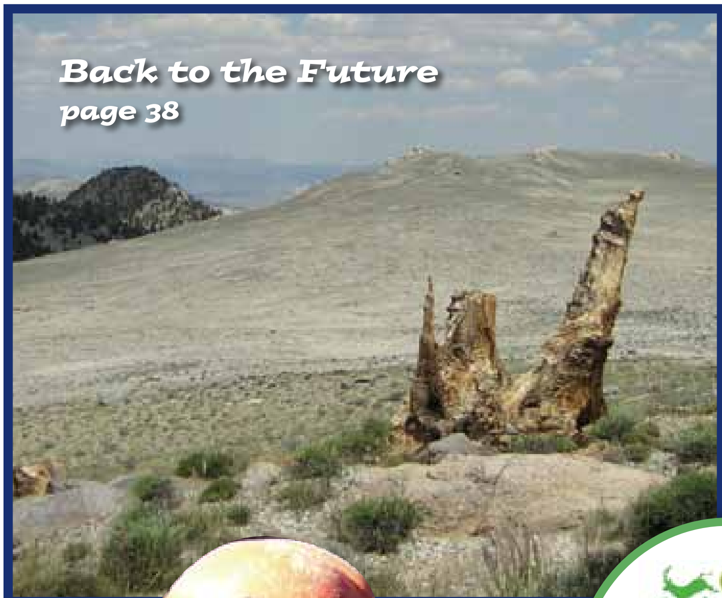
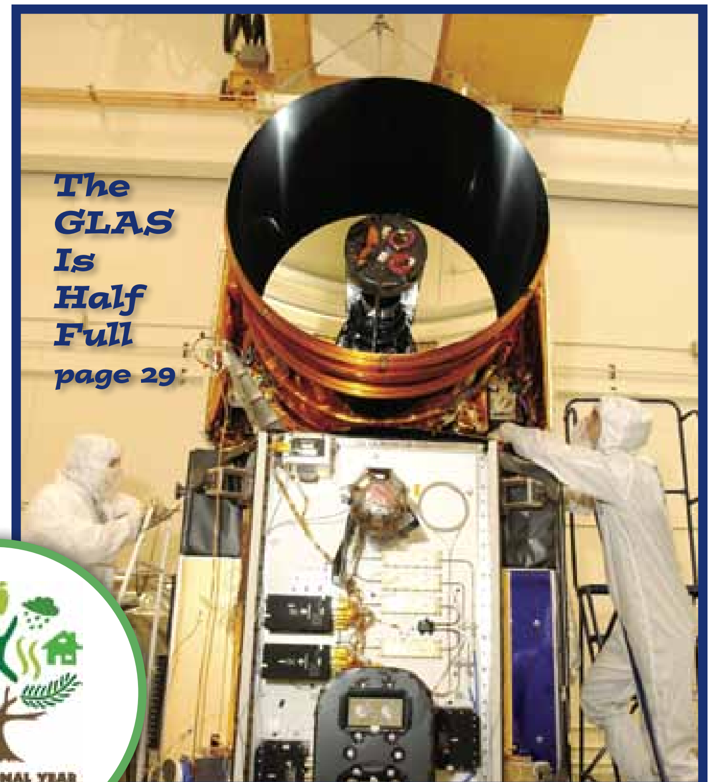
Natural INQUIRER

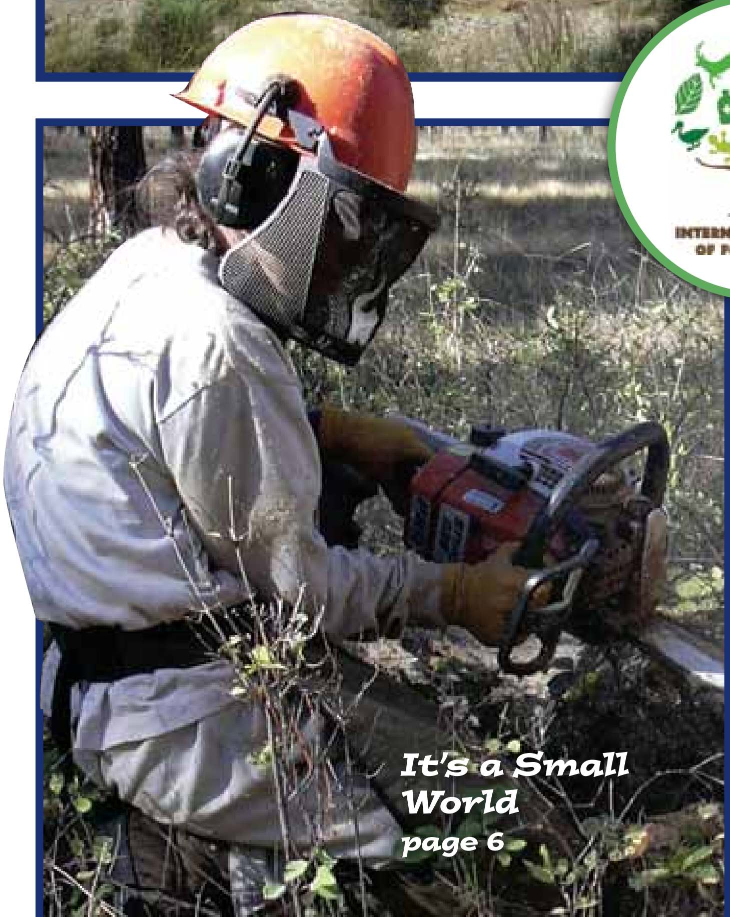
Climate Change Edition

Number 14





INTERNATIONAL YEAR OF FORESTS • 2011



Natural Inquirer

Climate Change Edition • Number 14 • Winter 2011

Produced by

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Cradle of Forestry Interpretive Association

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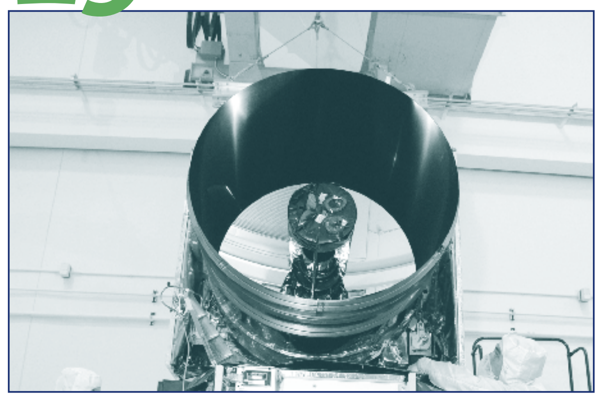

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Editorial Review Boards

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

Climate Change Editorial Review Boards' Comments

"I like the fact that it is useful for people who love science and it keeps us focused on our planet and why we should help keep it under control."

"This paragraph is very well written and is easy to understand."

"This is worthwhile! We need to learn about this.... We need to fix this problem soon."

"I think you should put in a lot more information. Kids want to know how to tell the age of a tree."

"Great to know but not everyone cares about GPS [global positioning systems] and longitude and latitude. Everybody should care, so spice it up a bit."

"I enjoy how this [Fire Safety Tips] ties into the article."

"Great facts but you need some that WOW us!"

"I think you should put the definitions near the words throughout the article."

"I like how there is a glossary."

"Cool, sounds like a cool job!"

Athens-Clarke County, Georgia Leisure Services Department, Memorial Park Day Camp, Counselors Michael James, Sanjay Rema, and Katie McMichael

Oconee County, Georgia Parks and Recreation Department, Teen Extreme Program, Oconee Veterans Park, Kelsey Tate, Assistant Youth Programs Coordinator and David Martin, Counselor

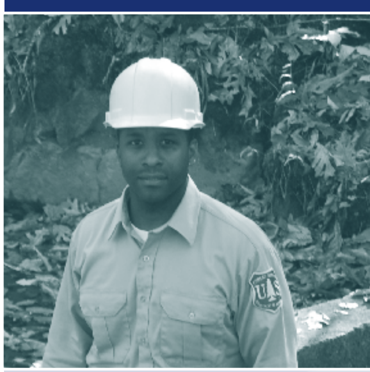
About the Natural Inquirer

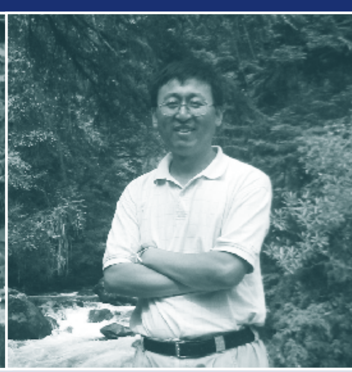
Scientists report their research in journals, which are special booklets that enable scientists to share information with one another. This journal, the *Natural Inquirer*, was created so that scientists can share their research with you and with other middle school students. Each article tells you about scientific research conducted by scientists in the Forest Service, U.S. Department of Agriculture. If you want to know more about the Forest Service, you can read about it on the inside back cover of this journal, or you can visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org.

All of the research in the *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.

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 environmental scientist, you must:

- **Be curious**—Are you interested in learning?
- **Be enthusiastic**—Are you enthused about an environmental topic?
- **Be careful**—Are you accurate in everything that 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 Climate Change edition of the *Natural Inquirer*!

Is the climate changing over time? You probably have heard many different opinions about climate change. In the past few years, most scientists have agreed on at least one thing about climate change. They have agreed that measured and recorded changes in Earth's climate over the past 100 or more years point to a warming of Earth's surface greater than they would have expected from normal cycles. Normal cyclical (**si** kli kəl) changes in Earth's ocean currents and atmospheric (**at** mə **sfir** ik) pressure cause changes in weather and climate patterns on land. (Read "It's a Small World" to learn more!)

What are Earth's normal cycles? Scientists have discovered that Earth has many different oceanic (ō shē **a** nik) and atmospheric cycles. In this *Natural Inquirer*, you will read about research concerning a short-term cycle called El Niño. El Niño is part of a cycle that occurs every 4 to 7 years. You will also read about cycles that occur every 30 to 40 years. Even longer cycles have been discovered as well; one of these cycles lasts about 1,500 years, and still longer cycles last for thousands of years. Each of these cycles has a cool phase and a warm phase, which occur when Earth's climate either cools a little or warms a little.

Earth's average temperature depends on how much of the Sun's energy comes through the atmosphere to Earth's surface, and how much escapes back into space. About 90 percent of the Sun's energy is trapped by gases in the atmosphere, including carbon dioxide, methane, and nitrous oxide. This trapped energy is sent back to Earth in all directions, warming the planet. This warming is called the greenhouse effect, and the gases are called greenhouse gases. Without these gases, humans and other forms of life would not be able to survive on our planet.

During the past 150 years, however, the amount of greenhouse gases in the atmosphere has risen sharply. This increase has been happening since the beginning of the Industrial Revolution. Scientists believe the sharp rise in greenhouse gases is caused by an increase in the burning of fossil fuels, such as oil, coal, and natural gas. These higher levels of greenhouse gases in the atmosphere trap more of the Sun's heat that is reflected off of Earth's surface. This additional trapped heat leads to increasing temperatures on Earth.

Evidence from scientific measurements gives scientists more confidence in their conclusions about global climate change. Every year, global temperatures have been rising, the amount of Arctic sea ice has been shrinking, and glaciers are getting smaller. Scientists are now able to use computer programs to track and predict both atmospheric and oceanic movements across the globe. They are able to see how these movements affect short-term and long-term weather patterns.

Global climate change is sometimes called global warming. Scientists use the term "global climate change" because many aspects of Earth's climate are changing. Along with rising yearly temperatures, scientists predict increases in both droughts and flooding. The effects of climate change will be different in different places on Earth. Some places will experience periods of heavy rain, for example, and others will experience periods of low rainfall.

As the global climate changes, we will experience changes on Earth. In "Did They Make the Gradient?" you will learn what

As the climate changes, scientists predict that sea level will rise. Photo courtesy of Babs McDonald.

scientists have discovered about rising stream temperatures. As the climate changes, the types and numbers of trees and other plants will shift where they grow. Some trees and plants will die off in areas, and they may grow in new areas. A warmer climate with more summer rainfall, for example, may cause an increase in the growth of grasslands in the United States. Trees that grow in the Southern United States may begin to grow farther north. You will read about how the habitat of trees may change in "Moving on Up." The places where animals are found will change, in connection with changes in vegetation and temperature. One type of butterfly, for example, is now found living farther north than it lived in the past. In "There's Snow Place Like Home," you will learn how the habitat of the wolverine has changed over time.

While humans work to reduce the amount of fossil fuels being burned, we also must work with the coming changes. To do so, scientists and forest managers are thinking in the following new ways:

1. Instead of fighting change, work with it. Do what you can to reduce the impact of climate change, but be prepared for change and adapt as needed.
2. Understand that we do not know exactly what will happen in the future, but we do the best job we can using predictions. Sometimes, we will make a decision about what to do only to discover that later, we may have to make a different decision.
3. Accept that the way we did things in the past may not be the best choice for the future.
4. Focus on the way forests and other natural systems live, grow, and change, instead of what they look like.

In this *Natural Inquirer,* you will learn how scientists are using trees that died many years ago to predict the future ("Back to the Future"). You will also learn how information from satellites is helping scientists to understand how forests are changing on Earth ("The GLAS is Half Full").

Although climate change is bringing challenges for everyone, it is also helping us to think in new ways and do some things differently. In this *Natural Inquirer,* you will find suggestions about things you can do to help. You might come up with new ideas yourself! Every day, every individual has a chance to do something to help our environment.

It's a Small World:

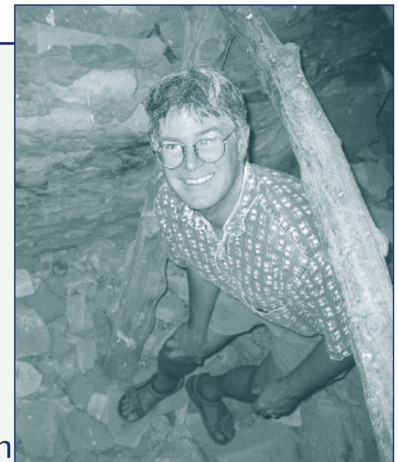
Photo courtesy of Emily K. Heyerdahl.

How Oceans and the Climate Can Affect Wildland Fires Thousands of Miles Away

Meet the Scientists

Dr. Thomas Kitzberger, Biogeographer (**bī** ō jē **ä** grə fər): My favorite science experience is scouting large unexplored areas in search of evidence of past fires from old trees. It is like time traveling to find an old tree with many fire scars. It makes you think, "This tree was born way before Columbus arrived in America. This tree witnessed cultures from which humankind does not have written reports." Through careful study, trees tell stories about people and how they interacted with their environment. ▶

▲ **Dr. Emily Heyerdahl**, Dendrochronologist: My favorite science experience is solving ecological puzzles about past wildland fires using tree rings. Just as when I was a young woman, I like being outside all summer collecting data and **samples** from trees that were alive hundreds of years ago. During the winter and in the laboratory, I also take joy in dating wood samples with a microscope and in exploring data with a computer.

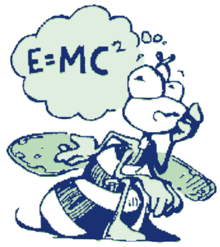


▶ **Dr. Peter Brown**, **Dendrochronologist** (**den** drō krə **nä** lə jist): My favorite science experience was certainly the earliest I can remember. I grew up on the Navajo Indian Reservation in northern Arizona. When I was in second grade, I rode a horse out to Keet Seel Ruin to visit a dendrochronologist named Jeff Dean. He was using tree rings to find the ages of the timbers used for construction of the village. Keet Seel is a very large and well-preserved cliff dwelling built by the Ancestral Pueblo people in the 13th century (1200s).

Using cross-dating, Dr. Dean documented the dates when people cut the trees used in their dwellings. Cross-dating is a method used to match tree-ring patterns in different trees. Cross-dating enables dendrochronologists to go back in time. This is what tree ring scientists do all the time, not only to study **archaeology**, but also to look at past rainfall and many other things that influence tree growth.

Dr. Thomas Veblen, Physical Geographer: My favorite science experience is learning what tree rings can tell us about the history of insect outbreaks on trees. ▼

Thinking About Science



Sometimes it is hard to study the past. This is especially true if the past you want to study was hundreds or thousands of years ago. It is made more difficult if the past you want to study has no written records. Some scientists, such as archeologists (**är** kē **ä** lə jists) and paleontologists (**pā** lē än **tä** lə jists), use items from the past as clues. Archeologists usually use human-made items, and paleontologists usually use natural clues. A dendrochronologist is a scientist who uses the natural clues found in tree rings (**figure 1**).

In this study, the scientists used clues provided by old trees to help them understand the past. The scientists used information from tree rings. As a tree grows, it adds a layer of new growth on its trunk. For trees growing in dry areas, a lot of growth in a wet year shows up as a thick ring. In a dry year, the tree's growth ring is thin. If something happens to the tree during a year, scientists can find clues in the tree's growth ring for that year. For example, if there was a **wildland fire** and the tree was not burned up or killed, a scar may be evident in that year's growth ring. Clues from a tree's growth rings also help scientists determine the past **climate** of an area, as well as when and where wildland fires occurred (**figure 2**).

Figure 1. Dendrochronologists are able to date Native American historic and cultural sites using wood samples. Photo courtesy of Peter Brown.

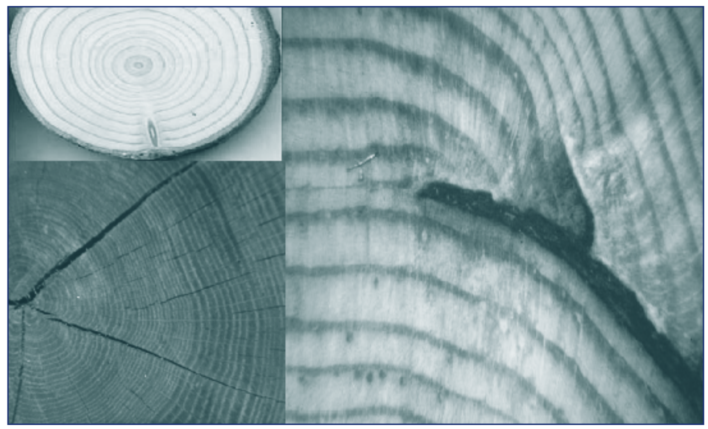


Figure 2. Tree rings provide clues about a tree's history. On the right, a fire scar was created when a surface fire burned near the tree. Photos courtesy of Emily K. Heyerdahl and the Forest Service.

Thinking About the Environment

You may have heard the expression, "It's a small world." It seems hard to believe, but many ecosystems on Earth are connected, even if they are located far apart. For example, glaciers in Arctic regions hold large amounts of fresh water when they are frozen and release that water when the temperature rises. This can cause changes in ocean temperatures and currents far from Earth's Arctic regions. Another example is the Gulf Stream, which is a current of seawater moving up the eastern North American coast and finally eastward to northern Europe. Although Norway is located close to the Arctic region, the Gulf Stream keeps that country's west coast free of ice all year.

The oceans, in particular, affect many climatic (klī **ma** tik) and weather events on land. You are probably aware of the formation of hurricanes and cyclones, which form over ocean waters and sometimes reach coastal areas. Scientists have discovered that oceans can even affect the occurrence of wildland fire.

The scientists in this study were interested in exploring the connection between ocean patterns, climate, and the timing of wildland fires in the Western United States.

What is dendrochronology?

Dendrochronology is the study of "tree time" and is also called tree-ring dating. Dendrochronology is a science based on the fact that every year a tree grows it adds a new layer of wood to its trunk; this process forms tree rings. Over a period of time, these rings form a series of light and dark circles that are visible on cross-sections of cut trees. A cross-section of a tree is when you cut a tree down and expose the middle of the tree (**figure 3**).

Often trees are sampled using a hand drill, called an increment (**iŋ** krə mənt) borer (**figure 4**). Neither of these techniques kills the trees.

Figure 4. Dendrochronologists do not have to kill trees to get information from tree rings. An increment borer allows scientists to pull a small sample of the tree's rings. The hole created by the borer is then sealed to protect the tree. The sample is a long, thin cylinder of wood. Photo courtesy of Edward Cook and the National Oceanic and Atmospheric Administration (NOAA) Paleoclimatology Program, U.S. Department of Commerce.

Figure 3. Dendrochronologists use chain saws to take samples from trees that are already dead, like these old stumps. Photo courtesy of James P. Riser, II, and Emily K. Heyerdahl.

Introduction

Scientists have identified a number of **periodic** changes in **sea surface temperatures** that affect climate over land. The scientists in this study were interested in three periodic changes, called **oscillations**, in sea surface temperatures that vary over different time scales (**figure 5**).

The most rapid periodic sea surface temperature change is called the El Niño-Southern Oscillation, or ENSO (**figures 6a and 6b**). ENSO changes every 2 to 7 years in the tropical Pacific Ocean. The change involves a warming or cooling of the water at the ocean's surface. The warm phase of ENSO is called El Niño, and the cool phase is called La Niña.

Oscillation	Where?	How long?	Sea Surface Temperature?
ENSO	Tropical Pacific Ocean	2 to 7 years	Warm and Cool
PDO	North Pacific Ocean	20 years	Warm and Cool
AMO	Atlantic Ocean	60 years	Warm and Cool

Figure 5. A comparison of El Niño-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and Atlantic Multidecadal Oscillation (AMO).

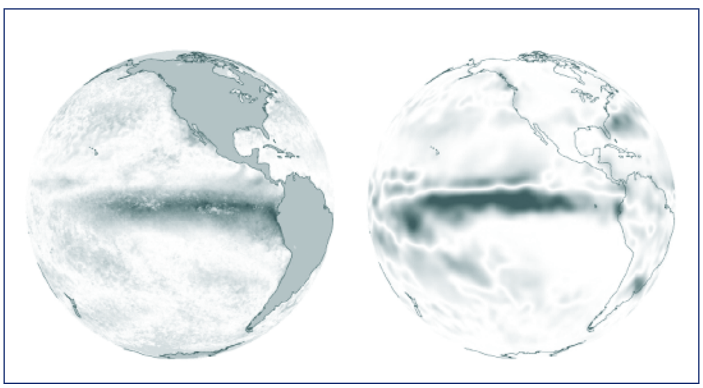


Figure 6a. These two globes show the relationship between ocean temperature and rainfall during the 1997 El Niño. On the left, the darkest streaks shows warmer ocean sea surface temperatures. The warm water easily evaporates and storms are more likely to form. On the right, the darkest areas indicate heavy rainfall. You can see that heavy rain fell in the Pacific Ocean, along the coast of Northwestern South America and in the Southeastern United States. From the National Aeronautics and Space Administration (NASA) Earth Observatory, http://earthobservatory.nasa.gov.

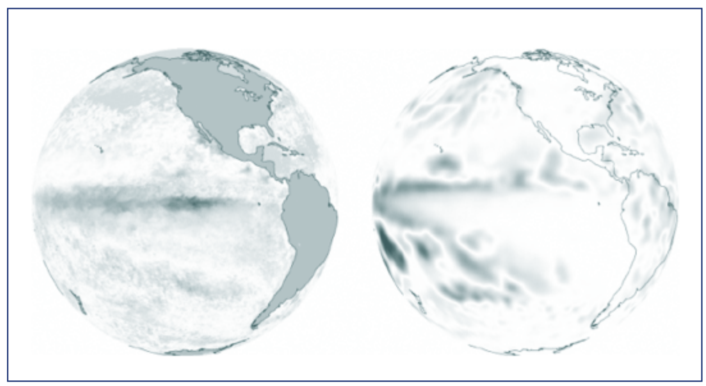


Figure 6b. These two globes show the relationship between ocean temperature and rainfall during the 1988 La Niña. On the left, the darkest streaks show that sea surface temperatures were cool in the east Pacific off of the coast of South America. Since cool air is dense, it does not rise and storms are not likely to form. On the right, the darkest areas show places where drought (very low rainfall) occurred in Northwest South America and the Southeastern United States. The Southeastern United States is the area in the United States most affected by ENSO. From NASA Earth Observatory, http://earthobservatory.nasa.gov.

