Natural Inquirer

The *Natural Inquirer* Monograph Series—Experimental Forests and Ranges

Number 3 | October 2009

Woolly Bully: Estimating the Effect of an Invasive Insect on an Area's Water Cycle

The *Natural Inquirer* Monograph Series, Number 3, October 2009

Experimental Forests and Ranges

Woolly Bully:

Estimating the Effect of an Invasive Insect on an Area's Water Cycle

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Contents

Who Are Scientists?

Scientists are people who collect and evaluate information about a wide range of topics. Some scientists study the natural environment.

To be a successful scientist, you must:

- **Be open minded:**
  You must be willing to listen to new ideas.

- **Be curious:**
  You must be interested in learning.

- **Be careful:**
  You must be accurate in everything you do.

- **Question everything:**
  You must think about what you read and observe.

- **Be enthusiastic:**
  You must be interested in a particular topic.

Welcome to the *Natural Inquirer* Monograph Series!

Scientists report their research in a variety of special books. These books enable scientists to share information with one another. A monograph is a book about research that focuses on a single science project. This monograph of a *Natural Inquirer* article was created to give scientists the opportunity to share their research with you and other middle school students. The monograph presents scientific research conducted by scientists in the Forest Service, U.S. Department of Agriculture. If you want to learn more about the Forest Service, you can read about it on the inside back cover of this monograph, or you can visit the *Natural Inquirer* Web site at **http://www.naturalinquirer.org**.

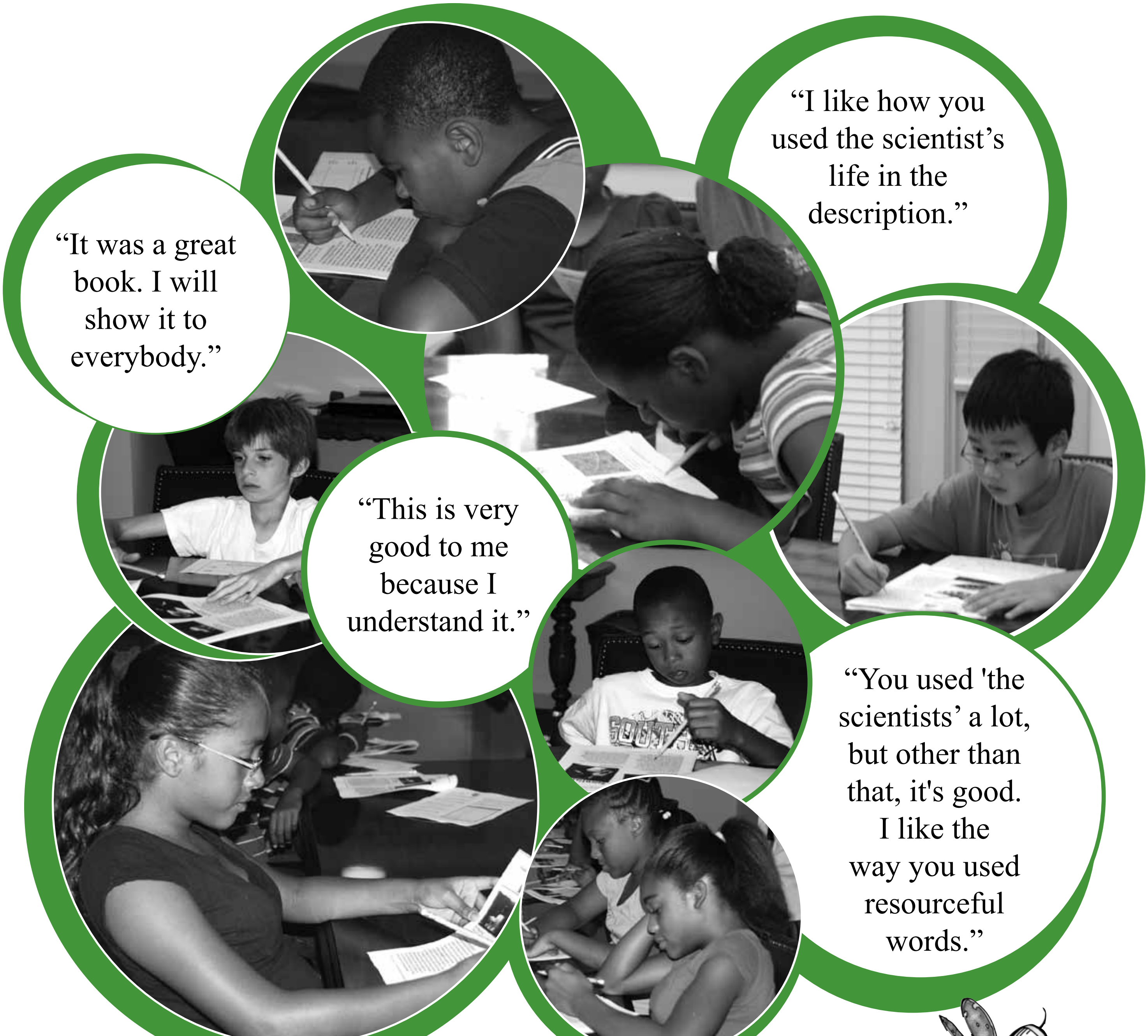
All of the research in *Natural Inquirers* is concerned with the natural environment, such as trees, forests, animals, insects, outdoor activities, and water. First, you will “meet the scientists” who conducted the research. Then you will read about one of the many interesting aspects of science and about the natural environment. You will also read about a specific research project. The research article is written in the format that scientists use when they publish research in scientific journals. Then YOU become the scientist as you go through the FACTivity associated with the article. Don’t forget to look at the glossary and the special sections highlighted in the article. These sections give you extra information that is educational and interesting.

At the end of each section of the article, you will find a few questions to help you think about what you have read. These questions will help you think like a scientist. They will help you think about how research is conducted. Your teacher may use these questions in a class discussion, or you may discuss these questions in a small group.

Each *Natural Inquirer* monograph will help you explore the exciting world of science and prepare you to become a young scientist. You will learn about the scientific process, how to conduct scientific research, and how to share your own research with others.

Editorial Review Board

Comments about "Woolly Bully" from the Editorial Review Board
Memorial Park Day Camp, Athens-Clarke County, Georgia,
Faye Dalton, Camp Director, and Jessica Affleck, Counselor



"It was a great book. I will show it to everybody."

"I like how you used the scientist's life in the description."

"This is very good to me because I understand it."

"You used 'the scientists' a lot, but other than that, it's good. I like the way you used resourceful words."

Visit http://www.naturalinquirer.org
for more information, articles, and resources.

Note to Educators
Before using the *Natural Inquirer* in your classroom, read the Note to Educators section on page 25.

What Are Experimental Forests And Ranges?

In 1908, the Forest Service established a system of natural areas to be set aside for environmental research. One hundred years later, 81 of these areas are spread across the United States **(figure 1)**. The smallest of these is 47 hectares, and the largest is 22,500 hectares. Multiply the number of hectares by 2.47 if you want to find out the size of these areas in acres.

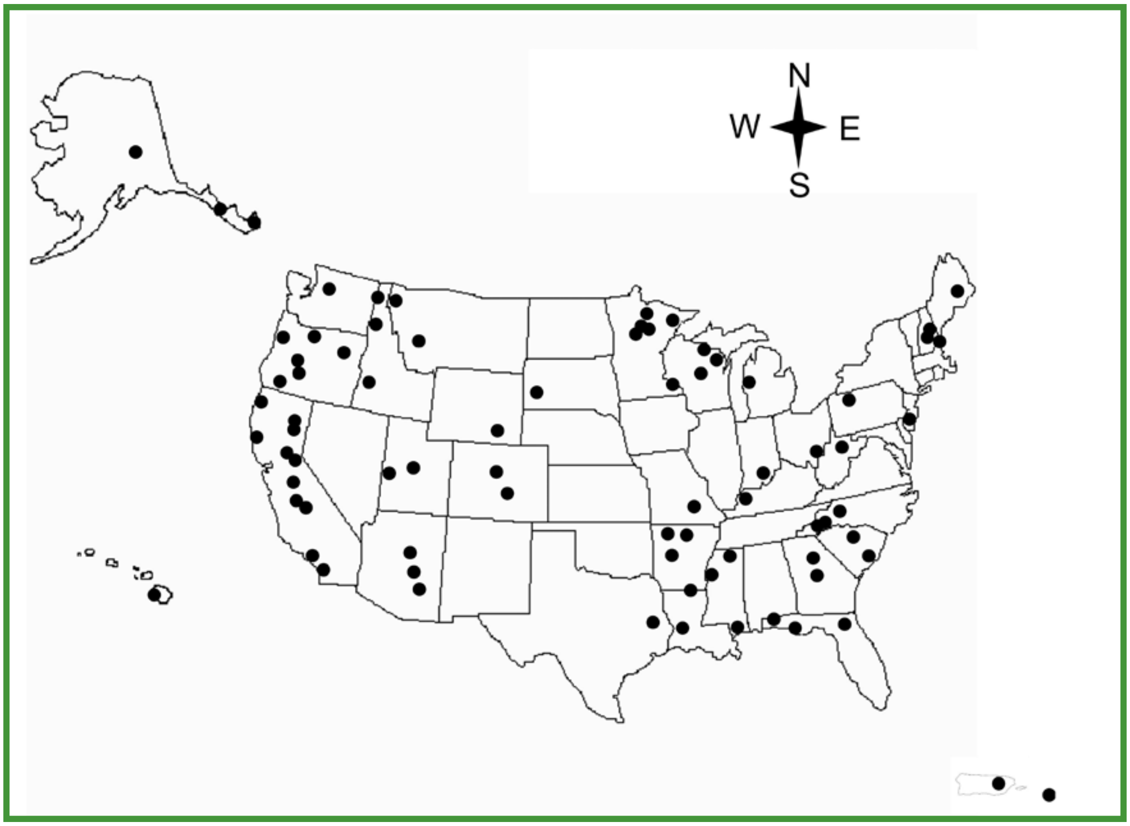


Figure 1. The system of natural areas known as experimental forests and ranges. Each dot shows the location of an experimental forest or range. Is an experimental forest or range located close to where you live?

