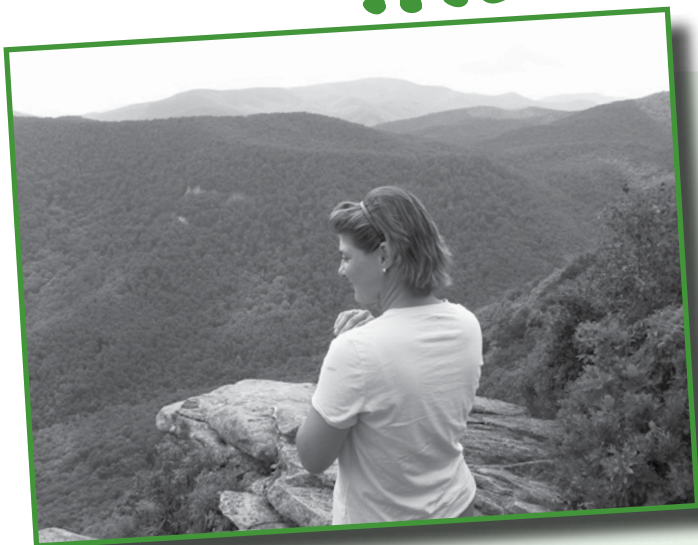
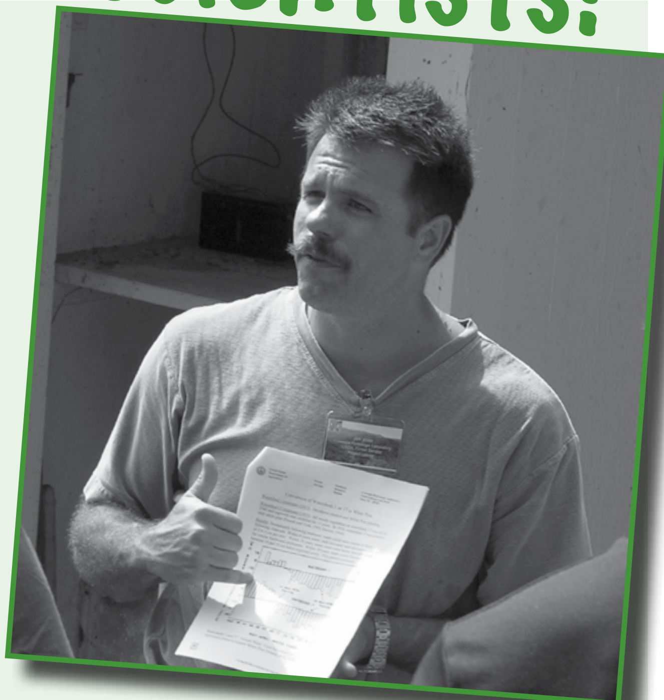
Woolly Bully: Estimating the Effect of an Invasive Insect on an Area's Water Cycle

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 (stō **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