A second sea surface temperature change is the Pacific Decadal (**de** kə dəl) Oscillation, or PDO. PDO changes like ENSO, but only about every 20 years, and it occurs in the North Pacific Ocean. The sea surface temperature pattern that changes the most slowly is the Atlantic Multidecadal (**mul** tī **de** kə dəl) Oscillation, or AMO. It occurs in the Atlantic Ocean and changes about every 60 years (**figure 7**).

These periodic changes in sea surface temperature affect climate on land. For example, during years when AMO is in its warm phase, the entire Western United States is generally warm and dry (**figure 8**). These warm, dry conditions mean wildfires are more likely.

ENSO and PDO affect climate in different parts of the Western United States in different ways. For example, during years when ENSO is in its warm phase, the Southwestern United States is generally cool and rainy whereas the Northwest is generally warm and dry. During these years, there is less chance of wildfires in the Southwest than in the Northwest.

The scientists in this study were interested in the relationship between the phases of ENSO, PDO, and AMO and when wildfires occurred in the Western United States over a 400-year time span.

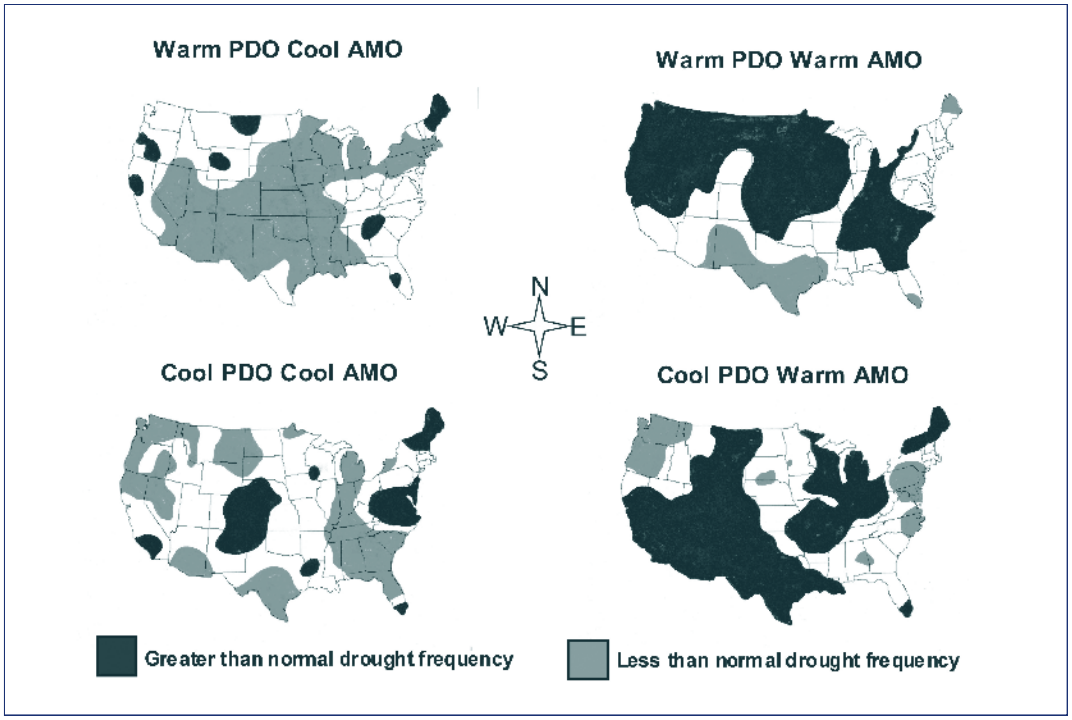


Figure 7. PDO and AMO patterns affect **drought** conditions in the United States. Image adapted from the U.S. Geological Survey (USGS).

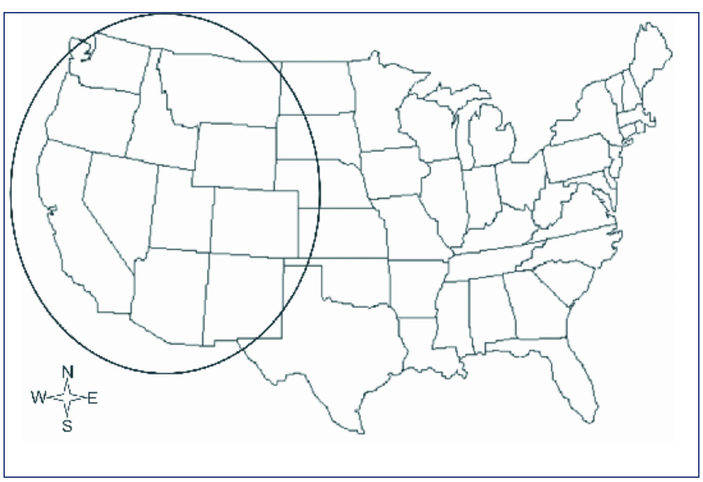


Figure 8. The Western United States.

Reflection Section

- What is the question the scientists were trying to answer?
- Do you think there were written records about fire or sea surface temperature patterns such as ENSO, PDO, and AMO hundreds of years ago? Why or why not?

Methods

The scientists studied the period of time between 1550 and 1924. They needed three kinds of information for the Western United States for each year of this 374-year period. First, they needed to know what the climate was like and how it differed across the area. For example, was it dry to the north but wet to the south or was it dry everywhere? Second, they needed to know the phase of each of the three oscillations. Finally, they needed to know when and where wildfires burned.

To get information about climate and sea surface temperatures, the scientists used information already collected by other scientists. From the ring widths of trees living during these 374 years, other scientists had identified which years were rainy and which were dry. Because sea surface temperature also affects climate, still other scientists had used ring widths from trees to identify sea surface temperature patterns. In other words, they identified which phases of ENSO, PDO, and AMO occurred each year.

Number Crunches

- About how many warm phases of the AMO did the scientists study? About how many cool phases did they study? How many would they have been able to study if they only used written records from 1900 to today?

To get information about when and where wildfires occurred, the scientists once again used data that had already been collected. They did not need to collect new data because a **database** is available that contains a history of wildfires recorded by tree rings. The database is like a fire history museum. Scientists from around the world give their tree-ring data to this database so anyone can use their data to study wildfires in the past. The scientists used information from the database that was collected from more than 4,700 trees whose rings had recorded 33,039 fire scars in the Western United States (**figure 9**).

Once they had collected the three kinds of information, the scientists identified the climate and phase of each oscillation during years when many fires occurred all across the Western United States and when many fires occurred only in certain areas. They used a computer to help them with their analysis because there was so much information.

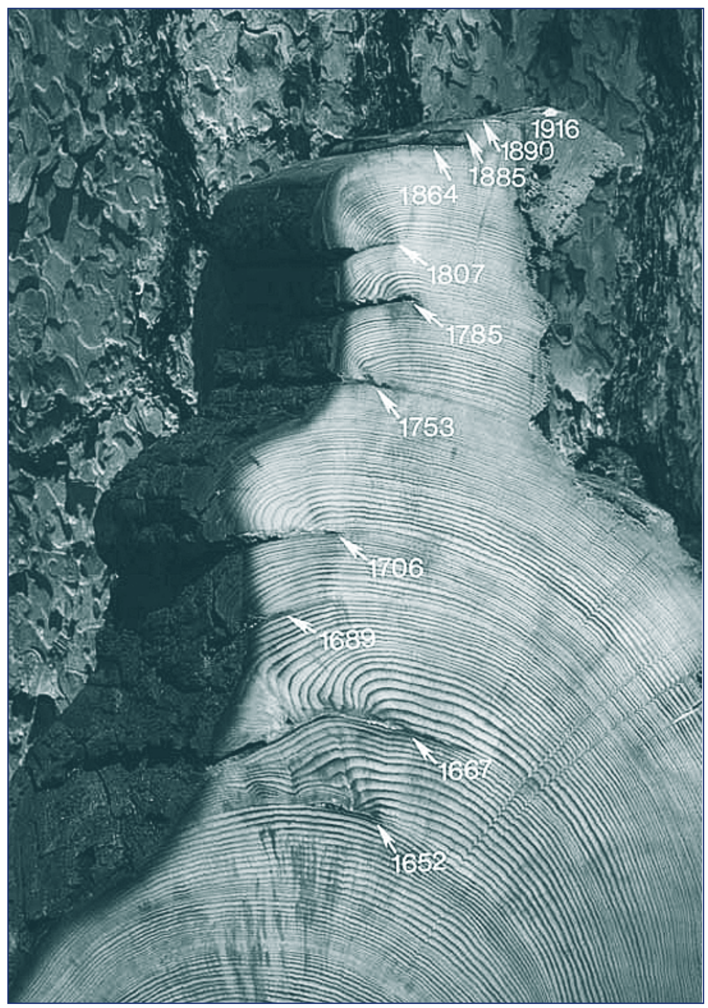


Figure 9. Scientists examined tree-ring fire scars from samples already collected. Photo courtesy of Peter Brown.

Wondering about wildfires

You might be surprised to learn that fire is a natural part of the environment. Fire scars in tree rings show that in the past, fires burned in some forests every 10 to 20 years for many hundreds of years. Certain ecosystems depend on wildland fires to be healthy and **sustainable.** Wildland fires help plants grow by replacing **nutrients** into the ecosystem from the fire's ash. There are many different types of fires. Some wildfires burn at low temperatures and burn slowly (**figure 10**). By trying to eliminate wildfires in the past, we have actually encouraged more fires to burn in forests that mostly had surface fires in the past. Now, **forest managers** sometimes start small, controlled fires that burn the fuel that is close to the ground. These fires are called prescribed fires. For more information on wildfires, check out the *Natural Inquirer's* two Wildland Fire Editions!

Figure 10. Many trees can survive lots of fires. Fire scars are created when a surface fire burns near a tree. Photo courtesy of Michael G. Harrington.

Reflection Section

- Why do scientists share their data with other scientists? What is one advantage of sharing data?
- Think about how the scientists gathered information about the past using tree rings. What are two other natural resources that contain information about the climate of the past?

Findings

The scientists found that it really is a small world! They found that the location of wildfires was related to the phase of the oscillations during the 374-year period they studied. When ENSO and PDO were both in their warm phases, many wildfires burned in the Southwest where it was dry, but few burned in the Northwest where it was wet.

The opposite was also true. When ENSO and PDO were both in their cool phase, few wildfires burned in the Southwest but many burned in the Northwest. AMO had a different effect on wildfires. When AMO was in its warm phase, wildfires sometimes burned all across the Western United States because it was dry everywhere.

Scientists can only predict the weather a few days in the future. This is not enough to help us know if or where wildfires are likely to burn during the next summer wildfire season. Sea surface temperature patterns, however, change periodically in ways that scientists can predict months or even years ahead. Because these oscillations affect climate, scientists can use them to predict whether and where wildfires are likely to burn in upcoming wildfire seasons.

Reflection Section

- In your own words, explain how trees that lived many years ago have helped scientists to understand what may happen in the future.
- How might global climate change affect sea surface temperatures ?

Discussion

The scientists noted that the AMO pattern is now entering a warm phase. This will likely affect the occurrence of more wildfires in the Western United States. Global climate change, with rising temperatures, may cause even more warming in the Atlantic Ocean. This may increase the effect of the AMO even more.

With climate change, temperatures are likely to increase. These warming patterns may also increase the chance of wildfires in the Western United States. Larger and more frequent wildfires may occur as a result. If the patterns uncovered by the scientists continue and average temperatures continue to rise, people living in the Western United States should prepare for the possibility of more frequent wildfires in the future.

Reflection Section

- Now you understand that sea surface temperature patterns and wildfires appear to be connected. What are other natural processes that might be connected to each other?
- Do you think the Western United States might have more frequent wildfires in the future? Why or why not?

Fire Safety Tips from the Firewise Communities Program

Do you live in or near a forest? If so, ask the adults in your household if they have protected the house from a forest fire. Here are some fire safety tips you can do to protect your homes from fire:

1. Establish a space around your house that does not have any combustible materials. This space should be at least 30 feet or 9 meters across. The larger the space, up to 130 feet or 40 meters, the better protected your house will be. Fire is less likely to jump across 40 meters and ignite new materials.
2. Reduce the amount of vegetation close to your home.
3. Remove or thin overcrowded or weak trees near your home.
4. Cut your grass and other plants regularly.
5. Move woodpiles and building materials away from your home.
6. Keep your roof and yard clean. Clean your gutters regularly. Remove dead limbs and branches from your yard, and from the base of your chimney and deck.
7. Make sure your address is easy to read from the road, and that your driveway is large enough for emergency vehicles.
8. If you have a wood shake roof, replace it with a material that is more fire resistant.
9. Recycle your yard waste.
10. Listen to your local radio and TV stations for fire reports and instructions.

For more information check out http://www.smokeybear.com or http://www.firewise.org

Glossary

archeology (**är** kē **ä** lə jē): The scientific study of historic or prehistoric peoples and their cultures by analysis of their artifacts, inscriptions, monuments, and other such remains.

climate (**klī** mət): The average condition of the weather over large areas, over a long time, or both.

database (**dā** tə bās): A comprehensive collection of related data organized for convenient access, generally in a computer.

dendrochronologist (**den** drō krə **nä** lə jist): A scientist who studies tree-rings.

drought (draüt): A period of dry weather with little or no rain.

forest manager (**för** əst **mə** ni jər): Skilled individual who takes care of natural resources.

oscillation (**ä** sə **lā** shən): A fluctuation between maximum and minimum values.

periodic (**pir** ē **ä** dik): Happening at intervals over time.

sample (**sam** pəl): Part or piece that shows what the whole group or thing is like.

sea surface temperature (**sē** sər fəs **tem** pə(r) chur): The temperature of the surface layer of sea or oceanic water.

weather (**we** thər): The state of the atmosphere with respect to wind, temperature, cloudiness, moisture, pressure, etc.

wildland fire (**wī**(-ə)l(d) land **fi**(-ə)r): Fires that burn in forests, on prairies, or over other large natural areas.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide

Time Needed:

1 class period

Materials:

- White unlined paper.
- An assortment of crayons. Every student will need access to black, light brown, dark brown, and tan crayons.

The question you will answer in this FACTivity is: How do yearly weather conditions affect the way a tree's growth rings look? The objective of this FACTivity is to learn how to interpret tree rings. You will gain an understanding of what environmental factors can affect tree rings, and you will use your creativity and knowledge to create a cross-section of a tree, based on information given in the FACTivity.

Your teacher will provide the following background (or you may read it on your own):

In doing the research for this article, the scientists used tree rings that had been analyzed by dendrochronologists. Tree ring analysis requires observation and pattern recognition. Each year of its life, a tree creates a tree ring that has two parts: a light part and a dark part. The light part is called the early wood. It is created during the spring and early summer when there is usually more water available. The dark rings are called late wood. The late wood is created during the summer and sometimes in early autumn. The late-wood rings are thinner and darker than the early-wood rings because the tree does not grow as much during this time. One early-wood and one late-wood ring signify 1 year of growth for the tree.

Tree-ring width varies with growing conditions, for example the rings are wider if a lot of water is available, and they are thinner during times of low rainfall. Disease or an insect invasion can stress the tree resulting in less growth and thinner rings. Fire can leave a scar that will appear in the rings (**See figures 11-13**).

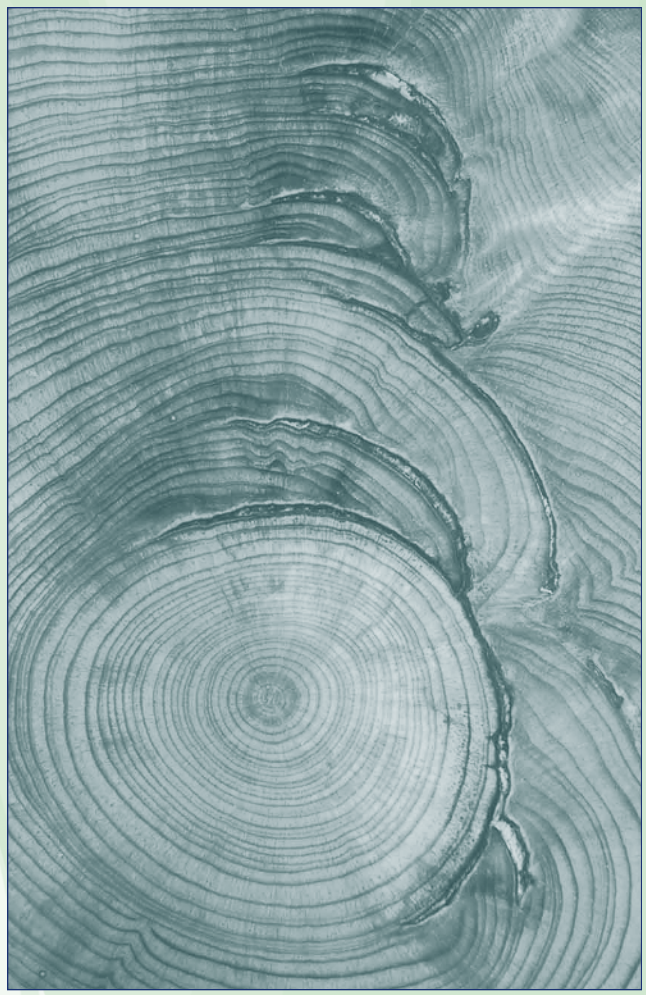


Figure 11. Tree cross-section showing fire scars. Photo courtesy of Peter M. Brown.

Scientists are able to study yearly weather conditions from observing tree rings. Scientists are also able to observe the tree rings and identify when insect invasions and damage from storms occurred.

Brainstorm with other students about the different events a tree could experience during a year of growth. How might the event affect the tree rings? For example, drought equals thinner tree rings, normal conditions will result in thicker tree rings, and insect damage could leave a scar and result in thinner tree rings.

Scenario: Scientists have the following information about the weather and other conditions that happened every year during the life of one tree. The scientists need your help to predict what the tree rings might look like during a 25-year period. Here is your opportunity to test the skills that many dendrochronologists use every day!

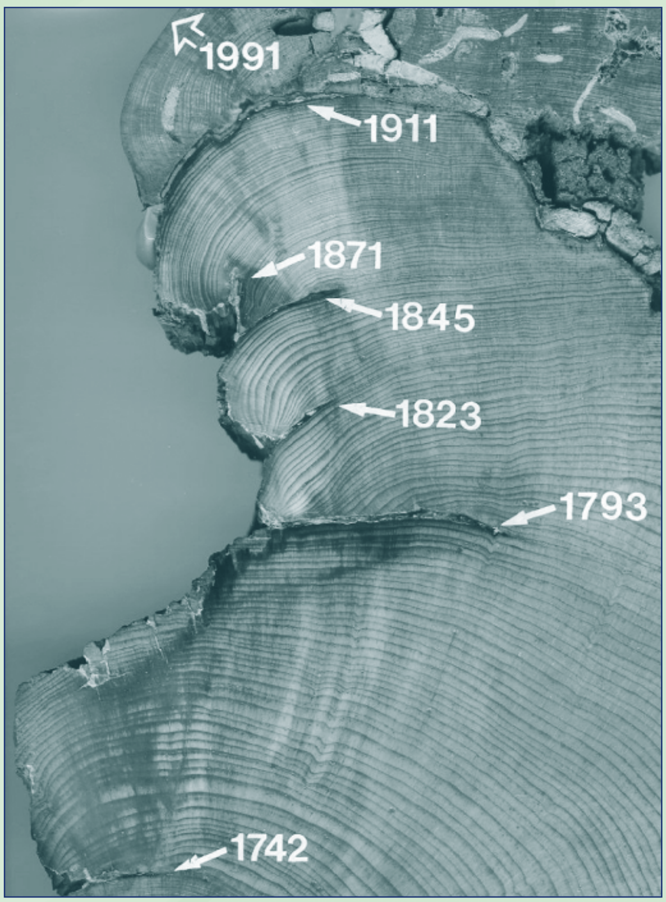


Figure 12. Tree cross-section showing insect damage. Photo courtesy of Peter M. Brown.

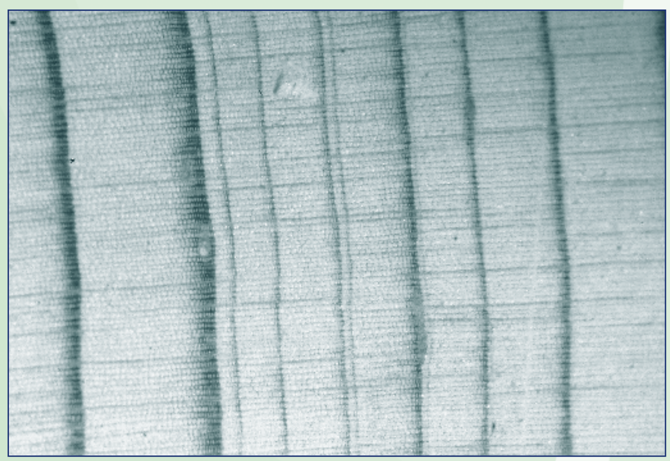


Figure 13. Tree cross-section showing years of plentiful rainfall and low rainfall. Photo courtesy of Peter M. Brown.

Refer to the chart below for the yearly conditions over the 25 years. Use a sheet of paper and crayons. Remember that one tree year includes two rings: an early-wood ring and a late-wood ring.

Based on the chart below, draw a cross-section of a tree. Remember that the tree rings for each year may look different, depending on the weather or other conditions for that year.

Compare your completed tree cross-sections with other students. Should the cross-sections look similar? Why or why not? If they do not look similar, how are they different? Why are they different?

The 25-year period of information about weather, insect, and fire for one tree.									
Year	Condition	Year	Condition	Year	Condition	Year	Condition	Year	Condition
1	Normal	6	Insect damage	11	Heavy Rain	16	Insect damage	21	Fire
2	Normal	7	Normal	12	Normal	17	Normal	22	Normal
3	Drought	8	Normal	13	Normal	18	Fire	23	Normal
4	Normal	9	Fire	14	Fire	19	Normal	24	Fire
5	Fire	10	Normal	15	Drought	20	Normal	25	Insect damage

Key to conditions:

Drought = little to no rain

Normal = adequate rain and no other major problems

Heavy rain = above average rain fall

Insect damage = invasion by insects with damage to tree

Fire = hot fire that did not kill tree

Extension

Draw another tree cross-section. This time, consider what a tree might look like growing 50 years from now in a changing climate. Explain why you drew the tree cross-section the way you did. What yearly weather and other conditions will affect tree-ring growth in the future?

For additional information and another FACTivity about dendrochronology, see "Back To the Future" in this *Natural Inquirer* edition.

What You Can Do:

RECYCLE!

You can recycle paper and cardboard in your classroom and at home. Recycling helps keep the paper out of landfills and helps reduce the amount of carbon dioxide produced by burning the paper. You can also reduce the amount of paper you use by using both sides of the paper or by using paper as scrap paper once one side has been used.

PLT®

Teachers: If you are a Project Learning Tree (PLT)-trained educator, you may use Activity #81, "Living with Fire" and Activity #86, "Our Changing World."

National Science Education Standards

Standards addressed in this article include:

Science As Inquiry:
Abilities Necessary To Do Scientific Inquiry, Understandings About Scientific Inquiry
Life Science:
Populations and Ecosystems, Diversity and Adaptations of Organisms
Science and Technology:
Understandings About Science and Technology
Science in Personal and Social Perspectives:
Science and Technology in Society
History and Nature of Science:
Science as a Human Endeavor, Nature of Science

Additional Web Resources

NOAA's El Niño Animations and Graphics
http://www.elnino.noaa.gov/ani.html

Prentice Hall's Geoscience Animations for El Niño and La Niña
http://esminfo.prenhall.com/science/geoanimations/animations/26_NinoNina.html

NASA's El Niño for Kids
http://kids.earth.nasa.gov/archive/nino/intro.html

NOAA's Ocean Temperatures and Currents
http://www.oar.noaa.gov/k12/html/oceans2.html

Adapted from Kitzberger, T.; Brown, P.M.; Heyerdahl, E.K.; Swetnam, T.W.; Veblen, T.T. 2007. Contingent Pacific-Atlantic Ocean influence on multicentury wildfire synchrony over western North America. *Proceedings of the National Academy of Sciences of the United States of America*. 104: 543–548. http://www.pnas.org/cgi/doi/10.1073/pnas.0606078104.