These areas are called experimental forests and ranges. Much of the research on these areas is concerned with environmental changes that occur over long periods of time, over large areas, or both. Over 30 of the areas were established at least 70 years ago. In some cases, experiments are designed to last 40 or more years. One experiment in Oregon is expected to last 200 years! On all experimental forests and ranges, scientists continually collect information about the weather, the amount of snowfall and rainfall, the soil, and about the trees and other plants growing in the area.

One concern of humans everywhere is the quality of their water. In 1934, the Coweeta (kow **we** tuh) Experimental Forest was created to study how forests affect the streams that flow through them. This area covers 2,187 hectares (5,400 acres). It was established in western North Carolina because of the area's high rainfall and steep mountains **(figure 2)**. Measurement of snowfall, rainfall, weather, and streamflow began almost immediately and continues today **(figure 3)**.

In 1948, the area was renamed the Coweeta Hydrologic (**hi̲** dro̲ **loj** ik) Laboratory **(figure 4)**. Hydrologic means having to do with water. The research you will read about in this monograph was done within the Coweeta Hydrologic Laboratory's study area. It is concerned with the movement of water into, through, and out of a part of the study area. Think about how water might get into the study area. How might it leave? After you read the monograph, you will know if you were right!

On experimental forests and ranges, the most important activity is learning. Each experimental forest and range is a big outdoor laboratory where scientific experiments are conducted. Although people may visit experimental forests and ranges, their most important function is to help scientists better understand our changing natural environment.

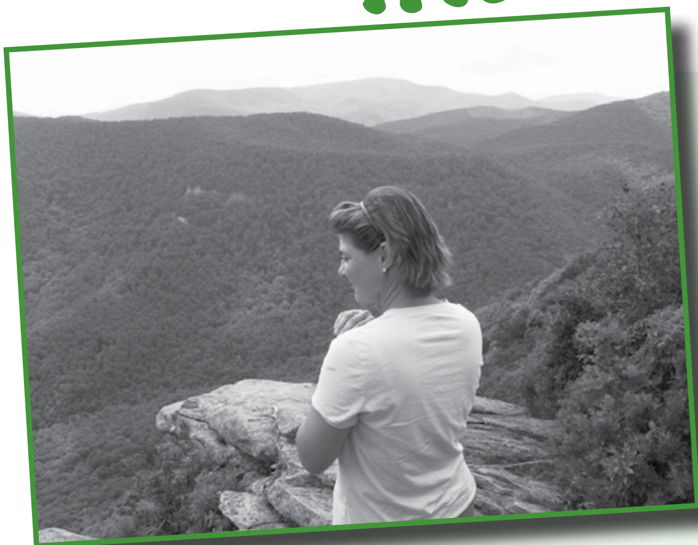
Figure 2. The Coweeta study area is within a heavily forested area.

Figure 3. Many experiments involve streams and streamflow in the Coweeta study area.

Figure 4. One of the buildings at the Coweeta Hydrologic Laboratory. The laboratory also has a building that can house 20 scientists.

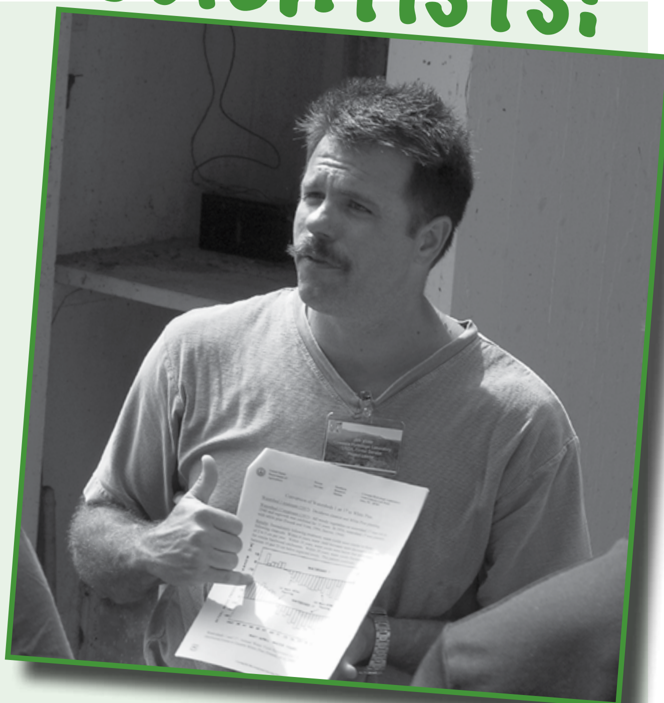
Woolly Bully: Estimating the Effect of an Invasive Insect on an Area's Water Cycle

Meet the Scientists!



Dr. Chelcy Ford
Tree Ecophysiologist
(e ko fiz e **ol** uh jist)

As a tree ecophysiologist, I study the various functions of trees in relation to the area in which they are growing. One aspect of my research that I enjoy more than any other is figuring out how to use technology in interesting ways that will help answer **ecological** questions. I get to tinker with all sorts of sensors, monitors, and field computers. I wire up trees and other parts of the forest to measure how the forest is working. We can easily walk through forests and experience them visually, but we often can't "see" how a forest or a tree is functioning. It is thrilling to "see" how a forest or tree is working when you view it through **data**.



Dr. James Vose
Forest Ecologist

I grew up near the city of Chicago, and I lived in a very crowded neighborhood. I spent Saturdays with my uncle who lived on a farm surrounded by woods. We explored the woods together. He taught me the tree **species**, we collected wild **edible** plants, and made tools from the rocks and wood we collected from the forest. My uncle was my first forest **ecology** teacher, and I knew from an early age that I wanted a job where I could figure out how a forest worked.

Glossary

ecological (**e** ko **law** juh kul): Having to do with ecology. Ecology is the study of organisms and their relationship to their environment.

data (**dat** uh): Facts or figures studied in order to make a conclusion. Datum (**da** tum) is the singular.

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

edible (**eh** duh bul): Fit to be eaten.

ecology (e **kä** luh je): The study of the interactions of living things with one another and with their environment.

numeric (nu **mair** ik): Having to do with numbers or a system of numbers.

average (**av** 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 (**e** ko sis tem): Community of plant and animal species interacting with one another and with the nonliving environment.

invasive (in **va** siv): Tending to spread or infringe upon.

larva (**lär** vuh): Wormlike feeding form that hatches from the eggs of many insects. Larvae (**lär** ve) is the plural.

runoff (**run** off): The portion of rain or snow that flows over or through land and into streams.

humid (**hu** mid): Containing or characterized by noticeable moisture, especially in the air.

Pronunciation Guide

a	as in ape
ä	as in car
e	as in me
i	as in ice
o	as in go
ô	as in for
u	as in use
ü	as in fur
oo	as in tool
ng	as in sing

Accented syllables are in **bold**.

Thinking About Science

To get answers to their questions, scientists often collect and record new pieces of information. These pieces of information are called data. Although data can be in the form of words or even pictures, most data are **numeric**. Using technology, some data can be collected and recorded automatically. For example, equipment placed in a particular location might collect and record the hourly air temperature over months and even years.

In this research, the scientists were interested in how water moves through a tree over a 24-hour period. The scientists used technology to measure and record the inside temperature of a tree's trunk. The inside temperature was used to estimate how much water is moving from a tree's roots to its leaves. The equipment measured and recorded the temperature every 30 seconds. Every 15 minutes, the equipment calculated the **average** temperature and recorded it. The equipment did this continuously from April 2004 until November 2005.

Number Crunches

Think about how many averages were calculated in a day's time. To do this, multiply 4 times 24 hours. To find out how many averages were calculated most months, multiply this number by 30 days. Now multiply this by 18 months (April 2004–November 2005). This will tell you how many averages were calculated over the entire project. As you can see, when scientists use technology to continuously collect data, they have a lot of numbers with which to work. It would be difficult for a scientist to collect and record this amount of information without the help of technology.

Thinking About the Environment

You know that all living things, including trees, need water to survive. Trees take water in through their roots and send it throughout the tree, all the way to the leaves. When the water reaches the leaves, it is released into the air. Water is released in the form of water vapor, and it exits the leaves through stomata (sto **mah** tah) in the leaves **(figure 1)**. Stomata are like the pores in your own skin, and they allow carbon dioxide to enter the leaf and water vapor to exit. They also allow oxygen to exit the leaf. When water vapor exits a tree through its stomata, scientists call this transpiration (**tran** spür **a** shun). The stomata close at night and transpiration stops. In turn, water movement into the tree's roots from the soil slows down. Think about using a straw to drink liquid. If you stop sucking, the liquid does not flow into the straw. As you can see, a tree has a daily cycle, just like other living things. How is a daily cycle evident in humans? In what way is this like a tree's daily cycle?