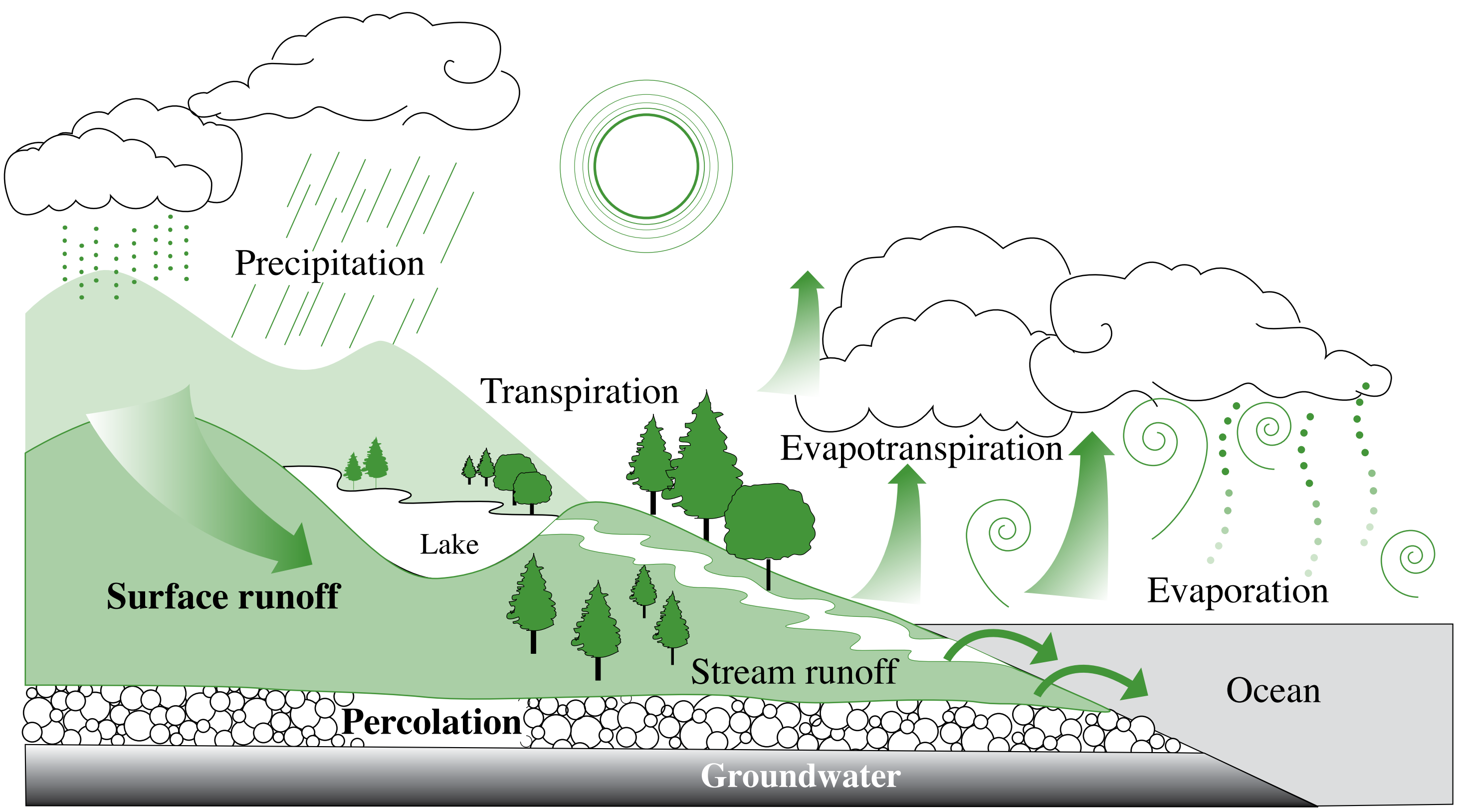
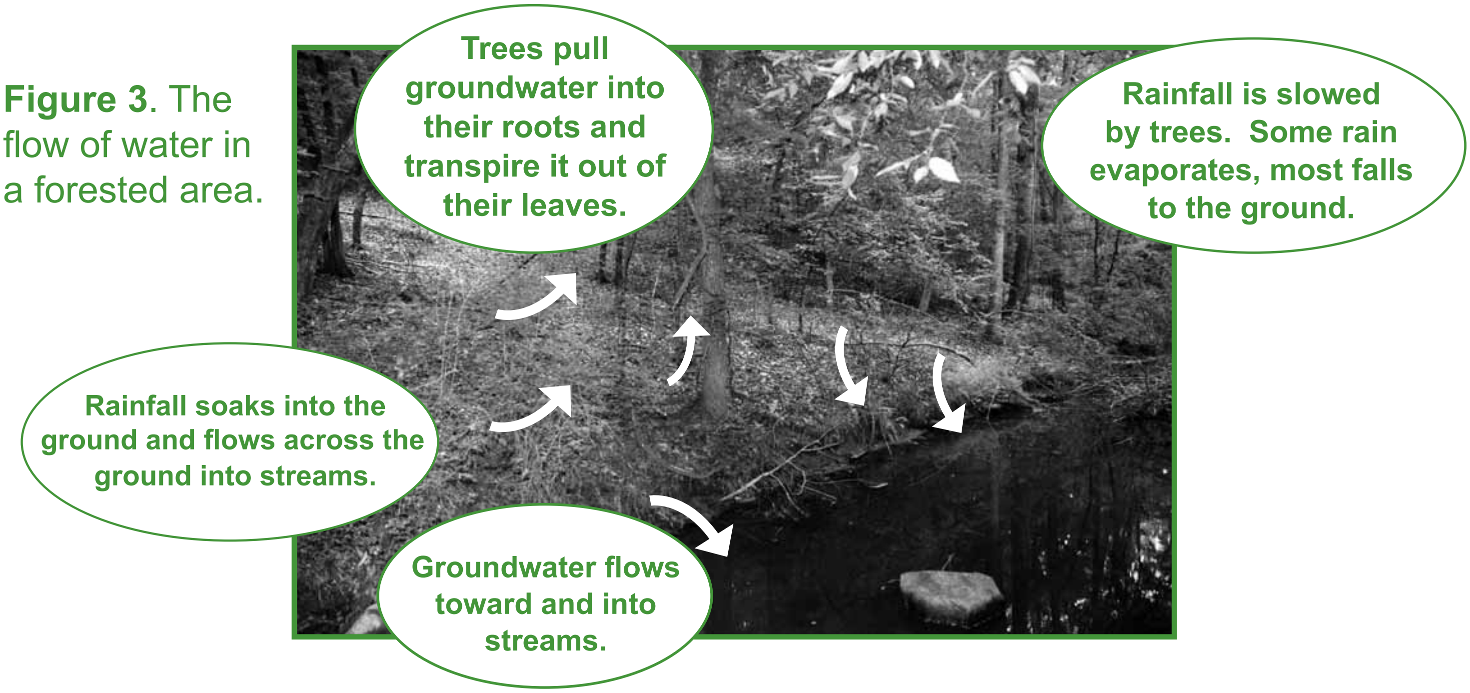