Moving on Up:

Photo courtesy of Paul Wray, Iowa State University, http://www.bugwood.org.

The Possible Impact of Climate Change on Forest Habitat

Meet the Scientists

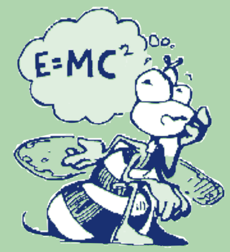
Dr. Louis Iverson, Landscape Ecologist: My favorite science experience is finding out new (to me) patterns, trends, or functions of nature. It really is amazing how organisms interact with other organisms and their environment! One great way to do this is to get out into as many places in nature as possible. ▶

▼ **Mr. Anantha Prasad**, Landscape Ecologist: My favorite science experience is combining what I have learned and gaining insights. For example, I like to look at information about climate change, **topography,** where different plant and animal species are found, and the properties of soils in a particular area. Then, I can tie these different characteristics of the area together to better understand how they relate to each other.

▼ **Mr. Matthew Peters**, Geographic Information Systems (GIS) Analyst (a **nə** ləst): A Geographic Information System, or GIS, is a system that collects, stores, manages, and presents information that is linked to a specific place on Earth. As a GIS Analyst, I work with geographic information to help solve problems. My favorite science experience has been collecting vegetation information in the Western United States for a project addressing forest fires. I was on a 6-month internship with the Student Conservation Association (SCA). During that time, I identified plant **species** in wilderness locations to improve our identification of these species using satellite data.

▼ **Dr. Stephen Matthews**, Wildlife Landscape Ecologist: My favorite science experience is coming up with new research questions based either on my current work or a new area of ecology. Then I like to go out and try to solve the problem in an attempt to advance my understanding of the natural world.

Thinking About Science



When scientists study climate change, they often look toward the future. The job of these scientists is to predict what might happen as the climate changes over time. Because no one knows for sure what will happen in the future, predicting it is a big challenge for scientists. In general, scientists take two main steps to predict what might happen.

First, they look at past or current situations. Often, scientists track what has happened over time, from a time period in the past to the present. This is called a trend. For example, scientists have tracked changes in the **average** yearly temperature since 1880 (**figure 1**).

The second thing scientists do to predict the future is create a computer model. A model is a mathematical representation of a **system**. For example, consider figure 1. If everything continues to be the same in the future as it was in the past, scientists can imagine what the line in figure 1 might look like in the future. They do this by taking the same information collected in the past and applying it to the future. Scientists studying climate change sometimes use different models to represent different possible futures. This is because what happened in the past might be different than what will occur in the future. In the case of rising temperatures, for example, scientists might consider both a future with a small rise in average temperatures, and one with a larger rise in average temperatures.

In this study, the scientists used one model that assumed people will continue to burn **fossil fuels** at an increasing rate for decades into the future. They used another model that assumed people will **conserve** fuels by doing things like driving less and using less electricity. In the second model, the amount of **carbon dioxide emitted** to the atmosphere was expected to be less than the amount emitted in the first model.

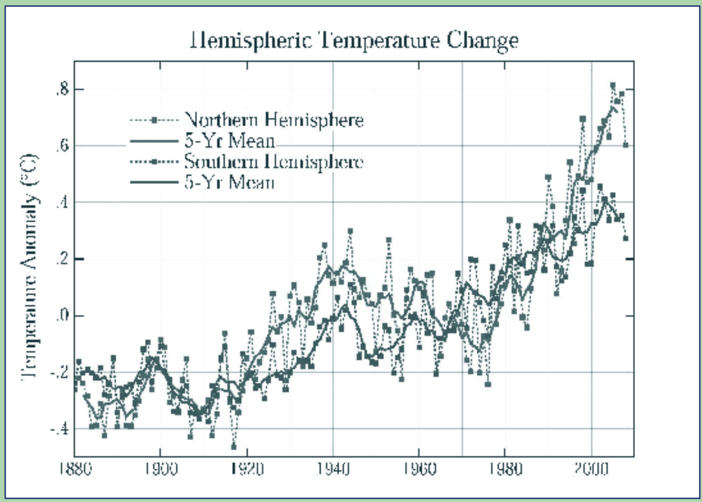


Figure 1. The trend in average yearly temperature since 1880. What trend do you see in this graph? (From http://data.giss.nasa.gov/gistemp/graphs/Fig.A3.pdf)

Thinking About the Environment

Almost everyone lives in a community. Did you know that trees live in communities too? These communities are different than human communities. Forest communities are made up of different species of trees that are commonly found living in the same area. Foresters name these forest communities after the most common species of trees living there.

The scientists in this study were interested both in individual species of trees and in forest communities. To understand how forest communities might change in the future, the scientists had to study individual species of trees. They did this because although trees in the same community live in the same general **habitat**, some trees can survive in other habitats as well. As the climate changes, therefore, some trees in the community might die off, and others might survive. If this happens, the forest community will change.

Introduction

Global climate change is likely to affect plants worldwide. One type of plant that will be affected is trees. Groups of different tree species are found together in forests because the habitat is well suited to those tree species' survival. Some elements of habitat include the amount of yearly rainfall an area receives, the average temperature in each season, the steepness of the land, the area's **elevation**, and the type of soil.

If any of the elements of an area's habitat change, some tree species may not be able to survive. For example, if the average temperature of the area rises, some trees species may not survive long term. If the temperature rises, however, in nearby areas that had previously been too cold for those species in the past, the seeds from those tree species may be transported away from the tree, **germinate**, and begin to grow in the new, warmer areas.

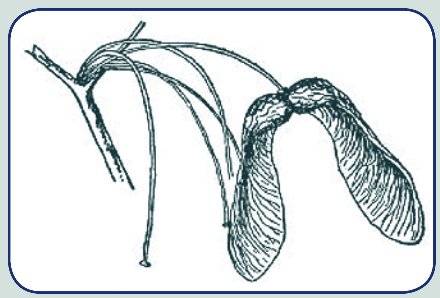
The scientists in this study were interested in trees that live in the Eastern United States (**figure 2**). They wanted to explore how the habitat of these trees might change in the future as the climate changes. They also wanted to know how different tree species might move in response to a changing climate.

Figure 2. The Eastern United States.

How do trees move?

As you know, individual trees cannot move from place to place. Through time and seed **dispersal,** however, the places a tree species lives may change. If the climate in a particular area changes, a tree species may no longer thrive in that original habitat.

The seeds of trees can spread in many ways. Birds and other animals may eat the seeds. Later, they will **defecate** and deposit the seeds in a new area. Seeds can be carried by animals in their fur or even in their mouths and then dropped in another location. Seeds are also blown away by wind or carried by water. If climate change causes the preferred habitat of some tree species to move in one direction or the other, those tree species, over time, will follow the preferred habitat through the movement of their seeds.



Reflection Section

- What questions were the scientists trying to answer?
- Do you think a changing habitat may also affect the animals that live in the Eastern United States? Why or why not?

Methods

The scientists wanted to predict how different tree habitats and forest communities in the Eastern United States might change over time. Scientists believe that the amount of carbon dioxide going into the atmosphere affects Earth's average temperatures. As higher levels of carbon dioxide go into the atmosphere, the average temperature rises. It is important to remember, however, that a certain range of carbon dioxide in the atmosphere is necessary to support life on Earth.

The scientists considered two different possibilities for future levels of carbon dioxide going into the atmosphere. First, they assumed that what happened in the past will continue to happen in the future. The amount of carbon dioxide going into the atmosphere has been rising over time. Therefore, the scientists assumed that the amount of carbon dioxide going into the atmosphere will continue to rise in the future. The scientists used existing information to estimate future average temperatures and future average rainfall in the Eastern United States, if this were the case.

Then, the scientists considered the possibility that people will begin to burn less fossil fuels in the future. This would mean that lower amounts of carbon dioxide would go into the atmosphere. The scientists then used existing information to estimate future average temperatures and future average rainfall in the Eastern United States. This time, however, they assumed that less fossil fuels would be burned than is currently predicted. The scientists considered the preferred habitat of 134 different tree species. Habitat includes things like the amount of rainfall and the average temperature preferred in each season by each species. Then, based on the two possible amounts of carbon dioxide going into the atmosphere, they created maps to show where the center of the preferred habitat of each tree species may be in the future.

Reflection Section

- Why did the scientists consider what may happen if people burn less fossil fuels in the future?
- What is one advantage of using maps to show research results?

Findings

The scientists discovered that, in both possible futures, the preferred habitats of tree species may move in a northerly direction. For the trees already living in the Northeastern United States, some of the preferred habitats may shift into Canada (**figure 3**). For trees living in the far Southeastern United States, their habitat might move across a larger area of the Southern United States (**figure 4**).

Regardless of the habitats studied, the scientists found that the preferred habitats of trees will likely move north if the amount of carbon dioxide going into the atmosphere continues to increase. Even if people burn less fossil fuels in the future, the preferred habitats of eastern tree species may move northward. They will not, however, move as far north from their existing location as compared with the other possibility.

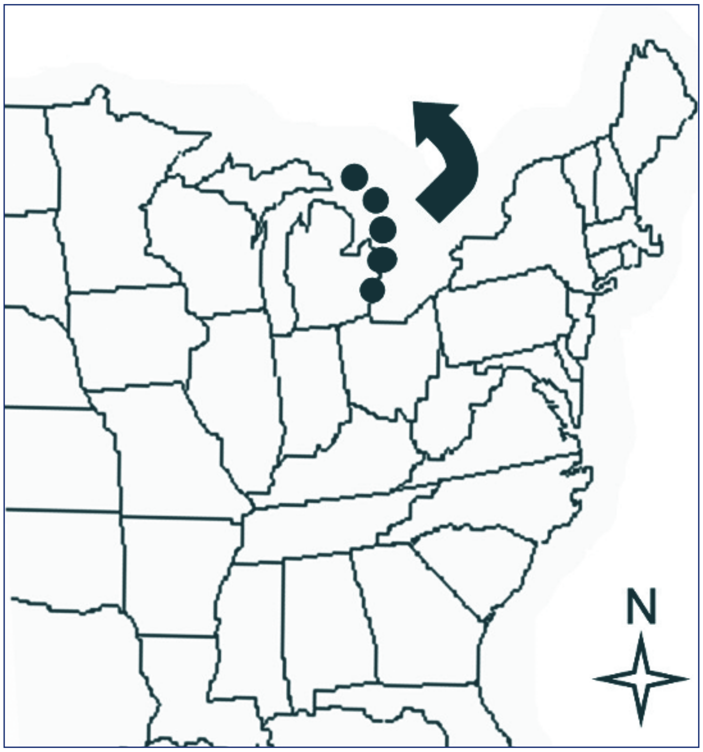


Figure 3. The center of the preferred habitat for sugar maple living in the Northeastern United States will move into Canada.

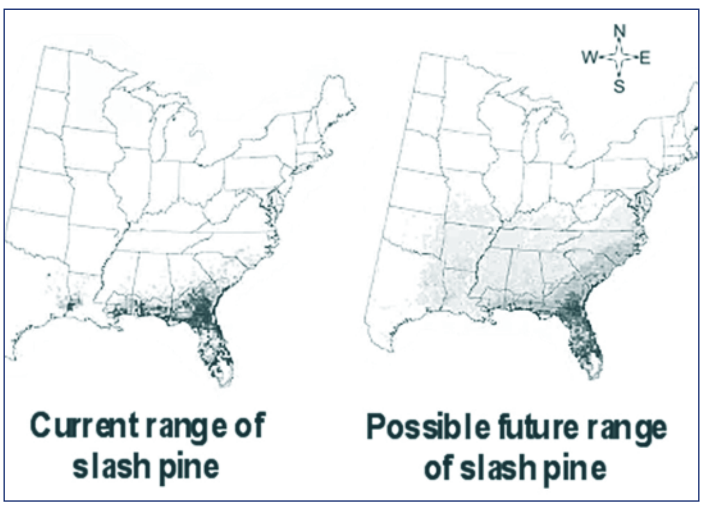


Figure 4. The future preferred habitat for the slash pine tree living in the Southeastern United States will likely move across the south. In which direction is the preferred habitat likely to move? The left map was created from Forestry Inventory and Analysis data, Forest Service. The right map was created using a General Circulation Model (GCM) of climate change.

Reflection Section

- If the preferred habitat of sugar maple trees moves farther into Canada, what possible impact might this have on U.S. businesses that sell the sweet product of maple trees?
- Why will the preferred habitats of most tree species move in a northerly direction?

Discussion

The forest communities of the Eastern United States are likely to change as the climate changes. Not all the possible changes are considered negative. For example, the habitat of some trees may expand. Other tree species, however, may experience a loss in habitat, which would not be a good thing for those tree species. As these changes occur, the forest communities will also begin to change.

Along with changes in forest communities, there may be increasing chances of threats to the trees' health. Examples include danger from invasive animals, plants, and insects. Other possible dangers include diseases, fire, floods, droughts, and changes in how the land is being used by people.

Reflection Section

- The scientists considered what might happen if people burned less fossil fuels in the future. If people burn even less fossil fuels in the future than the scientists considered, how might the predicted movement of eastern tree species change?
- What is one way people might respond to this knowledge of changing forest communities?

Glossary

average (a **v(ə-)**rij): The usual kind or amount. The number obtained by dividing the sum of two or more quantities by the number of quantities added.

carbon dioxide (**kär**-bən **dī** äk sīd): A gas made up of carbon and oxygen with no color or smell.

conserve (kən **sərv**): To avoid wasteful or destructive use of something.

defecate (**de** fi kāt): To have a bowel movement.

dispersal (**di** spər səl): The scattering or spreading in all directions.

elevation (e lə **vā** shən): The height above sea level.

emitted (ē **mit** əd): To throw out or eject.

fossil fuel (**fä** səl fyü(-ə)l): Fuel, such as coal, petroleum, or natural gas, formed from the fossilized remains of plants and animals.

germinate (**jər** mə nāt): To start growing or developing.

habitat (**ha** bə tat): Environment where a plant or animal naturally grows and lives.

invasive (in **vā** siv): Tending to spread.

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

system (**sis** təm): An ordered gathering of facts or processes to form a whole.

topography (tə **pä** grə fē): Detailed, precise description of a place or region. Physical features that make up the topography of an area include mountains, valleys, plains, and bodies of water.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide.

FACTivity

Time Needed

2 class periods

Materials needed per student group:

- Tree identification books (and/ or Internet access) and other resources about trees.
- Two blank maps of the United States.
- Two pieces of blank white 8.5″ X 11″ paper.
- Markers.

The question you will answer in this FACTivity is: What is the geographic distribution of a particular tree species?

Process for each student group:

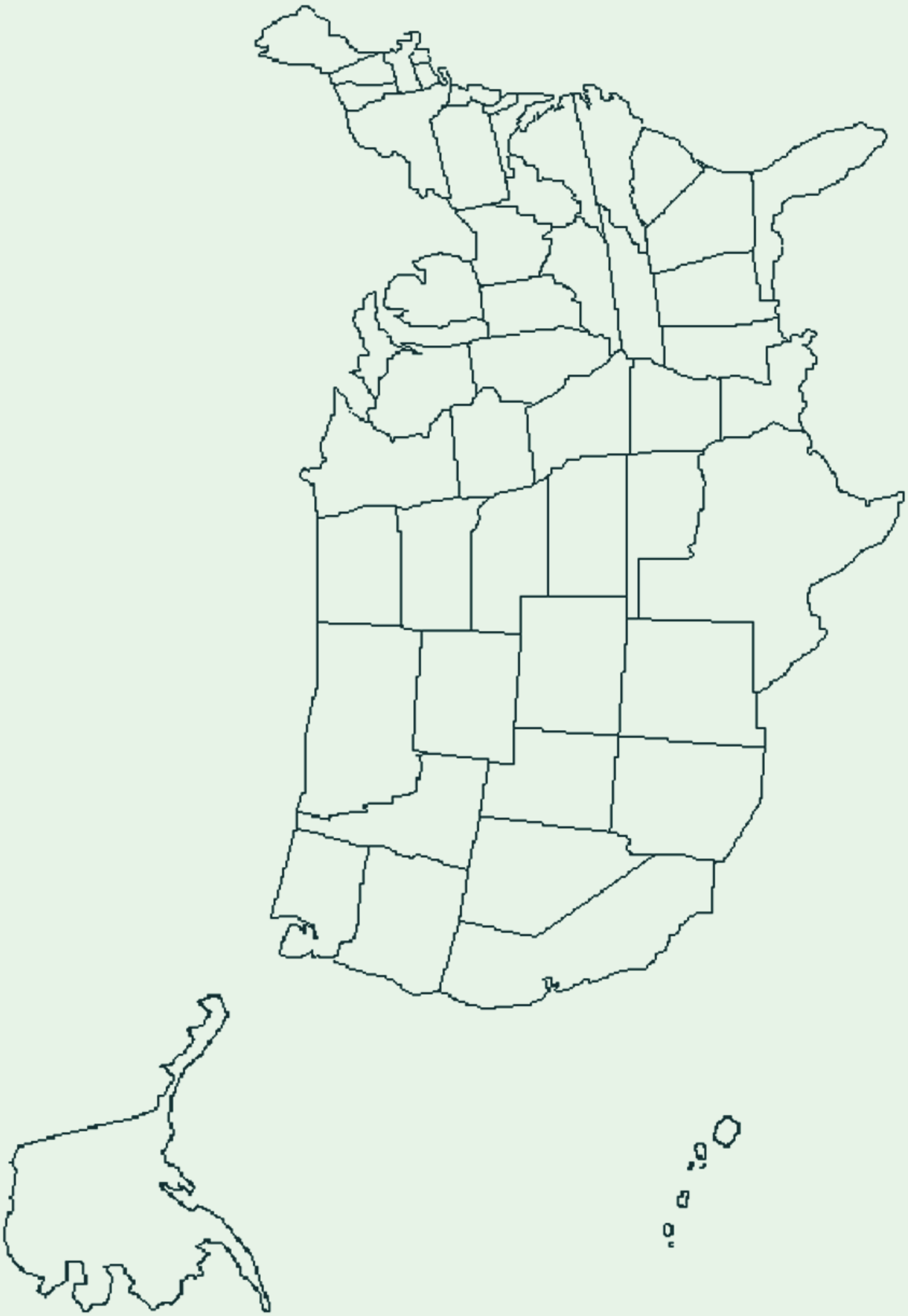
First class period:

Choose a tree species that you would like to study that lives in the United States. Use a tree identification book, the Internet, or the library.

Research information about this tree species. Find the following information about the tree:

Where is the tree species' habitat? When you find out about the areas in which it lives, mark those areas on one of the blank maps provided. Label this map "Current Geographic Distribution of [tree species]."

- What is the climate of the current habitat for the tree species?
- What is the average size of a tree of that species?
- What does the tree look like?
- What is the expected life span of the tree species?
- Do any invasive plants or insects threaten the tree species?



Second class period:

Use this information and any other interesting facts to create a Tree Fact File. The Tree Fact File should be displayed on two 8.5- X 11-inch pieces of paper.

One map should have already been filled out with the current areas where the tree species is found. You will use the other map to make a prediction about where you think the tree species will live as the climate becomes warmer. Think about what you read in the article to help you make this map. Label this map “Predicted Geographic Distribution of Tree Species.”

As you make this map, think about your own predictions about how much fossil fuels will be burned in the future.

Once all of the groups have created a Tree Fact File and completed the two maps, the files and maps can be compiled into a class book.

After answering the question posed at the beginning of this FACTivity, consider and discuss this question: “Why is it important to predict the future condition of our natural resources?”

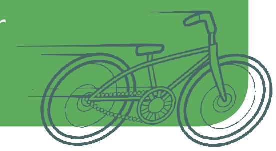
Extensions

If you have already read or will read “There’s Snow Place Like Home,” compare your maps of the tree species geographic distribution with the wolverine article animal geographic distribution.

- How are the maps similar?
- How are the maps different?
- What conclusions can you draw from comparing these maps?

What You Can Do:

Because keeping carbon emissions down will help the environment, maybe you could ride your bike or walk to school. Make sure it is safe to do so. If you can’t walk or ride your bike, take the school bus or have your family carpool with other families in the neighborhood.



If you are a PLT-trained educator, you may use Activity #22: “Trees as Habitats,” Activity #77: “Trees in Trouble,” and Activity #85: “In the Driver’s Seat.”

National Science Education Standards

Standards addressed in this article include:

Science as Inquiry:
Understandings About Scientific Inquiry

Life Science:
Regulation and Behavior,
Populations and Ecosystems,
Diversity and Adaptions of Organisms

Science in Personal and Social Perspectives:
Risks and Benefits

Additional Web Resources

U.S. Environmental Protection Agency’s Carbon Cycle Movie
http://www.epa.gov/climatechange/kids/carbon_cycle_version2.html

World Almanac for Kids’ Carbon Cycle
http://www.worldalmanacforkids.com/WAKI-ViewArticle.aspx?oldpin=xca041350a&pin=x-ca041350a

The Great Plant Escape- Seed Germination
http://urbanext.illinois.edu/gpe/case3/index.html

Student Conservation Association
http://www.thesca.org

Adapted from Iverson, L.R.; Prasad, A.M.; Matthews, S.N.; and Peters, M. (2007). Estimating potential habitat for 134 eastern U.S. tree species under six climate scenarios. *Forest Ecology and Management*. 254: 390-406.

The GLAS is Half Full:

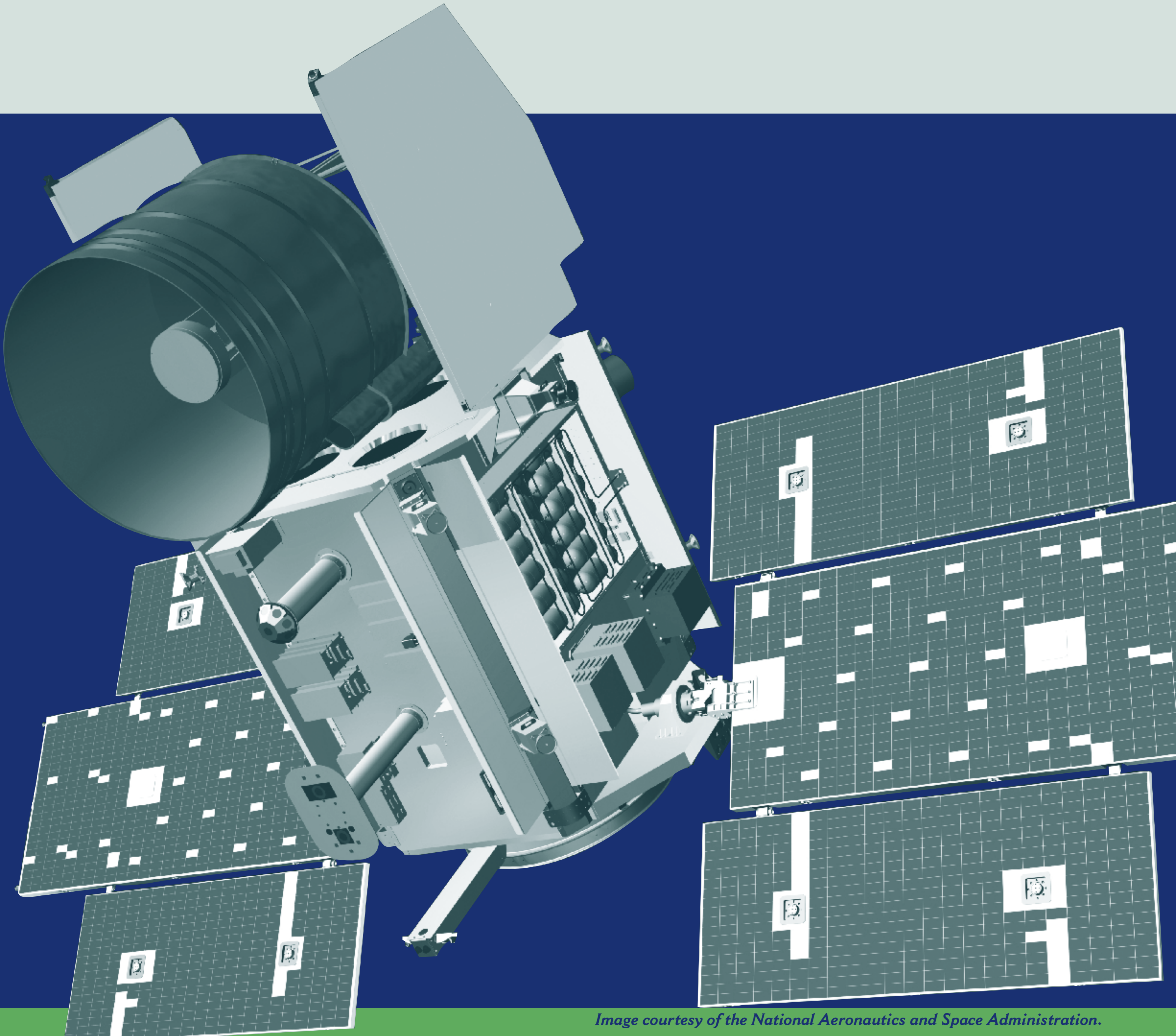


Image courtesy of the National Aeronautics and Space Administration.