Carbon dioxide enters, while water and oxygen exit, through a leaf's stomata.

Figure 1. Stomata are special cells in a leaf that allow carbon dioxide to enter and water vapor and oxygen to escape.

Adapted from http://evolution.berkeley.edu/evolibrary.

In this study, the scientists were interested in how much water a certain kind of tree species transpires every day and over a period of time. They know that when trees take up water from the ground and then transpire, trees are playing a role in the **ecosystem**. In this instance, trees are contributing to the ecosystem by taking water out of the ground during the day and releasing it back into the air as water vapor.

Introduction

Water is important to all life. Water is constantly moving throughout the natural environment. Think of rain and snowfall, of streams and rivers, and of evaporation. You probably have studied the water cycle **(figure 2)**. As you know, some water is held underground, and this is called groundwater. Groundwater flows through soil, sand, and between stone underground. Eventually, some groundwater flows into streams and rivers. Some scientists study the flow of water into, out of, and held within particular natural areas **(figure 3)**. They are interested in all of the things that might affect water's normal flow. If the normal flow of water is disrupted, the plants and animals living in the area and downstream will be affected.

Trees play a role in the flow of water in forested ecosystems. During the day, trees absorb groundwater through their roots. This water is pulled up the tree, and the tree releases the water as water vapor through stomata in its leaves (see "Thinking About the Environment" **(figure 1)**). At night, these processes slow down or stop **(figures 4 and 5).**

In the forests of the southern Appalachian (**ap** uh **lach** un) mountains, eastern hemlock trees grow near mountain streams from north Georgia and northeastward **(figures 6a and 6b)**. There are so many of these trees, they make up about half of the living plant material

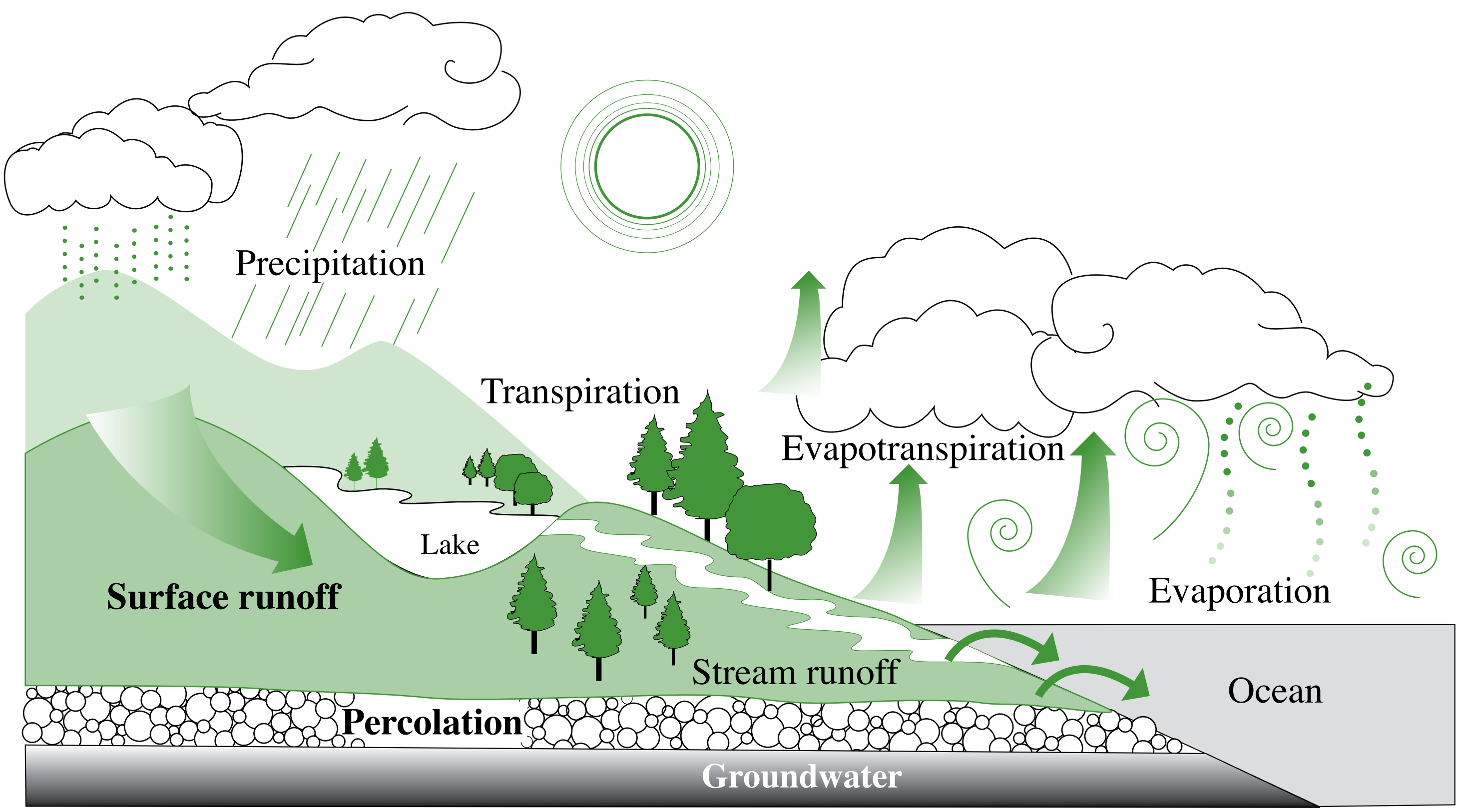
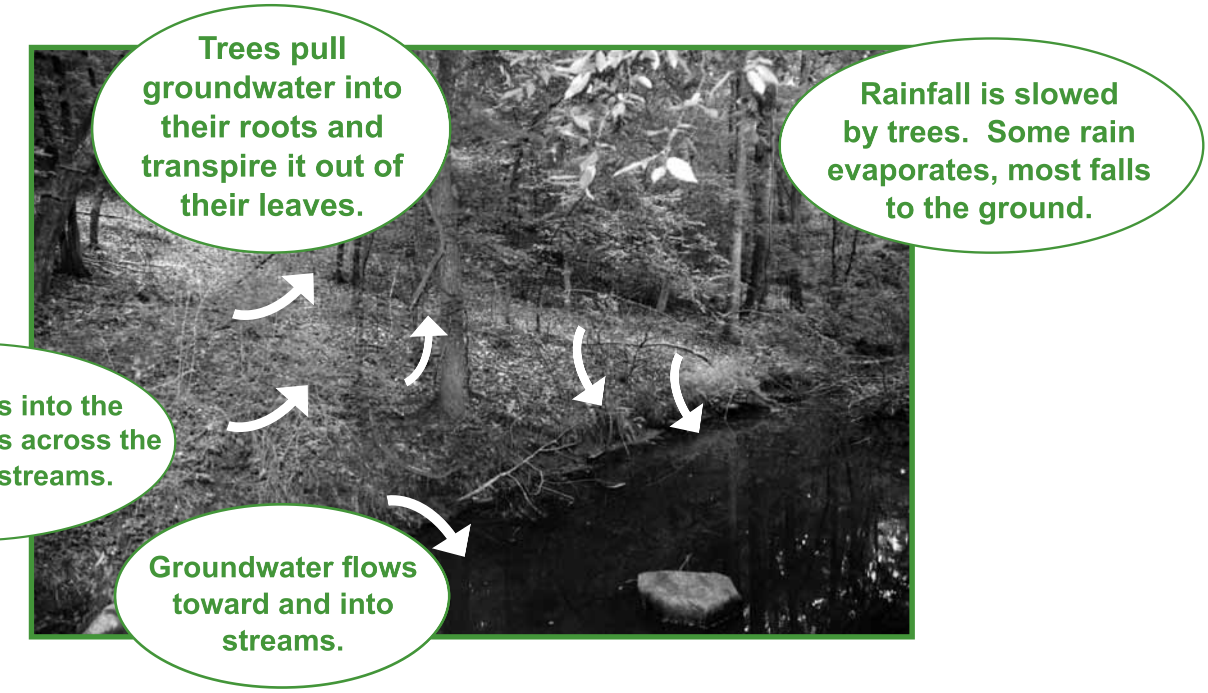


Figure 2. The water cycle.

Figure 3. The flow of water in a forested area.



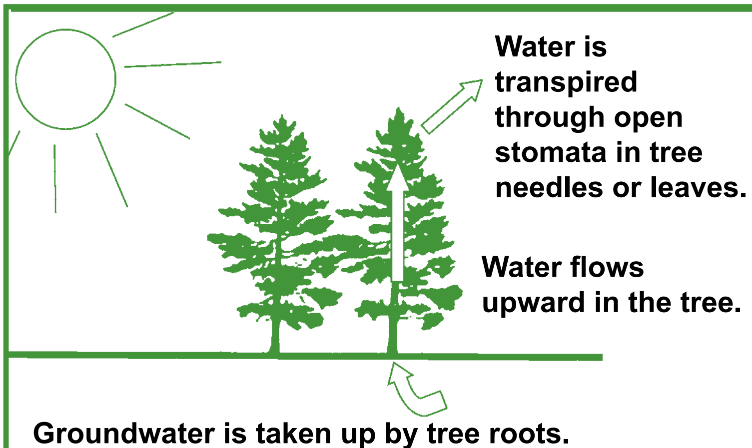


Figure 4. Water movement in a tree during the daytime.

