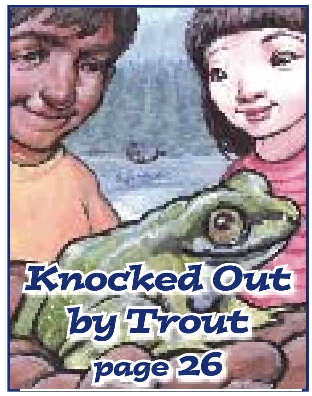
Natural Inquirer

Invasive Species Edition

Volume 8, Number 1 • Invasive Species Edition



Natural Inquirer

Invasive Species Edition • Volume 8, Number 1 • Winter 2006

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Editorial Review Board

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

Comments about individual articles in this edition from the *Natural Inquirer* editorial review board:

"I like the glossary!"

"I think you did a great job, but you could make the meaning of dispersal more clear."

"I think I learned a lot about how animals that are accidentally brought somewhere can do a lot of damage."

"I learned how important nature really is."

"Very nice pictures."

"The glossary is a good idea."

"I wouldn't put the questions! I think this article was full of facts and a lot of interesting stuff."

"That nun [moths] were very dangerous." (In reference to nun moths in article "And Then There Were Nun.")

"Personally I don't like questions in articles that I read. I just like to look at the pictures and read without 'quizes.' Every time I thought there was something that was needed in the article I read a little further and there it was! This is an interesting and factual magazine!"

"I like the title, it makes you think." (In reference to "Hurry Up and Wait" article)

"I like these pictures! Very colorful and they go along with what I am reading. I can understand more w/these."

"This is very kool!" (In reference to picture of quantum sensor in "Hurry Up and Wait.")

"This is very easy reading, but you also get a lot out of it! It's simple but to the point."

"Great fact to know!"

"The pictures are very helpful to understand about the meaning of a word."

"I learned that plants need lots of sunlight and about Oriental bittersweet."

"I think this article is very good. The article only had about one or two words I didn't understand."

"It was ok, but you should try to make it a little more interesting."

"Cool picture! It shows what the scientist are doing."

Natural Inquirer ***review board.***

Note to Educators

As a teacher 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 an educator, 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 U.S. 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, 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 learning about ecology, the natural environment, and natural resources.

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. You will also find evaluation forms in the back of the journal. Please make copies of these evaluation forms and have your students complete them after they complete each article. Also, please complete the evaluation form for teachers. Send the evaluation forms to the address listed below. The address is also listed at the bottom of the evaluation forms. You and your students may also complete the evaluation forms online by visiting http://www.naturalinquirer.usda.gov.

This journal is created by Environmental and Science Education, a science application program of the USDA Forest Service. If you have any questions or comments, please contact:

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Educator Resources

Visit the updated *Natural Inquirer* Web site at http://www.naturalinquirer.usda.gov/educators.cfm. From this site, you can 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.usda.gov

Contents

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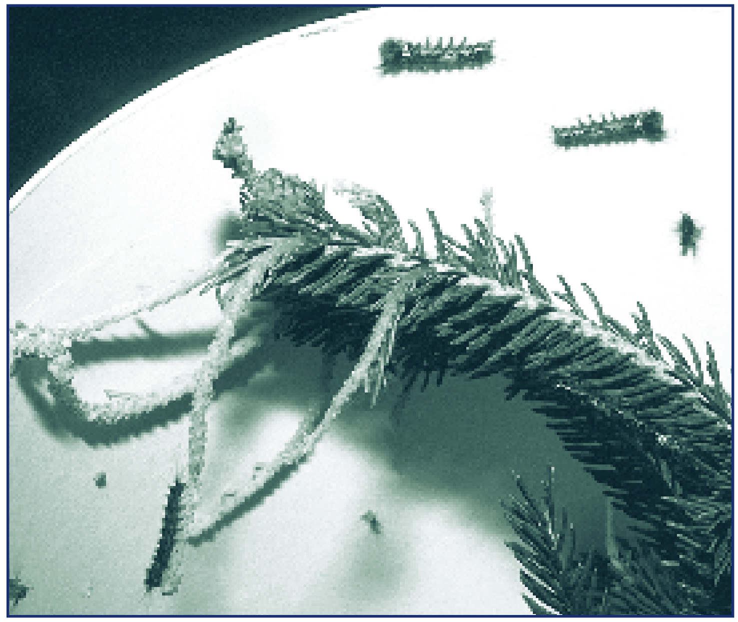

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About the Natural Inquirer

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 U.S. Department of Agriculture (USDA) Forest Service. If you want to know more about the USDA Forest Service, you can read about it on page 81 of this journal, or you can visit the *Natural Inquirer* Web site at http://www.naturalinquirer.usda.gov.