Satellites and Changing Tropical Forests

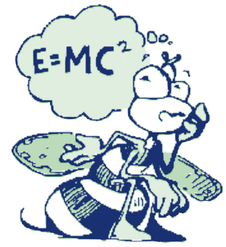
Meet the Scientists

Dr. Eileen Helmer, Ecologist: I have two favorite science experiences. The first was collecting field data on horseback in Costa Rica after a hurricane caused landslides that blocked most of the roads. The second was climbing Nevis Peak on Nevis Island in the Caribbean to find out how high on the mountain the cloud forests occurred.

Dr. Dar Roberts, Geographer: My favorite science experience was climbing a 44-meter tall tower to access tree canopies. I had a $70,000 instrument strapped on me to measure how light changes from the ground to the top of a forest. I have other favorite experiences, of course. I enjoyed flying in a small plane less than 500 meters over the Amazon rain forest, renting a small boat in Brazil where we saw sloths and pink dolphins, and building my own 20-meter tower to access tree canopies, then climbing it.

Thinking About Science

All life on Earth depends on sunlight to survive. Humans, however, also use light for convenience and to meet modern needs. In recent years, the use of light has increased. Light is used not just for human needs and comfort; it is also for science and technology. In the 1950s and 60s, light began to be used to improve electronic communications. Today, **optical** fibers are used for most land-based electronic communications.



Light is also used in satellite technology to communicate between Earth and space. In 2003, a satellite was launched carrying an instrument called the Geoscience Laser Altimeter (al **ti** mə tər) System, or GLAS. GLAS sends 40 beams of light every second to Earth's surface. GLAS provides continuous light beam observations of Earth. When each light beam reaches Earth, it is reflected back to the satellite. By tracking and recording the amount of time each beam of light takes to return to the satellite, GLAS can be used to calculate many properties of Earth's surface.

In this research, the scientists used GLAS to estimate the increase over time in living material, such as branches and leaves, in young and growing tropical rain forests. If this kind of research is successful, scientists will have a more accurate way to understand the world's rain forests.

Thinking About the Environment

When a large amount of carbon dioxide, or CO_2, is **emitted** into the air, it gets trapped in the atmosphere and causes the surface of Earth to warm beyond its normal range. This is happening now, partly because of the large amount of **fossil fuels** being burned for energy.

Carbon, one of the elements that makes up CO_2, is found in every living thing. As trees grow, for example, they absorb carbon from the atmosphere. Old forests also absorb and hold carbon. Because trees keep carbon on Earth, they help to reduce the rate of global warming.

Scientists need to know the location and age of forests to estimate how much carbon they absorb and hold. To do this, scientists must calculate how much living and once-living material, called **biomass**, is contained within a forest area. They also need to calculate how much the biomass of young forests is increasing as they grow. The amount of carbon absorbed and held by forests is related to the amount of biomass contained in the trees and other vegetation that make up the forests. If a forest has more trees, leaves, and other vegetation, it keeps more carbon on Earth.

Introduction

In the past, when scientists wanted to learn about a forest, they had to visit the forest in person. Although this first-hand knowledge of forests provides good information, it also limits the amount of information scientists can collect. It takes a lot of time and money to do research about forests in person, especially if the forests are located far away from home. In addition, the Earth is too large and forests too widespread for scientists to visit all of the forests.

Scientists are working to understand how forests across the world can help to address climate change. To do this, however, they need a more **efficient** way to study large areas of forest land. One way to do this is to use technology to help them do their research. They also need to know that the technology that they use will provide the same quality of information they would get if they studied each forest in person.

The scientists in this study wanted to discover whether information gathered by satellites could be used to identify the age of tropical rain forests and to estimate the increase in the amount of biomass in growing rain forests. They also wanted to know if information gathered by satellites could be used to estimate the amount of biomass held by old rain forests. The scientists wanted to know if the information gathered by satellites was as good as the information they would get if they gathered it in person.

Reflection Section

- What questions were the scientists trying to answer?
- How do you think using information gathered by satellites could be more efficient than collecting information in person?

Methods

The scientists decided to study an area in the Amazon rain forest of Brazil (**figure 1**). They decided to use this area because it contained both young and old tropical rain forests. They also used this area because other scientists had already collected the same information by doing research in person within the forests.

First, the scientists located forests in the Rondônia area. Then, for each forest they located, they estimated the forest's age. They did this to identify which forests were young and which were old. Young forests are those growing on land that had previously been cleared and had been either replanted in trees or allowed to grow back naturally. Any forest under 50 years old was considered a young forest.

The scientists used images from Landsat satellites to locate and estimate the age of each forest (**figure 2**). Landsat satellites contain technology that takes photographs of Earth as

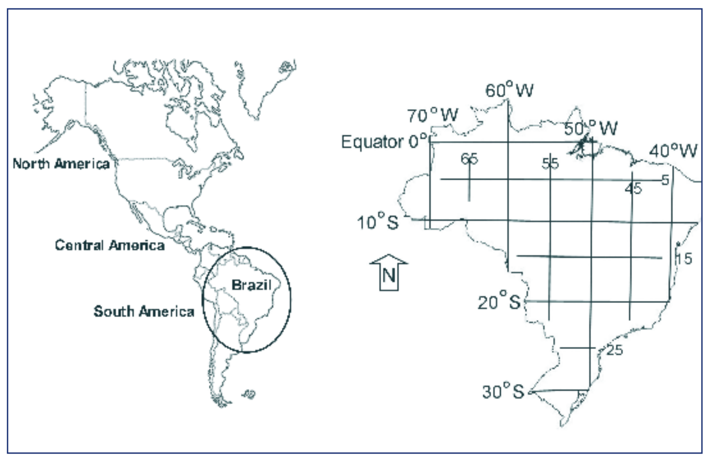


Figure 1. The scientists used **data** collected from forests in the State of Rondônia, Brazil, South America. Locate the State of Rondônia on the map using lines of latitude and longitude. Latitude and longitude are imaginary lines used to locate places on Earth. Lines of latitude are parallel to the Equator, and lines of longitude connect both of Earth's poles. Rondônia is located 10 degrees South, 64 degrees West. Is Rondônia located in the eastern or western part of Brazil?

the satellite orbits the planet (**figure 3**). The scientists used Landsat images of the Rondônia area taken between 1975 and 2003. They used photographs of the same forest areas taken over the 28-year period.

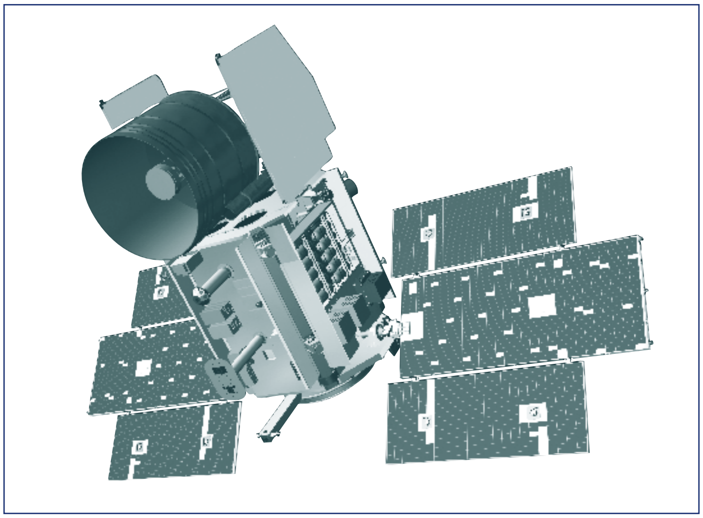


Figure 2. A Landsat satellite. Image courtesy of NASA.

Figure 3. A Landsat image of South America. Locate Brazil in this image. Now find Rondônia. (See figure 1 if you need help.)

The scientists used an **algorithm** to estimate each forest's age, which was based on the images taken over the 28 years. The algorithm's instructions were entered into a computer program. The computer program, following the algorithm's instructions, identified the changing color of the forests over time. As a forest ages, it changes from lighter to darker green. As a result, the computer program was able to use Landsat images, taken over a period of years, to estimate each forest's age.

Then, the scientists estimated the increase in the amount of biomass in each of these growing forests. To make these estimates, the scientists needed to know something about the height of the forest's trees (**figure 4**). They used another satellite to get this information.

Figure 4. The height of trees. Younger trees are usually shorter than older trees. Which tree has more biomass?

The scientists used data from a special satellite called the Ice, Cloud, and Land Elevation Satellite, or ICESat (**figure 5**). This satellite carries special equipment called the Geoscience Laser Altimeter (al **ti** mə tər) System, or GLAS (**figure 6**).

Figure 5. ICESat logo. Image courtesy of the National Aeronautics and Space Administration.

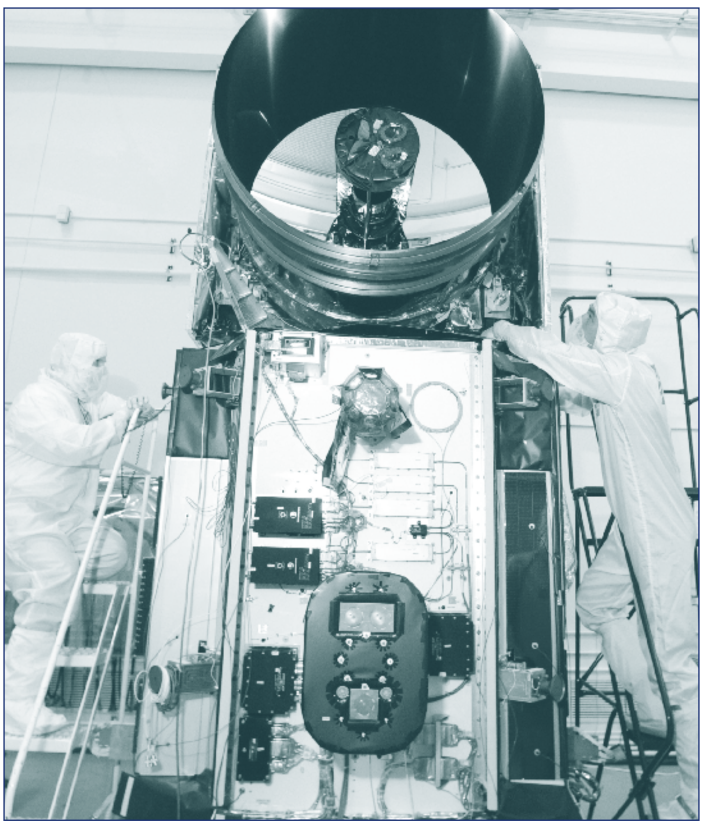


Figure 6. GLAS equipment was placed on the ICESat. Image courtesy of the National Aeronautics and Space Administration.

As ICESat orbits Earth, GLAS sends 40 light beams every second to an area of Earth's surface. These light beams reflect off of Earth's surface and back to the satellite (**figure 7**). GLAS's computer calculates how long it takes each beam of light to return to the satellite. Based on this information, scientists are able to identify the height of forest trees (**figure 8**).

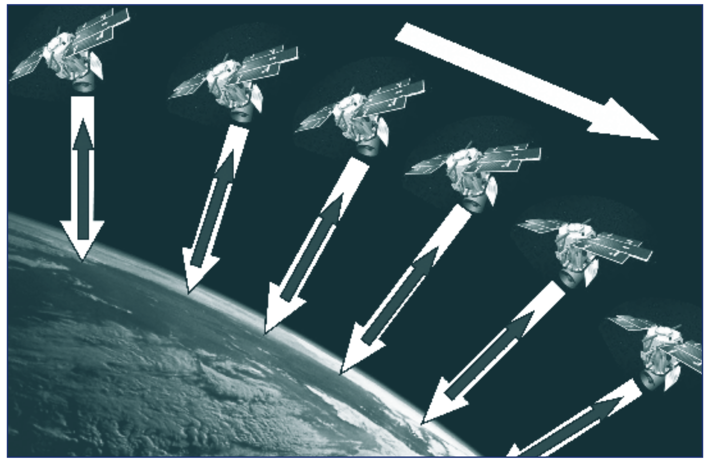


Figure 7. As ICESat orbits Earth, GLAS sends beams of light to Earth's surface. ICESat travels at 16,000 miles per hour and 370 miles above Earth.

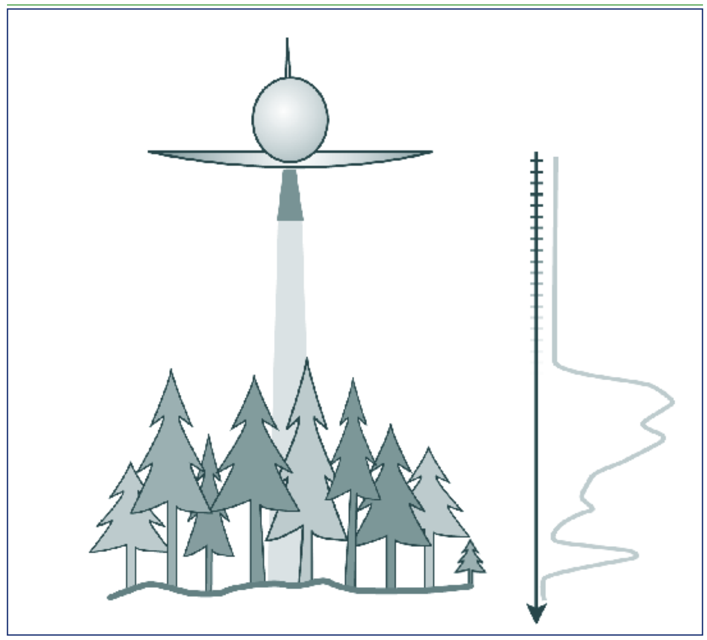


Figure 8. Scientists can calculate the height of trees based on the time it takes a light beam to travel from the ICESat satellite to Earth and back to the satellite. Scientists can do this because they know how fast light travels. The speed of light is 186,282 miles per second.

Remember that the scientists had already calculated the approximate age of each forest studied. Using another computer program and now knowing the forests' age and height, the scientists then estimated how much the biomass was increasing in young forests as they grew over time. They also estimated how much biomass was contained in old forests. The scientists then compared this information with the same information that had been collected by scientists working in person within the Rondônian forests.

Reflection Section

- Why did the scientists study an area that had already been studied by other scientists working within the forest?
- Do you think the information collected by the satellites is exact or an estimate? Why or why not?

Findings

For estimates of the forests' age, the scientists found that the algorithm's evaluation of Landsat photographs was 88 percent accurate. The algorithm had difficulty distinguishing some forms of agriculture and recently cleared forest land from young forests. Although there were some errors, the 88-percent accuracy rate was considered acceptable.

The satellite and computer estimates of the increasing amount of biomass in young forests was similar to the estimates made by scientists working within the forests. For some areas of the old forests, the satellite and computer estimates of the amount of biomass were smaller than what scientists had measured within the forests themselves. The scientists who did this study believe, however, that this difference can be explained by where the actual forest measurements were taken. When scientists were measuring biomass in person, they measured forests far from human disturbances that received more rainfall. This meant that the trees they measured were larger than trees closer to human disturbances, and therefore had more biomass.

The scientists then compared their estimates of biomass over the entire Rondônia area, including young and old forests, with estimates made by those studying the forests in person. They found that computer estimates made from the satellite data were similar to the overall estimates made within the forests of Rondônia.

Reflection Section

- Think about your own achievement of accuracy on a test. Is an 88-percent accuracy rate acceptable? Consider that the satellites collect a lot more data from all across the planet than scientists could collect by visiting forests in person. Do you think an accuracy rate of 88 percent is acceptable? Why or why not?
- Based on the results of this research, would you say that data collected by satellites may one day be used to help estimate the amount of carbon being held by the world's forests? Why or why not?

Discussion

The scientists doing this research studied tropical rain forests in the relatively flat areas of Western Brazil. They discovered that data gathered by satellites led to the same information as that gathered by scientists working within those same forests. They concluded that satellites can be used to study tropical rain forests in relatively flat areas. They do not know, however, if the method that they used to **interpret** the satellite images can be used to accurately collect the same type of information from drier, less forested, or more mountainous areas.

Tropical rain forests provide some of the most diverse habitats for plants and animals worldwide. They also contain a lot of biomass, which means that they keep a lot of carbon on Earth. It is important to understand as much as possible about Earth's rain forests. With the help of satellites and computer technology, scientists can study rain forests all around the world.

Reflection Section

- The scientists did not claim that their methods could be used to study all forests. Why do you think they did not make this claim?
- From a climate change perspective, why is it important to understand how fast the amount of biomass increases in young tropical rain forests?

Glossary

algorithm (**al** gə **ri** thəm): A step-by-step procedure for solving a problem that often involves a computer program. Usually, an operation is repeated over and over until the problem is solved.

biomass (**bī** ō mas): All the living and recently living things in a particular area.

data (**dā** tə): Factual information used as a basis for reasoning, discussion, or calculation.

efficient (i **fi** shənt): Bringing about the result wanted with the least amount of time, waste, or materials.

emit (ē **mit**): To throw out or eject.

fossil fuel (**fä** səl fyü(-ə)l): Fuel, such as coal, petroleum, or natural gas, formed from the fossilized remains of plants and animals.

habitat (**ha** bə tat): Environment where a plant or animal naturally grows and lives.

interpret (in **tər** prət): To explain or tell the meaning of.

optical (**äp** ti kəl): Relating to vision or to light.

pigment (**pig** mənt): A coloring matter in animals and plants. A substance that gives color to a material.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide.

FACTivity

Time Needed

35 minutes

Materials needed per student group:

- One sheet of blank paper, 8.5- X 11-inch.
- Crayons or colored markers (brown, black, red, orange, yellow, and gray).
- Stapler.
- Scissors.

The question you will answer in this FACTivity is: How can a series of Landsat images help scientists estimate a forest's age over time?

Process:

Cut the sheet of paper into 8 equal pieces. Staple one side to make a small book. Number each sheet of paper in the lower right hand corner. The first page will be 1, the next page will be number 10. Then number each page in increments of 10 (20, 30, 40, and so on, until you have numbered all of the pages). Draw a large empty circle on each page.

Each of these numbers represents a person's age, from age 1 to 70. The circle represents the top of a person's head, as if you were looking down at them from above.

Think for a moment of a person's hair color. Hair gradually loses its **pigment** and becomes white (or gray) as a person ages.

Now color the circle (the top of a person's head) for each age. You decide when your person starts to get some gray hairs. Over time, your person becomes completely gray. Make this as realistic as possible, based on when you think most people's hair starts to become gray, and when it becomes completely gray.

As a class, complete the chart below. (You may put this chart on the whiteboard or blackboard.)

According to your class, at which age are people most likely to see their first gray hairs? At which age are they most likely to become about half gray? At which age are people most likely to become completely gray? If you had a stack of photographs of the tops of people's heads, how could you use this activity's results to help you assign an age to each head?

Compare this activity with the use of Landsat images in the study you just read. How are they similar? How are they different? Answer the question posed at the beginning of the FACTivity. What in this FACTivity is similar to the actions of scientists working within forests on the ground? What makes them similar?

Age of person	1	10	20	30	40	50	60	70
Number of heads showing their first gray hairs								
Number of half-gray heads								
Number of completely gray heads								

What You Can Do:

For every plastic and paper bag created, some CO_2 was emitted into the atmosphere. One easy way you can help to reduce the amount of CO_2 going into the atmosphere is to carry reusable cloth bags with you when you go to a store. If you do not have a reusable bag with you and you only need to buy a few items, you don't have to use a bag at all! Another easy way to reduce energy use, and, therefore, carbon emissions is to take the stairs instead of the elevator. What is one other thing you can easily do to reduce the amount of energy you use?

National Science Education Standards

Standards addressed in this article include:

Science as Inquiry:
Abilities Necessary To Do Scientific Inquiry, Understandings about Scientific Inquiry

Earth Science
Structure of Earth System

Science and Technology
Understandings about Science and Technology

Science in Personal and Social Perspectives
Science and Technology in Society

History and Nature of Science
Science as a Human Endeavor, Nature of Science

Additional Web Resource

Video Clip of Deforestation in Rondônia, Brazil
http://www.youtube.com/watch?v=CwPq1CBTAx0

If you are a PLT-trained educator, you may use Activity #86: "Our Changing World."

For more information about carbon and forests, see the *Natural Inquirer* "World's Forests" edition, Inquiry 3: "How Much Carbon Is Being Held By the World's Forests?"

"The GLAS is Half Full" was taken from a well-known question: "Is the glass half empty or half full?" It is thought that people who see the positive side of things will say that a half-filled glass is half full. People who see the negative side of things will say that a half-filled glass is half empty. In reality, you cannot label a person as positive or negative from his or her answer to just one question.

Adapted from Helmer, E.H.; Lefsky, M.A.; and Roberts, D.A. 2009. Biomass accumulation rates of Amazonian secondary forest and biomass of old-growth forests from Landsat time series and the Geoscience Laser Altimeter System. *Journal of Applied Remote Sensing*. Vol. 3, 033505. http://www.tropicalforestry.net/Members/ehelmer/2009-mapping-amazonian-forest-type-age-and-secondary-forest-biomass-accumlation-rates-from-landsat-time-series-and-glas/.

Back to the Future:

Photo courtesy of Connie Millar.

Using Dead Trees To Predict Future Climates

Meet the Scientists

Dr. Connie Millar, Research Climate Ecologist: Recently, I had a great science treasure hunt in the wild lands of Nevada. We were looking for the lowest **elevation** living bristlecone pine. The bristlecone pine is known for its long life. These trees can live more than 5,000 years. The tree that we were hunting for had been documented in a remote canyon in 1984. We had a picture of the tree and knew its general whereabouts, but even though we searched and searched we couldn't find it.

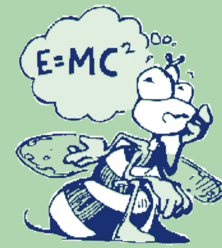
We kept trying to match the picture to the canyon, and, finally, I ran ahead to an old dead skeleton of a tree. Sure enough, there were disintegrated bristlecone pine cones on the ground. We **cored** the tree and found that it had died during a drought more than 10 years ago. We are determined to set another low-elevation record with a live bristlecone pine! ◀

▶ **Dr. Robert Westfall**, Quantitative Geneticist (**kwän** tə tā tiv jə **ne** tə sist): Dr. Millar and I were searching for pika in a boulder field on Warren Bench, above Mono Lake, California. Pika are small mammals in the same family as rabbits. We noticed tips of pine branches on the ground. This was evidence of pika because they like to eat the tender pine branches. Then, I found more pine tips hidden in the rocks. Dr. Millar and I wondered how the little pika got the pine tips because most of the pine branches were so high off the ground. I looked in a clump of pines up from the rocks—no clipped tips on the ground. Then I looked at a bunch of clipped pine branches that were 6 feet off the ground. The little pika had scampered across the deep snow that spring to collect the needles and tender spring buds.