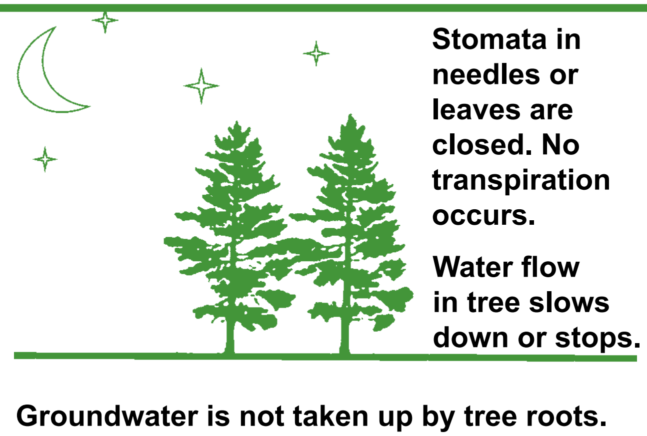


Figure 5. Water movement slows down in a tree during the nighttime.

Figures 6a. Eastern hemlock tree. Photo courtesy of the Pennsylvania Department of Conservation and Natural Resources and http://www.bugwood.org.

Figure 6b. A closer look at the needles of an eastern hemlock tree. Photo by Paul Wray, Iowa State University and courtesy of http://www.bugwood.org.

near mountain streams **(figure 7)**. Eastern hemlock trees are evergreen, unlike most of the other trees growing in the southern Appalachian mountains. The needles of hemlock trees only live for 3 years, then they die and fall off of the tree.

Hemlock trees are now threatened by a nonnative **invasive** insect called the hemlock woolly adelgid (uh **del** jid) **(figure 8)**. Nonnative means that it is not naturally found in the area. Hemlock trees in the southern part of the Appalachian mountains are in more danger than hemlock trees growing farther north. This is because colder winters in the north slow the reproduction of the adelgid.

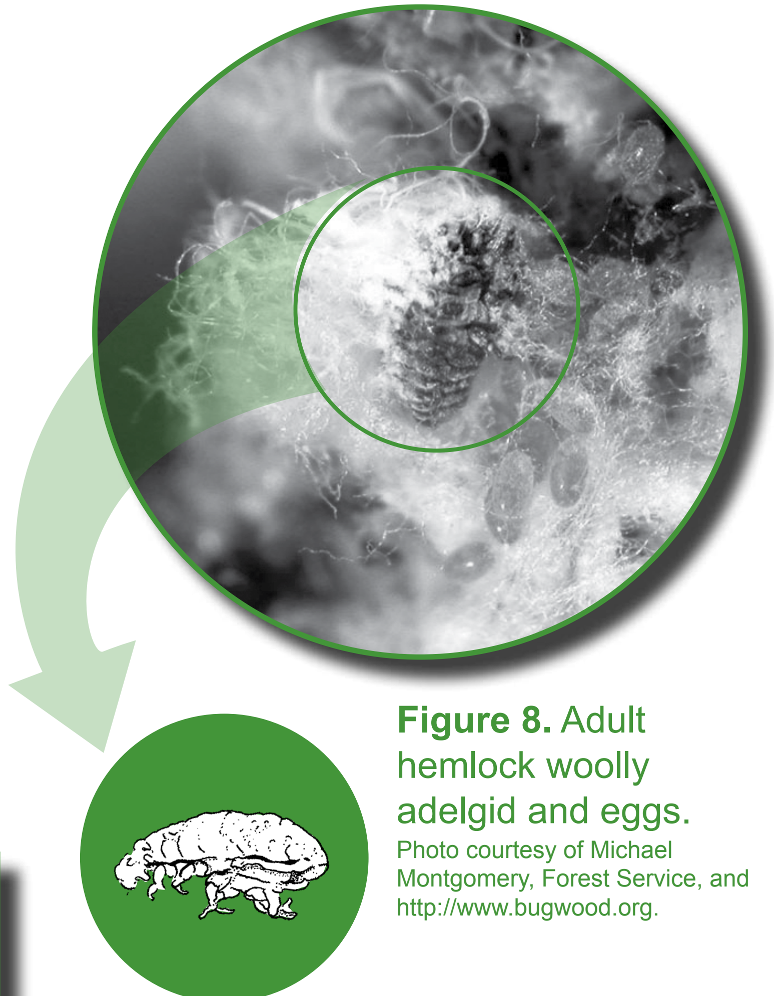


Figure 8. Adult hemlock woolly adelgid and eggs.
Photo courtesy of Michael Montgomery, Forest Service, and http://www.bugwood.org.

Figure 7. Eastern hemlock trees growing near a southern Appalachian mountain stream.

The hemlock woolly adelgid was accidently brought on ships from Asia to the Northwestern United States in 1924. It has been spreading ever since. This insect's **larva** feed at the base of hemlock needles, eating sugars stored in the twigs where the needles are attached. Sugar is a carbohydrate (**kär** bo **hi** drat). Trees store carbohydrates for energy. Carbohydrates are used by trees to protect new buds over the winter. Carbohydrates are also used by trees to grow leaves and needles in the spring. When the larva feeds, it takes carbohydrates from the tree. In the fall and winter, therefore, buds cannot be protected. In the spring, new needles cannot be formed. In the third year after being attacked by the adelgid, the hemlock tree begins to die **(figures 9 and 10)**.

Remember, all trees are a part of the water cycle. They absorb groundwater and release water vapor. Their leaves and needles also slow rainfall by intercepting raindrops. Some of the raindrops evaporate off the leaves and bark. This reduces the amount of rainfall falling on the soil. When this happens, the soil absorbs rain more slowly and this reduces **runoff**. As you can see, trees can have a big impact on the flow of water through a forest. The question the scientists in this study wanted to answer was: How might the flow of water change in areas near mountain streams if eastern hemlock trees are killed by the hemlock woolly adelgid?

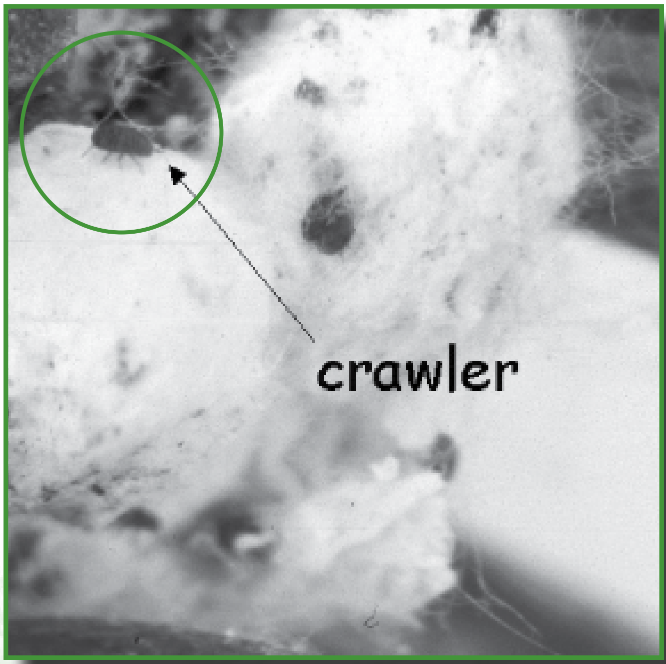


Figure 9. A hemlock woolly adelgid crawler. The sign of the adelgid's egg capsule is a white, cottony mass on the needles. The eggs hatch from the woolly egg capsules and have legs for a short time. They crawl to a suitable feeding site, then settle there. They stay in one place while feeding and developing. (Photo courtesy of Pennsylvania Department of Natural Resources and Conservation, Forestry Archive and http://www.bugwood.org.).

Figure 10. Many of the hemlock trees in this valley have been killed by the hemlock woolly adelgid. Photo courtesy of Chelcy Ford and the Forest Service, Coweeta Hydrologic Laboratory.

Reflection Section

- What is the question the scientists wanted to answer?
- Do you think the loss of a particular tree species can impact the flow of water in a natural area? Why or why not?

Method

The scientists studied an area along a stream in the mountains of western North Carolina **(figure 11)**. At least 50 percent of the vegetation in the area was eastern hemlock. This area receives an average of 1821 mm (millimeters) of rain every year.

