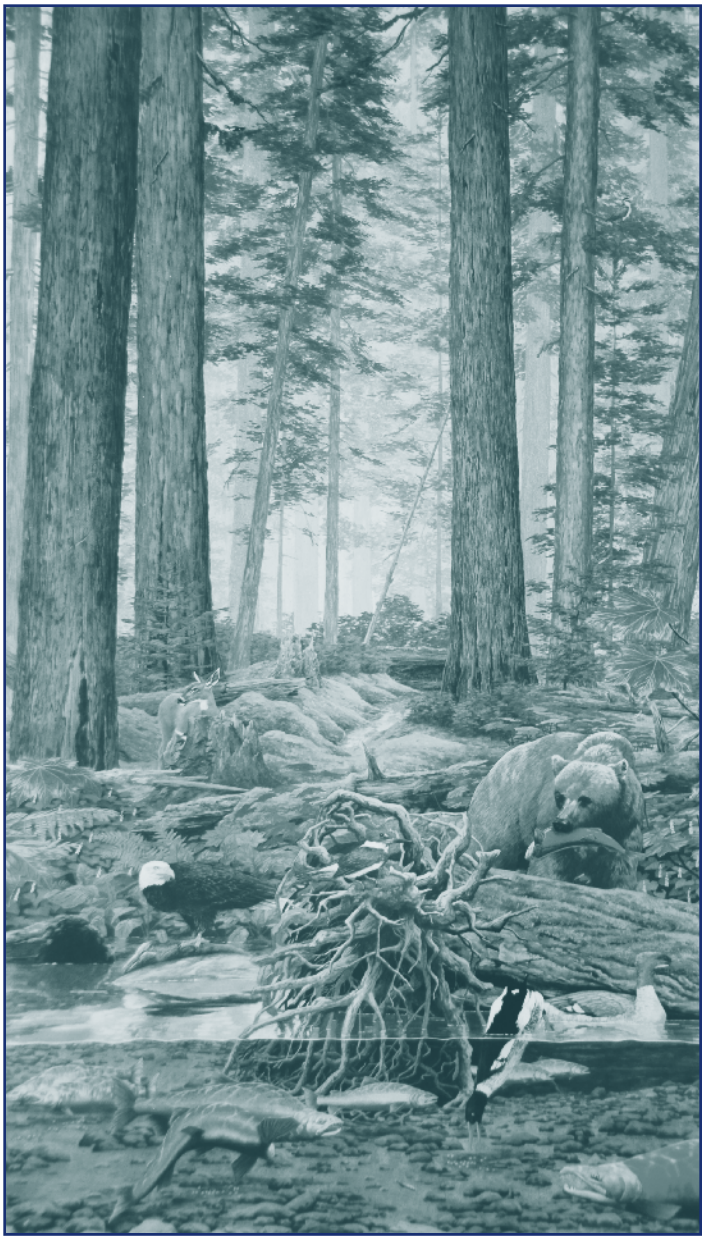


Figure 6. Southeastern Alaska is a **temperate** rain forest. Some areas of southeastern Alaska receive an average of 160 inches of rain every year. Poster courtesy of Paul Kratter, http://www.paulkratter.com.

Number Crunch

- How many centimeters of rain fall in some areas of Alaska's temperate rain forest? Multiply 160 inches by 2.54 centimeters to find out.

The scientists gathered this information from different sources. The scientists placed each of the **variables** under one of the three parts of the model shown in figure 4 (**figure 7**). These three parts of the model were called **criteria**.

Criteria	Variables
Provision of ecosystem services	Number of hectares of forest lands capable of providing timber or other forest products
	Number of hectares of forest lands providing deer and bear habitat
	Number of kilometers of rivers and streams providing salmon and trout habitat
	Number of kilometers of rivers and streams providing habitat for a variety of fish
	Number of hectares of areas providing waterfowl habitat
Use	Amount of seafood and shellfish caught; sport-fishing
	Numbers of deer and bear killed during hunting season
	Number of cabins available for people to use
	Number of hectares used to transfer logs from land to sea
	Number of hectares used for harbors
	Number of hectares used for fish **hatcheries**
	Hectares of water used for fish farming
Disturbance	Number of hectares of harvested forest lands
	Number of hectares in urban areas or for urban use
	Number of roads crossing salmon streams

Figure 7. The scientists grouped the variables under three criteria.

Adaptive Management in Your Life

Do you have an outdoor classroom in your schoolyard? If you do not, pretend that you do. Your class has decided to use adaptive management to improve the outdoor classroom. First, you must identify the problem and your objective. Let's say that the outdoor area has no habitat for lizards. A lack of lizard habitat is the problem. Your objective is to have at least one lizard species visiting the outdoor classroom. Your class does research in the media center. You identify a way to use rocks to create a habitat that is favorable to lizards. Your class creates the habitat. After 2 weeks, you observe and record any lizard species in the area. One lizard species is identified.

After evaluating your results, your class does more research. You discover that lizards like shallow pools of water. You create a shallow pool, wait 2 more weeks, and observe and record the lizard species present. After evaluating the results of your management, your class does more research. You discover that lizards like to have a variety of places to hide. What steps will you take next?

When the scientists were finished, they had one **database**. The database contained variables describing the ecosystem services provided, human use of the ecosystem, and any human-caused disturbance. For each of the criteria, the scientists calculated one number. This number represented the magnitude of the ecosystem services being provided, the amount of human use of the natural resource, or the amount of disturbance.

Using equations, the scientists calculated a score for each criterion (criterion is the singular of criteria) for every watershed in southeastern Alaska. Using the three scores, the scientists compared the relationships between provision, use, and disturbance for each watershed. The scientists wanted to identify the watersheds that provided a lot of ecosystem services, had a lot of human use, and had a high level of disturbance. Managers should focus their management activities on these watersheds.

What Is a Watershed?

A watershed is an area of land where all the water that is under it or drains off of it goes into the same place. The United States has 2,267 watersheds (**figure 8**).

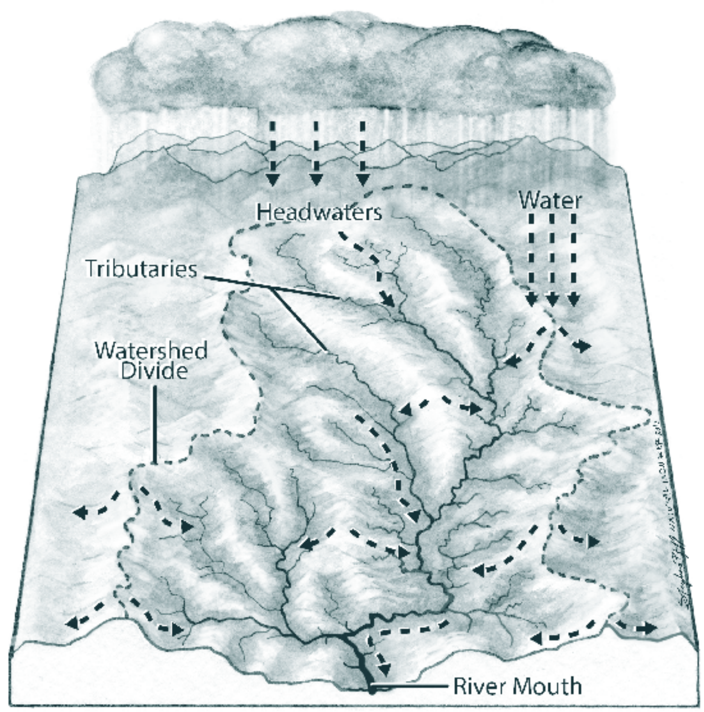


Figure 8. All the water in a watershed drains into the same place. Do you live in a watershed? How do you know? Illustration by Stephanie Pfeiffer.

Number Crunch

- The United States has 2,267 watersheds. In what place is the "6" in this number? Is it in the ones, tens, hundreds, or thousands?

Reflection Section

- Look at figures 3 and 4. Pick one of these figures and explain it in your own words.
- Look at figure 7. Do you think these variables completely described southeastern Alaska's ecosystems? Why or why not?

You Are the Adaptive Manager!

In this article, you are learning about research and evaluation as a part of the adaptive management process. One important feature of adaptive management is its focus on an uncertain future. Scientists help managers by doing research. Scientists provide information that can be used to predict what might happen in the future. Pretend you are the land manager of the area being studied in this research. How would you use the findings of this study? What management action would you take? After taking the action, what would you do next?

Findings

The scientists identified a group of watersheds in which high provision, high use, and high disturbance were closely related. The scientists were able to use some of this information to create a map of southeastern Alaska (**figure 9**). This map is a geographic model of natural resource relationships in southeastern Alaska.

Reflection Section

- Which illustration in figure 4 describes the situation in which the scientists were most interested? Based on this model, what is likely to happen to an ecosystem described by illustration B?
- How will the identification of high provision, high use, and high disturbance areas help managers make better natural resource decisions?

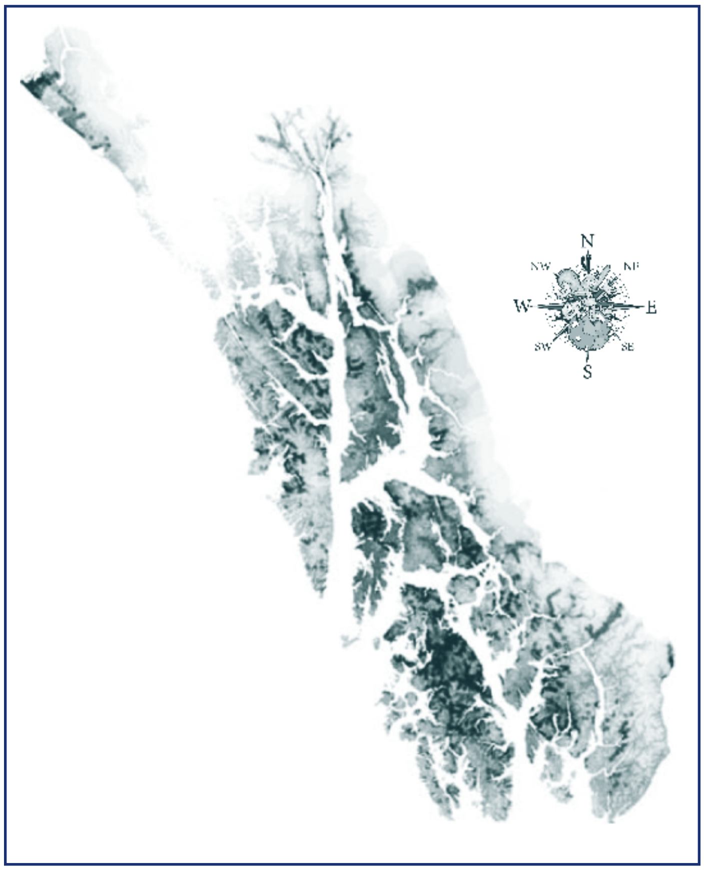


Figure 9. The relationship of ecosystem provision, human use, and human disturbance in southeastern Alaska. Darker areas show a closer relationship among the three criteria. These dark areas represent priority areas for management.

Discussion

The scientists believe that more accurate and complete information about southeastern Alaska should be included in the model. Managers need the most accurate information available to successfully identify priorities. The number of people using an area for recreation, for example, would be a more accurate measure of use than the number of cabins available.

The scientists believe the model they developed will be useful to natural resource managers. Identifying areas where ecosystem provision, use, and disturbance are greatest can help managers set management priorities. Identifying these areas will help managers take action based on these priorities. By using models, mathematical equations, and new information in those equations, managers can make better decisions and take better actions as conditions change.

Reflection Section

- If you were a scientist doing this study, would you recommend that managers base their natural resource management decisions on the map in figure 9? Why or why not? (Hint: Reread the first paragraph in the "Discussion" section.) What is one advantage and one disadvantage of basing management decisions on the map in figure 9?
- Explain in your own words how models and mathematical equations can help natural resource managers make better decisions about changing ecosystems.

Glossary

criteria (krī **tir** ē ə): Standards upon which a judgment or decision may be based. Singular is criterion.

database (**dā** tə bās): A usually large collection of data organized especially for rapid search and retrieval (as by a computer).

degrade (dē **grād**): To lower to an inferior or less effective level.

dilemma (də **le** mə): A usually undesirable or unpleasant choice.

economy (ē **kä** nə mē): A system of interaction and exchange; often relates to the exchanges of goods, services, and money.

ecosystem (**ē** kō sis təm): A system made up of an ecological community of living things interacting with their environment especially under natural conditions.

erosion (i **rō** zhən): The state of being washed away.

hatchery (**ha** chə rē): A place for hatching eggs.

magnitude (**mag** nə tüd): Size, quantity, or number.

monitor (**mä** nə tər): To watch, keep track of, or check usually for a special purpose.

priority (prī **or** ə tē): A condition of being given attention before others.

variable (**ver** ē ə bəl): Something that is able or apt to vary.

Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.

Adapted from Beier, C.M.; Patterson, T.M.; Chapin, F.S. III. 2008. Ecosystem services and emergent vulnerability in managed ecosystems: A geospatial decision-support tool. Ecosystems. 11:923–938. http://www.fs.fed.us/pnw/pubs/journals/pnw_2008_patterson(beier)002.pdf.

FACTivity

Time Needed

One class period

Materials

- "At Your Service" article
- Blank piece of paper (one for each student, plus a blank paper for each group)
- Pencils (one for each student)
- Graphic organizers (in the following section)

A model is a simple representation of a system. The model can be an illustration (as **figures 3** and **4**), it can be a mathematical model and include symbols such as the equation v = h * w * l (volume = height times width times length), or it can be a physical model, such as a model car. A map may also be considered a model.