◀ **Ms. Diane Delany**, Biological Technician: When I was a little girl I loved to collect things in nature. I collected rocks, shells, bird nests, and pine cones. I collected them everywhere I went. I would sort my collections, put them in order, and look for patterns. Now that I am a scientist, my favorite scientific experiences are those where I am collecting, observing, and taking notes with the smell of the trees and the mountain air all around me. I love working with our team of scientists to find answers in our observations, collections, and data.

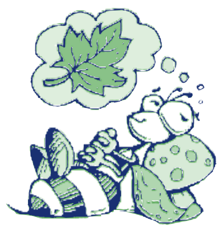
Thinking About Science

Often, scientists have to understand the past to predict what might happen in the future. The scientists in this study examined trees that died during a volcanic explosion in 1350. How many years ago was that? The scientists wanted to discover what the **climate** was like during the trees' lifetime. They wondered if knowing this would help them to make predictions about our future climate.



Climate change is a topic that scientists are interested in understanding. Climate change refers to the change in Earth's climate over time. One way to predict our future climate is to understand the patterns of past climates, including those long ago and those more recently. Think of one other situation where learning about the past can help us to predict the future.

Thinking About the Environment



Volcanoes are powerful forces of nature that can quickly change the way Earth looks. In this study, many trees were killed by an eruption from Glass Creek Vent in the Inyo Craters in California (**figure 1**). A vent is the opening of a volcano through which magma comes to the surface. After they were killed, the trees near the Glass Creek Vent were **preserved** by tephra that came from the explosion of the volcano. Tephra is the volcanic rock that is blasted into the air from the explosion (**figures 2a and 2b**). The amount of tephra can vary widely. Between 1 and 8 meters of tephra fell on the area that the scientists studied, burying the lower portions of the tree trunks. These well-preserved tree trunks helped the scientists learn a lot about this area's past.

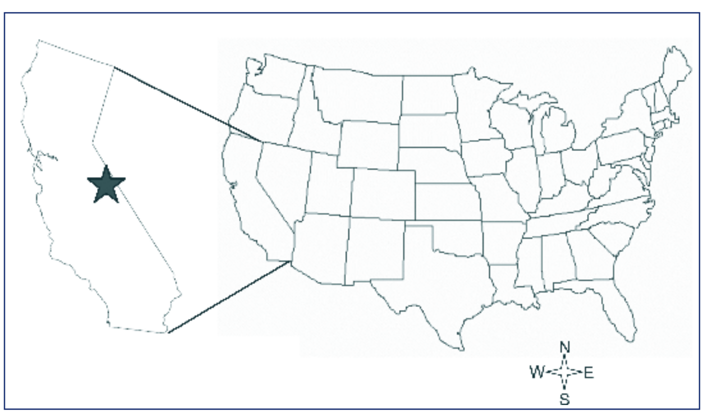


Figure 1. The area the scientists studied.

Figure 2a and 2b. Notice how the tephra covers the land under the trees and partially buries the tree trunks. Photos courtesy of Connie Millar, Forest Service.

Number Crunches

- How many feet of tephra fell? Multiply the number of meters by 3.28 feet.

Introduction

The tree line is the edge of a habitat at which trees are capable of growing (**figure 3**). In this study, the scientists wanted to examine dead trees that they found above the current tree line. These dead trees are known as deadwood. The deadwood found above the current tree line indicated that the climate during the trees' lifetime was different than it is now. The scientists were interested in learning about the climate that existed when these trees were alive.

Figure 3. Notice the line above which trees cannot grow. Photo courtesy of Connie Millar, Forest Service.

Reflection Section

- What was the question the scientists were trying to answer?
- Think of an example of something that happened to you in the past that helped you better understand something in the future. For example, last week you did not study for your science quiz and failed, so this week you studied.
- Why did the existence of the dead trees above the tree line indicate that the climate might have been different when the trees were alive?

Methods

The scientists studied two areas close to Glass Creek Vent. One area was Whitewing Mountain and the other area was San Joaquin Ridge (**figure 4**). To better understand the area, the scientists created a map that showed the location of all deadwood in the area. The scientists identified the location where the deadwood was greater than 1 meter in length and 10 centimeters in diameter (**figure 5**). They only mapped deadwood located above the current tree line. They mapped 1,675 dead trees from Whitewing Mountain and 60 from San Joaquin Ridge.

Figure 4. Whitewing Mountain. Photo courtesy of Connie Millar, Forest Service.

Figure 5. Trees varied in size and length. Photo courtesy of Connie Millar, Forest Service.

The scientists used a Global Positioning System (GPS) to determine the location of each piece of deadwood. In addition to mapping the deadwood, the scientists examined the tree rings (**figure 6**). The tree rings helped the scientists understand how old the trees were and how well they grew. The tree rings also helped the scientists to learn about the climate conditions in which the trees were growing. The study of tree rings to help understand climate and the environment is called dendrochronology (**den** drō krə **nä** lə jē). You will learn more about dendrochronology in the FACTivity at the end of this article.

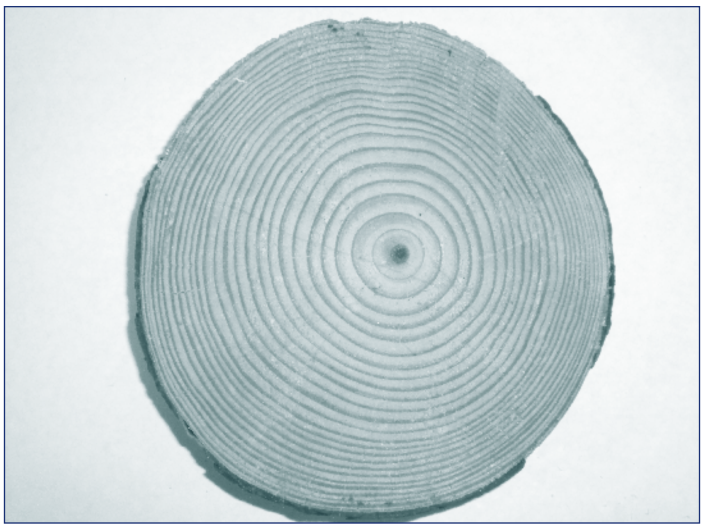


Figure 6. Tree rings tell a story about the tree. Tree rings show how old a tree is and provide clues to what the environment was like during its lifetime.

Reflection Section

- Why did the scientists only map the deadwood above the tree line?
- How did technology help the scientists in this study?

A Global Positioning System, or GPS

You probably are familiar with a GPS. You might even have one in your family car! A GPS tells your exact location on Earth's surface, based on the lines of latitude and longitude. Latitude and longitude are imaginary lines on Earth, and are included on most globes and many maps. A GPS unit gives the unit's location by communicating with GPS satellites orbiting Earth. At any one time for any location on Earth, 4 of the 24 GPS satellites are above the horizon. The GPS unit communicates with three of the satellites. Each satellite sends information to the unit. The unit receives information from all three satellites, and then displays the unit's location.

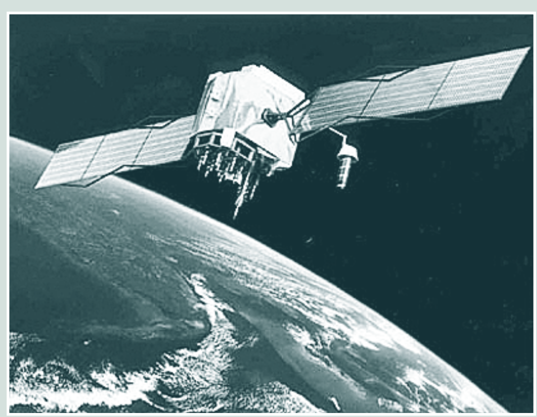


Photo courtesy of United States Army.

Findings

The scientists found that a variety of trees had lived above the tree line. Some of the types of trees included whitebark pine, sugar pine, western white pine, lodgepole pine, Jeffrey pine, and mountain hemlock (**figures 7-10**). These species currently grow much lower in elevation than the Whitewing summit where the deadwood occurs. The scientists found that the climate, when the trees were alive, was much warmer and slightly drier than the area's current climate. The **mean annual** temperature was warmer by 3.2 degrees Celsius, annual **precipitation** was 24 millimeters less.

Figure 7. Whitebark pine. Photo courtesy of Dave Powell, http://www.bugwood.org.

Figure 9. Lodgepole pine. Photo courtesy of Dave Powell, http://www.bugwood.org.

Figure 8. Sugar pine. Photo courtesy of Connie Millar, Forest Service.

Figure 10. Mountain hemlock. Photo courtesy of Donald Owen, http://www.bugwood.org.

Number Crunches

- How many degrees warmer was it in Fahrenheit? To calculate, multiply the degrees Celsius by 9/5, and then add 32.
- What was the precipitation loss in inches? To calculate, multiply the number of millimeters by 0.039.

Reflection Section

- The scientists measured the change in temperature in Celsius. Why did they use Celsius to measure and report temperature rather than Fahrenheit?
- Why are these findings important to our understanding of the future?

Discussion

The scientists discovered that their climate findings from the past were similar to climate projections for California between 2070 and 2099. In earlier climate change projections, other scientists thought that an increase in temperature would cause a decrease in the amount of forest land.

The scientists in this study, however, found that a variety of trees were living in a warmer climate and at a higher elevation than they are currently found. Therefore, the scientists think that the predicted future decrease in forested area may not be as great as some earlier studies suggest. They predicted that the location where the trees may be found in the future will likely be different and the tree line will likely move higher.

Reflection Section

- Based on this article and your own experience, why do you think it is important to study the past?
- Why do you think scientists try to predict things that will happen in the future? For example, why do you think scientists want to know what trees may be alive in the future as the climate becomes warmer?

Glossary

annual (**an** yü əl): Covering the period of 1 year.

climate (**klī** mət): The average condition of the weather over large areas, over a long time, or both.

core (kȯr): To use a hollow drill to take a small cylindrical sample of a tree's trunk.

elevation (e lə **vā** shən): The height above sea level.

Global Positioning System (GPS) (**glō** bəl pə **zi** shə ning **sis** tem): A radio satellite navigation system that allows users to determine their position on Earth's surface.

mean (mēn): The average in a set of numbers.

precipitation (pri **si** pə **tā** shən): Rain, hail, snow, mist, or sleet that falls on Earth.

preserve (pri **zərv**): To keep free from decay.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide

FACTivity

Time Needed

2 to 3 days

Materials needed for each group of two to four students:

- A copy of the sample tree-ring cores on page 47.
- One 1-meter strip of adding machine tape or thick ribbon.
- Colored pencils and markers.
- Reference material, such as almanacs, that provide students with the dates of social, cultural, environmental, and scientific events over the past five decades.
- A notebook for recording results (optional).
- Tape and scissors.

The question you will answer in this FACTivity is: How does dendrochronology help us understand the environment in which a tree lives?

Day 1:

In this FACTivity, tree-ring core samples showing the tree-ring patterns of four trees are represented by four strips on page 47. You can imagine what real cores look like if you take a straw and draw one of the patterns on the straw. These cores are taken from a tree using an instrument borer. An instrument borer is a hand drill that pulls out a thin cylinder of wood from the trunk of a tree. The borer must go all the way to the center of the trunk to accurately read the tree-ring patterns. After the core sample is pulled, scientists seal the hole so the tree is protected from insects and disease.

Using the four core samples on page 47, each group will construct the climatic (klī **ma** tik) history of the trees. You will then record social, cultural, environmental, and scientific events that occurred during the lifetime of these four trees.

Process:

1. Read the background information provided at the end of this FACTivity.
2. Make sure your group of students has a copy of the four tree core samples printed on page 47.
3. Imagine that you have tree core samples from:

Sample 1: A living tree that was cored this year in Oakwood Forest.
Sample 2: A log found near the main trail in Oakwood Forest. The log was cored four years after it fell.
Sample 3: A tree that was cored 1 year before it was cut down in Oakwood Forest.
Sample 4: A barn beam from Oakwood Hollow Farm. The beam was cored this year.

4. Cut the tree core samples into four strips.
5. The left side of each tree core sample represents the first year of growth of the tree. The right side represents the bark and, just to its left, the year the tree core sample was pulled. The tree rings are represented by the rectangles making up each strip.
6. Each year of growth is represented by a larger light-colored "ring" and a smaller dark-colored "ring." The larger light-colored ring represents fast spring growth and the smaller dark-colored ring represents slower summer (and sometimes autumn) growth. Beginning with Samples 1 and 2, match the tree ring patterns and tape the two strips together. Continue this by adding Samples 3 and 4. Sample 1 represents the youngest tree and Sample 4 represents the oldest tree that was sampled.

Now, on the strips,

7. Write the current year in space provided.
8. Counting backwards from the current year, identify the years each tree was cored. To keep track, write any year where you find room on the strip.
9. Identify the year Sample 4 tree began to grow and write it in the space provided.
10. Complete the following chart:

	Age of tree	Year tree was cored	Year growth began
Sample 1			
Sample 2			
Sample 3			
Sample 4			

11. Look for patterns in the rings. Answer the following questions:

    a. In what years was there low rainfall or other unfavorable growing conditions?
    b. What 2 years were the most favorable for tree growth? What might have happened in those years to support tree growth?
    c. What overall patterns do you notice in the year-to-year weather patterns?

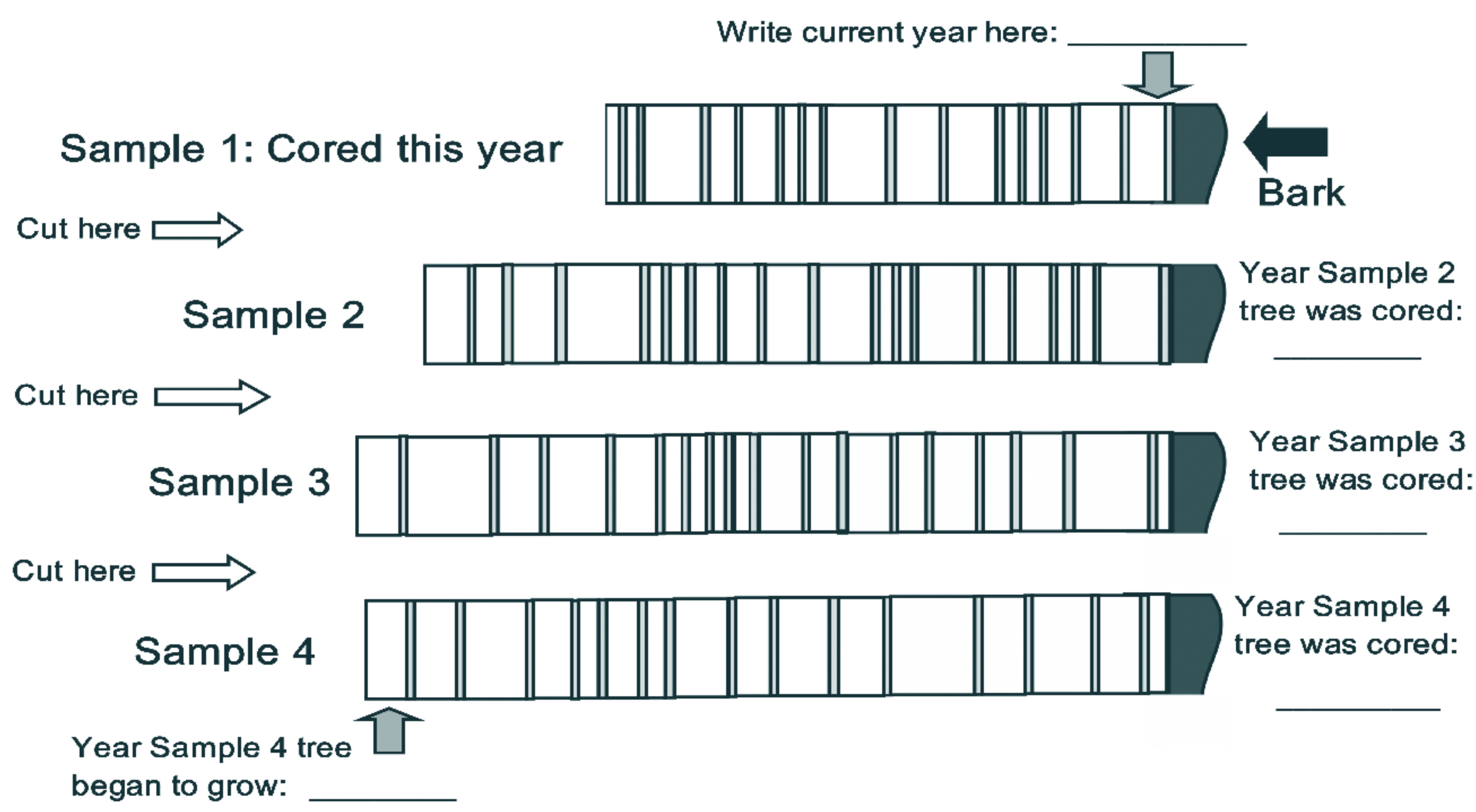
Day 2:

12. Make a timeline. Spread out the adding machine tape. Beginning at the left end of the tape, record each year from the earliest year identified on the tree-ring samples through the current year. After the years are recorded on the strip, identify years that were good growing years for the trees in Oakwood, and years that were poor growing years. Think of other events that might have happened during this time period such as birthdays, Presidential elections, important scientific discoveries, environmental events, cultural or social events, and record-setting sports achievements. Fill them in on the timeline. Color the timeline and illustrate it with drawings, photographs, or newspaper clippings.

13. Here are some follow-up questions.
    - Which ring on which trees represents your birth year?
    - What kind of growing season existed that year in Oakwood?
    - What buildings in your area were built during the lifetime of these trees?

Optional:

Before doing this FACTivity, the teacher may simulate tree core samples using straws. The "tree rings" may be drawn on the straws, based on the "core strips." If straws are used in place of the strips, each group of students should be given a set of four straws.


Write current year here: ________
Sample 1: Cored this year
Bark
Cut here
Sample 2
Year Sample 2 tree was cored: ________
Cut here
Sample 3
Year Sample 3 tree was cored: ________
Cut here
Sample 4
Year Sample 4 tree was cored: ________
Year Sample 4 tree began to grow: ________

FACTivity

Background

Dendrochronology is the study of tree rings to learn about climatic and environmental changes in an area surrounding a tree. Each year's tree-ring width is unique. They are like a barcode. From these rings, scientists can work backward from the present to determine climate conditions where the tree lived. Using this technique, scientists can date trees that have been dead for centuries. The tree rings help tell a story about climate because the width of the tree ring indicates something about the climate. For example, narrower rings indicate poor growing conditions and wider rings indicate more favorable growing conditions.

Reading Tree Rings

Tree rings are formed from the center of the tree outward. The ring closest to the bark is the youngest and final growth ring. The ring closest to the center of the tree is the oldest and first growth ring. Neither the outer layer of bark nor the central pith layer of a sample is counted when determining the age of a sample.

Similar ring patterns are found between trees growing under the same conditions. The most obvious feature of these patterns is varying widths. Widening of a ring indicates good growing conditions, and narrowing indicates poor conditions. Conditions can include climatic factors such as temperature and moisture and factors such as erosion, insects, fire, landslides, etc.

This FACTivity is adapted and reproduced with permission from U.S. Geological Survey (USGS). The activity can be found in USGS's Global Change Teacher Packets. This activity and others can be found at http://egsc.usgs.gov/isb/pubs/teachers-packets/globalchange/globalhtml/time.html

Note: For more in-depth background information and a teacher's guide, please visit the Web site listed above. This Web site is linked from the *Natural Inquirer* Web site at http://www.naturalinquirer.org.

Extension

Find and map the locations of some of the oldest known trees in your neighborhood. Sketch what you think a core from one of these trees might look like. To help you, research the weather history of your area.

Contact your local forestry service or science museum and obtain some actual cross-sections of trees that have been cut in your area. Use the techniques applied during this activity to "read the tree." If a tree has been cut in your neighborhood recently, look at the tree rings on the stump or ask if you can keep a small piece of the trunk.

Create some simulated core straws of your own for another group to analyze and report about.

What You Can Do:

See the light! Use compact fluorescent light bulbs. These energy-efficient bulbs help fight climate change because they reduce the amount of fossil fuels that utilities burn. You will save 100 pounds of carbon for each incandescent bulb that you replace with a compact fluorescent bulb, over the life of the bulb. (From http://www.nature.org/initiatives/climatechange/activities/.)

PLT

If you are a PLT-trained educator, you may use Activity #76: "Tree Cookies" and #40: "Then and Now."

National Science Education Standards

Standards addressed in this article include:

Science as Inquiry:
Abilities To Do Scientific Inquiry,
Understandings About Scientific inquiry

Life Science:
Populations and Ecosystems,
Diversity and Adaptation of Organisms

Science and Technology:
Understandings About Science Science and Technology

Science in Personal and Social Perspectives:
Science and Technology in Society,
Natural Hazards

History and Nature of Science:
Science as a Human Endeavor,
Nature of Science

FACTivity Extension

Students may compare and contrast "Moving On Up" (page 20, this edition) with this article in a class discussion.

Additional Web Resources

USGS Pictures of Inyo Craters
http://lvo.wr.usgs.gov/gallery/InyoCraters_1.html

USGS History of Eruption
http://lvo.wr.usgs.gov/InyoEruption/index.html

NOVA Anatomy of a Volcano
http://www.pbs.org/wgbh/nova/volcano/anat_06.html

EPA's Kids Climate Change
http://www.epa.gov/climatechange/kids/index.html

Arbor Day's Life of a Tree
http://www.arborday.org/kids/carly/lifeofatree/

National Park Service's Webrangers Dendrochronology Activity
http://www.webrangers.us/activities/dendrochronology/?id=04

For more information about dendrochronology, see "It's a Small World" in this edition of the *Natural Inquirer*.

Adapted from Millar, C.I.; King, J.C.; Westfall, R.D.; Alden, H.A.; and Delany, D.L. (2006). Late Holocene forest dynamics, volcanism, and climate change at Whitewing Mountain and San Joaquin Ridge, Mono County, Sierra Nevada, CA, USA. *Quaternary Research*. 66: 273–287. http://www.treesearch.fs.fed.us/pubs/31776#.

Did They Make the Gradient?

Climate and Stream Temperatures Now and Into the Future

Photo courtesy of Ge Sun.

Meet the Scientists

▶ **Mr. Johnny Boggs,** Biological Scientist: My favorite science experience is having the opportunity to continuously explore how and why our environmental system works the way it does. Growing up as a kid, I used to hunt, fish, and farm, so I have always felt a connection to nature and natural resources. In my current position, I offer scientific stories in the form of published papers. I hope these papers add further understanding to how our environment will respond to future changes and offer a benefit for future generations.

◀ **Dr. Ge Sun**, Research Hydrologist (hī **drä** lə jist): My favorite science experience is getting my ideas and study results published in scientific journals. That way, they will be recorded and hopefully used by future generations to understand their environment and improve their lives. I come to work every day with excitement because I meet bright people with good ideas and I learn and see new things around the world. Most importantly, I am excited about my work because I can contribute to solving problems and can answer questions to make people happy.

▶ **Dr. Steve McNulty,** Ecologist: My favorite science experience is when I am analyzing data and learn something that no one else has ever known before. It's sort of like being the first person to ski down a mountain of fresh snow, or being the first person to canoe down a remote river. This photo was taken on a recent trip to China. To the left and in the middle are Dr. Ge Sun, Hydrologist, and Dr. Jim Vose, Ecologist. Dr. Sun and Dr. Vose are also Forest Service scientists. You can read more about Dr. Vose's research in the *Natural Inquirer* "Woolly Bully" monograph (http://www.naturalinquirer.org).