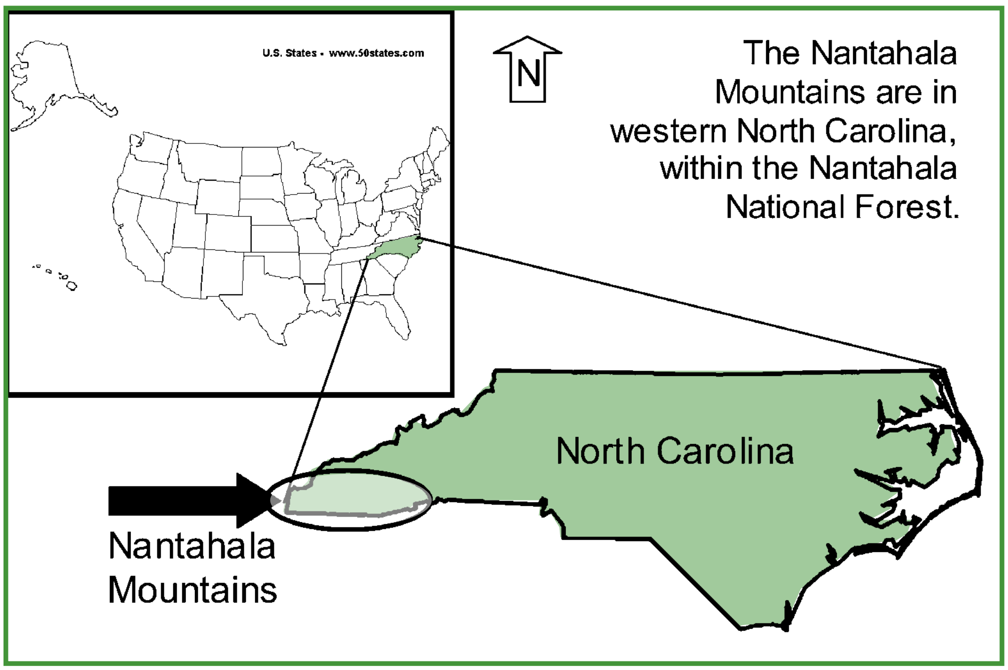


Figure 11. The Nantahala (nan tuh **ha** la) mountains are in western North Carolina.

Number Crunches

How many inches of rain does this area receive annually?

Multiply 1,821 by 0.039 to find out.

Recall that trees take in water through their roots, and the water flows up to the leaves. Water also flows downward through a tree. The water in trees, when combined with other substances, is called sap. The sap that flows upward is mostly made up of water. This is called xylem (**zi** lem) sap. The sap that flows downward also contains sugars, salts, and minerals. This is called phloem (**flo** em) sap. Not surprisingly, the woody material through which xylem sap flows is called sapwood **(figure 12)**.

The scientists placed two probes in the trunks of 16 different hemlock trees, so that both probes went into the xylem sapwood **(figures 13a and 13b)**. The 16 trees were a variety of sizes. One probe was placed 5 cm (centimeters) directly above the other. The top probe was heated. The temperature of the sapwood was measured at both probes. The difference in the temperatures enabled the scientists to estimate the amount of xylem sap flowing up the tree. Recall from “Thinking About Science” that the temperatures were automatically measured and recorded every 30 seconds, and every 15 minutes an average was calculated and recorded. The scientists collected these data from April 2004 until November 2005.

Think about the air around you. You know that air holds some water, because

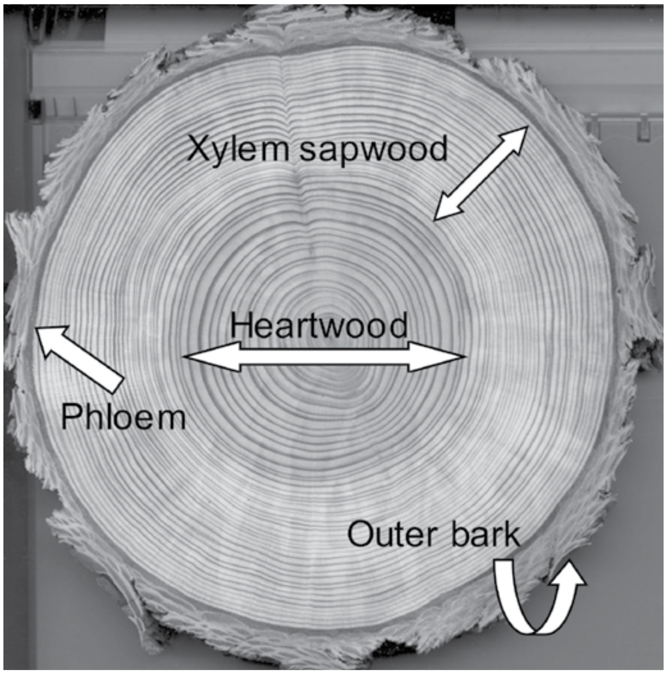
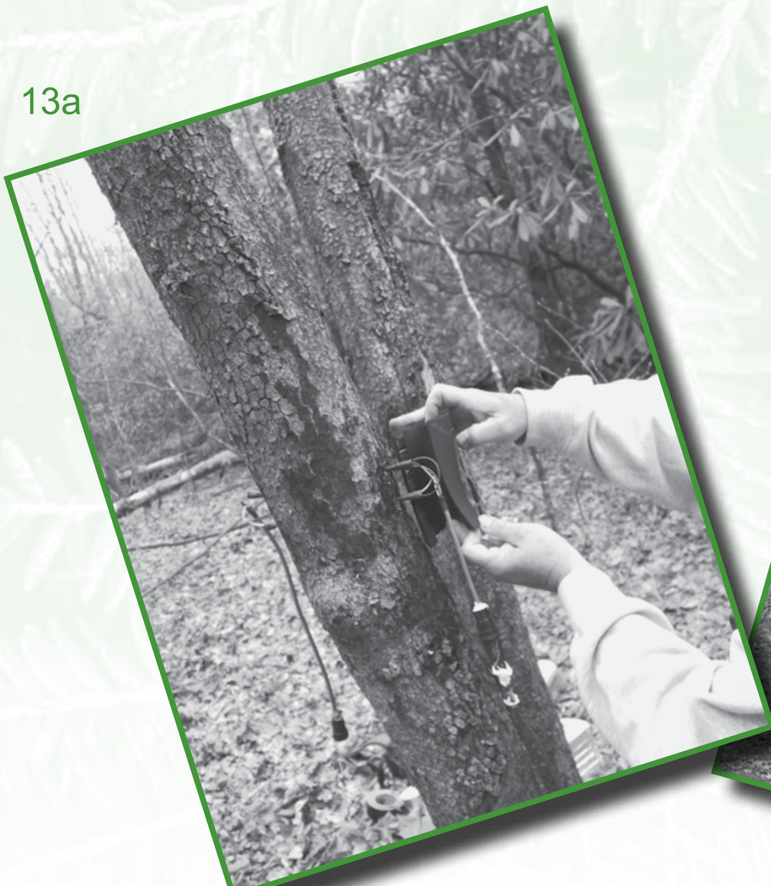


Figure 12. The xylem sap flows through a tree's sapwood.

some days are more **humid** than others. When the relative humidity is high, there is more water in the air. If the air around a tree has close to the maximum amount of water it can hold, then trees will not transpire very much.

The scientists measured weather data, such as temperature and relative humidity. The scientists used these data to calculate the amount of water in the air at different temperatures. They also identified the total amount of water the air was able to hold at each temperature. The temperature and relative humidity were recorded every minute **(figure 14)**. The equipment calculated and recorded the average temperature and relative humidity every 15 minutes.

13a



13b

Figures 13a and 13b. The probes were placed into the tree's sapwood.

Recall that the scientists measured the amount of xylem sap flowing upward in each of the 16 trees. Once the scientists had this information for the 16 trees, they estimated how much water all of the eastern hemlock trees in the study area would transpire in total, depending on the weather conditions for each day and season. They were then able to estimate how much groundwater the roots pulled in and the trees transpired every 15 minutes.

Figure 14. Weather data were measured and recorded automatically.

Reflection Section

- **If the relative humidity is high, do you think trees transpire more or less than if the relative humidity is low? Why or why not?**
- **Why did the scientists take measurements from some of the trees, instead of taking measurements from all of the trees?**

Findings

The scientists found that eastern hemlock trees used water all year, but they used more water in the spring than in any other season. Since trees do not transpire at night, more water flows from the ground into the streams at night, raising the streamflow at night. Less water flows into the streams during the day, because groundwater is taken up by the trees' roots. The scientists found that hemlocks were quick to respond to changes in relative humidity. For example, if relative humidity decreased, the amount of water flowing up the tree increased after about 15 minutes.

If all of the eastern hemlock trees in the study area were killed by the hemlock woolly adelgid, the scientists predicted the following would happen to the water flow in the area near the stream:

The amount of transpiration in the area would be reduced, especially in the winter and spring, thus increasing the amount of water in the soil. This would lead to more groundwater flowing into streams during the day, leading to a more even flow of groundwater into streams both day and night **(figure 15)**.