In this FACTivity, you will create an illustration model of your schoolyard's ecosystem. The question you will answer in this FACTivity is: How is a schoolyard ecosystem model similar to and different from the ecosystem model created for southeastern Alaska?

Methods

Your teacher will have you work with other students in small groups. First, you will critically review **figure 3** from this article. Based on what you learned in the article, draw a model of your schoolyard's ecosystem. The goal is to produce a model that describes how the schoolyard ecosystem works. The model should include natural and human criteria. (You may go outside to observe and record your observations about the schoolyard ecosystem.)

Use your own paper and pencil to sketch ideas. The final model for each group should be developed as a group and drawn on the extra blank paper. Ask questions such as:

- What ecosystem services are provided by the schoolyard ecosystem?
- Is the schoolyard ecosystem used and if so, how and by whom?
- Does the schoolyard ecosystem experience disturbance and if so, what kinds?

You should also ask whether other criteria should be added to your schoolyard model. Use your imagination and creativity to create your model. Develop a list of criteria that will become a part of you model.

Think about every aspect of your schoolyard ecosystem. For example, think about the ecosystem services your schoolyard provides. One way to analyze this process is to identify variables for each identified criterion. Thoroughly label each model. After your group completes its model, compare and contrast it with **figure 3**. Use the graphic organizers on pages 32 and 33 to guide your work.

Your teacher will hold a class discussion about the model-building exercise. Compare and contrast each group's model. What do the models reveal about the similarities and differences between the schoolyard ecosystem and the ecosystem studied in southeastern Alaska? The graphic organizers presented next may be used to guide the discussion and listing. Finally, as a class, brainstorm a list of model characteristics.

Schoolyard ecosystem criteria	Schoolyard ecosystem variables
Example: Ecosystem: natural characteristics	Example: Number of trees
	Example: Number of acres/hectares
Example: Ecosystem services provided	Example: A place to play outside
	Example: Habitat for songbirds

Similarities between schoolyard ecosystem and southeastern Alaska ecosystem	Differences between schoolyard ecosystem and southeastern Alaska ecosystem

Model characteristics

FACTivity Extension

Time Needed

At least 30 minutes

Using the list of criteria and variables for the schoolyard ecosystem, develop ways to measure the variables you have identified. After this exercise has been completed, your teacher will hold a class discussion about measurement and its importance to scientific study.

Another FACTivity

In this FACTivity, you will create a management objective for your schoolyard. Then you will create an adaptive management process. Review the sidebar titled, "Adaptive Management in Your Life" on page 28. You may also review the adaptive management models on page 5.

Time Needed

One class period

Materials

- "At Your Service" article
- A blank piece of paper
- Pencils (one for each student)

Methods

Working in small groups with other students, draw a circle on your paper. Beginning at the top, write a statement that describes your management objective. Examples of management objectives include: (1) develop a wildflower garden, (2) reduce stormwater runoff from parking lots, (3) improve landscaping at the school's entrance, and (4) provide habitat for three songbird species. Pretend you are a land manager practicing adaptive management. Write the cyclical steps you would take to address your management objective. Your teacher should emphasize that adaptive management includes the following four steps:

- Plan (in which a management objective and actions are identified)
- Act (in which a management action is taken)
- Monitor (in which data are collected and analyzed to determine the effect of the management action)
- Evaluate (in which learning occurs and informs the next round of management actions)

Remember that adaptive management does not have an endpoint. Focus on developing a cyclical process where you are learning from experience.

Note that you can use the information and model created in the first FACTivity to help identify management objectives.

Your teacher will hold a class discussion about adaptive management. Explore whether this process could be used in other areas of an individual's life. You may want to develop an adaptive management process for a personal objective.

Note to Educators: If you are a trained Project Learning Tree (PLT) educator, you may use "Forest Consequences" as an additional activity.

The title "At your service" is a phrase that means "Committed to satisfying you." How do you think this title relates to the article you read?

Web Resources

Ecological Society of America: Ecosystem Services
http://www.esa.org/ecoservices/comm/body.comm.fact.ecos.html

Forest Service: Ecosystem Services
http://www.fs.fed.us/ecosystemservices/

Natural Inquirer Ecosystem Services edition
http://www.naturalinquirer.org/Ecosystem-Services-Natural-Inquirer-i-26.html

Ecological Disturbances
http://en.wikipedia.org/wiki/Disturbance_(ecology)

Tying the Knot

How Do Horseshoe Crab and Red Knot Populations Affect Each Other?

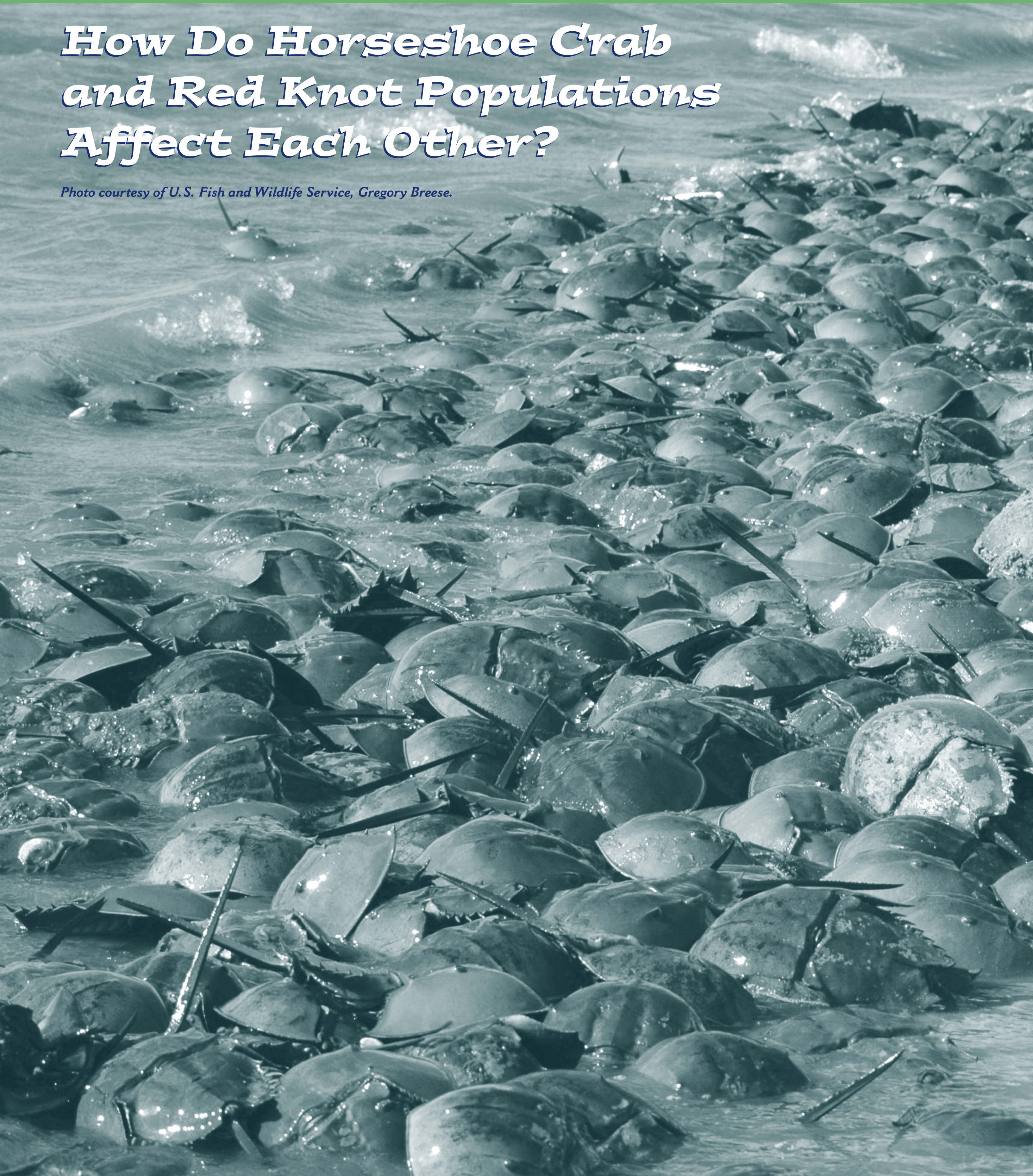
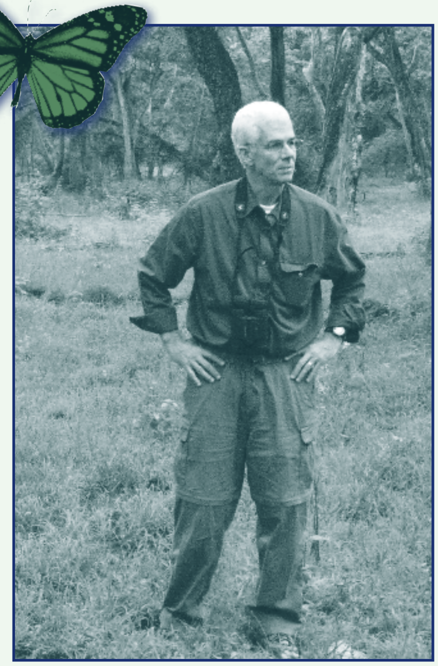


Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Meet the Scientists

◀ **Dr. Conor McGowan**, Population Ecologist: My favorite science experiences always involve being out in the field with the animals I am studying. The best one has to be when I trapped and banded waved albatross in the Galapagos Islands as an undergraduate student. The Galapagos Islands are such a beautiful, amazing place, and the waved albatross are such powerful, awesome birds.



▶ **Dr. Jim Nichols**, Population Ecologist: Science experiences can sometimes be scary. One time, I was working with other scientists who were studying Weddell seals in Antarctica. To do our study, we had to place plastic identification tags on the seals' flippers. The tags enable scientists to track the activities of individual seals.

I was out on the sea ice tagging seals with another scientist. We came upon a large female without a tag. She probably weighed about 1,000 pounds (453 kilograms). I was given the task of "catching" her, which involved throwing a cloth bag with rope handles over her head and jumping on her back. Then, holding on to the rope handles, I rode on her back until she got tired. She was tired in less than 2 minutes. When she stopped moving, I remained on her back and held the bag in place. The other scientist moved behind her to apply the tags to her rear flippers.

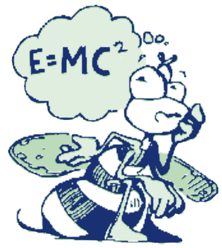
Suddenly, the seal began to roll to one side. I tried to pull my leg up so it would not be crushed by her rolling motion. I discovered that my crampons (metal spikes on the bottoms of my boots) were stuck in the ice. My leg was so far under the seal that I could not pull it loose. I yelled to my partner, who quickly moved to the front of the seal. He distracted her in the opposite direction of her roll, causing her to roll back to the other side. This movement gave me room to remove my leg. So thanks to the quick thinking of my partner, my leg was not crushed. I made sure in future captures that my leg did not get stuck again.

What Kind of Scientist Did This Research?

population ecologist: This scientist studies the populations of different species and how the population interacts with its environment.

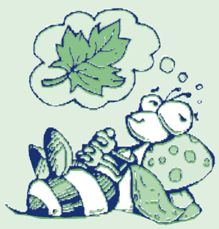
Glossary words are **bold** and are defined on page 44.

Thinking About Science



Land managers and other natural resource professionals are skilled individuals who take care of the land and natural resources. Every day, land managers and natural resource professionals must make decisions about how best to maintain the resources that are in their care. To help managers make the most informed decisions possible, scientists sometimes work with these professionals. In this case, science is used to help solve identified problems and meet objectives. In this study, scientists and managers worked together. The scientists designed models to help managers make good decisions about a population of horseshoe crabs and a certain type of **migratory** shorebird called the red knot.