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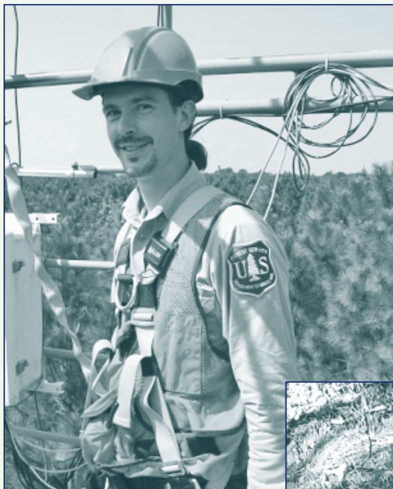
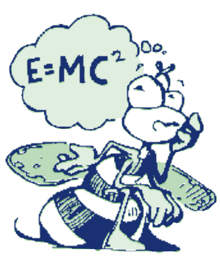


▶ **Mr. Emrys Treasure**, Forestry Technician: My favorite science experience happens almost every day. I learn something new by testing my beliefs about how the natural world works. These are often quite simple observations about the water cycle, how trees grow, or how soils form. Sometimes these thoughts lead to a breakthrough in understanding more complex aspects of the natural world, including the impacts of climate change. It is through this step-by-step process that science and scientists solve problems.

▼ **Mr. Will Summer**, Forest Hydrologist: My favorite science experience is being outside during a rainstorm. As a forest hydrologist, I study what happens to water from the time it falls from the sky until it gets to a stream. During a rainstorm is the best chance I have to really understand what is happening. Did you know that only a tiny fraction of rainfall falls directly on a stream? Most of it falls on land and must travel along the ground's surface or through the soil to get to the stream. Everything the water encounters as it flows towards the stream will affect how clean the water is when it gets to the stream. That is why understanding hydrology is so important to keeping our streams and rivers clean.

Thinking About Science



Scientific knowledge usually advances in small steps. When similar results are reported by different scientists, scientists have more confidence that the results are accurate. When scientists generally agree that existing results are accurate, they do new studies to push their knowledge even further. For example, scientists agree that a change in air temperature will cause a change in stream temperature. Scientists also generally agree that if the air temperature in an area rises, then stream temperatures in the area will likely rise as well.

In this study, the scientists wondered if the shape of a stream would also affect the stream's temperature. In other words, they wondered if the temperature of some streams would change more than other streams, if the temperature rose by the same amount and the only difference was the stream's shape. The scientists designed a study to answer this question.

You can see that scientists develop specific questions to answer. Research advances our knowledge one question at a time. Scientists are like detectives who must answer one question before they can move to the next.

Thinking About the Environment

Streams are found all over the world. Streams are waterways that carry water to rivers, and rivers carry water to oceans. Streams provide habitat for many animals, including **invertebrates**, fish, reptiles, amphibians, birds, and mammals. To provide **habitat** for animals, the water temperature of streams must not exceed an upper limit. The State of North Carolina has determined that mountain and upper **Piedmont** streams must not be higher than 29 degrees Centigrade (**figure 1**). The State has also determined that the temperature should not be higher than 32 degrees Centigrade for lower Piedmont and coastal streams and rivers.

Many things affect a stream's temperature. The amount of shade over a stream may affect its temperature. The air temperature also affects a stream's temperature. What else might affect a stream's temperature? The scientists in this study were interested in discovering as much as they could about what causes a stream's temperature to rise during the day. You may be surprised at what they discovered!

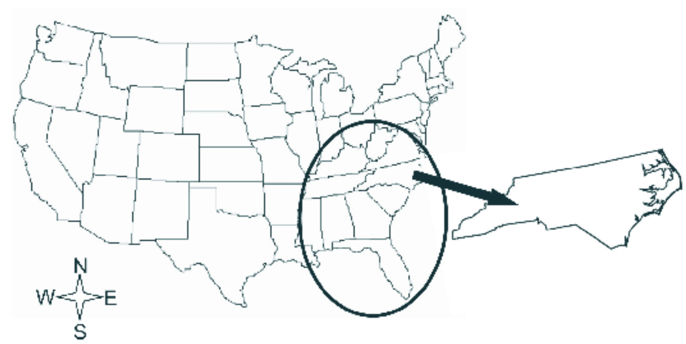


Figure 1. North Carolina is in the Southeastern United States.

Number Crunches

- What is the upper temperature limit of North Carolina streams in Fahrenheit? To calculate, multiply the degrees in Centigrade by 9/5 and then add 32.

Introduction

If the temperature of a stream rises too high, the animals that live in the stream may find it difficult to survive. Big changes in a stream's daytime temperature as compared with its nighttime temperature may also cause a problem for **aquatic** animals. It is important, therefore, for daytime stream temperatures to stay as low as possible.

In a natural forest **ecosystem**, streams are protected from high daytime temperatures by natural processes. First, trees and other plants growing beside the stream provide shade from the Sun. Second, the depth of the stream may affect its water temperature, with deeper streams generally cooler than shallow ones. Another process that affects stream temperatures is the way water comes into the stream. If a stream is fed by an underground spring or by **groundwater**, the cooler water from underground may keep the stream's temperature cooler, at least in that area.

People can affect some of these natural processes. For example, people might remove trees from a streambank, allowing more sunlight to reach the stream. This would raise the stream's temperature. Another way people might affect stream temperatures is through activities that result in global climate change. If the **average** air temperature continues to rise in an area, a stream's temperature will likely rise too.

The scientists in this study were interested in answering three questions: (1) How does the shape of a stream affect its daytime water temperature? (2) How does the shape of a stream affect the difference between its daytime and nighttime water temperatures? (3) How might a rise in average air temperature over time affect a stream's water temperature?

Reflection Section

- What do you think determines the shape of a stream?
- Do you think that a rise in the average air temperature would cause a rise in a stream's water temperature? Why or why not?

Methods

The scientists studied four watersheds in the Piedmont area of North Carolina. A watershed is an area of land where all of the water that is under it or drains off of it goes into the same place (**figure 2**). Two of the watersheds contained rocks that formed from the deposits of ancient volcanoes and minerals. The other two watersheds contained rocks formed from the deposits of mud, sand, silt, and gravel that were carried away by mountain streams millions of years earlier (**figure 3**). Although the **geology** of these areas was different, the areas were only 8 kilometers apart.

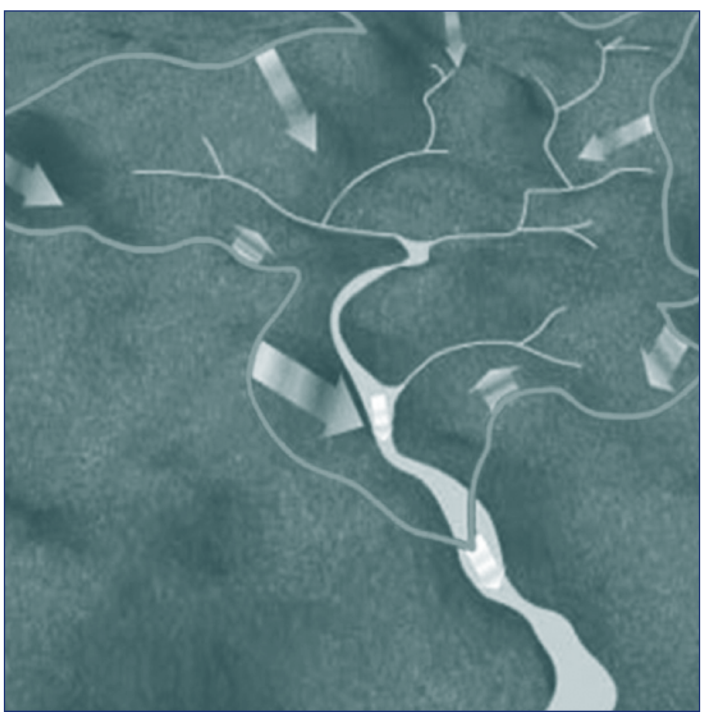


Figure 2. A watershed. Image from http://www.kidsgeo.com.

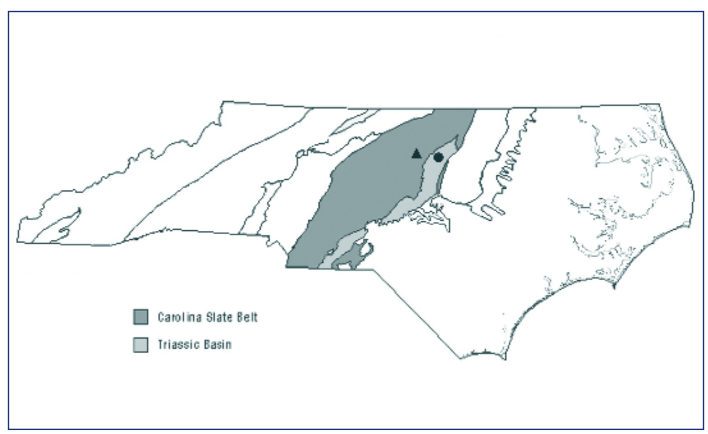


Figure 3. The four watersheds studied by the scientists were located in two areas indicated by the circle and the triangle. One watershed was in the Carolina Slate Belt, and the other was in the Triassic Basin.

Number Crunches

How far apart were the watersheds in miles? To calculate, multiply 8 times .621.

The scientists first located the stream in each watershed. Then, they located the area closest to the stream's beginning. This is called the stream's headwaters. The scientists placed equipment in the stream's headwaters to measure the amount of streamflow (**figure 4**). Streamflow is the rate at which water passes a given point in a stream. The scientists also measured the height of each streambank and the stream's depth. They measured how much of the stream was covered by the leaves of trees. A thermometer was placed in each stream to measure water temperature. Every 10 minutes, this equipment automatically measured and recorded the amount of streamflow and the water temperature. Each stream's **gradient** was also measured (**figure 5**).

On the bank nearby, weather equipment measured and recorded things like air temperature, solar radiation, rainfall, and humidity. The weather equipment recorded the data every 10 minutes. The scientists then used a computer program to compare each of the weather measurements with daytime and nighttime stream temperatures. They also compared daytime and nighttime stream temperatures with streamflow and the amount of leaves covering and shading the stream (**figure 6**).

The scientists then used a computer program to investigate what effect an increase in air temperature would have on the streams' temperatures. They assumed everything else was the same, except that they added 2 degrees Centigrade to each air temperature value.

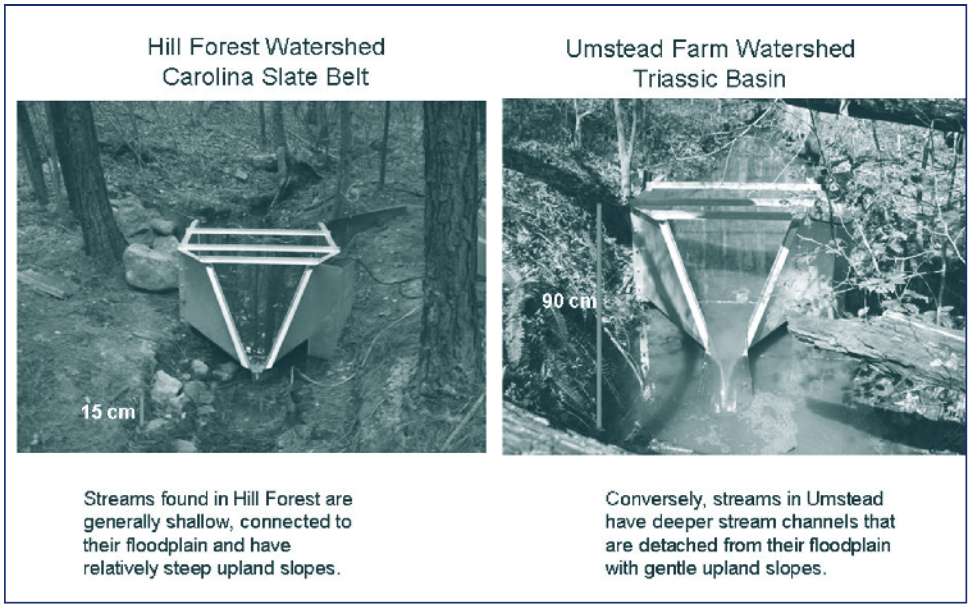


Figure 4. A **flume** was placed in each stream to measure the amount of streamflow. You can see the differences in the two streams. Forest Service photo.

Figure 5. Different stream gradients. Photos courtesy of Babs McDonald.

Stream Temperatures ▶ / Weather and Stream Properties ▼	Daytime water temperatures (measured and recorded every 10 minutes)	Nighttime water temperatures (measured and recorded every 10 minutes)
Weather data (measured every 10 minutes, recorded every hour): • Air temperature • Amount of solar radiation • Amount of rainfall • Humidity		
Height of streambank		
Depth of stream		
Gradient of stream		
Amount of streamflow (measured and recorded every 10 minutes)		
Amount of shade over the stream (measured once using a fisheye lens) (**figure 7**)		

Figure 6. The scientists compared daytime and nighttime stream temperatures with weather information and stream properties.

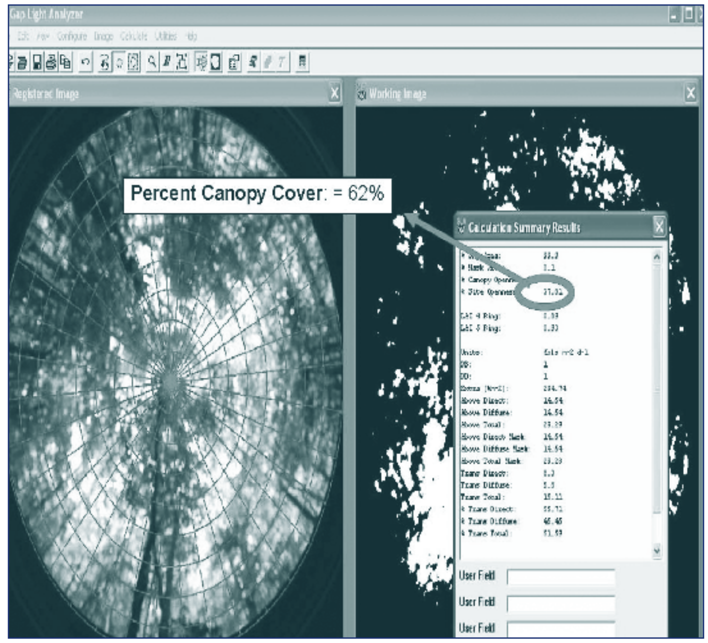


Figure 7. A fisheye lens and a computer program were used to calculate the amount of shade over the stream. Forest Service image.

Reflection Section

- Why do you think the scientists studied streams that were near each other but had a different geology?
- Why was it important to study streams with similar day-to-day weather?
- Look at figure 6. Why did the scientists not compare the two **variables** represented by the lower right rectangle? Which other variable in this figure would not be compared with nighttime water temperatures?

Findings

The scientists found that the most shaded streams had the lowest daytime temperatures during the summer. They also found that for all streams, the difference between daytime and nighttime temperatures was greatest during the summer. When the scientists compared the stream's temperature with the stream's gradient, they found that the steeper the gradient, the lower the water temperature.

The scientists also found that if the air temperature were to rise 2 degrees Centigrade over time, stream temperatures would likely rise between 0.6 and 1.0 degrees Centigrade.

Reflection Section

- Why do you think the most shaded streams had the lowest daytime summer temperatures?
- Why do you think that stream temperatures in a future warmer climate might rise more in the winter than the summer? (Hint: think about what is different about many of the trees along streambanks in the summer and winter.)

Discussion

The scientists believe a stream's gradient affects its temperature in this way: When the gradient is steeper, molecules of water stay in any area of the stream for a shorter period of time because of gravity pulling them quickly downstream. The heat energy in each of the water molecules is carried away before it can affect the stream's temperature.

A stream's gradient is a result of the geology of the area. Gradient is also one way to describe the stream's shape. The shape of a stream affects both its daytime temperature and the difference between daytime and nighttime temperatures. The steeper the gradient, the lower the daytime temperature, which means there is less difference between nighttime and daytime temperatures.

Although people cannot change the gradient of a stream, they can plant and protect trees along a stream's banks. This will help keep the daytime stream temperature lower. Although stream temperatures in the North Carolina Piedmont may rise in the future as the climate changes, they are not predicted to go higher than the upper limit for healthy streams set by the State of North Carolina.

Reflection Section

- Think back to the first question in the first Reflection Section. Did you or your class consider the gradient of the stream as one way to describe its shape? Do you agree that the gradient of a stream is part of its shape? Why or why not?
- Most States have laws that protect streams and rivers. These laws prohibit the removal of trees and other plants within a certain number of feet from the water's edge. Do you think this is a good thing? Why or why not?

Glossary

aquatic (ə **kwä** tik): Growing or living in or upon water.

average (**a** v(ə rij): The usual kind or amount. The number gotten by dividing the sum of two or more quantities by the number of quantities added.

ecosystem (**ē** kō sis təm): Community of plant and animal species interacting with one another and with the nonliving environment.

flume (flüm): A sloping channel for directing the flow of water.

geology (jē **ä** lə jē): Earth's matter, including its materials, structure, physical properties, dynamics, and history, and the processes by which Earth's matter is formed, moved, and changed.

gradient (**grā** dē ənt): The rate of sloping upward or downward.

groundwater (graund **wä** tər): Water that sinks into the soil.

habitat (**ha** bə tat): Environment where a plant or animal naturally grows and lives.

invertebrate (in **vər** tə brət): An animal with no spinal column. About 95 percent of all animals are invertebrates. These include all animals except mammals, birds, reptiles, amphibians, and fish.

Piedmont (**pēd** mänt): An area of land lying at or near the base of a mountain range. In the Eastern United States, the Piedmont area lies between the Appalachian Mountains and the Atlantic coastal plain.

solar radiation (**sō** lər **rā** dē **ā** shən): Electromagnetic energy from the Sun; sunlight.

variable (**ver** ē ə bəl): Thing that can vary in number or amount.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide.

FACTivity

Time Needed

1 class period

Materials needed:

- Three clear 1-quart plastic containers (or four for extension). A plastic soft drink bottle will work, but the tops should be cut so that the opening is at least 3 inches across.
- Two aquarium thermometers (or four for extension).

In this FACTivity, you will answer the following question: Does the movement of water affect its temperature?

You may do this FACTivity in pairs or in groups, depending on how many thermometers and containers are available.

First, develop and write a hypothesis for this FACTivity. You should develop your hypothesis based on your reading of this article and a review of the FACTivity. A hypothesis is an educated guess about something. Your hypothesis should take the form of a specific statement, and it should be written as if no change is expected as a result of the experiment. It should also be something you can test in an experiment. The following is an example of a hypothesis: "A glass of water left in the Sun for 3 hours will not have a higher water temperature than a glass of water left in the shade."

After you have read the article and reviewed the FACTivity, write your hypothesis on a piece of paper.

Test your hypothesis using the following process:

Perform this experiment outside on a sunny and warm day.

Fill two of the plastic containers with water up to 3 inches from the top. Use water from a refrigerated water fountain or refrigerated water. The water must be cooler than the outdoor air temperature, and the water must come from the same source at about the same time. The temperature of the water should be exactly the same in each container. If the two samples vary at all, mix them together and then divide the water between the two containers. Put one water-filled container in the Sun and place a thermometer in the water. Record the beginning water temperature after 3 minutes, then every 3 minutes until the temperature has raised 2 degrees.

At the same time a student, holding one filled container and one empty one, should stand in the Sun close to the area where the first water container has been set. The student will pour the water continually from container to container. If more students want to be involved, a relay may be set up. The important thing is to keep the water moving from container to container while in the Sun.

Continue pouring the water back and forth until the water in the "still" container has raised 2 degrees.

Using the second thermometer, measure the water temperature of the "moving" water. Is it 2 degrees warmer than its starting temperature? Why do you think it is the temperature that it is? Has your hypothesis been proven true or false? What is the answer to the question posed at the beginning of this FACTivity? Do the results of your experiment agree with the results in the research you just read? Develop and write an explanation of your results. How is this FACTivity similar to and different from the scientists' research?

Assessment

Collect students' written hypotheses and explanations of results. Use the rubric below to assess their work.

HYPOTHESIS	Included in report?	Clearly written?	Grammar/punctuation correct/no mistakes?
In form of statement?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)
In form of null hypothesis (no change expected)?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)
Is hypothesis testable?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)
RESULTS			
Written statement of results?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)
Stated whether hypothesis is proven true or false?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)
Provided answer to FACTivity question?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)
Stated whether results agree with article research?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)
Provided written explanation of results?	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)	Yes (1 pt) No (0 pt)

Scoring categories: 0-6, 7-12, 13-19, 19-24 (0-6=Lowest achievement, 19-24=Highest achievement)

Extension

Repeat the experiment in the shade. Compare all four temperatures.

What You Can Do:

Be a stream detective! Around your home, school, and community, notice whether streams and rivers have trees and other plants growing near their banks. If not, begin a campaign to grow and care for trees and other plants along waterways. Always have an adult you know and trust with you when you begin your detective work. Also, always get permission from the landowner to walk on his or her private land. In addition, you can create posters to educate adults about the importance of having trees and other plants near waterways.

PLT®

If you are a PLT-trained educator, you may use Activity # 38: "Every Drop Counts."

National Science Education Standards

Standards addressed in this article include:

Science As Inquiry:
Abilities Necessary To Do Scientific Inquiry,
Understandings About Scientific Inquiry

Earth Science:
Structure of Earth System

Science and Technology:
Understandings about Science and Technology

History and Nature of Science:
Science as a Human Endeavor,
Nature of Science

Additional Web Resources

More possible impacts of climate change on streams:

http://www.sciencedaily.com/releases/2009/07/090723142116.htm

http://www.sciencedaily.com/releases/2007/05/070504101355.htm

Adapted from Boggs, J.L.; Sun, G.; McNulty, S.G.; Swartley, W.; Treasure, E.; and Summer, W. 2009. Temporal and spatial variability in North Carolina Piedmont stream temperature. *AWRA 2009 Spring Specialty Conference*, May 4-6, Anchorage, AK. http://www.srs.fs.usda.gov/pubs/ja/ja_boggs005.pdf.

There's Snow Place Like Home:

Photo courtesy of Ken Curtis.

Tracking the Range of Wolverines Over Time

Meet the Scientists

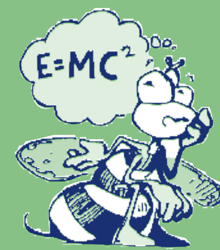
▲ Dr. Keith Aubry, Research Wildlife Biologist: One of my most interesting and exciting science experiences occurred last winter when I traveled around the island of Tasmania (which is part of Australia). This was my first opportunity to experience the diversity of **marsupials** (pouched mammals) and **monotremes** (egg-laying mammals) that occur in the Australian region. I saw and photographed a Tasmanian devil, ringtail and brushtail possums, a Bennett's wallaby (a small kangaroo), and a wombat (a chunky, **herbivorous** marsupial). I also learned all about the **extinct** Tasmanian tiger. One of my most memorable experiences was watching an **echidna** (one of only two egg-laying mammals in the world) hunt for bugs in decaying leaves and under rotting logs. The echidna (also called a spiny anteater) looks like a slightly deflated soccer ball that is covered with poisonous spines!

▼ Dr. Kevin McKelvey, Wildlife Ecologist: My favorite experience was digging out a wolverine snow-den in Glacier National Park. To study wolverines, scientists capture wolverine kits (baby wolverines) and put tracking instruments on them. These instruments help us follow their movements. To put the instruments on them, we first dig down through the snow to the wolverine den site. The den site is usually under about 8 feet of snow and under large rocks or downed trees. To find the dens, we have to look for wolverine tracks.