Figure 2. The water cycle.

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



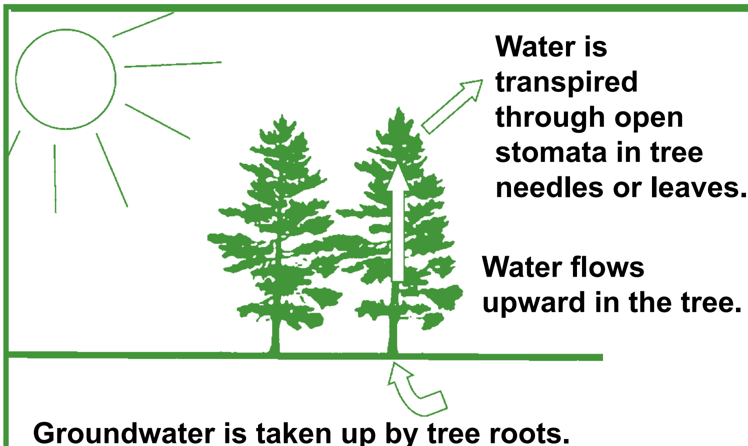


Figure 4. Water movement in a tree during the daytime.

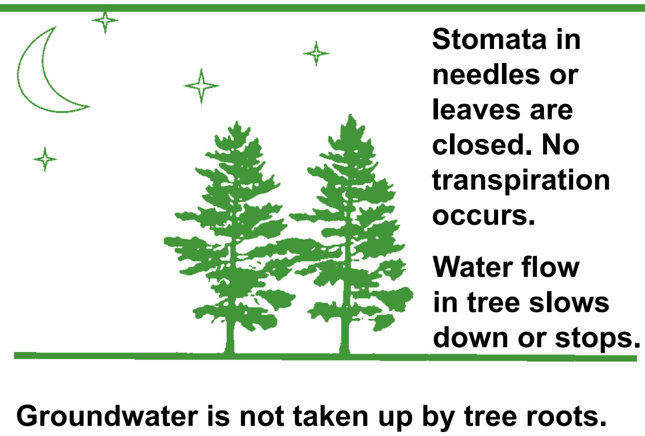


Figure 5. Water movement slows down in a tree during the nighttime.

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.