Thinking About the Environment



Some birds **migrate** during winter months and then return to summer habitats for **breeding**. In this study, the red knot is a bird species that migrates south from its breeding grounds in the Canadian Arctic to southern South America. The one-way migratory journey for these birds can be up to 14,000 kilometers. The birds must stop frequently to rest and refuel to complete this journey. Certain locations are ideal stopover areas for these migratory birds because of food availability. The three areas are Tierra del Fuego (Argentina and Chile), northern Brazil, and the Mid-Atlantic United States (**figure 1**). Red knots spend November through February in these wintering areas and then migrate back to Canada in time for

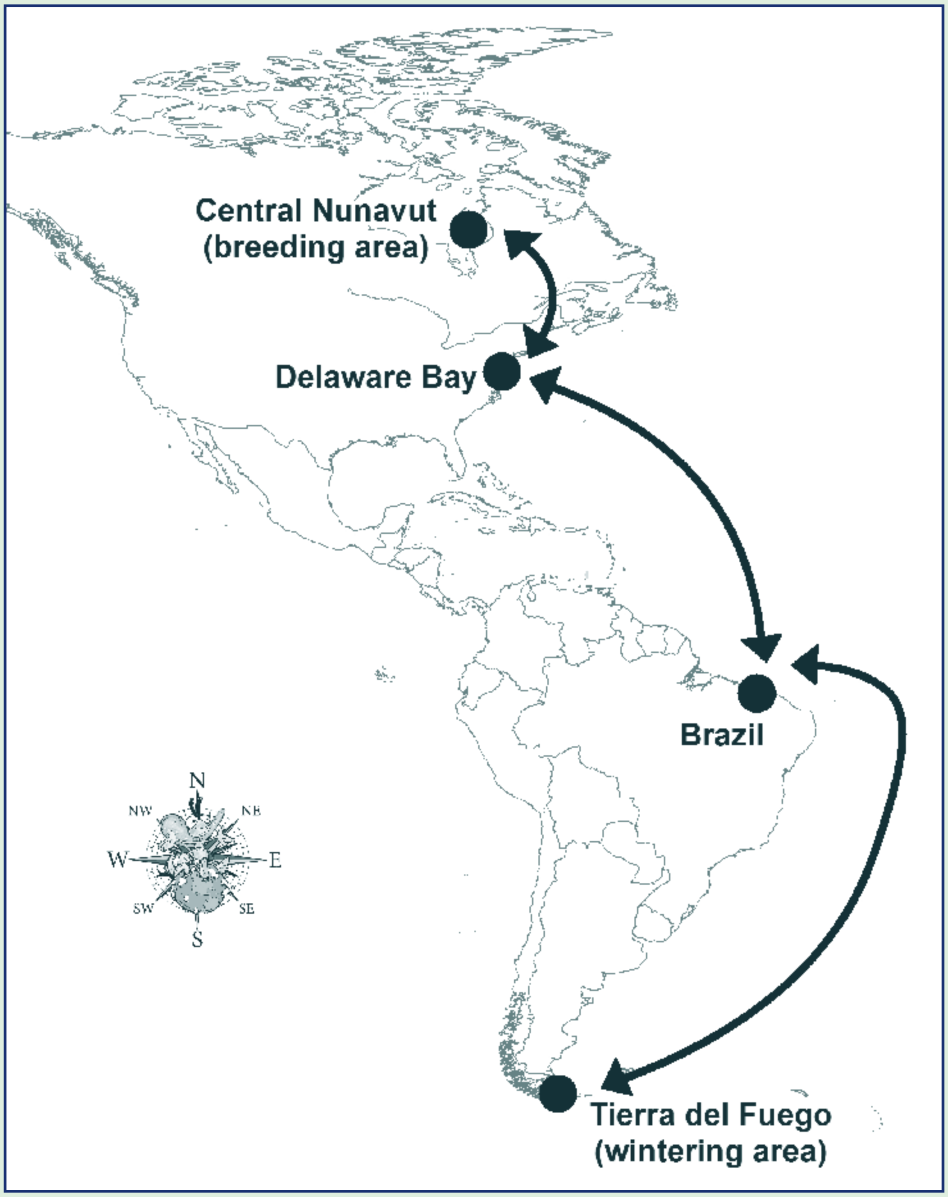


Figure 1. Stopover points for migrating red knots that spend the winter in three locations: Tierra del Fuego, northern Brazil, and the Mid-Atlantic United States. Map by Lindsay Gnann.

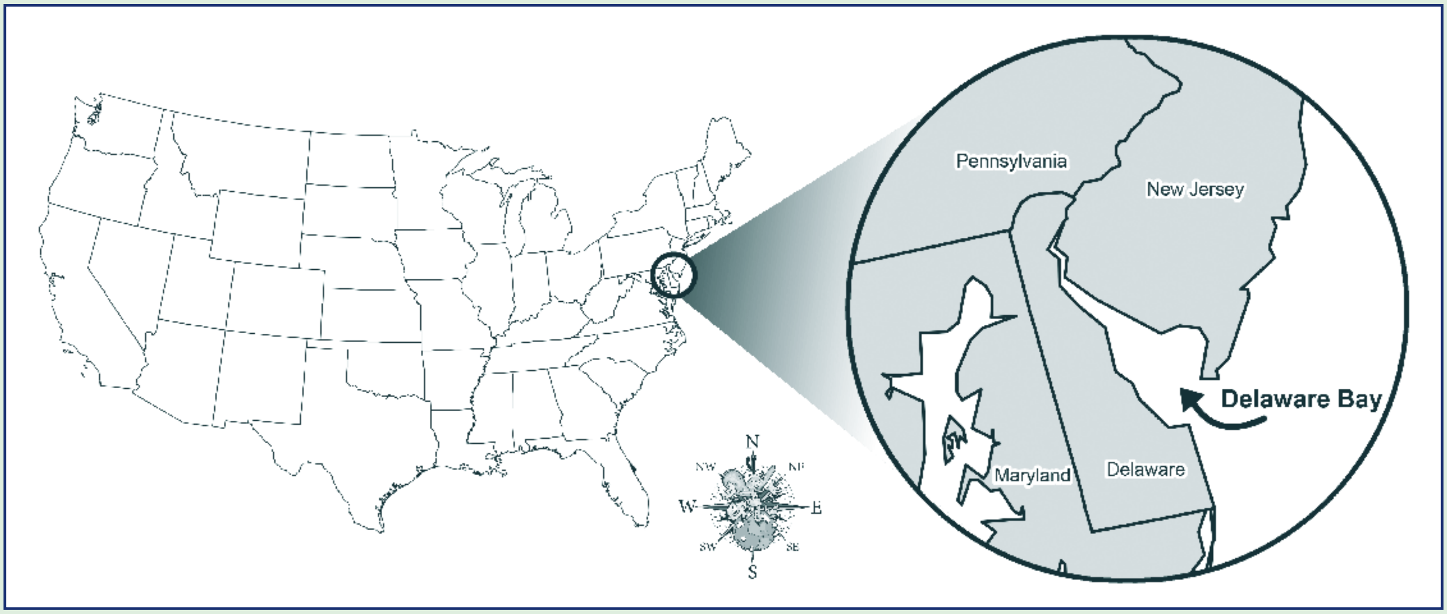


Figure 2. Delaware Bay is located in the Mid-Atlantic United States. Map by Lindsay Gnann.

summer. Delaware Bay in the Mid-Atlantic United States is a perfect stopover location for the birds (**figure 2**).

Delaware Bay is an **estuary** (**figure 3**). Because estuaries are transition zones between the ocean and freshwater areas, the mix of ocean water and fresh water provides a lot of nutrients in the area. For red knots, the big draw is horseshoe crab eggs. In this study, you will learn how the horseshoe crab population may affect the red knot population.

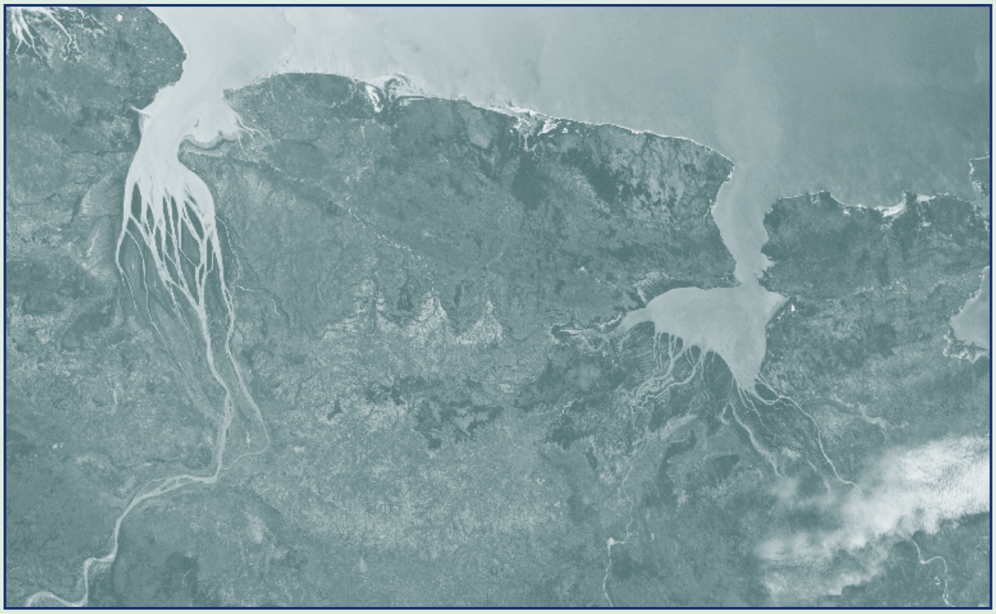


Figure 3. Two estuaries on the northwestern coast of Madagascar. The Republic of Madagascar is located off the southeastern coast of Africa, in the Indian Ocean. This photo was taken by an Expedition 28 crew member on the International Space Station. Photo courtesy of the National Aeronautics and Space Administration.

Number Crunch

- How many miles is a one-way migratory trip for the red knot? (Hint: 1 km= 0.621 miles)

Introduction

In this study, the scientists used a **structured** decisionmaking process called adaptive management (see page 4 for more information about adaptive management). Structured decisionmaking is a process where managers first define management **objectives**. After managers have defined their objectives, scientists use models to predict results of different possible actions managers could take. Then managers select one of the actions. Next, people monitor the ecosystem and see if the objectives are achieved by the action that was chosen. Then managers adjust the next action based on the new information they learned.

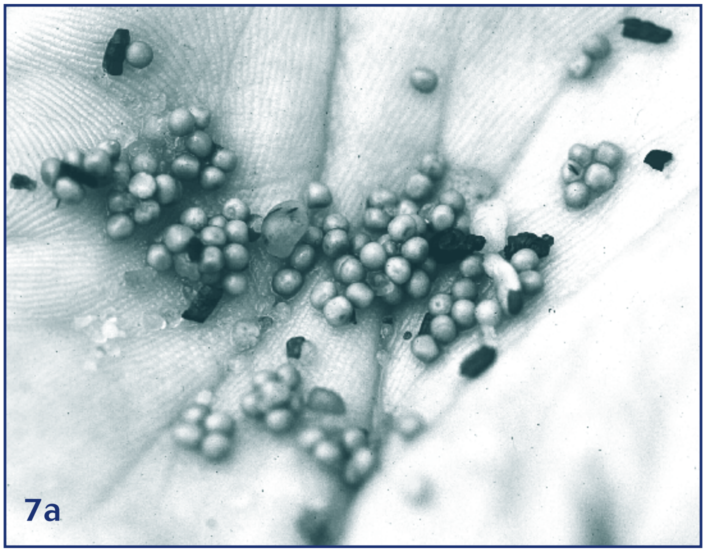
The cycle of taking action, monitoring results, and adjusting the next action is how managers learn more about the ecosystem. They can, therefore, make better decisions. It is important to design accurate models to help managers understand the ecosystem. This modeling also helps the managers make the most informed decisions possible about managing the ecosystem.

In this study, scientists wanted to examine how the **harvest** of horseshoe crabs in Delaware Bay affects the red knot (**figures 4 and 5**). The red knot is a migratory bird (**figure 6**). The red knot feeds primarily on the eggs of horseshoe crabs during its stopover in Delaware Bay (**figures 7a and 7b**). Thousands of shorebirds make the same stopover as the red knots and **gorge** themselves on food. Although the red knots eat a lot of horseshoe crab eggs, these eggs are mostly ones that would not have hatched. The eggs will not hatch because they are too close to the sand's surface. As red knots feed, they nearly double their weight in 2 weeks. This weight gain allows the birds to continue on their **strenuous** migratory journey north to the **Arctic** to breed during the summer months.

Figure 4. Thousands of horseshoe crabs come up onto the beaches in Delaware Bay to lay their eggs. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Figure 5. Red knots stop to eat in Delaware Bay. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Figure 6. Thousands of red knots fly to Delaware Bay and land there to refuel for their long migratory journey. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.



Figures 7a and 7b. These tiny horseshoe crab eggs are what red knots eat to store energy. Photo 7a courtesy of U.S. Fish and Wildlife Service, Gregory Breese. Photo 7b courtesy of Dr. Conor McGowan.

The population of red knots has declined from approximately 150,000 birds in the 1990s to 15,000 birds in 2008. Today's red knot population is low enough to be listed as a threatened species. A threatened species benefits from some protection under U.S. law. During this same time period, the harvest of horseshoe crabs has increased. Horseshoe crabs are harvested as bait for eels and whelk (**figure 8**).

Figure 8. Horseshoe crabs are harvested as bait for whelk. Whelk is a word used for many species of sea snails. Photo courtesy of Jo O'Keefe: http://okeefes.org/Whelks/Whelks.htm.

What Is Adaptive Management?

Have you ever heard that experience is the best teacher? This idea is the foundation of adaptive management. Adaptive management is a way for land managers to deal with an unknown future and to learn from trying new things. When land managers try something new, the outcome is evaluated. Based on the evaluation, the managers try another approach to improve their management. The process continues, with managers continuing to learn and adapt.

Scientists often help managers by designing and implementing the evaluation process. As you can see, scientists are involved in some parts of the adaptive management process. Land managers, however, treat the entire adaptive management process as an experiment. What happens when you do an experiment? Hopefully, you learn from your experience!

The red knot population decline may be because of fewer horseshoe crab eggs in Delaware Bay. In addition, horseshoe crab blood is collected from live horseshoe crabs for **pharmaceutical** testing. This blood collection, however, is not believed to affect the horseshoe crab population. The scientists in this study wanted to figure out how to manage the harvest of horseshoe crabs in such a way that the populations of red knots and horseshoe crabs stopped declining.

Number Crunch

- What is the difference in the number of red knots stopping in Delaware Bay now compared with 15 years ago?

Reflection Section

- In your own words and in the form of a question, state what the scientists wanted to know.
- Do you think it is important for managers to define objectives for their management decisions? Why or why not?

What Are Horseshoe Crabs?

Horseshoe crabs are one of the world's oldest creatures. This type of animal is estimated to be at least 300 million years old. That's pretty old, especially when you consider that the beginning of the Age of Dinosaurs was 230 million years ago. Were horseshoe crabs living on Earth before the dinosaurs? How do you know?