I was lucky enough to follow tracks that led to the den. The den was visible by a small hole in the snow. I was digging down, with the surface of the snow about 2 feet above my head when I broke through into the center of the den. Immediately, I heard the mother wolverine growling right beneath my feet. I had this image of an **enraged** female wolverine crawling up my leg and gnawing on my head. But Mr. Jeff Copeland, who has years of experience with wolverines (but who was also standing safely on top of the snow) said: "It will be fine." It ended up being fine.

We were able to capture the two kits, and conditions were perfect for putting the instruments on them without causing them a lot of stress. We had to work quickly with mom circling about 50 meters away, waiting for us to be done! (In the picture, the wolverine kit is covered with a blanket to protect its eyes while we are studying it. The wolverine kit was released back to its mother when we were finished.)

Thinking About Science



It is important for scientists to gather correct information or **data** about the topic they are studying. Not all information is **reliable** information. Scientists, therefore, need to be able to determine whether the data they are collecting are reliable. In this study, scientists gathered information from museums, literature, and **archived** material at State and Federal buildings. Once they gathered all their information, they did not use any that was unreliable or not well documented. When scientists (or you) use the Internet, care must be taken to know the source of the information. Usually, it is best to use Internet sites from State and Federal Governments (.gov), universities (.edu), or trusted sites like *National Geographic*.

If the scientists in this study did not feel confident about their data source, they did not use that information. As a result, some information that may have been useful was lost. It is important for scientists to keep **accurate** and reliable data so that their findings will be correct. You have heard your teacher ask you to carefully write down your **observations** and data during experiments at school. Now you can see why that is important!

Thinking About the Environment

The Endangered Species Act is a law that was created in 1973 to protect **species** that are threatened with or in danger of extinction. There are many reasons a plant or animal species may be placed on the endangered species list. For example, an animal's **habitat** may be getting smaller because humans are building their houses in that area. If an animal loses its habitat, it may not be able to survive in another habitat. In this study, scientists examined wolverine habitat to see what things may be shrinking the wolverine's **geographic range**. Their geographic range is where wolverines are found across the United States and Canada.

Number Crunches

- How old is the Endangered Species Act?

Introduction

Wolverines, the largest **terrestrial** member of the weasel family, are mammals that are difficult to find (**figure 1**). Because they live in areas far from humans and human development, therefore, not much is known about these mammals. Wolverines are primarily scavengers, and they sometimes travel great distances in a day in search of food or shelter. In North America, they are currently found in most of Alaska and Canada, but only in the mountainous northern portion of the lower 48 States (**figure 2**). Wolverines may seek shelter under fallen logs or boulders, and female wolverines give birth to their kits in snow-dens.

Neither the current nor historical range of wolverines in the lower 48 States was well known before the work of these scientists. This was a problem because some groups had **petitioned** for the wolverine to be listed as an endangered species. One of the reasons the petitions were denied was because no one was certain where wolverines occurred in the United States. The scientists in this study, therefore, wanted to accurately map the wolverines' range over time and evaluate how climate change might be affecting their range.

Figure 1. The wolverine is well adapted for living in snowy environments. By looking at the picture, name one adaptation the wolverine has to allow it to live in the snow. Photo courtesy of Keith Aubry.

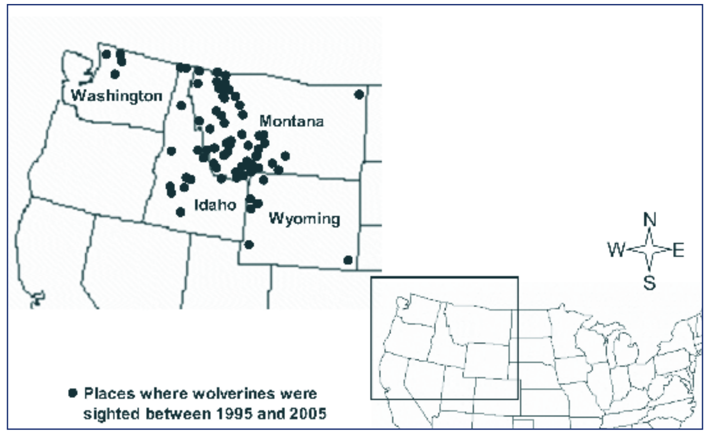


Figure 2. In the lower 48 States, the wolverine's current range (1995–2005) is restricted to northern portions of the western mountains. The scientists studied wolverine habitat in these States.

Reflection Section

- What questions were the scientists trying to answer?
- What are some other animals that burrow or make dens for their homes?

Methods

The scientists gathered information about wolverine trapping and sightings between 1801 and 2005. They also gathered information about wolverines from museums. Each record included geographic information identifying where the wolverines were seen. The scientists divided the records into three time periods—

- 1995–2005 (current)
- 1961–1994 (recent)
- 1801–1961 (historical)

The scientists used computer software to create maps with the data. The scientists also collected information about the type of vegetation in the area. They collected information about climatic (klī **ma** tik) conditions over time and about the spring snow cover from recent years. The scientists added all this information to the maps to see how particular climatic conditions or spring snow cover compared with the wolverine records.

Number Crunches

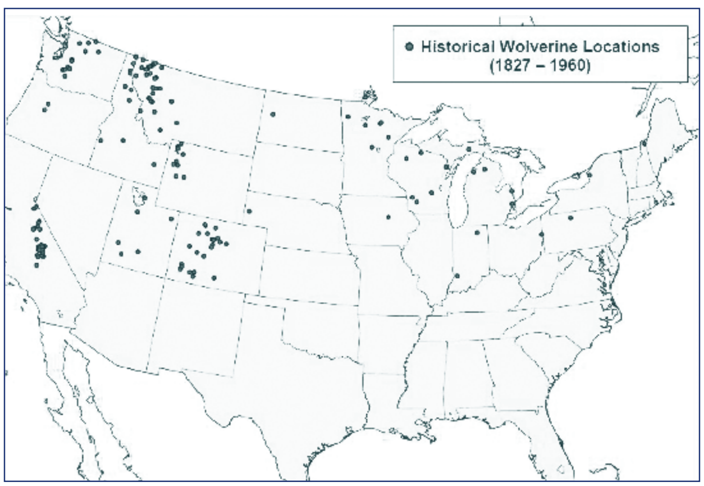
- What is the total number of years that the scientists obtained information about wolverines?

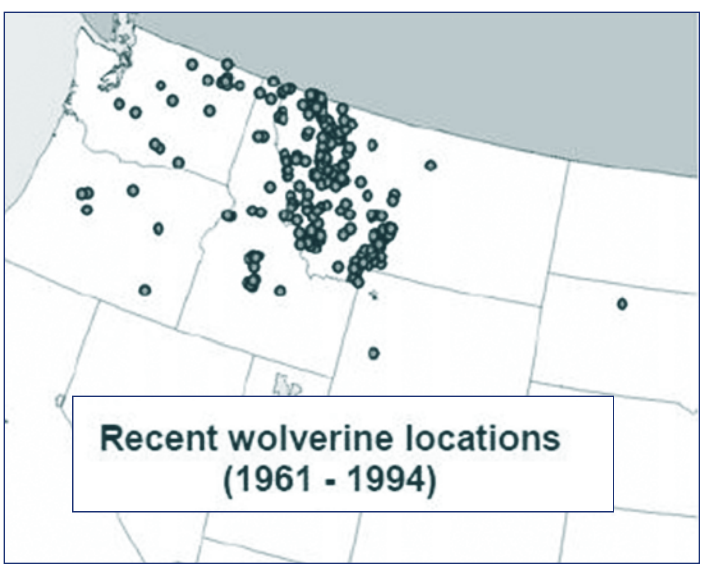
Reflection Section

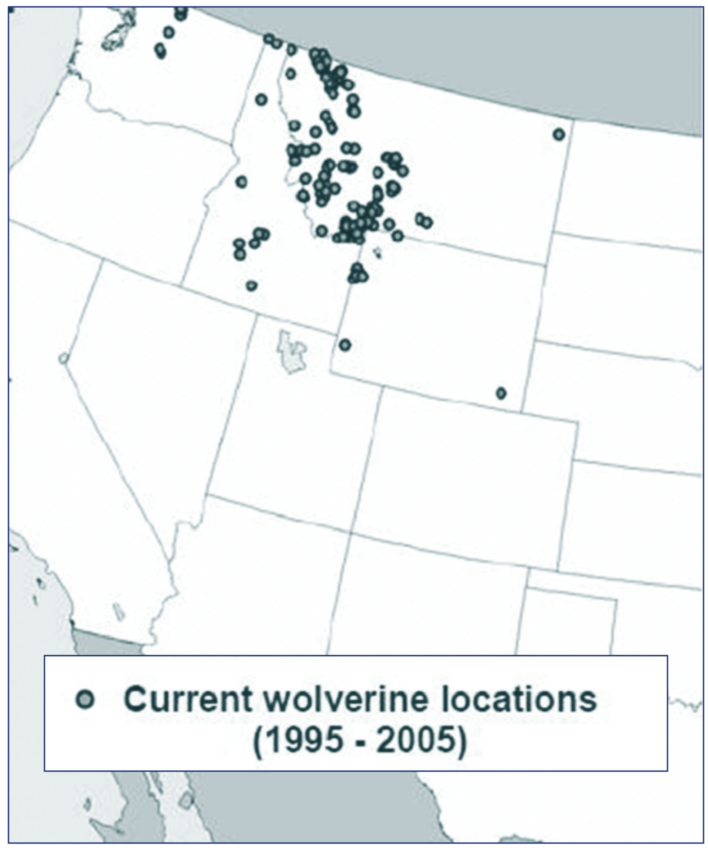
- Why do you think the scientists divided the years into three different time periods?
- How do you think warmer temperatures might affect wolverines? (Hint: look back at the Introduction section to see where wolverines typically give birth.)

Findings

The completed maps showed that the range of wolverines shrunk over time, as illustrated by wolverine records from historical to current times (**figures 3a, 3b, and 3c**).

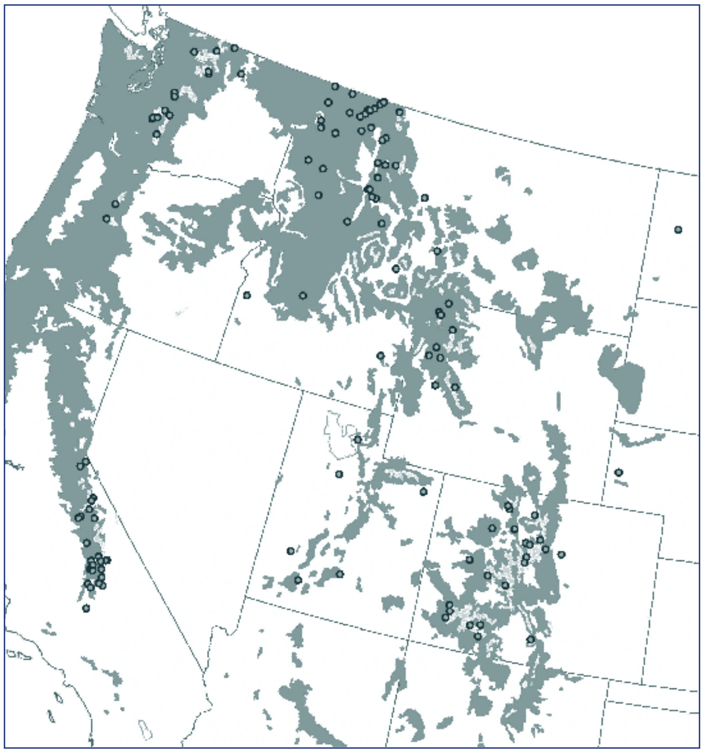


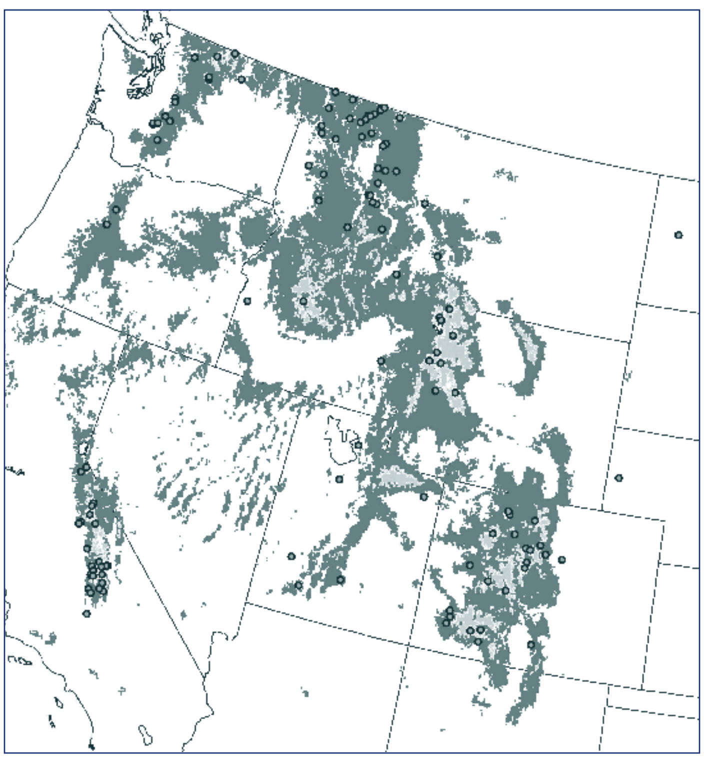




Figures 3a, 3b and 3c. The historical, recent, and current distribution of wolverines in the northern mountains of the Western United States. Forest Service image.

It was also evident that wolverines depend on particular habitat conditions for survival (**figures 4a and 4b**).





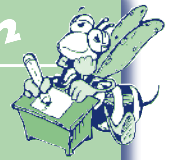
Figures 4a and 4b. Wolverine distribution and the location of alpine areas and conifer forests. What do you notice about where the wolverines live?

This study was the first time anyone accurately assessed the range of wolverines over time. The scientists found that wolverines live in areas of the United States where snowpacks remain through the spring period. This is the time when wolverines make their dens. The scientists also found that most wolverine sightings were in alpine meadows and conifer forests. Alpine meadows are found high in the mountains (**figure 5**). Conifer forests are areas with trees that have cones and that typically do not lose their leaves in the fall or winter (**figure 6**).

Figure 5. Alpine areas have plants that are low to the ground so they can live in the cold temperatures.

Figure 6. Some types of conifer forests are found in Earth's cooler regions.

Reflection Section



- In your own words, summarize what the scientists found.
- Do you think the findings support the idea that the wolverine's habitat may be in danger? Why or why not?

Discussion

Wolverines have already experienced habitat losses. Discovering that wolverines live near areas that have spring snow cover is important. It is important because as the climate changes and becomes warmer, the snow in these areas will melt earlier in the year. As the climate in these areas warms, the range of suitable wolverine habitat will change. In addition, the wolverine's reproduction may be affected. The scientists believe that more research needs to be done to fully understand the potential impact of climate change on wolverine populations.

Reflection Section

- Why would the wolverine's reproduction be affected? (Hint: Think about why wolverines need spring snow cover.)
- Based on what you have learned from this article, do you think it is possible that the wolverine may need to be listed as an endangered species? Why or why not?

Glossary

accurate (**a** kyə rət): Free from error.

archived (**är** kīvd): Collected or filed.

data (**dā** tə): Factual information used as a basis for reasoning, discussion, or calculation.

echidna (i **kid** nə): A type of egg-laying mammal that is also known as a spiny anteater.

enraged (en **rājd**): Angered.

geographic range (jē ə **gra** fik rānj): The area defined by the location of the farthest populations of a species.

extinct (ik **stiŋ (k)t**): No longer living.

herbivorous ((h)ər **biv** rəs): Feeding on plants.

marsupial (mär **sü** pē əl): A pouched mammal.

monotreme (**mä** nə trēm): Any of the order of egg-laying mammals.

observation (**äb** sər **vā** shən): Watching carefully and making note of details to help arrive at a judgment.

petition (pə **ti** shən): To make a request.

reliable (ri **lī** ə bəl): Dependable.

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

terrestrial (**təs** t(r)ē əl): Of or relating to land as opposed to air or water.

Accented syllables are in **bold**. Marks are from the Merriam-Webster Pronunciation Guide.

FACTivity

Time Needed

1.5 class periods

Materials needed per student group:

- Animal field guides that include range maps, such as bird, reptile, amphibian, or mammal guides and other resources with wildlife information.
- Two blank maps of the United States. (See page 27, “Moving on Up,” for a blank map.)
- Two pieces of blank white 8 ½ x 11 paper.
- Markers.

The question students will answer in this FACTivity is: What is the range of an animal?

Process:

In the first class period:

Choose an animal to study that lives in the United States. This animal may be selected from one of the field guides. Using the field guide and other sources, find the following information about the animal:

- What is the animal’s habitat? When you find out about the areas it lives, mark those areas on one of the blank maps. Label this map “Where [animal species name] Currently Lives.”
- What does the animal eat?
- Does the animal have predators? If so, what are they?
- What is the average size of the animal?
- What does the animal look like?
- What is the climate where the animal lives?
- What are three adaptations the animal has so that it can live successfully in its habitat?

Use this information and any other interesting facts to create an Animal Fact File. The Animal Fact File should be displayed on two pieces of 8.5- by 11-inch paper.

In a short paragraph, answer the question posed at the beginning of this FACTivity.

In the second class period:

One of your blank U.S. maps should already be filled out with the animal’s current range. You will use the other map to make a prediction about how you think the animal’s range will move as the climate changes. Think about what you read in the wolverine article to help you make this map. Label this map “Predicted Future Range of [animal species].” Once all of the groups have created an Animal Fact File and completed the two maps, the files and maps can be compiled into a class book.

Extension

If students have read and done the FACTivity from “Moving On Up” in this edition of the *Natural Inquirer*, they may compare their animal range maps with the tree range maps.

PLT®

If you are a trained Project WILD educator, you may use the activity “Shrinking Habitat” on page 310.

What You Can Do:

Turn it off! Using less energy means producing less carbon dioxide. Some examples of things you can turn off when you are not using them are lights around your house, water when you are brushing your teeth, and your computer or television. You can also save energy by turning down your thermostat and using cold water when you wash your clothes.

Additional Web Resources

National Geographic Wolverine Information and Pictures
http://animals.nationalgeographic.com/animals/mammals/wolverine.html

University of Michigan's Animal Diversity Web: Wolverine Information
http://animaldiversity.ummz.umich.edu/site/accounts/information/Gulo_gulo.html

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Adapted from Aubry, K.B.; McKelvey, K S.; and Copeland, J.P. (2007). Distribution and broadscale habitat relations of the wolverine in the contiguous United States. *Journal of Wildlife Management*. 71(7): 2147–2158. http://www.treesearch.fs.fed.us/pubs/28925.

National Science Education Standards

Standards addressed in this article include:

Science as Inquiry:
Abilities To Do Scientific Inquiry,
Understandings About Scientific Inquiry
Life Science:
Regulation and Behavior,
Populations and Ecosystems,
Diversity and Adaptation of Organisms,
Reproduction and Heredity
Earth Science:
Structure of Earth System
Science and Technology:
Understandings About Science and Technology
Science in Personal and Social Perspectives:
Science and Technology in Society,
Natural Hazards
History and Nature of Science:
Science as a Human Endeavor,
Nature of Science

Climate Change Word Search

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

1. Free from error.
2. A step-by-step procedure for solving a problem that often involves a computer program.
3. Growing or living in or upon water.
4. Scientific study of historic/prehistoric peoples and their cultures by analysis of their artifacts, inscriptions, monuments, and other such remains.
5. All the living and recently-living things in a particular area.
6. The average condition of the weather over large areas, over a long time, or both.
7. To use a hollow drill to take a small cylindrical sample of a tree's trunk.
8. A comprehensive collection of related data organized for convenient access, generally in a computer.
9. To have a bowel movement.
10. A scientist who studies tree-rings.
11. Height above sea level.
12. To throw out or eject.
13. A sloping channel for directing the flow of water.
14. To start growing or developing.
15. The rate of sloping upward or downward.
16. An animal with no spinal column.
17. A pouched mammal.
18. A fluctuation between maximum and minumum values.
19. To keep free from decay.
20. Detailed, precise description of a place or region.

Word Scramble

Unscramble the words to create a sentence from this edition of the *Natural Inquirer.*

____

spread can seeds ways many in the trees of

____

everyone a almost in community lives

____

story about tree the tree tell a rings

____

familiar you GPS a are probably with

____

sunlight life survive to Earth depends all on on

____

affect things many temperature stream's a

____

steps knowledge in advances usually scientific small

____

low areas are plants the ground to alpine have that

____

have already losses wolverines experienced habitat

____

grows layer it tree a as new growth trunk on a adds its of

____

time over refers climate to change the Earth's change in climate

____

beams ICESat surface light of GLAS as Earth to orbits Earth's sends

____

understand the used trees by old scientists past them to the clues provided help

____

forests provide most tropical animals worldwide plants habitats the of diverse rain some for and

Word Scramble Answers

The seeds of trees can spread in many ways.
Almost everyone lives in a community.
Tree rings tell a story about the tree.
You are probably familiar with a GPS.
All life on Earth depends on sunlight to survive.
Many things affect a stream's temperature.
Scientific knowledge usually advances in small steps.
Alpine areas have plants that are low to the ground.
Wolverines have already experienced habitat losses.
As a tree grows, it adds a layer of new growth on its trunk.
Climate change refers to the change in Earth's climate over time.
As ICESat orbits Earth, GLAS sends beams of light to Earth's surface.
The scientists used clues provided by old trees to help them understand the past.
Tropical rain forests provide some of the most diverse habitats for plants and animals worldwide.

Note to Educators

The Forest Service's mission is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. For more than 100 years, our motto has been caring for the land and serving people. The Forest Service, U.S. Department of Agriculture (USDA), recognizes its responsibility to be engaged in efforts to connect youth to nature and to promote the development of science-based conservation education programs and materials nationwide.

The *Natural Inquirer* is a science education resource journal to be used by students in grade 5 and up. The *Natural Inquirer* contains articles describing environmental and natural resource research conducted by Forest Service scientists and their cooperators. These are scientific journal articles that have been reformatted to meet the needs of middle-school students. The articles are easy to understand, are aesthetically pleasing to the eye, contain glossaries, and include hands-on activities. The goal of the *Natural Inquirer* is to stimulate critical reading and thinking about scientific inquiry and investigation while teaching about ecology, the natural environment, and natural resources. In this edition of the *Natural Inquirer*, you will find six articles on climate change written in the scientific method format.

The Format of a Natural Inquirer Article

Each *Natural Inquirer* article follows the same format. *Natural Inquirer* articles are written directly from a published science article and all have been reviewed by the scientists for accuracy. Each article contains the following sections, which you may introduce to your students as they read.

Meet the Scientists: Introduces students to the scientists who did the research. This section may be used in a discussion about careers in science.

Thinking About Science: Introduces something new about the scientific process, such as a scientific habit of mind or procedures used in scientific studies.

Thinking About the Environment: Introduces the environmental topic being addressed in the research.

Introduction: Introduces the problem or question being addressed by the research.

Method: Describes the method used by the scientists to collect and analyze their data.

Findings: Describes the results of the analysis.

Discussion: Discusses the findings and places them into the context of the original problem or question.

Reflection Section: Presents questions aimed at stimulating critical thinking about what has been read or predicting what might be presented in the next section. These are placed at the end of each of the main article sections.

Number Crunches: Presents an easy math problem related to the research.

Glossary: Defines potentially new scientific or other terms to students. The first occurrence of a glossary word is **bold** in the text.

FACTivity: This is a hands-on activity that reinforces an aspect of the research.

Citation: Gives the original article citation with a Web link to the original article.

Science Education Standards and Evaluations

In the back of the journal, you will find a matrix that enables you to identify articles by the national science education standards that they address. Each article also contains a list of the standards addressed. Evaluation forms for both educators and students are available on our Web site. We welcome any feedback, so please visit http://www.naturalinquirer.org and complete the online evaluation forms. In addition, you may contact Dr. Barbara McDonald at the address below with any comments you have.