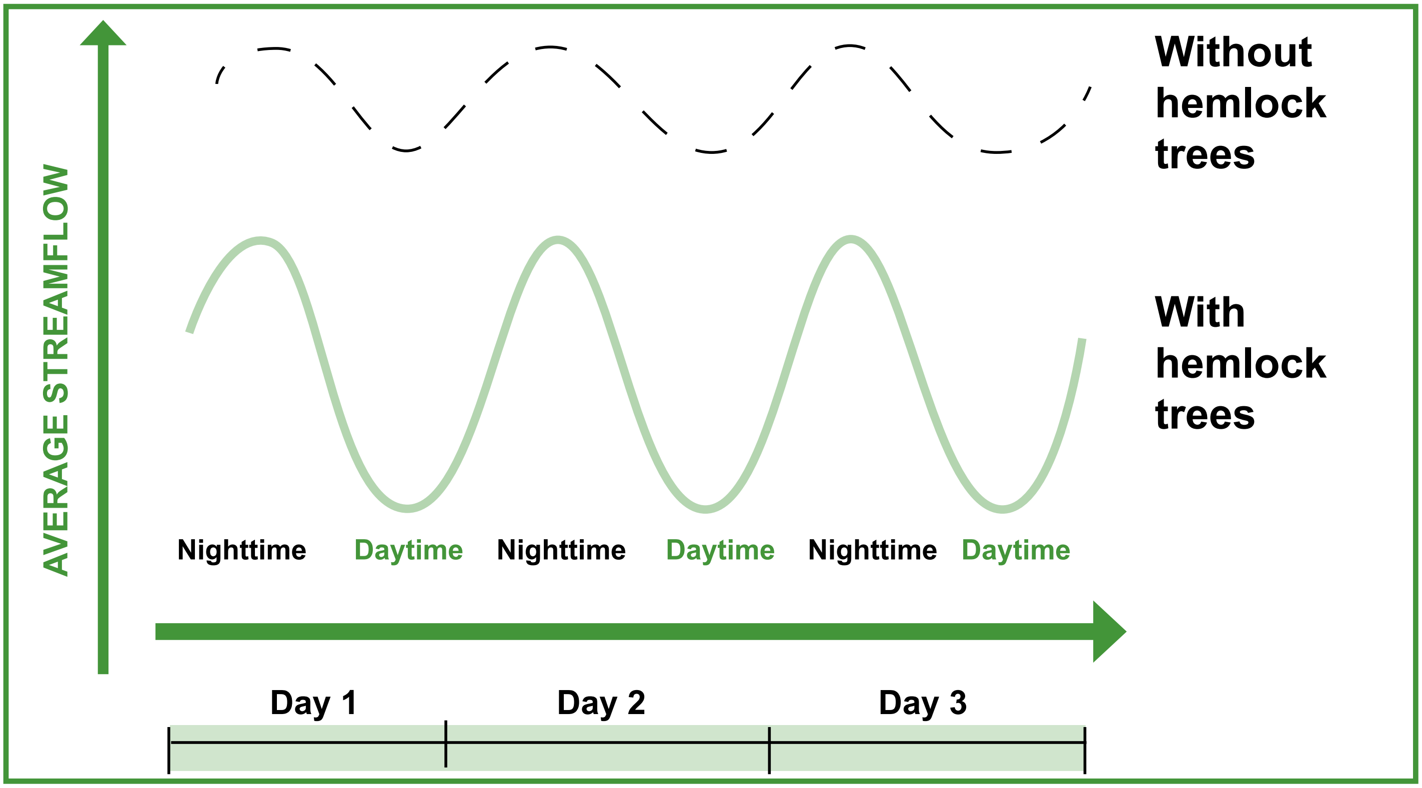


Figure 15. The amount of streamflow during a typical cycle of day and night (solid line) and the amount of streamflow likely after the death of eastern hemlock trees in the area (broken line). This figure shows that there will be a greater streamflow after the hemlocks have died. The streamflow will also be more even across day and nightime.

- **From the findings, how do you think the loss of eastern hemlock trees would change the flow of water in the ground and in streams in areas like the one studied by the scientists?**
- **Look at figure 15. Describe in your own words what the figure is showing.**

Discussion

If the hemlock woolly adelgid were to kill all of the hemlock trees in the southern Appalachian mountains, the flow of water in that area would be different than it is now. This would probably bring many other changes to the natural area and to areas downstream. For example, more water in streams might affect animals that live in the streams. There may be more soil washed into the streams. This would reduce the quality of the soil left behind and add soil particles to the stream water. These changes would affect plants as well as animals that live in the area and the areas downstream.

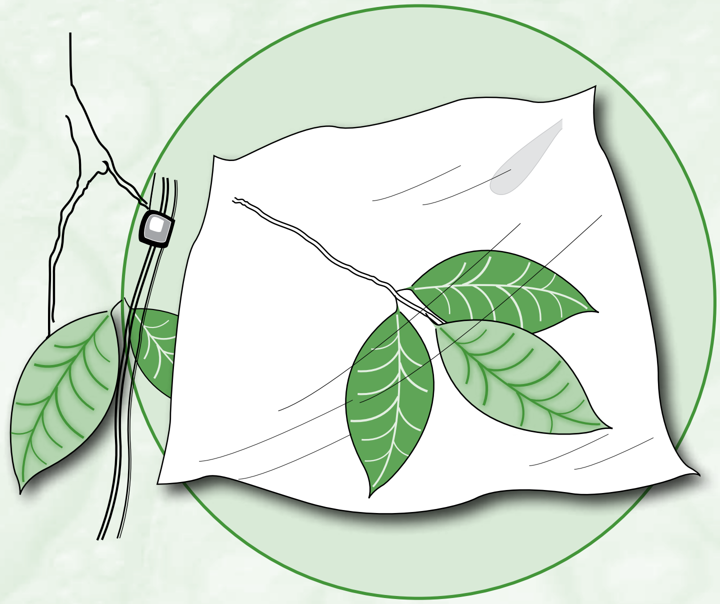
Reflection Section

What is one thing scientists could do to help prevent changes in the flow of water in southern Appalachian mountain areas that have a lot of eastern hemlock trees?

What do you think will happen to eastern hemlock trees growing in the Northeast United States as the climate continues to get warmer?

A scientist who studies insects such as the hemlock woolly adelgid is called an **entomologist** (**en** to **ma** la jist). A scientist who studies the flow of ground and stream water is called a **hydrologist** (hi **draw** la jist). A scientist who studies the growth of trees is called a **silviculturist** (**sil** va **kul** jür ist). One of the scientists in this study is a tree **ecophysiologist** (**e** ko fiz e **ol** uh jist). She studies how trees work in relation to where they live. The other scientist is an ecologist. He studies the relationships of living and nonliving things in an area. From reading this study, do you think different kinds of scientists should work together? Why or why not?

FACTivity



Materials needed for each student pair:

- **1 pint ziplock plastic bag**
- **Permanent marker or small piece of paper, tape, and a pencil**
- **Graduated cylinder (1 to 5 ml)**
- **1 piece of blank or lined paper and a pencil**

In this FACTivity, you will answer the question: How much water is transpired by a tree during daylight hours? The method you will use to answer this question is:

Day 1: 10 minutes

Your teacher will divide the class into pairs of students, and will give each pair a plastic bag with a ziplock closure. Write your names on the plastic bag (or use paper and tape to identify the bag as yours). Go outside and select a tree that has leaves or needles that can be easily reached when you stand on the ground. You may select the same tree as another pair of students, but you must be able to use a separate branch and leaves.

Place the plastic bag on a branch and seal the bag as tight as possible around two to three of the leaves. The leaves should be inside the plastic bag. **The bag must be placed on a tree branch the following morning (on Day 2), before school starts for the day.**

Day 2:

If possible, allow the plastic bag to stay on the branch for at least 2 hours. Regardless, be sure to note the amount of time each bag is on the tree and, if possible, keep as close to an hourly schedule as possible.

Before removing the bag from the tree, estimate the percentage of the tree's total leaf area contained in the plastic bag. To do this, estimate the total number of leaves on the tree. Count the number of leaves on your branch (including the leaves inside and outside of the bag). Then, estimate the number of branches on the tree and multiply the two numbers. Record the total number of leaves. The estimation of the total number of leaves can be difficult, and will always be an estimate. Make the best estimate you can.

Count the number of leaves in your bag and divide this number into the estimated total number of leaves. Record this number. Before removing the bag, gently shake it to dislodge water from the leaves'

surface. Carefully remove the plastic bag from the branch and leaves, keeping the water in the plastic bag and sealing the bag after removing it from the tree. Gently wave the bag to move the water into one corner of the bag.

Inside the classroom, measure the amount of water in each bag by pouring contents into the graduated cylinder. Calculate how much water was transpired in 1 hour. For example, if the bag was on the tree for 2 hours, divide the amount in half. Then, multiply that amount by 10, assuming there are 10 hours of daylight during which the tree transpires. Finally, calculate how much water would be transpired by all of the leaves on the tree during the 10 hour period.

For example, say there are 3 leaves in the bag and an estimated 27,000 leaves on the tree. Divide 27,000 by 3 to get 9,000. If the three leaves transpired 1 milliliters in 1 hour, students would estimate the leaves would transpire 10 milliliters in 10 hours. To estimate how many milliliters the entire tree transpired in 10 hours, multiply 9,000 X 10 = 90,000 milliliters. Multiply .001 by 90,000 = 90 liters. To convert this to gallons, multiply 90 X .264 = 23.76 gallons. In this example, the tree transpired an estimated 90 liters or 23.76 gallons of water in 10 hours of daylight.

Compare your findings with other students' findings. Larger trees should be found to transpire much more water than smaller trees. Is anyone surprised at how much water is transpired by a tree during daylight hours? Now, reread the second and third paragraphs under "Findings." Would the loss of schoolyard trees cause any changes to the water cycle of the schoolyard? If so, how?