The horseshoe crab is an **invertebrate**. The horseshoe crab belongs to the **arthropods**. It may look like a crab but it is more closely related to spiders and scorpions (**figure 9**). Horseshoe crabs lay their eggs during breeding season in sandy beach habitats. During spring breeding, millions of crabs crawl up the beaches of Delaware Bay. This breeding cycle occurs at the same time as the **lunar cycles**. Horseshoe crabs, in particular, like to lay their eggs during the full moon and **new moon** in May and June. Visit http://www.udel.edu/research/explore/loader.html to learn more about horseshoe crabs!

Figure 9. Horseshoe crabs may look like crabs, but they are more closely related to spiders and scorpions. Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.

Methods

The scientists had to make a basic mathematical **model** to test different management practices. (Read about a mathematical model of a zombie attack on page 7.) The basic model had two parts. First, the scientists needed a horseshoe crab population model that looked at the effects of harvesting on both male and female horseshoe crabs. Second, the scientists needed a red knot population model that linked red knot survival to horseshoe crab breeding in Delaware Bay. After the scientists combined these two parts, they had a basic model in which they could run **simulations**.

Using this basic model, the scientists created two specific mathematical models to represent two competing **assumptions**. The first model assumes that the amount a bird weighed at the end of the stopover had large effects on its survival. The second model assumes that the amount a bird weighed at the end of the stopover had a small effect on its survival. The second model assumes that heavy and light birds, in general, have similar survival rates.

When the scientists were building the models, they needed to include certain types of data. For example, the scientists set initial population sizes at 1998 levels. They also included data about the number of horseshoe crabs coming onto the beaches for the period 1998–2008. These data included the number of horseshoe crabs harvested in Delaware Bay. The scientists then used the models to predict what might happen with eight different possible management actions (**figure 10**).

Reflection Section

- Why do you think the scientists wanted a population model for horseshoe crabs that looked at both male and female horseshoe crabs?
- Why did the scientists consider different possible management actions?
- Why did the scientists group the red knots into two weight categories?

Adaptive Management in Your Life

Do you have a butterfly garden in your schoolyard? If you do not, pretend that you do. Your class has decided to use adaptive management to improve the garden. First, you must identify the problem and your objective. Let's say that only one species of butterfly visits your garden. This lack of variety is the problem. Your objective is to have as many butterfly species as possible visiting the garden. Your class does research in the media center. You identify two additional flowering plants and plant them in the garden.

After 2 weeks, you observe and record the butterfly species in the garden. You identify two additional species. After evaluating your results, your class does more research. You discover that butterflies like shallow pools of water. You create a shallow pool, wait 2 more weeks, and observe and record the butterfly species. Another species is identified. After evaluating the results of your management, your class does more research. You discover that butterflies like to have shady as well as sunny spots to rest. What steps will you take next?

Action	Female Harvested	Males Harvested
1	0	0
2	0	200,000
3	0	400,000
4	100,000	200,000
5	200,000	400,000
6	300,000	300,000
7	300,000 – (Red knot threshold is 30,000)	300,000 – (Red knot threshold is 30,000)
8	300,000 – (Red knot threshold is 60,000)	300,000 – (Red knot threshold is 60,000)

Figure 10. Different management actions were based on different numbers of horseshoe crabs that could be harvested. In actions 7 and 8, no horseshoe crabs can be harvested when red knot **abundance** is less than the **threshold**.

Findings

The scientists found that both models were sensitive to changes in horseshoe crab egg survival rates and **juvenile** horseshoe crab survival rates. Heavy harvest of horseshoe crabs decreased red knot abundance in both models, but had a much greater effect in model 1. Recall that model 1 assumed that a bird's survival was related to its weight. Harvesting only male horseshoe crabs had little effect on red knot population numbers in both models.

Models 1 and 2 produced different predictions for the eight different possible management actions shown in **figure 10**. With no harvesting, for example, model 1 predicted that the median abundance of red knots 90 years in the future would be about 65,000 birds. Model 2, however, predicted a population of around 200,000 red knots. The management action that restricted horseshoe crab harvesting until a certain number of red knots was present improved population predictions for the red knot.

Reflection Section

- Why do you think harvesting only male horseshoe crabs had little effect on red knot abundance?
- If you were the scientist, would you recommend that horseshoe crab harvests be limited in the future? Why or why not?

You Are the Adaptive Manager!

In this article, you are learning about research and evaluation as a part of the adaptive management process. One important feature of adaptive management is its focus on an uncertain future. Scientists help managers by doing research. Scientists provide information that can be used to predict what might happen in the future. Pretend you are the manager of the area being studied in this research. How would you use the findings of this study? What management action would you take? After taking the action, what would you ask the scientists to monitor?

Discussion

The scientists in this study developed the first models for predicting effects of management actions on horseshoe crab and red knot populations in Delaware Bay. The two models showed different results. Model 2 showed faster red knot population growth.

What is the reason for using both models to make a management decision? Using two models helps scientists include things they are unsure about in the decisionmaking process. Let's say the manager's objective is to maximize the number of red knots. Using action 8 would be best even though scientists don't know for sure whether red knot weight is important for survival. If the manager's objective is to maximize the horseshoe crab harvest, however, action 7 would be the best. The models' results show that managers may be able to **conserve** the red knot population, while allowing some horseshoe crab harvesting.

The scientists suggested the best management strategy would be for managers to take actions based on what the models predicted. The best strategy would also take into account the current state of the ecosystem and management objectives. The scientists believed that additional data would help them decide which of the two models provides the best predictions. Additional data would also help create better models. Specifically, scientists suggested that more information is needed about the relationship between a red knot's weight gain and the availability of horseshoe crab eggs.

Reflection Section

- Do you think this model will be useful to managers and natural resource professionals? Why or why not?
- Should the scientists continue to estimate the populations of horseshoe crabs and red knots next year? Why or why not?

Glossary

abundance (ə **bən** dənt(s)): A degree of plentifulness.

Arctic (**ärk** tik): The Arctic Ocean and lands in and adjacent to it.

arthropod (**är** thrə päd): Any of a phylum of invertebrate animals (such as insects, arachnids, and crustaceans) having a segmented body, jointed limbs, and a shell of chitin that is shed periodically.

assumption (ə **səm(p)** shən): A fact or statement taken for granted.

breed (**brēd**): To produce offspring by sexual reproduction.

conserve (kən **sərv**): To avoid wasteful or destructive use of; to use carefully.

estuary (**es** chə **wer** ē): A passage where the tide meets a river current; especially: an arm of the sea at the lower end of a river.

gorge (gȯ(ə)rj): To eat in large amounts.

harvest (**här** vəst): To gather or collect.

invertebrate (in **vərt** ə brət): Lacking a backbone.

juvenile (**jü** və nīl): Showing incomplete development.

land manager (**land ma** ni jər): A skilled professional who takes care of the land.

Adapted from McGowan, C.P.; Smith, D.R.; Sweka, J.A.; Martin, J.; Nichols, J.D.; Wong, R.; Lyons, J.E.; Niles, L.J.; Kalasz, K.; Brust, J.; Klopfer, M.; Spear, B. 2011. Multi-species modeling for adaptive management of horseshoe crabs and red knots in the Delaware Bay. Natural Resource Modeling. 24: 117–156. http://www.fws.gov/northeast/fisherycenter/pdfs/McGowanetal2011.pdf.

lunar cycle (**lū** nər **sī** kəl): The changing appearance of the moon as seen from Earth.

migrate (**mī** grāt): To pass from one region or climate to another usually on a regular schedule for feeding or breeding.

migratory (**mī** grə tōr ē): Having a way of life that includes migrations.

model (**mäd** əl): A simplified copy or representation of something to help human understanding.

new moon (**n(y)ü** mün): The moon's phase when its dark side is toward Earth.

objective (əb **jek** tiv): An aim or goal.

pharmaceutical (**fär** mə **süt** i kəl): Of, relating to, or involved in pharmacy or the manufacture and sale of medicinal drugs.

simulation (**sim** yə **lā** shən): The imitation by one system or process of the way in which another system or process works.

strenuous (**stren** yə wəs): Marked by or calling for strength or energy.

structured (**strək** chərd): Organized.

threshold (**thresh** hōld): A level, point, or value above which something will take place and below which it will not.

Accented syllables are in **bold**. Marks and definitions are from http://www.merriam-webster.com.

FACTivity

In this FACTivity, you will learn about the migration of the red knot and why different areas where the red knot stops are important for the red knots' survival. This journey is one of the longest migratory journeys, marking close to 9,000 miles or 14,000 kilometers!

Time Needed

Three 50-minute class periods

Materials

- A copy of the map for each student (see map on page 46)
- Pencils (one for each student)
- Books or Internet resources about stopover locations and the red knot
- Paper to make pamphlets
- Colored markers

Methods

1. First, take a map and locate each stop that the red knot makes on its migratory journey. Mark the Hudson Bay area, then the Delaware Bay area, Brazil, and finally Tierra Del Fuego.
2. After you have marked the areas on the map, draw lines in between the points to mark the entire length of the journey.
3. Learn a little bit about each area and why it is important for the red knot. To complete this activity, your teacher will divide the class into small groups. Each group will be assigned a migratory stop. (Note: If you have more than four groups, multiple groups can study the same stopover location).
4. Each group will pretend to be travel agents for the area assigned. You and other students are travel agents for red knot birds (not people). You will need to research your assigned stopover location and create a short presentation and pamphlet to entice the red knot to come and stop over at the assigned location. You will make a presentation to the class and can display your pamphlets on a bulletin board.
5. After you and the other students have shared your presentations, your teacher will facilitate a group discussion. This discussion will focus on the challenges of such a long journey and the importance of safe stopover locations.

Map by Lindsay Gnann.

Note to Educators: A rubric for this FACTivity can be found at http://www.naturalinquirer.org. After arriving at this Web site, click on educational resources and then lesson plans. Scroll down and you will see "Article Lesson Plans." The rubric will be listed here.

If you are a Project Learning Tree (PLT) educator, you may use "Habitat Pen Pals" and "Web of Life" as additional activities.

Web Resources

Shorebirds and Horseshoe Crabs
http://www.delawareestuary.org/publications/factsheets/Horsecra.pdf

All About Horseshoe Crabs
http://www.udel.edu/research/explore/loader.html

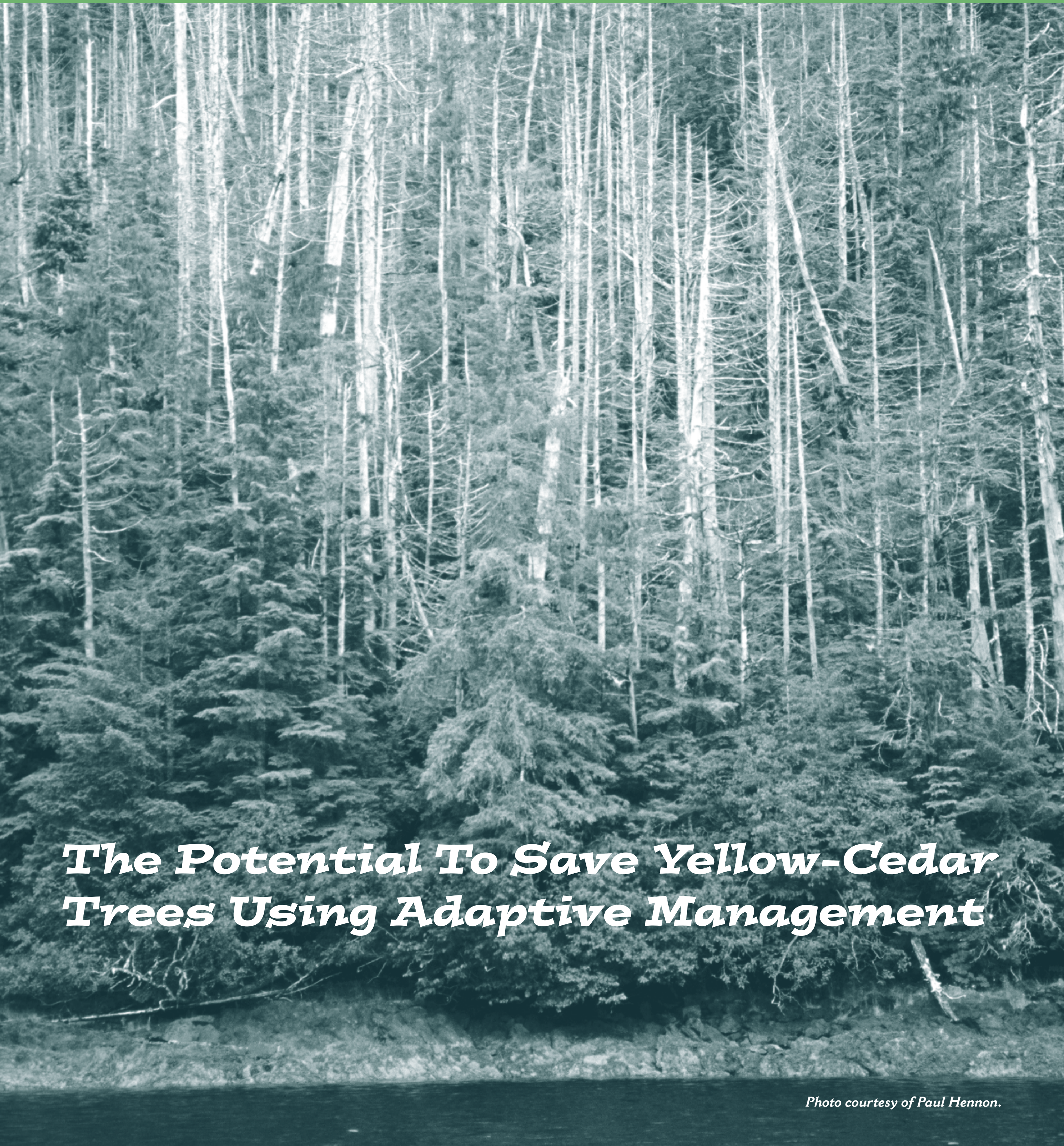
Smithsonian Migratory Bird Game
http://nationalzoo.si.edu/scbi/migratorybirds/Education/Kids_Stuff/Woth_game/default.cfm

Animal Planet Horseshoe Crab Information
http://animals.howstuffworks.com/arachnids/horseshoe-crab-info.htm

U.S. Fish and Wildlife Service Blog
http://www.fws.gov/news/blog/index.cfm/2011/5/3/Delaware-Betting-on-Survival-in-Delaware-Bay

PBS Video Series About Red Knots and Horseshoe Crabs
http://www.pbs.org/wnet/nature/episodes/crash-a-tale-of-two-species/introduction/592/

Cedar Waxing or Waning?