If you have any questions or comments, please contact:

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320 Green St.
Athens, GA 30602-2044
706.559.4224
bmcdonald@fs.fed.us

(Please put "Educator Feedback" in the subject line)

Educator Resources

Visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org. From this site, you can order more editions and read and download lesson plans, word games, and other resources to help you use the *Natural Inquirer* in your classroom. You can also view and download a yearlong lesson plan aimed at helping your students learn about the scientific process.

Visit the *Natural Inquirer* Web site at http://www.naturalinquirer.org.

Lesson Plan

Note: This is a generic lesson plan that can be used with any article in this edition or with any *Natural Inquirer* article. This is because each *Natural Inquirer* article follows the same format (See Note to educator, page 72).

If students have not yet been introduced to the *Natural Inquirer* and the written scientific format used by scientists, spend 5 minutes on this topic. Below is a sample introduction:

Just as you know the general format of a book or of a Web site, scientists use a particular format when they write up their research. This format usually follows the process they used when they did their study. Because this format is widely used, other scientists know what to expect when they read a scientific paper. Think about the format of a Web site. If you go to a new Web site that has the elements and format that you expect, you can much more easily understand how to search the Web site and find what you want to know. Scientists are able to do the same thing when they read the papers of other scientists.

The *Natural Inquirer* is a science journal that was written at your reading level. It was written directly from research papers that were written by scientists. Because of this, the *Natural Inquirer* follows the same format as the actual scientific paper and it includes additional sections to help you better understand what you are reading. The heart of a scientific paper has four sections: Introduction, Methods, Findings, and Discussion.

- Introduction: Introduces the problem or question the scientists addressed.
- Methods: Presents the method used by the scientists to collect and analyze their data.
- Findings: Presents the results of the research.
- Discussion: Places the findings into the context of the original problem or question.

The extra sections of a *Natural Inquirer* article:

- Meet the Scientists: This section introduces the scientists whose research is presented.
- Thinking About Science: This section provides one big idea, addressed in the article, about the nature of scientific inquiry.
- Thinking About the Environment: This section provides background information that introduces the topic studied by the scientists.
- Reflection Sections: These are questions placed after the Introduction, Methods, Findings, and Discussion sections to help you think about what you have read.
- Number Crunches: These are easy math problems that provide greater understanding about the research.
- Glossary: This section introduces potentially new terms used in the article.
- FACTivity: This is a chance to become a scientist as you conduct an inquiry or activity related to the article you read.

Scientific writing is nonfiction. Nonfiction is informational or factual. Although most nonfiction writing does not have a plot, scientific papers come somewhat close to having a storyline. This is because a scientific paper's format generally follows the process used by the scientists to do their research. To better understand a scientific paper, it is best to read it in the order it is presented. You can think of a scientific paper as a factual mystery that unfolds in the four sections outlined previously: Introduction, Methods, Findings, and Discussion sections. Scientists are like detectives who solve scientific mysteries.

Today we are going to read [title of the article you have chosen]. To help us think about what we are reading, we are going to follow a process. First, we will all become THIEVES. As THIEVES, we will think carefully about what we have read, and then we will identify our thinking as "Facts, Questions, or Responses."

Note: Students can do this exercise independently or in a small group.

Give each student or group a copy of the THIEVES chart reproduced at the end of this lesson plan. You may either write the questions below on the board, or give a copy to each student or group. Each student should have a copy of the *Natural Inquirer* article.

Go over the elements of THIEVES. Then, with the *Natural Inquirer* articles and their THIEVES chart, students may begin reading. Follow each step in THIEVES, which are as follows:

The Elements of THIEVES:

Title, **H**eadings, **I**ntroductory sections, **E**very paragraph, **V**isuals and **V**ocabulary, **E**nd of section questions, **S**ummary and **S**ection 1.

T

- Read the **t**itle. Using the THIEVES chart, complete the following:
- What is the title?
- Based on the title, what do I think I will be reading about?
- Does the title express a point of view? If so, what is it?

H

- Read each of the four main article **h**eadings, beginning with "Introduction." Using the THIEVES chart, complete the following:
- What do I think I will find out in the Introduction section?
- What do I think I will find out in the Methods section?
- What do I think I will find out in the Findings section?
- What do I think I will find out in the Discussion secction?

I

Introductory sections:

- Read Thinking About Science.
- Using the THIEVES chart, complete the "Facts, Questions, Responses" chart for that section.
- Read Thinking About the Environment.
- Using the THIEVES chart, complete the "Facts, Questions, Responses" chart for that section.
- Based on these introductory sections, what do I think the article will be about?

E

- Under each of the four headings, read **e**very paragraph. (This is the heart of the scientific article.)
- If you find a bolded word that you do not know, go to the step labeled "V," for vocabulary.
- If you come to a visual (photograph, map, chart, graph, or drawing), go to the step labeled "V2" for visuals.
- After reading each paragraph, complete the "Facts, Questions, Responses" chart
  for that section.
- Write a sentence or two summarizing each of the four sections.

V

- Review the **V**ocabulary (Glossary).
- Identify words that you do not know.
- Sound out words that you do not know how to pronounce.
- Make sure you understand every word.

V2

- Look at the **v**isual.
- Write the visual's number (such as figure 1, chart 1, etc.)
- What can I learn from the visual?
- How do the captions help me to understand each visual?

E

- At the **e**nd of each section, read the Reflection Questions. Think about (or discuss, if you are in a group) your answers to these questions.
- What do the questions ask?
- What do I learn from the questions?
- What do I learn from answering the questions?

S

Summary and **S**ection 1

- Reread the Discussion section, which serves as a summary. Review your "Facts, Questions, and Responses" to that section.
- Reread the Introduction. Review your "Facts, Questions, and Responses" to that section.
- What have I learned about the scientific process from reading this article?
- What have I learned about the natural environment from reading this article?

Reading Thieves

T (Title)

What is the title?	What do I think I will be reading about?	Does the title have a point of view? If so, what is it?

H (Headings)

What do I think I will find out in the Introduction?	What do I think I will find out in the Methods?	What do I think I will find out in the Findings?	What do I think I will find out in the Discussion?

I (Introductory Sections)

	WHAT QUESTIONS DO I HAVE?	WHAT IS MY REACTION TO THIS SECTION?
Thinking About Science FACTS?		
Thinking About the Environment		

E (Every Paragraph)

Introduction FACTS?	WHAT QUESTIONS DO I HAVE?	WHAT IS MY REACTION TO THIS SECTION?
Methods		
Findings		
Discussion		

V V (vocabulary and Visuals)

Write new vocabulary (glossary) words here.

Visuals (Phhotos, charts, graphs, illustrations): Write the number here:	What can I learn from the visual?	How does the caption help me to understand the visual?

Two reflection Questions - At the **E**nd of each section

E	What does the question ask?	What do I learn from the question?	What do I learn from answering the question?
Introduction			
Methods			
Findings			
Discussion			

S Summary and Section 1

What have I learned about the scientific process from reading this article?

What have I learned about the natural environment from reading this article?

THIEVES was adapted from "Read Write Think," *http://www.readwritethink.org/lesson_images/lesson112/elements.pdf*

"Facts, Questions, and Responses" was taken from *www.readinglady.com*

Reflection Section Answer Guide

It's a Small World

Introduction

- **What is the question the scientists were trying to answer?** *How did climate and the three oscillations affect the timing and location of wildfires in the Western United States in the past, and how might this change as the global climate changes?*
- **Do you think there were written records about fire or sea surface temperature patterns such as ENSO, PDO, and AMO hundreds of years ago? Why or why not?** *Students should logically conclude that there were no written records of large-scale sea surface patterns hundreds of years ago because people were not aware of these patterns at that time and therefore did not keep a written record of them.*

Methods

- **Why do scientists share their data with other scientists? What is one advantage of sharing data?** *There is no reason to collect information that has already been collected. Sharing data saves time and money and when data are shared, a better understanding often is the result. There may be many other explanations that students may give. Students should be able to support their explanations with logical reasoning.*
- **Think about how the scientists gathered information about the past using tree rings. What are other natural resources that contain information about the climate of the past?** *Glaciers, rocks, coral, lake sediments that contain charcoal from past fires, pollen from plants, and soil cross-sections are examples of resources that can give clues about climate and major events that occurred in the past.*

Findings

- **In your own words, explain how trees that lived many years ago have helped scientists to understand what may happen in the future.** *Students should recall that tree rings and fire scars were used to identify how climate and sea surface temperature patterns affected wildfire in the past. This enables scientists to predict what might happen to wildfire in the future given predictions of future climate and sea surface temperature changes.*
- **How might global climate change affect the sea surface temperatures?** *There is no right or wrong answer to this question because we do not know what will happen. If the changing global climate results in rising temperatures as predicted, the ocean's surface water temperatures may also rise. The cooler phase may not be as cool as in the past and the warmer phase may be warmer than in the past. Students should reflect on this question but realize that we do not have an absolute answer.*

Discussion

- **Now you understand that sea surface temperature patterns and wildfires appear to be connected. What are other natural processes that might be connected to each other?** *There are many different answers for students to think about. A student's answer may be accepted if he or she can support the answer with evidence. Some of the choices could be glaciers and ocean salinity, rainfall in the mountains and ocean nutrients, salmon migration bringing deep-ocean nutrients to mountain streams, etc.*
- **Do you think the Western United States might have more frequent wildfires in the future? Why or why not?** *This is an*

individual question, that each student may answer uniquely. Students should back up their answer with logic. A student's answer to this question depends in large part on whether or not he or she believes that the global climate is changing and that climate change might affect sea surface temperatures and the occurrence of wildfires, as described in this research.

Moving on Up

Introduction

- **What questions were the scientists trying to answer?** *How might the habitat of eastern trees change in the future as the climate changes? How might different tree species move in response to a changing climate?*
- **Do you think a changing habitat may also affect the animals that live in the Eastern United States? Why or why not?** *Students will have to answer this using logic. They should, however, realize that as an area's habitat changes, the animal species that live there will also change.*

Methods

- **Why did the scientists consider what may happen if people burn less fossil fuels in the future?** *People are becoming more aware of the impacts of burning fossil fuels and have begun to use less. It is important to understand whether conservation of fossil fuels may actually make a difference in the future habitat of trees.*
- **What is one advantage of using maps to show research results?** *Maps can show a lot of information quickly. They also easily compare the two possible future conditions. Maps show where something is happening or change is occurring. Students may come up with more advantages.*

Findings

- **If the preferred habitat of sugar maple trees moves farther into Canada, what possible impact might this have on U.S. businesses that sell the sweet product of maple trees?** *If there are fewer sugar maple trees to produce maple syrup in the United States, the U.S. businesses that produce and sell maple syrup may have to change to a new product, close down, or buy raw syrup from Canadian businesses.*
- **Why will the preferred habitats of most tree species move in a northerly direction?** *Students should realize that, as the average temperature rises across all areas, average temperatures will also be "moving" in a northerly direction.*

Discussion

- **The scientists considered what might happen if people burned less fossil fuels in the future. If people burn even less fossil fuels in the future than the scientists considered, how might the predicted movement of eastern tree species change?** *Students will have to use logic (and may need help), but should understand that if people burn a lot less fossil fuels in the future, the climate may not change as much as the scientists have predicted. If this is the case, the trees and forests may not move as far north as predicted.*
- **What is one way people might respond to this knowledge of changing forest communities?** *If people know in advance how forest communities will change, they can better plan for those changes. For example, if in the future there may be fewer maple trees in the United States to make maple syrup, companies that make maple syrup might plan to switch to another product. If it is predicted that the preferred habitat of some pine trees will expand, this might create opportunities for companies in the wood products industry. If people know that*

the habitat of a particular tree species is changing, they can be better prepared to lose that species and welcome new tree species to their area.

The GLAS is Half Full

Introduction

- **What questions were the scientists trying to answer?** *Can information gathered by satellites be used to identify the age of tropical rain forests and to estimate the increase in the amount of biomass in growing rain forests? Can this information be used to estimate the amount of biomass held by old rain forests? Is this information as good as the information that would be available by studying the forests in person?*
- **How do you think using information gathered by satellites could be more efficient than collecting information in person?** *Satellites can gather information about large areas of land from around the world. Many of the satellites are already in orbit collecting data. If those data can be used to help scientists understand forests, then using satellite data can be more cost effective than trying to study all of the forests in person. This is because it would cost a lot of money and take a lot of time and many people to study all of the world's forests in person, if it were even possible to do so.*

Methods

- **Why did the scientists study an area that had already been studied by other scientists working within the forest?** *The scientists wanted to know if data from satellites could be used to accurately estimate the amount of biomass contained in forests. The only way to do this was to collect data from satellites, and then compare it with reliable information collected by scientists working within the forests, where the calculations were known to be accurate.*
- **Do you think the information collected by the satellites is exact or an estimate? Why or why not?** *Students will have to reason this for themselves. They should, however, conclude that information collected by the satellites is an estimate.*

Findings

- **Think about your own achievement of accuracy on a test. Is an 88-percent accuracy rate acceptable? Consider that the satellites collect a lot more data from all across the planet than scientists could collect by visiting forests in person. Do you think an accuracy rate of 88 percent is acceptable? Why or why not?** *Students should realize that some accuracy must be sacrificed for data collection happening from orbit. They should also realize that an 88-percent accuracy rate is quite high, considering that using this method, data can be collected for forests all over the world. It is much better to have an accuracy rate of 88 percent for forests worldwide, than to have a 100-percent accuracy rate for just a small portion of the world's forests. To help students understand, this might be compared with getting 100 percent of a two-question test correct, compared with 88 percent of a 100-question test correct. Which of these is the better measure of knowledge?*
- **Based on the results of this research, would you say that data collected by satellites may one day be used to help estimate the amount of carbon being held by the world's forests? Why or why not?** *Students should understand that the methods used in this research, if they can be applied to forests worldwide, would provide the kind of information that scientists could use to more accurately estimate the amount of carbon being held by forests world-wide. You may have them read the last sentence in "Thinking About the Environment," if they need a hint.*

Discussion

- **The scientists did not claim that their methods could be used to study all forests. Why do you think they did not make this claim?** *This research dealt only with tropical rain forests in the Rhondônia area of Brazil. Until the scientists have a chance to study other types of forests, they will only report specifically what they have found.*
- **From a climate change perspective, why is it important to understand how fast the amount of biomass increases in young tropical rain forests?** *Tropical rain forests have a large amount of biomass, and therefore they hold a large amount of carbon. Understanding how fast young tropical rain forests gain biomass helps us to understand how effectively these forests can help hold some carbon on Earth, instead of having it go into the atmosphere.*

Back To the Future

Introduction

- **What was the question the scientists were trying to answer?** *What was the climate like during the time the dead trees were alive on Whitewing Mountain and San Joaquin Ridge, California?*
- **Think of an example of something that happened to you in the past that helped you understand something in the future better. For example, last week you did not study for your science quiz and failed, so this week you studied.** *Each student may uniquely answer this question. Students should use reason and logic to support their answer.*
- **Why did the existence of the dead trees above the tree line indicate that the climate might have been different when the trees were alive?** *Because the tree line is the line above which trees cannot survive. Evidence of trees above this line indicates that the climate must have been warmer in the past.*

Methods

- **Why did the scientists only map the deadwood above the tree line?** *They were interested in discovering something about the past climate of the area in which trees can no longer grow, but in which trees grew in the past.*
- **How did technology help the scientists in this study?** *The scientists were able to use GPS to map the deadwood.*

Findings

- **The scientists measured the change in temperature in Celsius. Why did they use Celsius to measure and report temperature rather than Fahrenheit?** *The metric system is the system scientists use to report their information. Celsius is the temperature measurement in the metric system.*
- **Why are these findings important to our understanding of the future?** *If climate change predictions are correct, the future is likely to be warmer. This study revealed that the area above the current tree line was once warmer and drier. If the area above the current tree line is warmer and drier in the future, it may once again be habitat for the tree species that lived in the area in 1350.*

Discussion

- **Based on this article and your own experience, why do you think it is important to study the past?** *Things that happened in the past may be able to help us predict what might happen in the future.*
- **Why do you think scientists try to predict things that will happen in the future? For example, why do you think scientists want to know what trees may be alive in the future if the climate becomes warmer?** *If we have a good idea of what might happen in the future, we can better plan for it. Each student may answer this question uniquely, and each answer should be backed up with logic and reasoning.*

Did They Make the Gradient?

Introduction

- **What do you think determines the shape of a stream?** *A stream's shape is more than its direction of flow. Students should consider a stream's width and depth as things that help determine its shape. They should also think about the type of bedrock through which the streamflows. Some streams, for example, are relatively straight because they cut through softer rocks. Other streams have a lot of bends and turns because they must flow around rocks, or their soils are easily eroded. Brainstorm with your students to come up with factors that determine a stream's shape.*
- **Do you think that a rise in the average air temperature would cause a rise in a stream's water temperature? Why or why not?** *Students should reason that, if air temperature affects a stream's water temperature, then a rise in average air temperature over time would result in an average rise in a stream's water temperature over time.*

Methods

- **Why do you think the scientists studied streams that were near each other but had a different geology?** *The geology, or underlying rock type, helps determine the stream's shape. To compare different stream shapes, the scientists needed to find streams with different underlying geology (or structure). To be comparable, however, it was best to find streams that would otherwise be close geographically, so that air temperature, solar radiation, and other weather data would be similar for all streams. This question gives students an opportunity to understand the concept of controlling as many variables as possible in a study.*
- **Why was it important to study streams with similar day-to-day weather?** *Because the scientists were interested in how a stream's shape affects water temperature, the weather data needed to be as similar as possible for all streams. This would remove one of the sources of variation from the study. This question gives you another opportunity to discuss with your students how scientists control independent variables so that the dependent variable(s) can be more accurately studied.*
- **Look at figure 6. Why did the scientists not compare the two variables represented by the lower right rectangle?** *Because at nighttime, there would be no shade without sunlight.*
- **Which other variable in this figure would not be compared with nighttime water temperatures?** *Solar radiation.*

Findings

- **Why do you think the most shaded streams had the lowest daytime summer temperatures?** *Students should realize that shade provides some protection from the Sun's warmth.*
- **Why do you think that stream temperatures in a future warmer climate might rise more in the winter than in the summer? (Hint: think about what is different about many of the trees along streambanks in the summer and winter.)** *Because trees provide more shade in the summer, they will moderate the rise in stream temperatures. They will do this no matter the air temperature. This does not mean that stream temperatures will not rise in a warmer climate. It means, however, that trees can help reduce the effect of a warmer climate on stream temperatures, especially in the summer when they have leaves.*

Discussion

- **Think back to the first question in the first Reflection Section. Did you or your class consider the gradient of the stream as one way to describe its shape? Do you agree that the gradient of a stream is part of its**

shape? Why or why not? *Students will have to answer this question themselves. They should, however, explore why they did or did not think of the gradient as part of a stream's shape. If they have difficulty with this, challenge them to think of whether the steepness (or gradient) of a mountain is a part of its shape. How is a mountain's shape similar to and different from a stream's shape?*

- **Most States have laws that protect streams and rivers. These laws prohibit the removal of trees and other plants within a certain number of feet from the water's edge. Do you think this is a good thing? Why or why not?** *Students will have to answer based on their own assessment. Most students should come to the conclusion that laws meant to protect streams are good for a number of reasons. You may challenge your students to think of other ways streamside vegetation protects streams. These include, for example, the reduction of soil erosion into streams, the provision of wildlife habitat, the protection of the scenery along streams, and the protection from pollutants that might wash into the streams and waterways.*

There's Snow Place Like Home

Introduction

- **What questions were the scientists trying to answer?** *What is the geographic range of wolverines over time? How might climate change affect the geographic range of wolverines?*
- **What are some other animals that burrow or make dens for their homes?** *There are many different animals that burrow or make dens. Some examples include groundhogs, ants, hamsters, foxes, ferrets, chipmunks, badgers, moles, prarie dogs, pikas, rabbits, shrews, and sand dollars.*

Methods

- **Why do you think the scientists divided the years into three different time periods?** *The scientists divided the time because it was easier to discuss and analyze their findings based on smaller time periods. Scientists often place large amounts of information into categories so that it can be more easily analyzed and understood.*
- **How do you think warmer temperatures might affect wolverines? (Hint: look back at the Introduction section to see where wolverines typically give birth.)** *Warmer temperatures may cause the snow to melt earlier. If the snow melts earlier, the wolverine's denning habitat won't be as good or may not be available at all.*

Findings

- **In your own words, summarize what the scientists found.** *The scientists found that spring snow cover, alpine areas, and conifer forests were important to the range of wolverines. They also found that by the 1950s, wolverine range had begun to shrink.*
- **Do you think the findings support the idea that the wolverine's habitat may be in danger? Why or why not?** *This is an individual question. Each student may answer this question uniquely. Students should be able to support their answers with examples from the article.*

Discussion

- **Why would the wolverine's reproduction be affected? (Hint: think about why wolverines need spring snow cover.)** *The wolverines make their dens in the snow. They reproduce and raise their kits in these dens.*
- **Based on what you have learned from this article, do you think it is possible that the wolverine may need to be listed as an endangered species?** *Each student may uniquely answer this question. Students should be able to support their answers with examples from the article.*

Which National Science Education Standards Can Be Addressed by These Articles?

	It's a Small World	Moving on Up	The GLAS is Half Full	Back to the Future	Did They Make the Gradient?	There's Snow Place Like Home
Science As Inquiry						
Abilities Necessary To Do Scientific Inquiry	✓		✓	✓	✓	✓
Understandings About Scientific Inquiry	✓	✓	✓	✓	✓	✓
Life Science						
Regulation & Behavior		✓				✓
Populations & Ecosystems	✓	✓		✓		✓
Diversity & Adaptations of Organisms	✓	✓		✓		✓
Reproduction & Heredity						✓
Earth Science						
Structure of Earth System	✓		✓		✓	✓
Science and Technology						
Understandings About Science and Technology	✓		✓	✓	✓	✓
Science in Personal & Social Perspectives						
Risks & Benefits		✓			✓	
Science & Technology in Society	✓		✓	✓		✓
Natural Hazards				✓		✓
History & Nature of Science						
Science As a Human Endeavor	✓	✓	✓	✓	✓	✓
Nature of Science	✓	✓	✓	✓	✓	✓

What Is the USDA Forest Service?

The Forest Service is a part of the United States Department of Agriculture (USDA). It is made up of thousands of people who care for the Nation's forest land. The USDA Forest Service manages over 150 national forests and almost 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 that 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.

What Is the Cradle of Forestry Interpretive Association?

The Cradle of Forestry Interpretive Association is a 501(c)3 nonprofit organization based out of Brevard, North Carolina. The Interpretive Association strives to help people better understand ecology through recreation and education opportunities. Their projects include:

- Campground and recreation area management.
- Educational programs and services, including the *Natural Inquirer*.
- 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.

United States Department of Agriculture

Forest Service

FS 955

Winter 2011

Oconee County, Georgia Parks and Recreation Department, Teen Extreme Program, Kelsey Tate, Assistant Youth Programs Coordinator and David Martin, Counselor

Athens-Clarke County, Georgia Leisure Services Department, Memorial Park Day Camp, Counselors Michael James, Sanjay Rema, and Katie McMichael

Additional Web Resources

Natural Inquirer

http://www.naturalinquirer.org

Investi-gator

http://www.scienceinvestigator.org

Forest Service Conservation Education

http://www.fs.fed.us/kids/ (Click on Conservation Education)

Forest Service Climate Change Resource Center

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

Climate Change Atlas

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

EPA's Climate Change Web site

http://www.epa.gov/climatechange/wycd/school.html

EPA's Climate Change Kids' site

http://www.epa.gov/climatechange/kids/

Climate Change Calculator

http://www.americanforests.org/resources/ccc/

Forests and Climate Change Toolbox (USAID)

http://www.cifor.cgiar.org/fctoolbox/