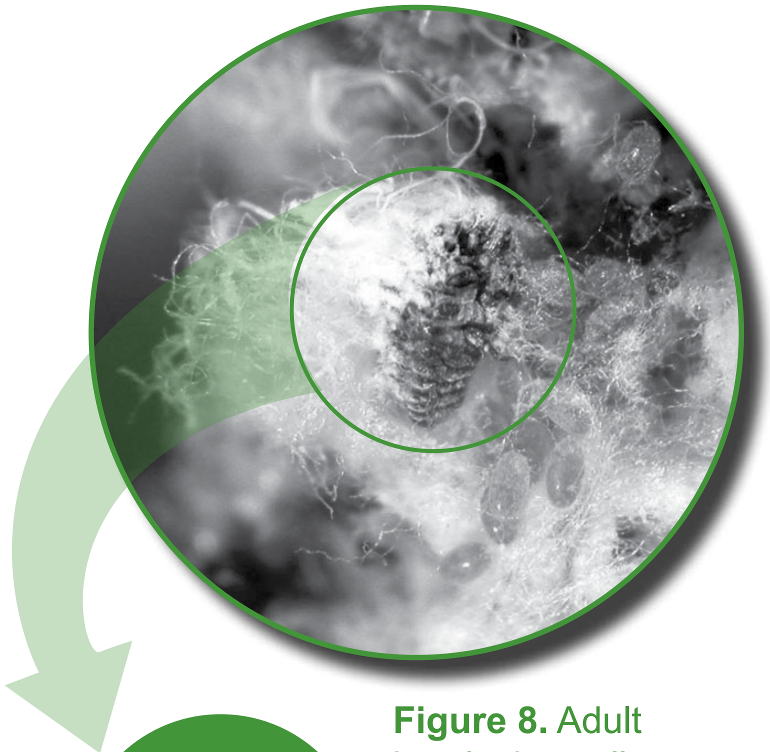


Figure 8. Adult hemlock woolly adelgid and eggs.
Photo courtesy of Michael Montgomery, Forest Service, and http://www.bugwood.org.

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?

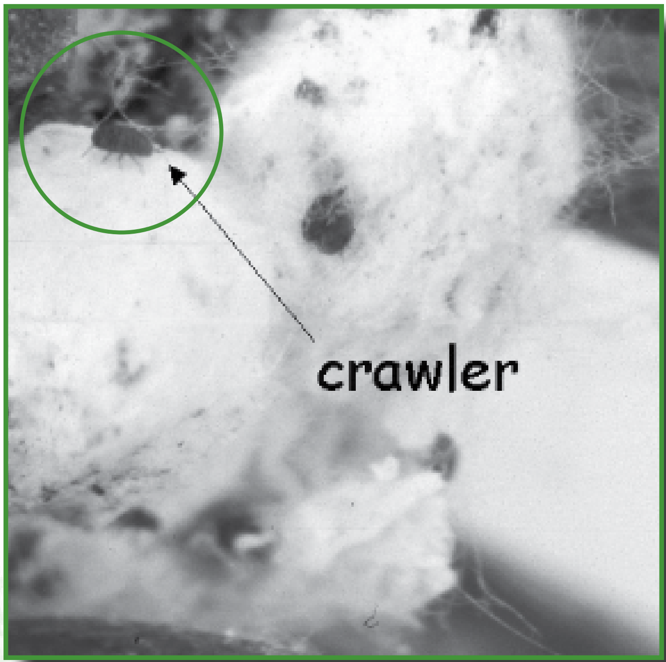


Figure 9. A hemlock woolly adelgid crawler. The sign of the adelgid's egg capsule is a white, cottony mass on the needles. The eggs hatch from the woolly egg capsules and have legs for a short time. They crawl to a suitable feeding site, then settle there. They stay in one place while feeding and developing. (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.