The Potential To Save Yellow-Cedar Trees Using Adaptive Management

Photo courtesy of Paul Hennon.

Meet the Scientists

◀ **Dr. Paul Hennon**, Plant Pathologist: My favorite science experience is working on a research team with scientists from different fields. Plus, my job takes me to so many remarkably beautiful, **pristine**, and remote places.

▼ **Dr. David D'Amore**, Soil Scientist: My favorite science experience was conducting bird surveys in the forest. I assisted the bird survey crew and had to get up before dawn, which meant 2 a.m. in Alaska. We hiked up into the forest, sat down in an area, remained very quiet, and listened to the different birds calling in the early morning light. During my normal workdays, I would be moving around making all kinds of noise, measuring trees, shouting instructions, or digging soil pits. I was amazed to hear the "noise" of the forest after I was quiet enough to listen.

◀ **Dr. Dustin Wittwer**, Geospatial Services Specialist: My favorite science experience is collecting and analyzing geographic data from the remote and wild locations of Alaska. I love testing and using new and innovative technology to collect geographic data. After collecting the **spatial** data, I feed it into Geographic Information Systems (GIS), like Google Earth, and then use the geographic data to solve scientific puzzles.

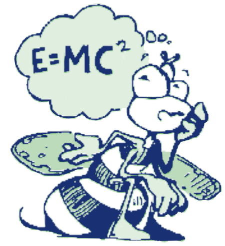
I used geographic data to help determine the causes of tree death in Alaska. I flew in small floatplanes and used mobile computer mapping systems and global navigation satellite systems to collect the data. We would be so remote at times that the airplane pilot would camp with us at the end of each day. The work, however, wasn't always without risk. One time the airplane's engine failed, and we had to land without power. Fortunately, the plane had floats, and we could glide to the water. I've also encountered bears, wolves, whales, caribou, moose, and musk ox while collecting data. I think seeing Alaskan wildlife is pretty cool!

▶ **Dr. Colin Shanley**, Geographic Information Systems Analyst: My favorite science experience was spending the summer tracking mountain goats by foot in the Cascade Mountains of Washington and Oregon.

◀ **Dr. Paul Schaberg**, Plant Physiologist: My favorite science experience is getting an unexpected result to an experiment. Sure, it is great to develop a hypothesis, test it in an experiment, and then get results that show your hypothesis was correct. But sometimes you get results that are surprising and interesting. The results teach you something totally new. These **novel** results can be very exciting. They help open up your imagination to unique thoughts and lead to the development of new hypotheses, new experiments, and new insights about the natural world.

Glossary words are **bold** and are defined on page 58.

Thinking About Science



Some research questions are complicated and can take many years to answer. Sometimes, many research studies are needed to discover the answer. When a research question is complicated, it may be answered slowly by different studies and over many years. Each study usually confirms or disproves what is thought to be true about one aspect of the question. In this research, the scientists wanted to know why a particular tree **species** was dying in the north Pacific coastal rainforest. To discover why this species was dying, scientists had to investigate aspects of the question one by one. When they got one answer, they were ready to advance to the next study.

This process of asking research questions, getting answers, and then asking more questions is similar to adaptive management. In adaptive management, however, managers make decisions and take actions each time new information is discovered. For scientists and managers, these actions create new research questions to explore.

What Kinds of Scientists Did This Research?

geographic information systems analyst: This scientist uses the relationship of information and places on Earth's surface to produce maps. Using these maps and other information, these scientists evaluate what the maps reveal about any place shown on the map.

geospatial services specialist: Like a geographic information systems analyst, this scientist uses any type of technology that accurately relates information to a place on Earth's surface to increase understanding of that place.

plant pathologist: This scientist studies plant diseases. Most diseases in trees are caused by fungi. Plant pathologists also investigate other injuries to plants and trees, such as those caused by weather and climate.

plant physiologist: This scientist studies how plants function.

soil scientist: This scientist studies Earth's soils.

Thinking About the Environment

A changing climate is causing some plant and animal species to move from their current habitat to a new habitat. For plants, the need to move might cause a problem. How does this move happen for plants, which are unable to move like animals? In new areas where the climate is favorable, plants spread through their seeds. Plant species move, therefore, by having their seeds **germinate** in more favorable environments.

Natural resource managers want to make the best possible decisions as the climate changes. To make these decisions, managers need as much information as possible. They get some of that information from scientists. In this study, the scientists wanted to understand how climate change was affecting the health of a particular tree species.

The scientists developed information to find the best way for the tree species to survive as the climate changes. Many tree species may be able to survive on their own as the climate changes. Others might need the help of humans. In this study, the scientists showed that the tree species they studied might need human help to survive in a changing climate. Now, managers can experiment with adaptive management options to see which one works best for this tree species.

How Do Plants Move?

To learn more about the movement of plants, visit http://www.scienceinvestigator.org, Climate Change edition, and read, "Seed Ya Later!"

Introduction

One factor affecting the type, number, and location of tree species within forests is climate. As the climate changes, the tree species living in a forest may also change. This change means that some trees species may die and new species may move into the area. Scientists find it difficult to know for sure whether tree movement and tree death result from a changing climate. Other factors, not related to climate, may also cause a forest's tree species to change.

In this study, the scientists were interested in a change they observed in a particular rainforest. This rainforest is located along the Pacific coast in southeastern Alaska (**figure 1**). In this rainforest, about 70 percent of the

What Is Adaptive Management?

Have you ever heard that experience is the best teacher? This idea is the foundation of adaptive management. Adaptive management is a way for land managers to deal with an unknown future and to learn from trying new things. When land managers try something new, the outcome is evaluated. Based on the evaluation, the managers might try another approach to improve their management. The process continues, with managers continuing to learn and adapt.

Scientists often help managers by designing and implementing the evaluation process. As you can see, scientists are involved in some parts of the adaptive management process. Land managers, however, treat the entire adaptive management process as an experiment. To use adaptive management to solve the problem of dying trees, managers must learn many things. What occurs when you do an experiment? Hopefully, you learn from your experience!

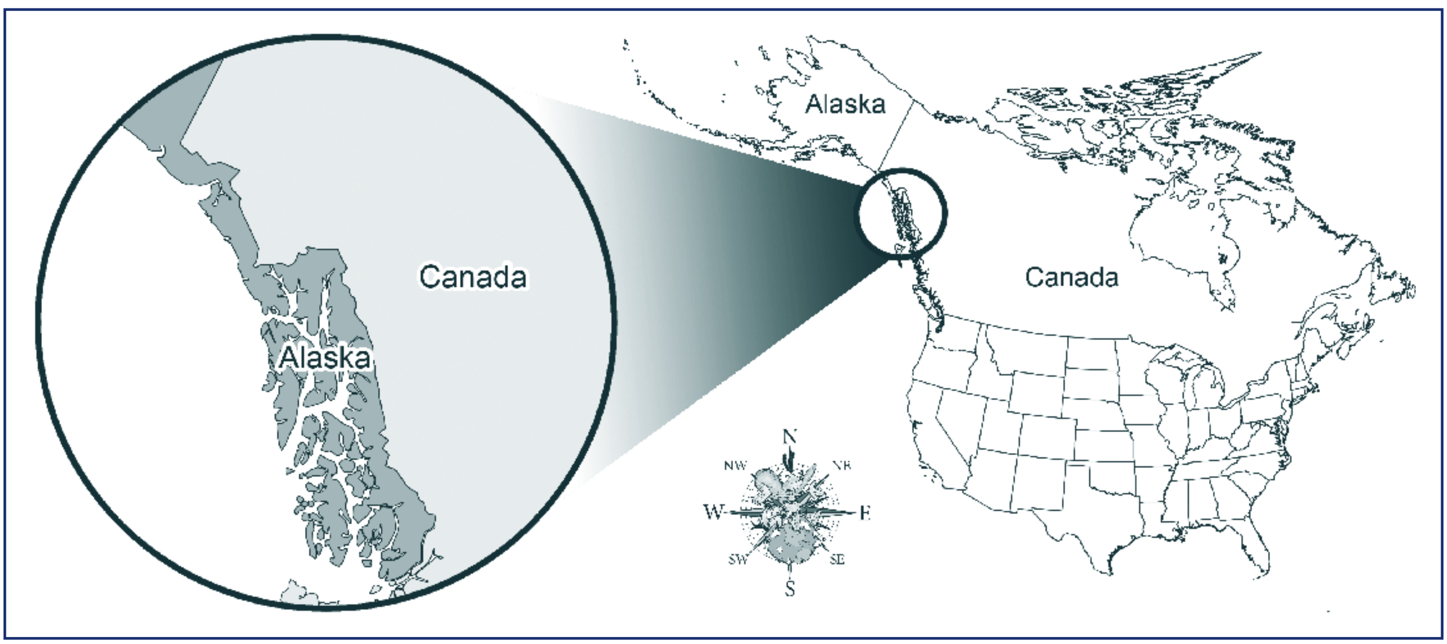


Figure 1. Yellow-cedar grows in the north Pacific coastal rainforest of southeastern Alaska. Map by Lindsay Gnann.

yellow-cedar trees have died in the past 100 years (**figures 2 and 3**).

The cause of yellow-cedar death was unknown for many years. The scientists in this study spent 20 years discovering the probable cause of yellow-cedar death. Like detectives, when the scientists solved one riddle, they moved to the next. The question the scientists hoped to answer was, "What is causing the death of yellow-cedar trees in the north Pacific coastal rainforest?"

Figure 2. A mature yellow-cedar tree. Photo courtesy of Dr. Paul Hennon.

Reflection Section

- What change did the scientists observe in the north Pacific coastal rainforest?
- Name two reasons why yellow-cedar is important to Alaskans. You must read "What Is Yellow-Cedar" on page 53 before you answer this question.
- What might be lost if yellow-cedar trees continue to die in the north Pacific coastal rainforest? You must read "What Is Yellow-Cedar" on page 53 before you answer this question.

Figure 3. The light-colored tree **boles** show what is left of dead yellow-cedar trees in the West Chichagof-Yakobi **Wilderness Area** of coastal Alaska. Dead yellow-cedar trees can remain standing for 80 years after death. They can remain standing because of **aromatic** chemicals in their wood. These chemicals protect the wood from fungi. Photo courtesy of Dr. Paul Hennon.

What Is Yellow-Cedar?

To Alaska Natives and all Alaskans, yellow-cedar is a culturally important tree. The wood and bark of yellow-cedar trees are used by Alaska Natives for constructing shelter, clothing, baskets, canoes, canoe paddles, and **totem poles** (**figure 4**). Yellow-cedar is resistant to insects and decay. Because of this resistance, yellow-cedar wood is used for many durable products and is important to Alaska's economy. Yellow-cedar trees grow slowly and can live up to 1,000 years.

Figure 4. A handmade, yellow-cedar canoe made by Larry Bowers. Photo courtesy of Larry Bowers, http://www.westcountrycanoes.com.