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 scientist" 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. This 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. These sections give you extra information.

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 are not a test! They should help you to think more about the research. 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**—You must be interested in learning.
- **Be enthusiastic**—You must be interested in an environmental topic.
- **Be careful**—You must be accurate in everything that you do.
- **Be open minded**—You must be willing to listen to new ideas.
- **Question everything**—You must think about what you read and observe.

Welcome

to the Invasive Species Edition of the *Natural Inquirer*!

Do you know what an invasive *species* is? If you are thinking of invaders from a distant planet, you are close, except that these species invade from right here on Earth. Invasive species are any plant, animal, or *organism* that is not *native* to the ecosystem it is in, and is likely to cause harm to the environment, the economy, or human health. Although invasive species do not come from another planet, they can come across oceans from distant countries. Invasive species have the potential to cause a lot of damage. They have been estimated to cost the United States $100 billion each year!

Because invasive species have the potential to cause so much harm, the U.S. President in 1999 signed an Executive Order that created a special council to address invasive species. The council, which includes people from 13 departments of the Federal Government, created a special plan to address the threat of invasive species.

The plan identified four main ways to address invasive species:

1. *Prevention.* Stop invasive species from entering the country in the first place.
2. *Early identification and rapid response.* Look for new areas where an invasive species is spreading and quickly destroy it before it can spread further.
3. *Control.* When the invasive species cannot be destroyed, keep it from spreading further.
4. *Restoration.* Recreate native ecosystems whenever possible.

Glossary:

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

organism: (**ôr** gä niz um): Any living thing.

native: (**nat** iv): Naturally occurring in an area.

restoration: (**rest** or **a** shun): The act of bringing back to an earlier condition.

nonnative (nän **na** tiv): Not naturally occurring in an area.

exotic: (ig **zät** ik) Strange, different, or foreign.

Pronunciation Guide

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

Accented syllables are in **bold.**

Did You Know?

Invasive species are a special type of *nonnative* species. Nonnative species, sometimes called alien species or *exotics*, may not be harmful to an ecosystem. They may even provide benefits to an area. Examples include nonnative bushes and flowers that are planted in gardens around homes and offices. Invasive species are nonnative species that cause harm to the environment, the economy, or human health. It is important to realize that not all nonnative species are invasive and harmful.