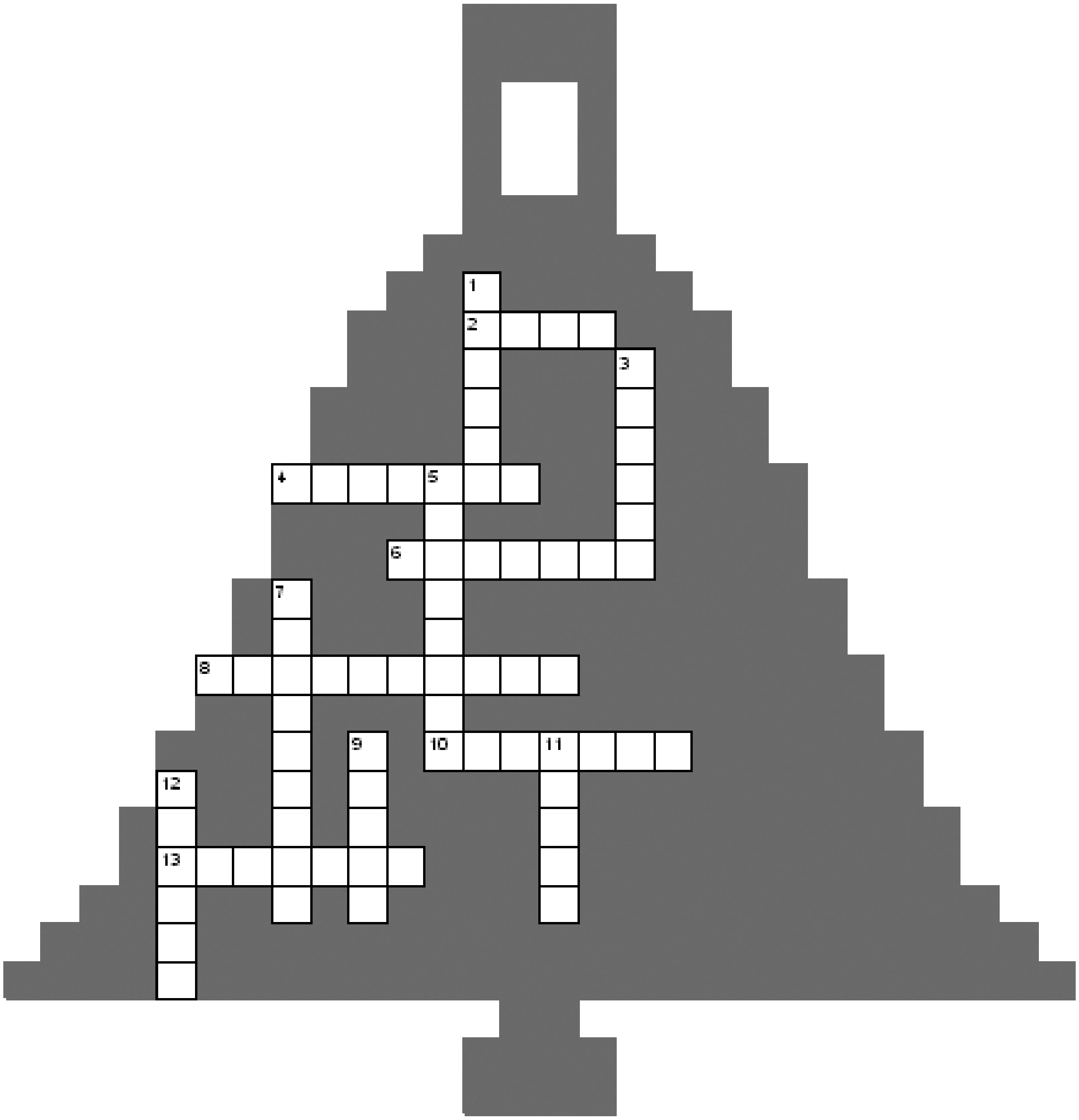
(**Note:** This FACTivity was adapted from the USDA Natural Resources Conservation Service http://members.tripod.com/~crossg/edaid1.htm), which had adapted it from Project Learning Tree.

Article adapted from: Ford, Chelcy R. and Vose, James M. 2007. Tsuga canadensis (L.) Carr. mortality will impact hydrologic processes in southern Appalachian forest ecosystems. *Ecological Applications*, 17(4), pp. 1156-1167. http://www.srs.fs.usda.gov/pubs/ja/ja_ford006.pdf.

PLT

If you are a trained PLT educator, you may use Activity #5: "Poet-Tree," Activity #63: "Tree Factory," Activity # 77: "Trees in Trouble."

Woolly Bully Crossword Puzzle



Across

2. Facts or figures studied in order to make a conclusion
4. Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure
6. The usual kind or amount
8. Having to do with ecology
10. The study of organisms and their relationship to the environment
13. Having to do with numbers or a system of numbers

Down

1. Fit to be eaten
3. The plural form of larva
5. Tending to spread or infringe upon
7. Community of plant and animal species interacting with one another and the nonliving environment
9. Containing or characterized by noticeable moisture, especially in the air
11. Wormlike feeding form that hatches from the egg of many insects
12. The portion of rain or snow that flows over or through land and into streams

Woolly Bully Word Search

B

C U Y

K R V U P

M K J N A O E

L A R V A G B P Z

S C L D U S G H X G Z

E H H Y G T N H U O U G N

E Z R N U B U S O P F N T R C

A X A E F J M E C H F I E A R I Z

A S C Z V Y E T I E X F F V K U M P L

E D B W M V R E L U D P B H S C C L A R E

C E E V I S A V N I U P E X O E C Q N

H X C L L Y L X B W I C C G I I H

P H O Y Y W P L C K J J G N E

T O S Q O F E C O L O G Y

L L Y J P G D D L N U

S L S Z A M O Q X

U N T R C D S

A L E E V

Z V M

A

1. The usual kind or amount
2. Facts or figures studied in order to make a conclusion
3. Having to do with ecology
4. The study of organisms and their relationship to the environment
5. Community of plant and animal species interacting with one another and the nonliving environment
6. Fit to be eaten
7. Containing or characterized by noticeable moisture, especially in the air
8. Tending to spread or infringe upon
9. Wormlike feeding form that hatches from the egg of many insects
10. The plural form of larva
11. Having to do with numbers or a system of numbers
12. The portion of rain or snow that flows over or through land and into streams
13. Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure

Note to Educators

As teachers of science, you want your students to acquire abilities that will enable them to conduct scientific inquiry, and you want them to gain an understanding of the scientific inquiry process. Scientific inquiry can best be taught by integrating minds-on and hands-on experiences. Over time, such experiences encourage students to independently formulate and seek answers to questions about the world we live in. As educators, you are constantly faced with engaging your students in scientific inquiry in new and different ways. In an age of abundant technology, standard teaching strategies can become monotonous to today's learners. The *Natural Inquirer* provides a fresh approach to science and a view of the outside world that is larger than the classroom and can still be used while in the school setting.

The *Natural Inquirer* is a science education resource journal to be used with learners from Grade 5 and up. The *Natural Inquirer* contains articles describing environmental and natural resource research conducted by the United States Department of Agriculture (USDA), 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, 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 learning about ecology, the natural environment, and natural resources.

A *Natural Inquirer* journal contains six to seven articles, rewritten from the original published scientific paper. This *Natural Inquirer* monograph contains just one article. When you use this monograph in your classroom, you may take advantage of the educational resources available in the monograph and on the Web site. The monograph stands alone as a classroom resource. The following sections will provide everything you need to use this monograph in your classroom:

Meet the Scientists: Introduces the scientists whose research is presented. This section can be used to discuss careers in science.

Glossary: Introduces potentially new terms used in the monograph.

Thinking About Science: Provides one idea about the nature of scientific inquiry.

Thinking About the Environment: Provides background information to introduce the topic studied by the scientists.

Introduction: Introduces the problem or question the scientists addressed.

Method: 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.

Reflection Sections: These questions are not a test! They are placed after the Introduction, Method, Findings, and Discussion sections to help students critically think about what they have read. They can also be used to informally assess student comprehension.

FACTivity: Presents an activity that can be done in the classroom and out-of-doors.

Citation: Gives the original article citation.

Lesson Plan: Presents a lesson plan for using the *Natural Inquirer* monograph in the classroom.

Lesson Plan for Woolly Bully

Note: This lesson plan may be used with this and any *Natural Inquirer* monograph or article.

Time Needed: Day One—5 minutes, **Day Two**—Full class period, **Day Three**— 10–15 minutes. **Note:** You may also choose to make Day 3 a full class period by completing the FACTivity associated with the article.

Materials Needed:

- *Natural Inquirer* article
- Pencils
- A set of four note cards per group. Write one of the following on each set of four note cards: Summarizer, Clarifier, Questioner, Predictor
- **Optional:** A blank piece of paper per student

Day 1

5 minutes

Introduce the *Natural Inquirer*. Explain how scientists conduct research and write it up using a standard format. The format scientists use to write their research generally, but not always, includes the following:

- **Introduction:** Gives the background of and reasons for the research question or problem, which is almost always found near the end of the introduction.
- **Method:** Gives the method the scientist(s) used to collect and analyze their data.
- **Findings:** Presents the findings. This usually, but not always, includes tables, charts, and graphs.
- **Discussion:** Explains what the findings mean in light of the research question or problem presented in the Introduction.