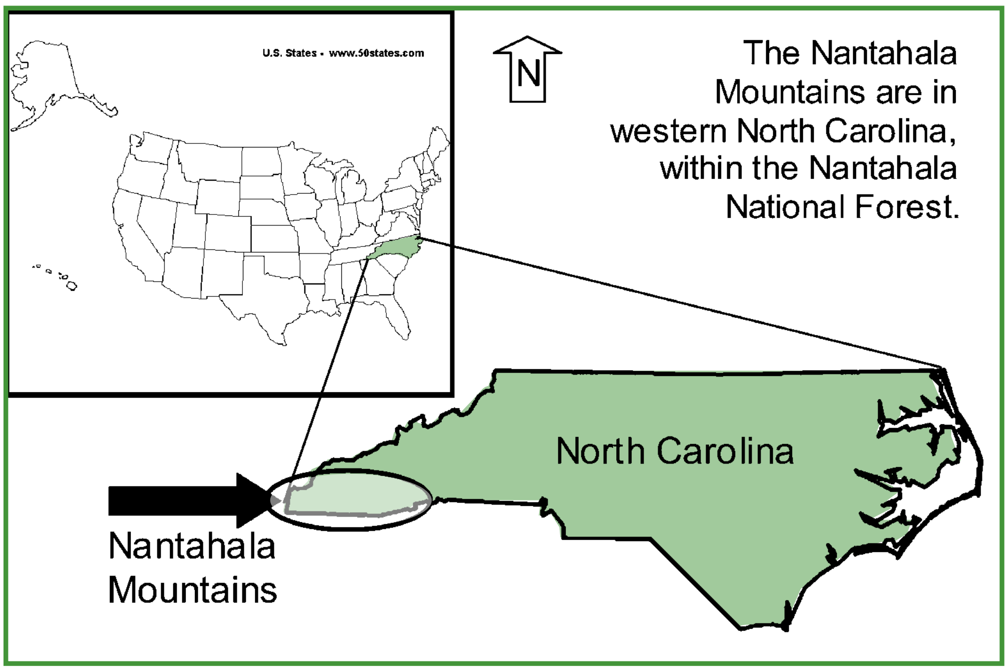


Figure 11. The Nantahala (nan tuh **ha** la) mountains are in western North Carolina.

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

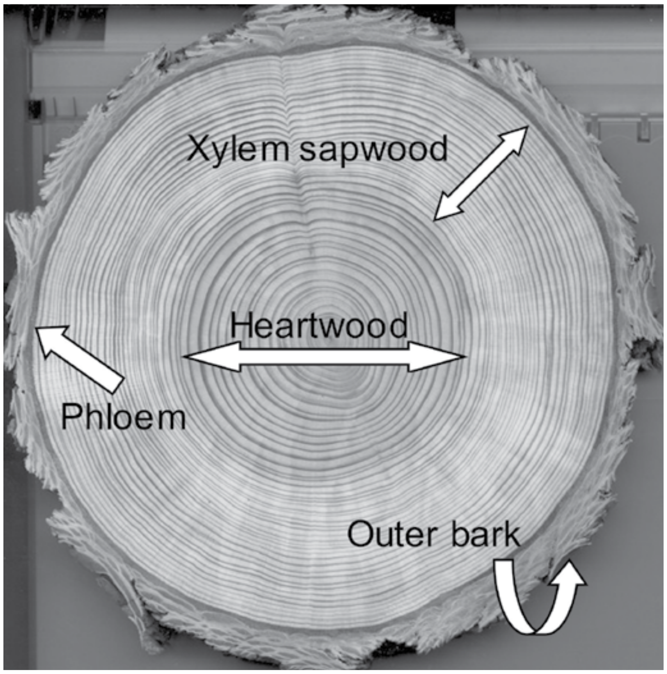
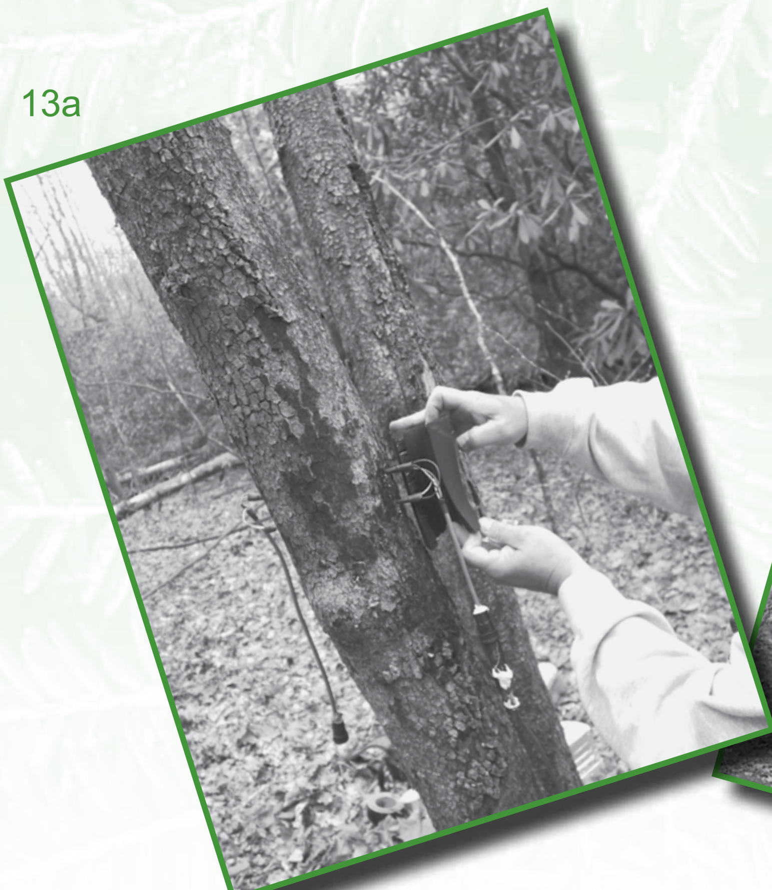


Figure 12. The xylem sap flows through a tree's sapwood.