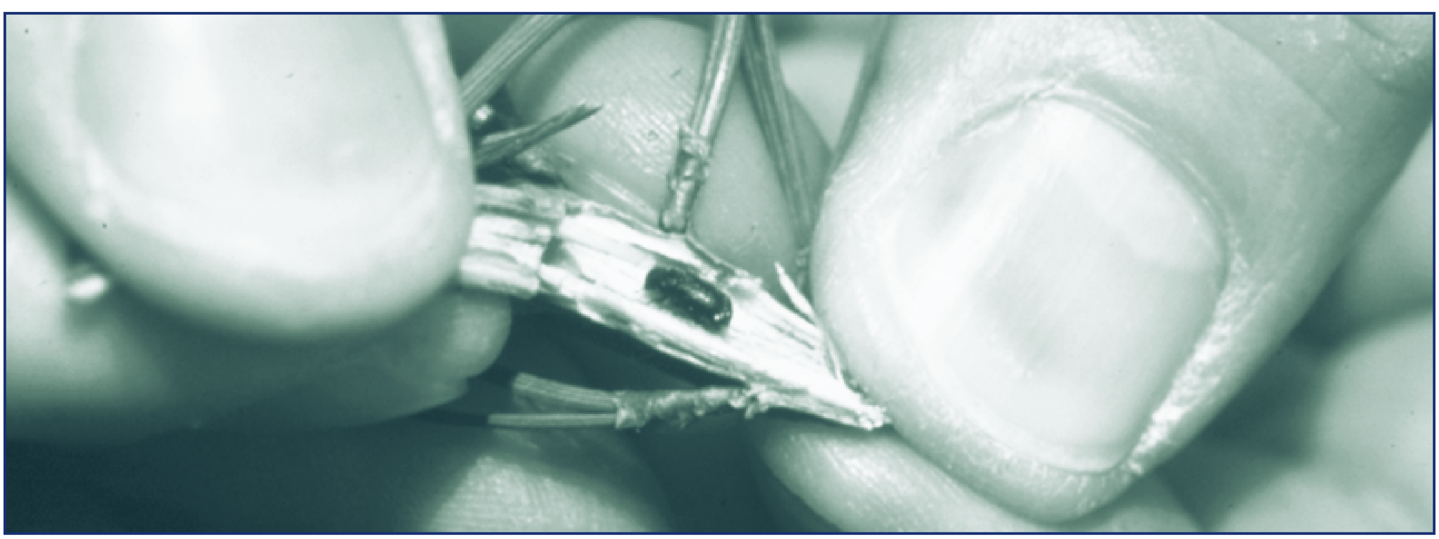
The introduction of invasive species can be on purpose or accidental. Some invasive species are introduced for a specific purpose, such as controlling another invasive species. An invasive species that is brought into an ecosystem by accident is sometimes called a "hitchhiker." For example, a person hiking may accidentally carry an invasive species to another area on a hiking boot, or a dog might carry an invasive species on its fur! Many invasive species are spread to another country in the packing material that carries the goods being shipped.

For more information on invasive species impacts, visit http://www.invasivespeciesinfo.gov/impacts.shtml.

What you can do—

- Whenever possible, garden with plants native to your area.
- Do not transport plants or animals from one country to another.
- Learn and share with others about invasive species and how they spread.

In this edition of the *Natural Inquirer*, you will learn about several different invasive species. You will learn about how these invasive species spread and the studies that scientists conduct to better understand and stop the spread of invasive species. After reading the *Natural Inquirer's* Invasive Species Edition, you will be able to help spread the word about what invasive species are and how to stop them!



Moving Spore-adically:

The Spread of Sudden Oak Death in California Forests

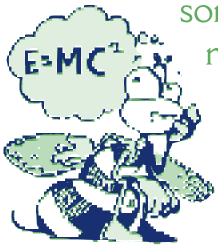
Meet the Scientists

Dr. Davidson: ◂ My most exciting moment as a scientist came while walking in the forest in the rain, collecting bay laurel leaves infected by sudden oak death and quickly taking them to the field station for viewing under the microscope. There, on the underside of the leaves, were hundreds of *spore* sacs. Some had already released spores that were swimming in the film of rainwater across the surface of the leaf. In that one moment, I saw the power of this invasive, disease-causing organism. Each leaf had thousands of swimming spores and there were hundreds of infected leaves on most of the bay laurel trees that year. The forest was swarming with spores to be carried in the rain onto oak trees. In this photo, I am testing diseased oaks in Mexico. Photo by Melissa Morris, University of California, Davis.

Ms. Patterson: ▸ I have really enjoyed all the hiking around I get to do in beautiful State parks. My favorite science experience was the time Kristen Falk, another scientist in this experiment, got chased by a turkey while we were tagging trees for an experiment. I don't think it liked her red pants!

Ms. Falk: ◂ This past winter I was collecting data in the woods. I was putting data into the computer from a weather station. When I'm in the woods, I hear all kinds of sounds, sometimes an owl, a hawk, a woodpecker, or a squirrel squawking at me to get out of their territory. I had the computer all set up, then I heard this distinctly different sound. It was not loud, but it gave me an uneasy feeling. I looked around for another person or other woodland creatures. Nothing. I continued working and then I heard the sound again. My ears told me the sound was close. I looked around and saw a lot of fallen trees downhill from me. I wondered if this large tree in front of me was about to fall. I panicked and didn't have much time to think, so I grabbed my computer and ran uphill. Not a minute later, a 20-foot piece of the tree cracked off of the top and crashed to the ground, right where I had been working. My heart was racing, but I'm glad that I relied on my senses to get out of there when I did! I am the one on the right in this photo.