Methods

In the late 1980s, a team of scientists observed the roots, boles, and **crowns** of yellow-cedar trees that were in various stages of dying. The scientists carefully observed the trees. The scientists found that in order of occurrence, the symptoms of upcoming death were: (1) **fine root** death; (2) **coarse root** death; (3) attack of the weakened tree's bole by insects, fungi, viruses, and other organisms; and (4) crown death (**figure 5**). The last leaves in the crown to die were the ones most distant

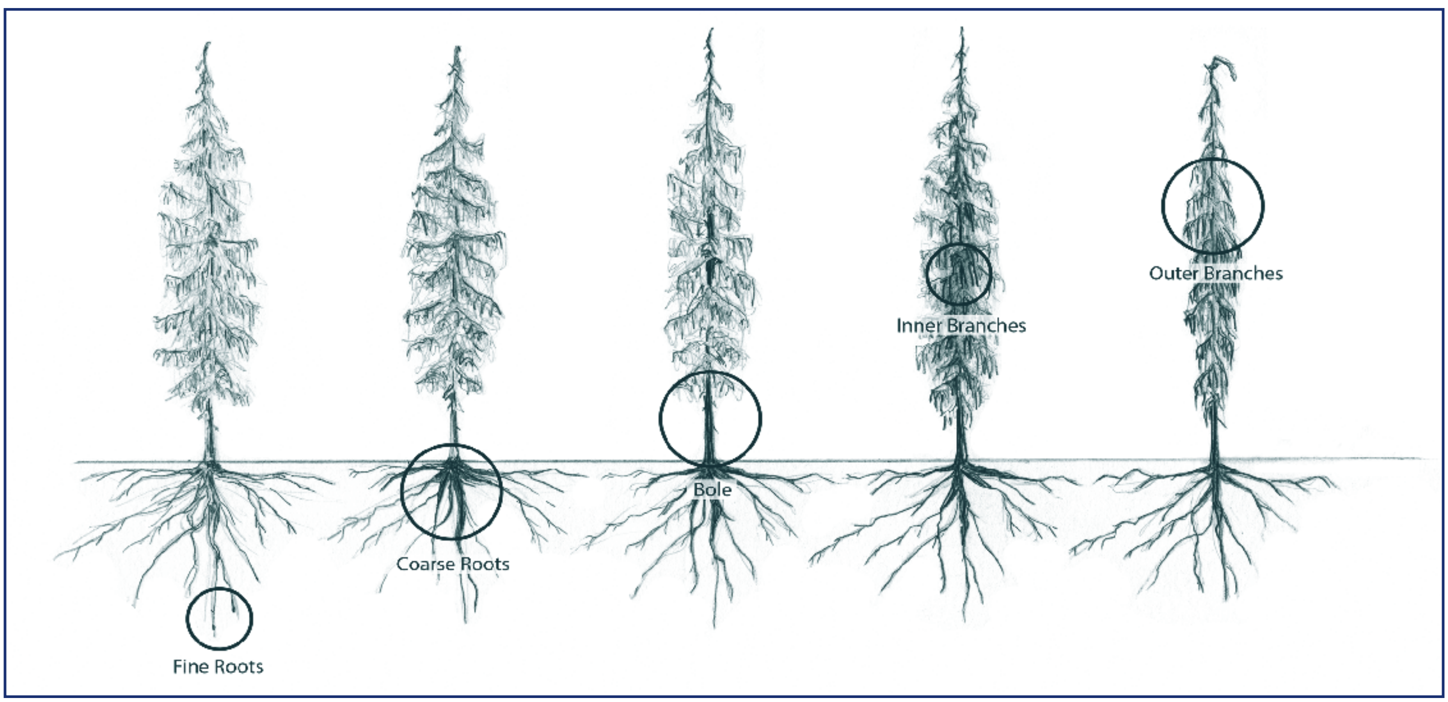


Figure 5. Death of yellow-cedar trees seemed to start from the fine roots and move upward through the tree. (1) shows a tree's fine roots and (2) shows a tree's coarse roots. Illustration by Stephanie Pfeiffer.

from the tree's bole. From these observations, the scientists concluded that a living organism, such as an insect, did not cause the trees' death. The scientists concluded the deaths had a nonliving cause related to the fine roots. It would be unlikely for an insect to cause the fine roots to die. It was only after the fine and coarse roots had died that insects attacked the trees.

To determine the cause of death, the scientists divided their research into smaller studies. In each of these studies, scientists observed and measured a different abiotic (**ā** bī **ä** tik) factor. Abiotic means it is a nonliving factor. Examples of abiotic factors studied include the amount of water in the soil, soil temperature, soil chemistry, air temperature, amount of **forest cover**, and the state of the climate near the soil surface. The scientists spent nearly 20 years studying these different abiotic factors.

One of the abiotic factors studied was how well fine roots tolerated cold temperatures. It was difficult to study the roots because they were underground, so the scientists used a **surrogate** for the roots. The scientists measured the cold tolerance of leaves. They observed whether the tips of the leaves died following cold temperatures (**figure 6**). Cold tolerance is the degree to which leaves can live despite freezing temperatures. The scientists compared the cold tolerance of leaves of yellow-cedar with western-hemlock trees. Western-hemlock trees growing in the same area were not dying. If the yellow-cedar trees were less cold tolerant than western hemlock trees, the scientists had another clue about yellow-cedar tree death.

The scientists also **simulated** snow cover on young yellow-cedar trees (**figure 7**). They did this simulation because snow has an insulating effect on the ground. In cold climates, a blanket of snow keeps the ground warmer than it would be without the snow.

Adaptive Management in Your Life

Do you have a vegetable garden in your schoolyard? If you do not, pretend that you do. Your class has decided to use adaptive management to improve the garden. First, you must identify a problem and your objective. Let's say that all of the vegetables in the garden are ready during the summer. This summertime harvest is a problem because your class observes a summer holiday.

The class objective is to produce vegetables that can be harvested during the school year. Your class does research in the media center. You identify four fall and winter vegetables and plant them in the garden. After 2 months, you observe and record the plants' progress. One of the vegetables has not survived. Two additional winter vegetables are identified. These vegetables are planted, and all vegetables are evaluated after another 6 weeks. After evaluating your results, your class does more research. What steps will you take next?

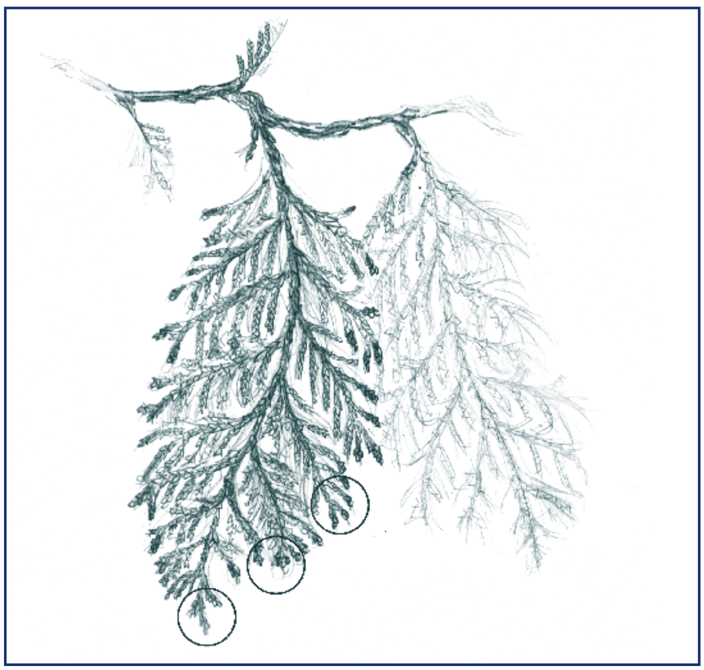


Figure 6. The scientists measured the cold tolerance of leaves as a surrogate for the cold tolerance of roots. Illustration by Stephanie Pfeiffer.

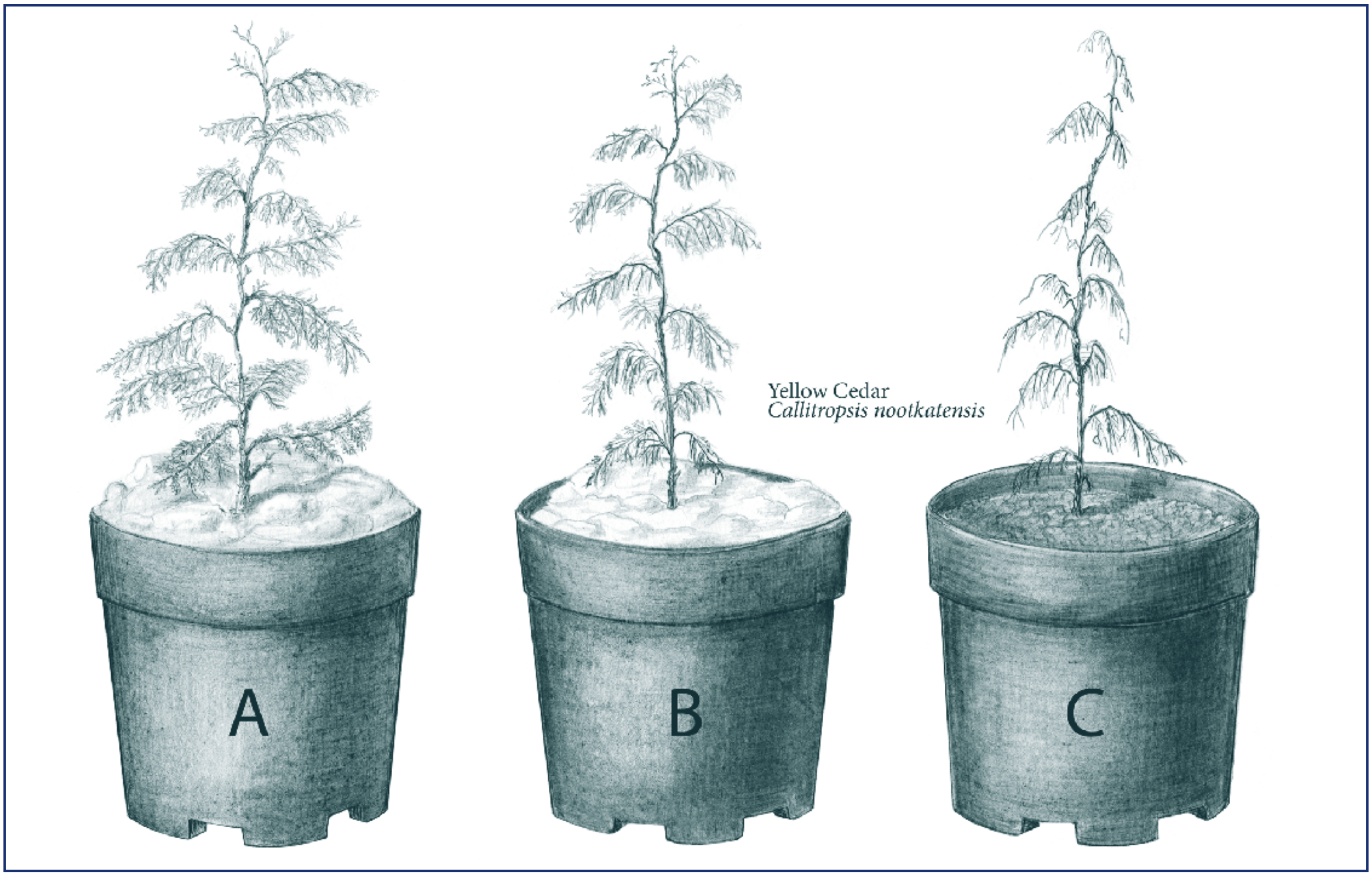


Figure 7. The scientists simulated snow cover around young yellow-cedar trees to measure the snow's insulating effect on the ground and the yellow-cedar roots. What do you notice about the tree on the right? This tree did not have simulated snow cover. Illustration by Stephanie Pfeiffer.

Reflection Section

- Examine figure 5 and reread the final two paragraphs of the previous section. What do you think the scientists discovered about the cold tolerance of yellow-cedars?
- How might climate change be involved in the death of yellow-cedar fine roots?

Findings

The scientists discovered that when the soil temperature around a **seedling** dropped to less than -5 degrees Celsius (C), the fine roots were severely injured and the seedling died. The temperature dropped below this point when snow cover had melted enough so that it no longer provided protection from the cold. Later, the scientists discovered that when the temperature was less than -5 degrees C, fine roots of large, mature trees also died. This temperature was reached in shallow soils when no snow was on the ground.

The scientists also discovered that the yellow-cedar trees were dying on wet, poorly drained soils. When soils are wet, the fine roots tend to be shallow. These shallow roots are more likely to be affected by freezing temperatures when no snow is present.

The scientists compared the progression of yellow-cedar tree death with other studies of tree death. When the roots of trees are injured, they cannot provide the tree with water and nutrients, and the tree eventually dies.

The scientists concluded that snow cover that remains into the spring protects yellow-cedar roots from injury. As the climate warms, snow cover does not remain as long into the spring. Although the climate is gradually warming, Alaskan spring temperatures may still drop to less than freezing. A lack of or reduced snow cover enables the soil to freeze, killing the fine roots near the soil surface.

Reflection Section

- A paradox is a seeming contradiction. What is the paradox of this study's findings?
- Reread "Thinking About the Environment." What do you think the scientists recommended to help keep yellow-cedar trees alive in Alaska?

Discussion

The scientists' research revealed some actions that managers can take to help yellow-cedar trees adapt under changing climate conditions. Yellow-cedar trees grow slowly. Without help from managers, the trees may be unable to reproduce in colder areas that still have enough spring snow cover. The scientists recommended that managers plant yellow-cedar seedlings in colder areas (**figure 8**).

The scientists also recommended that yellow-cedar seedlings be planted in deeper, well-drained soils. Yellow-cedar trees need help to move into these two kinds of areas. Without help, the trees may not be able to move fast enough on their own to adapt to climate change.

You Are the Adaptive Manager!

Pretend you are the natural resource manager for these areas of yellow-cedar. You have just been told about the findings of this research. You want to use adaptive management in your practice. What are two things you would do next?

Reflection Section

- Adaptive management is a way to manage natural resources so the best decisions can be made under changing conditions. Explain how the scientists' recommendation about yellow-cedar can be used in adaptive management.
- Why would yellow-cedar trees need managers' help to move into a more suitable environment? See "Thinking About the Environment" for a clue.
- How could the model in figure 8 be used in adaptive management?

Adapted from Hennon, P.E.; D'Amore, D.V.; Schaberg, P.G.; Wittwer, D.T.; Shanley, C.S. 2012. Shifting climate, altered niche, and a dynamic conservation strategy for yellow-cedar in the North Pacific coastal rainforest. Bioscience. 62: 147- 158. http://www.treesearch.fs.fed.us/pubs/40035.