Explain that the sections they will read for homework were added to give them additional background to better understand the upcoming article, which they will read in class.

Homework

Have students read the "Glossary." Then students should read "Meet the Scientists," "Thinking About Science," and "Thinking About the Environment." Students should think about and write a short paragraph summarizing the topic they think the article will address. You may use this paragraph for assessment.

Day 2

5 minutes

Hold a class discussion about their homework assignment. What are some ideas students have about what topic they think the article will address? What words or sentences did they use as clues? You may write these on the whiteboard or blackboard (or have a student do it).

40 Minutes

Put students in groups of four. Distribute one note card to each member of the group identifying each person's unique role (Each role is described later in this lesson plan).

Summarizer

Questioner

Clarifier

Predictor

In groups, have students read the "Introduction." Encourage them to use note-taking strategies such as selective underlining or sticky-notes to help them better prepare for their role in the discussion.

At the end of the section, the Summarizer will highlight the key ideas up to this point in the reading. Do not read the Reflection Sections at this time.

The Questioner will then pose questions about the selection:

- **Unclear parts**
- **Puzzling information**
- **Connections to other concepts already learned**
- **Motivations of the scientists**
- **Any other questions**

The Clarifier will address confusing parts and attempt to answer the questions that were just posed by the Questioner.

The Predictor will offer guesses about what might come next in the text.

The roles in the group then switch one person to the right, and the next section is read. Students repeat the process using their new roles. This continues until the entire article is read. There are four sections to each article. Each student should have an opportunity to play every role.

5 minutes

Hold a class discussion that compares and contrasts what the students discovered while playing the various roles.

Homework

Assign each student a set of Reflection Section questions from the Introduction, Method, Findings, or Discussion sections. Have students write down the answers to their appropriate section. You may use these answers for assessment.

Day 3

10-15 Minutes

Remind the students that they have read the Introduction, Method, Findings, and Discussion sections. Address any questions the students had about the previous day's activity. Review the article by discussing their answers to the Reflection Questions from each section.

Optional: Continue with the FACTivity associated with the article.

Possible Answers to Questions in the Reflection Sections

INTRODUCTION

What is the question the scientists wanted to answer? *How might the flow of water change in areas near mountain streams if eastern hemlock trees are killed by the hemlock woolly adelgid?*

Do you think the loss of a particular tree species can impact the flow of water in a natural area? Why or why not? *Students will have to answer this question based on the information they have read in the first sections of this article. Therefore, they can only speculate on the answer. However, students should be able to back up their answer with logic.*

METHOD

If the relative humidity is high, do you think trees transpire more or less than if the relative humidity is low? Why or why not? *Students should realize that if there is more moisture in the air, trees will transpire less because the air will be less able to hold more water.*

Why did the scientists take measurements from some of the trees, instead of taking measurements from all of the trees? *Students should realize that it would cost too much and take too much time to take measurements from all of the trees. Plus, it would make little sense to damage all of the trees. This question provides an opportunity to discuss the concept of taking a sample and how samples are used by scientists to represent the whole population.*

FINDINGS

From the findings, how do you think the loss of eastern hemlock trees would change the flow of water in the ground and in streams in areas like the one studied by the scientists? *Students should realize that the loss of hemlock trees would increase the amount of water in the soil and the amount of water flowing into streams. Students may also remember that hemlock trees intercept rain, causing it to fall more gently to the ground and allowing some of it to evaporate off of needles. Thus, the loss of hemlock trees will also increase the amount of rain falling directly onto the ground, which would cause more rain to flow directly into nearby streams. This could also cause an increase in soil erosion into the streams.*

Look at figure 15. Describe in your own words what the figure is showing. *Figure 15 shows normal streamwater flow during the night and daytime when the hemlock trees are present. This is because hemlock trees transpire during the day and streamflow is lower then. At night when hemlock trees are not transpiring, more groundwater is flowing into the stream. The figure contrasts the normal condition with what might happen after hemlock trees are killed by the adelgid. The figure shows that following hemlock tree death, there is less difference between streamflow in the day and nighttime. This is because with the hemlock trees gone, transpiration is much lower in the daytime, and, therefore, more groundwater is flowing into the stream.*

DISCUSSION

What is one thing scientists could do to help prevent changes in the flow of water in southern Appalachian mountain areas that have a lot of eastern hemlock trees? *The first thing they could do is what they are currently doing; that is, they are trying to stop the spread of hemlock woolly adelgid in eastern hemlock trees. Students may come up with other things that scientists could do to prevent changes in the flow of water in these areas. An example is planting other evergreen tree species that are native to the southern Appalachian mountains in place of the hemlock trees.*

What do you think will happen to eastern hemlock trees growing in the Northeast United States as the climate continues to get warmer? *Students should realize that a warmer climate would be more favorable to the hemlock woolly adelgid. This will probably result in greater rates of death of eastern hemlock trees, especially in the Northeast, where cold winters currently reduce the numbers of hemlock woolly adelgids.*

A scientist who studies insects such as the hemlock woolly adelgid is called an entomologist (en t<u>o</u> ma la jist). A scientist who studies the flow of ground and stream water is called a hydrologist (h<u>i</u> draw la jist). A scientist who studies the growth of trees is called a silviculturist (sil va kul jür ist). One of the scientists in this study is a tree ecophysiologist (<u>e</u> k<u>o</u> fiz <u>e</u> ol uh jist). She studies how trees work in relation to where they live. The other scientist is an ecologist. He studies the relationships of living and nonliving things in an area. From reading this study, do you think different kind of scientists should work together? Why or why not? *Students should realize that different kinds of scientists must work together to discover the answers to some of their questions. Without working together, the scientists would only have part of the information they need to answer questions and solve problems.*

Which National Science Education Standards Can Be Addressed Using This Monograph?

Standards • Journal Article: *Woolly Bully*

Science as Inquiry

- Abilities Necessary To Do Scientific Inquiry
- Understanding About Scientific Inquiry

Life Science

- Structure & Function in Living Systems
- Regulation & Behavior
- Populations & Ecosystems
- Diversity & Adaptations of Organisms

Earth Science

- Structure of Earth Systems

Science in Personal & Social Perspectives

- Natural Hazards
- Risks & Benefits

Science & Technology in Society

- Science & Technology
- Understanding About Science & Technology

History & Nature of Science

- Science as a Human Endeavor
- Nature of Science

Web Site Resources

Publication on Experimental Forests and Ranges:
http://nrs.fs.fed.us/pubs/gtr/gtr_ne321R.pdf.

This publication describes every experimental forest and rangeland in the system and would be a great resource for students.

Forest Service Hemlock Woolly Adelgid
http://www.na.fs.fed.us/fhp/hwa/

Hemlock Woolly Adelgid Pest Alert
http://na.fs.fed.us/spfo/pubs/pest_al/hemlock/hwa05.htm

National Invasive Species Center—Hemlock Woolly Adelgid
http://www.invasivespeciesinfo.gov/animals/hwa.shtml

Forest Service Experimental Forests and Ranges
http://www.fs.fed.us/research/efr/

Coweeta Long Term Ecological Research
http://coweeta.ecology.uga.edu/

Coweeta Schoolyard Program
http://coweeta.ecology.uga.edu/ecology/education/schoolyardmain.html

Forest Service Pest Alert
http://na.fs.fed.us/spfo/pubs/pest_al/hemlock/hwa05.htm

Save Our Hemlocks
http://www.saveourhemlocks.org

Harvard LTER Schoolyard Program
http://harvardforest.fas.harvard.edu/museum/hwa.html

Please Let Us Know What You Think!

Science education standards and evaluations

On page 29, you will find a list that identifies the national science education standards that the article addresses. On the *Natural Inquirer* web site, you will find educator and student evaluation forms. You and your students may complete the evaluation forms online by visiting **http://www.naturalinquirer.org**. If you have any questions or comments, please contact:

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bmcdonald@fs.fed.us

(Please put "Educator feedback" in the subject line.)

What Is the Forest Service?

The Forest Service is an agency of the United States Department of Agriculture. It is made up of thousands of people who care for the Nation's forests and grasslands. The Forest Service manages over 150 national forests and almost 20 national grasslands. National forests, like national parks, provide places for people to recreate, they provide homes for wildlife, and they provide clean water and air for everyone. 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 this monograph (**mon** o graf). These scientists work to solve problems and provide new information about natural resources so we can make sure our natural environment is healthy, now and into the future.

Learn more about the Forest Service by visiting
http://www.fs.fed.us

What Is the Cradle of Forestry Interpretive Association?

The Cradle of Forestry Interpretive Association (CFIA) is a nonprofit organization founded in 1972 by a group of people interested in forest conservation. The CFIA helps the Forest Service tell the story of forest conservation in America, and it helps people better understand both forests and the benefits of forest management. The CFIA invites everyone to visit its Forest Discovery Center in the Pisgah National Forest near Brevard, NC.

Learn more about the CFIA by visiting
http://www.cradleofforestry.org

Editorial Review Board

Memorial Park Day Camp, Athens–Clarke County, Georgia

Web Resources

Natural Inquirer: **http://www.naturalinquirer.org**

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

Cradle of Forestry Interpretive Association: **http://www.cradleofforestry.org**

Project Learning Tree: **http://www.plt.org**

FS-945