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)**.

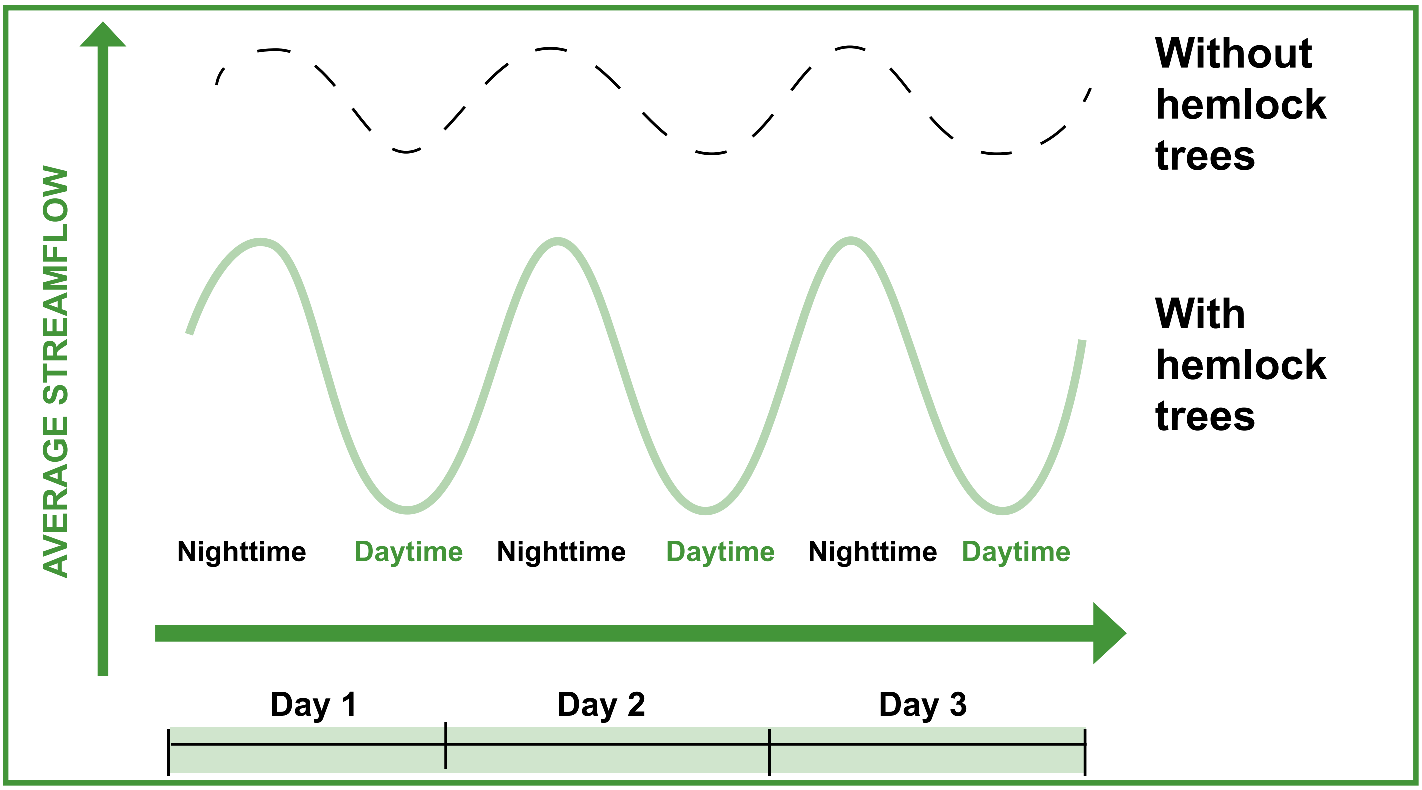


Figure 15. The amount of streamflow during a typical cycle of day and night (solid line) and the amount of streamflow likely after the death of eastern hemlock trees in the area (broken line). This figure shows that there will be a greater streamflow after the hemlocks have died. The streamflow will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

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?

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?