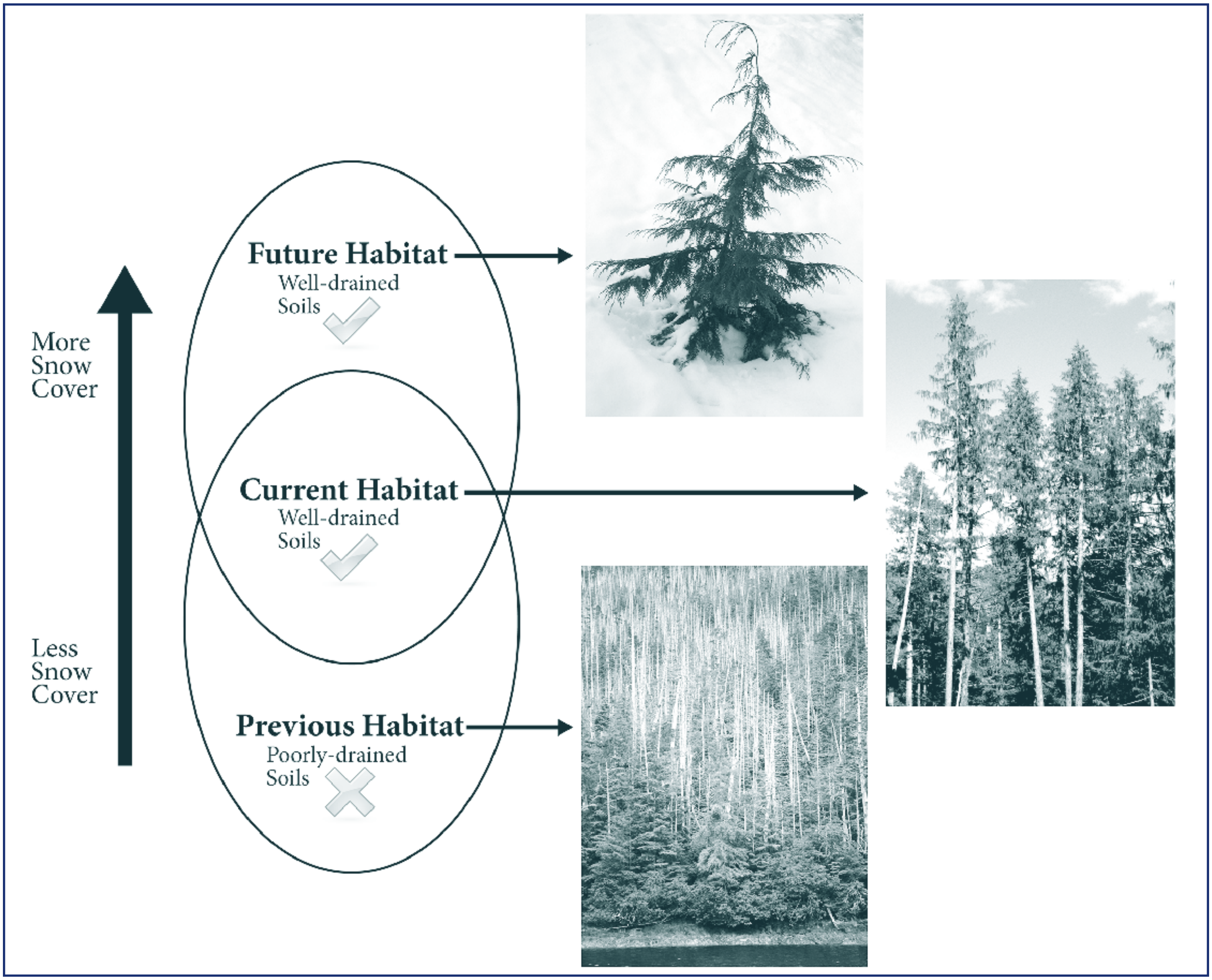


Figure 8. Three zones for yellow-cedar were identified. This illustration is a model of the scientists' yellow-cedar management recommendations. The scientists recommended that managers take action to help yellow-cedar move into a zone that will help them live into the future. Illustration by Stephanie Pfeiffer.

The title, "Cedar Waxing or Waning?" comes from two sources. Waxing means getting larger and waning means getting smaller. The moon, except for its full and new moon phases, is always either waxing or waning. (Will the moon be waxing, waning, full, or new tonight?) The second source is the cedar waxwing (**figure 9**). The cedar waxwing is a migratory bird that eats fruit, particularly berries. In the winter, the bird migrates from Southern Canada to the Southern United States. The cedar waxwing can be found in the Northern United States all year.

Figure 9. Cedar waxwing. Photo by Bill Thompson and courtesy of the U.S. Fish and Wildlife Service.

Glossary

aromatic (**a** rə **ma** tik): Having a strong smell.

bole (bōl): Tree trunk.

coarse root (kȯrs rüt): The thicker root structure of a plant when compared with the finer roots.

crown (kräun): The leaves of a tree.

fine root (fīn rüt): The small, hair-like roots growing out of a plant's coarse roots.

forest cover (**fȯr** əst **kə** vər): The area of land covered by forest crowns.

iconic (ī **kän** ik): Of or pertaining to an icon. An icon is a picture representation, a symbol.

maladapted (ma lə **dap** təd): Poorly suited or unsuited.

novel (**nä** vəl): New and not resembling anything used or known before.

pristine (pris **tēn**): Not spoiled or polluted.

seedling (**sēd** liŋ): A young plant grown from seed.

simulate (**sim** yə lāt): To give the appearance or effect of.

spatial (**spā** shəl): Relating to, occupying, or having the character of space or area.

species (**spē** sēs): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

surrogate (**sər** ə gāt): Substitute.

totem pole (**tō** təm pōl): A pole carved and painted with totems and set up by native Alaskan peoples. A totem is an honored symbol.

wilderness area (**wil** dər ness **er** ē ə): An area in the United States designated by law for preservation and protection in its natural condition. A wilderness area also refers to a large unspoiled natural area.

Accented syllables are in **bold.** Marks and definitions are from http://www.merriam-webster.com.

FACTivity

Common Core Connection

Time Needed

One class period

Materials (for each small group)

- Blank sheets of paper
- Pencils
- *Natural Inquirer* Wilderness Benefits edition (order for free or download at http://www.naturalinquirer.org)
- *Natural Inquirer* Invasive Species edition (order for free or download at http://www.naturalinquirer.org)
- USA Today article on yellow-cedar decline: http://www.usatoday.com/weather/climate/2006-03-27-yellow-cedar_x.htm
- Wikipedia article on assisted tree migration: http://en.wikipedia.org/wiki/Assisted_migration
- This article

In this FACTivity, you will consider the recommendation made by the scientists in this study. You will also discuss the advantages and disadvantages of following the scientists' recommendation. You will then consider a bigger question: When, if ever, should natural resource managers make changes to large areas of wildland?

Background

When managers practice adaptive management, they anticipate and prepare for the future. They take actions now that they believe will bring about desired results in the future. Managers continually evaluate what they are doing and make changes as needed. In this research, the scientists recommended planting yellow-cedar trees in areas where they have not been found before. In Alaska, these areas are large areas of undeveloped forest land where other tree species currently grow.

Methods

Consider a section of a newspaper article written by Barry Saxifrage. This newspaper article was published on February 9, 2012, in the Vancouver (British Columbia, Canada) *Observer*. This newspaper article was written about the yellow-cedar research you just read. The first sentence that follows refers to the scientists' suggestion that yellow-cedar seedlings be planted in areas where they do not now live.

> In other words, we may be forcing ourselves and future generations to become permanent gardeners of the "wilderness." And not just for yellow-cedars. Already serious discussions are underway for other **iconic** long-lived trees like the giant sequoias of California. They too are becoming "**maladapted**" to their ancient habitat as a result of fossil fuel pollution reducing snowfall and overall precipitation. Surveys show the number of giant trees dying each year has doubled. Concern is growing over the inability of seedlings to thrive in the drying climate. Scientists and forest managers talk about the need to water, raise, and even possibly transplant these trees to new regions. For trees that can live thousands of years, the rapid climate shift underway now is going to be a struggle.

Note that Mr. Saxifrage also mentioned another tree species humans may need to rescue from a warming climate. Many tree species may need help being located to a new habitat. Mr. Saxifrage asked the question:

> How long will humans choose to garden increasingly large swaths of the wild to try to prevent a collapse of species richness and biodiversity? How much can we really do even if we decide we want to?

Your teacher will divide the class into small groups. Each group will do research and decide which of the following two positions to take: (1) We must modify large areas of forest now by planting yellow-cedar tree seedlings or (2) We should not modify native forests by planting yellow-cedar tree seedlings where yellow-cedar has not grown before. You may use the resources given to you by your teacher, or you may access the Internet, use the media center, and simply reflect on and discuss the question.

Take a blank sheet of paper and write either "Plant yellow-cedar" or "Do not plant yellow-cedar" at the top. Draw a line down the middle of the page and across the page, half way down. Label the top section "Advantages" and the bottom "Disadvantages." As a group, research and discuss your topic.

As a group, take 20 minutes to discuss and list the advantages and disadvantages of planting or not planting yellow-cedar. Then, present your findings and hold a class discussion about planting yellow-cedar. Share your group's position and reasons for taking that position. Finally, consider and discuss the related larger question, "When, if ever, should natural resource managers make purposeful changes to large areas of wildland?"

FACTivity Extension

You will write a short newspaper editorial or a blog that responds to Mr. Saxifrage's questions.

Common Core Connection

Additional FACTivity Extension

In small groups, create an adaptive management experiment to figure out where yellow-cedar seedlings grow best. Write up your experiment to include a research question, management action, and what and how you will monitor the effects of the management action. Use your knowledge of adaptive management to place this experiment into an adaptive management process.

Common Core Connection

Note to Educator: If you are a Project Learning Tree (PLT) educator, you may use "Trees in Trouble" as an additional activity.

PLT

Web Resources

How trees might move in a changing climate
http://www.naturalinquirer.org and read, "Moving On Up" in the Climate Change edition

"Freezing to Death in a Warming Climate: Yellow-Cedars in Trouble"
http://www.vancouverobserver.com/blogs/climatesnapshot/2012/02/09/freezing-death-warming-climate-yellow-cedars-trouble?page=0,0

USA Today article on yellow-cedar decline
http://www.usatoday.com/weather/climate/2006-03-27-yellow-cedar_x.htm

Assisted tree migration
http://en.wikipedia.org/wiki/Assisted_migration

Totem poles
http://www.native-languages.org/totem.htm

For a *Natural Inquirer* article about the roots of trees
http://www.naturalinquirer.org, "FACE Look"

Scientific Models in Adaptive Management Word Search

S	P	V	S	F	L	O	H	Q	Z	Q	R	L	A	B
P	R	N	O	E	U	I	X	V	I	Q	I	I	G	E
E	U	C	V	M	E	R	N	U	B	H	R	N	Z	T
G	J	O	R	V	C	D	E	O	X	E	O	L	I	A
N	N	N	V	G	B	E	L	S	T	I	M	J	Y	G
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L	F	R	R	Q	P	C	R	C	C	G	A	C	K	R
E	A	V	H	M	T	G	P	C	K	K	K	R	H	U
A	M	A	G	N	I	T	U	D	E	J	S	X	Y	S
Q	M	T	O	M	O	N	I	T	O	R	O	B	H	R
G	E	I	H	B	U	F	A	O	A	X	K	L	C	J
E	L	O	P	M	E	T	O	T	O	Y	F	P	N	G
T	I	N	Q	W	K	Y	K	C	E	M	O	R	G	X
A	D	O	X	F	K	J	V	A	P	Q	H	A	J	E

1. Tree trunk.

2. Planned management of a natural resource to prevent explotiation, destruction, or neglect.

3. Standards upon which a judgment or decision may be based.

4. A usually undesirable or unpleasant choice.

5. A water passage where the tide meets a river current.

6. To cause to sprout or develop.

7. The appearance of the sunlit portion of the moon.

8. Size, quantity, or number.

9. The act of passing periodically from one region to another for feeding or breeding.

10. To watch, keep track of, or check usually for a special purpose.

11. New and not resembling anything used or know before.

12. An aim, goal, or end action.

13. A young plant grown from seed.

14. Substitute.

15. A pole carved and painted with totems and set up by native Alaskan natives.

Scientific Models in Adaptive Management Photo Challenge

Each of the following appeared in one of the articles in this journal. Explain what each of these photos represent. You may write your explanation or hold a class discussion. If you write your explanation, use complete sentences and proper spelling, grammar, and punctuation.

Common Core Connection

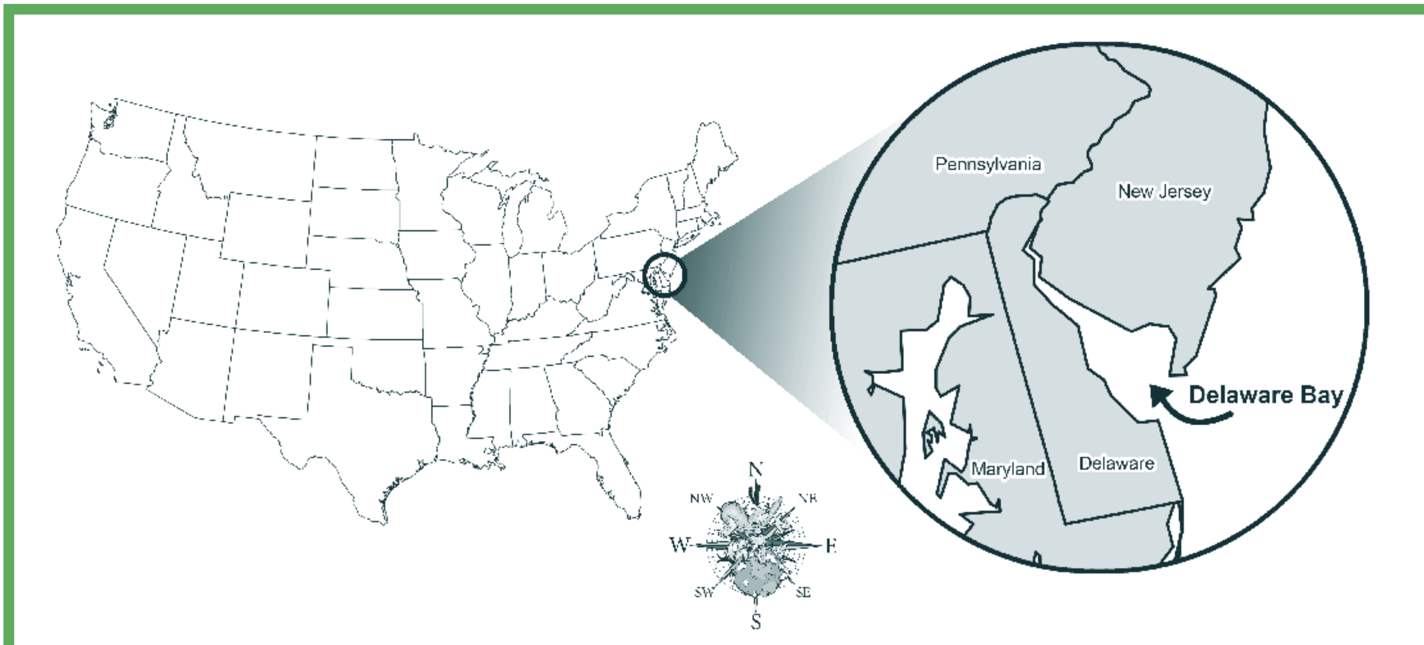
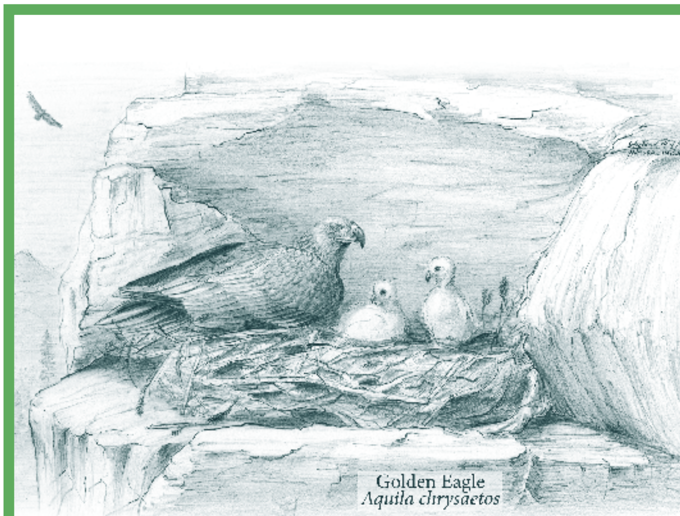
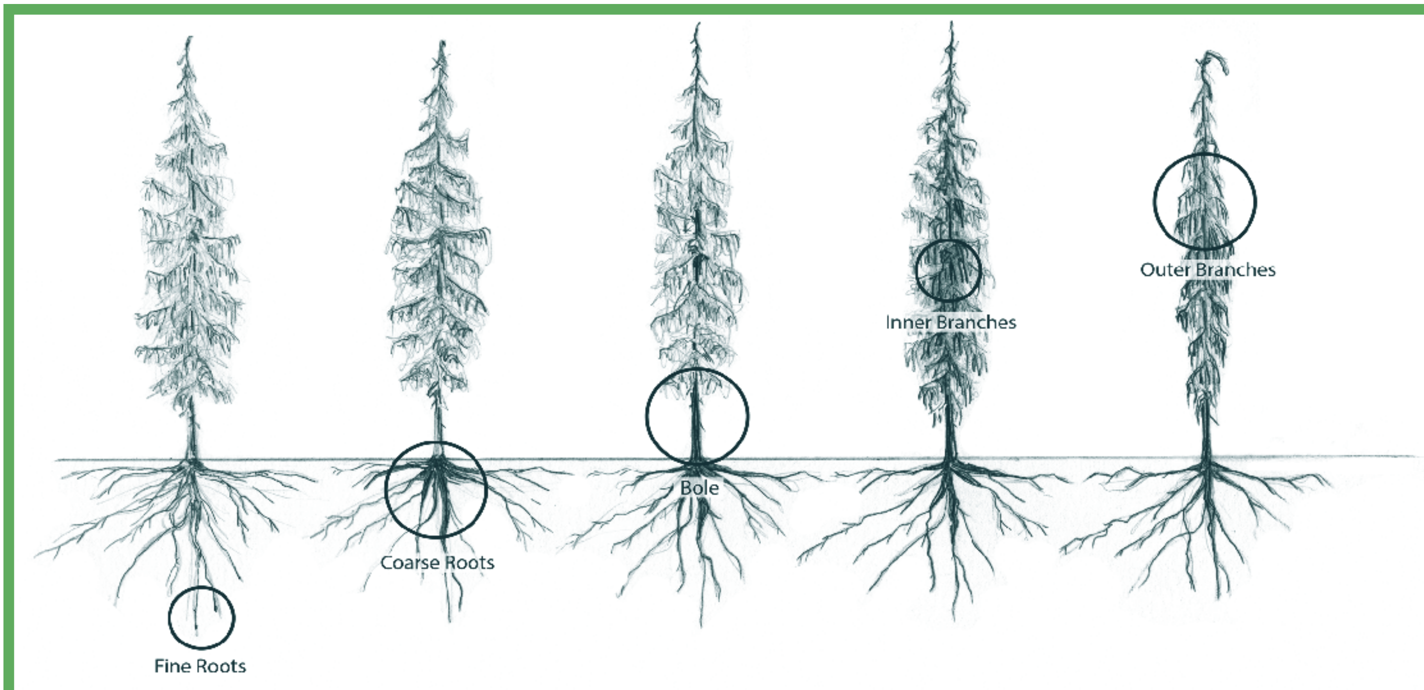
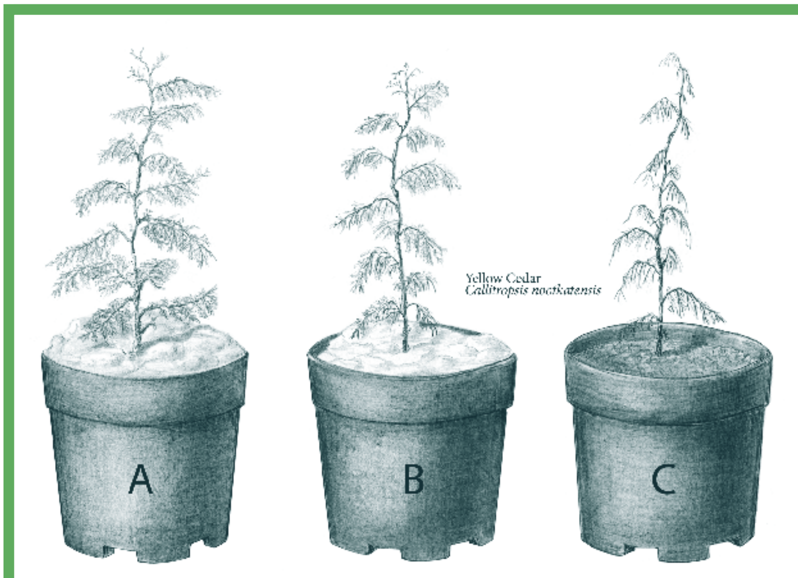
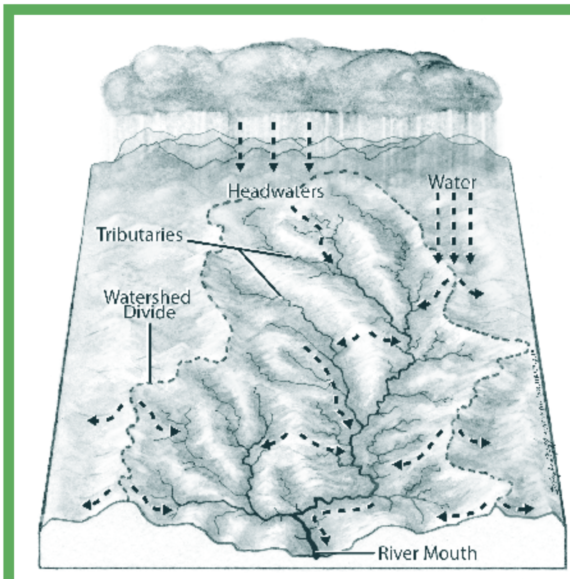


Photo courtesy of U.S. Fish and Wildlife Service, Gregory Breese.









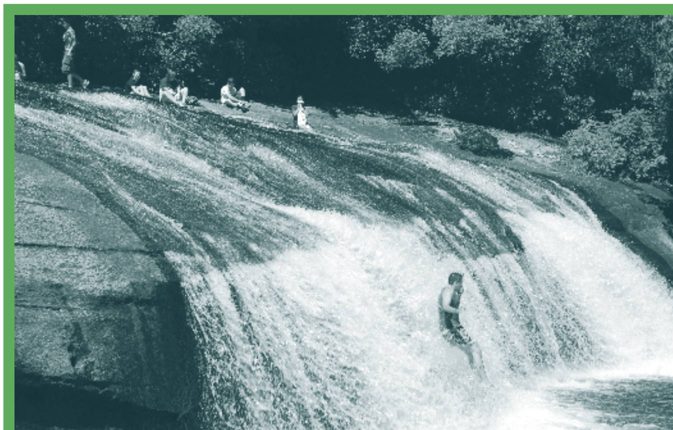


Photo by Babs McDonald.

National Education Standards

(A generic Common Core State Standards alignment for the *Natural Inquirer* can be found on the "Education Standards" page under "Educational Resources" at the *Natural Inquirer* Web site, http://www.naturalinquirer.org.)

Which National Science Education Standards Can These Articles Address?

	The Golden Egg	At Your Service	Tying the Knot	Cedar Waxing or Waning?
Science as Inquiry				
Abilities Necessary To Do Scientific Inquiry	✓	✓	✓	✓
Understandings About Scientific Inquiry	✓	✓	✓	✓
Life Science				
Regulation and Behavior	✓		✓	✓
Populations and Ecosystems	✓	✓	✓	✓
Diversity and Adaptations of Organisms	✓	✓	✓	✓
Reproduction and Heredity	✓		✓	
Earth Science				
Structure of Earth System		✓		
Science in Personal and Social Perspectives				
Risks and Benefits				✓
Science and Technology in Society	✓	✓	✓	
Natural Hazards	✓		✓	
History and Nature of Science				
Science as a Human Endeavor	✓	✓	✓	✓
Nature of Science	✓	✓	✓	✓

Which National Curriculum Standards for Social Studies Can These Articles Address?

	The Golden Egg	At Your Service	Tying the Knot	Cedar Waxing or Waning?
Culture		✓		✓
Time, Continuity, and Change		✓	✓	✓
People, Places, and Environments	✓	✓	✓	
Power, Authority, and Governance	✓			
Production, Distribution, and Consumption		✓	✓	✓
Science, Technology, and Society	✓	✓	✓	
Global Connections			✓	

What Is the Forest Service?

The Forest Service is part of the United States Department of Agriculture (USDA). The Forest Service is made up of thousands of people who care for the Nation's forest land. The Forest Service manages more than 150 national forests and nearly 20 national grasslands. These are large areas of trees, streams, and grasslands. National forests are similar in some ways to national parks. Both are public lands, meaning they are owned by the public and managed for the public's use and benefit. Both national forests and national parks provide clean water, homes for the animals that live in the wild, and places for people to do fun things in the outdoors. National forests also provide resources for people to use, such as trees for lumber, minerals, and plants used for medicines. Some people in the Forest Service are scientists whose work is presented in the journal. Forest Service scientists work to solve problems and provide new information about natural resources so that we can make sure our natural environment is healthy, now and into the future.

http://www.fs.fed.us.

What Is the Cradle of Forestry in America Interpretive Association?

The Cradle of Forestry in America Interpretive Association is a 501(c)3 nonprofit organization based in Pisgah Forest, North Carolina. The interpretive association strives to help people better understand ecology through recreation and education opportunities. Their projects include the following:

- Campground and recreation area management
- Educational programs and services, including *Natural Inquirer, Investi-gator*, and *Nature-Oriented Parenting*
- Sales of forest-related gifts and educational materials
- Workshops, newsletters, and publications
- Partnership with the Forest Service to provide programming at the Cradle of Forestry Historic Site

http://www.cfaia.org

What Is the United States Geological Survey (USGS)?

The USGS is part of the United States Department of the Interior. The USGS is a science organization that provides impartial information about the—

- Health of our ecosystems and environment
- Natural hazards that threaten us
- Natural resources on which we rely
- Effects of climate and land use change
- Core science systems that help us provide timely, relevant, and useable information

http://www.usgs.gov.

United States Department of Agriculture

Forest Service

FS-1030
Summer 2014

Sandy Creek Teen Camp, Athens-Clarke County, Georgia, Katie Barnett, Camp Director

Editorial Review Boards

Brethren Middle School, Brethren, Michigan, Gail Bennett and Rachel Edmondson, Teachers

Web Site Resources

Natural Inquirer
http://www.naturalinquirer.org

Investi-gator
http://www.scienceinvestigator.org

Forest Service Conservation Education
http://www.fs.usda.gov/conservationeducation

U.S. Geological Survey
http://www.usgs.gov

U.S. Geological Survey Education
http://education.usgs.gov/

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