Thinking About Science



When scientists prepare to study something, they do as much research about the topic as possible before designing their study. That way, they will be more successful at asking the right questions and finding the clearest answers. In this study, the scientists studied the organism that causes sudden oak death. They found that the organism is like a *fungus*. Therefore, they learned everything they could about how fungi spread from place to place. By understanding how fungi spread from place to place, they were able to look for a similar process in the organism that causes sudden oak death.

Thinking About the Environment

When homeowners create gardens or do landscaping around their homes, they often use plants that are not *native* to the area in which they live. These nonnative plants are often transported from country to country, and across the country from *nursery* to nursery. When a plant is infected with a disease, it is not just the plant that is transported from nursery to nursery. Sometimes, these plants and diseases escape into the natural environment, where they become disruptive to the natural *ecosystem*. You can see that although we usually think of plants as not being *mobile*, their reproduction and transport by humans allows them to spread from place to place. If a plant has a disease, the disease can spread as well.

Glossary:

spore (spor): A tiny cell of a plant or animal that can grow into a new plant or animal.

fungus (**fu*ng*** gus): An organism without chlorophyll that reproduces by spores. Mushrooms, molds, mildews, and toadstools are types of fungus. (Plural is fungi, **fu*ng*** gi).

native (**nat** iv): Naturally occurring in an area.

nursery (**nür** sür e): A place where young trees or plants are raised for study or for sale.

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

mobile (**mo** bul): Able to move from location to location.

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

canker (**ka*ng*** kür): An open sore.

broadleaf (**brôd** lef): Flat broad leaves.

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

Pronunciation Guide

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

Accented syllables are in **bold.**

Introduction

Sudden oak death is a new disease of trees and plants in the United States and Europe. Although scientists are not certain, they believe the fungus-like organism that causes sudden oak death was brought into the United States from another country. At first, the disease was found only in California (**figure 1**). Since that time, nursery plants affected with the organism that causes sudden oak death have been shipped to other nurseries across the United States (**figure 2**).

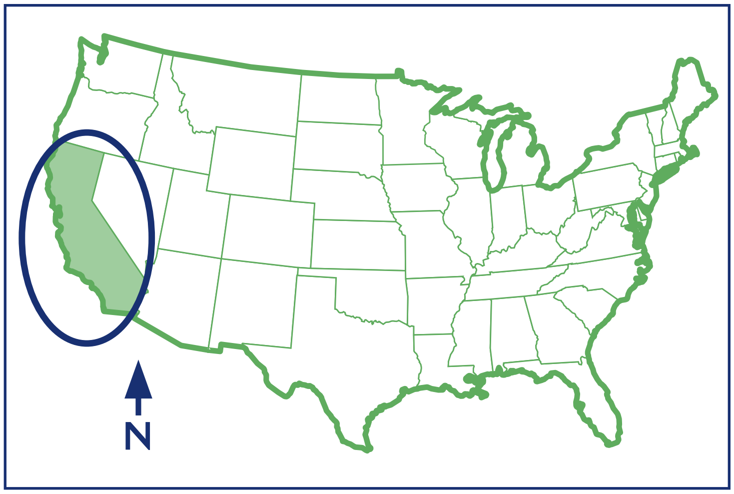


Figure 1. California.

One way the organism spreads is through the sale of infected nursery plants to homeowners or to nurseries in other locations. When such movement occurs, the organism can be spread quickly across long distances. Spraying plants with a chemical to kill the organism does not always work well enough to keep the organism from reappearing and spreading.

The organism can also spread from plant to plant. When the organism that causes sudden oak death infects a plant, it is hard to stop its spread to other plants and trees. Although the organism damages but does not kill all the tree *species* that it infects, it does kill some of them. In this study, the scientists wanted to learn how the organism that causes sudden oak death is spread from tree to tree within a forest.

Reflection Section

- What is the problem the scientists wanted to study?
- Which type of tree would you guess is most often killed by the organism that causes sudden oak death?

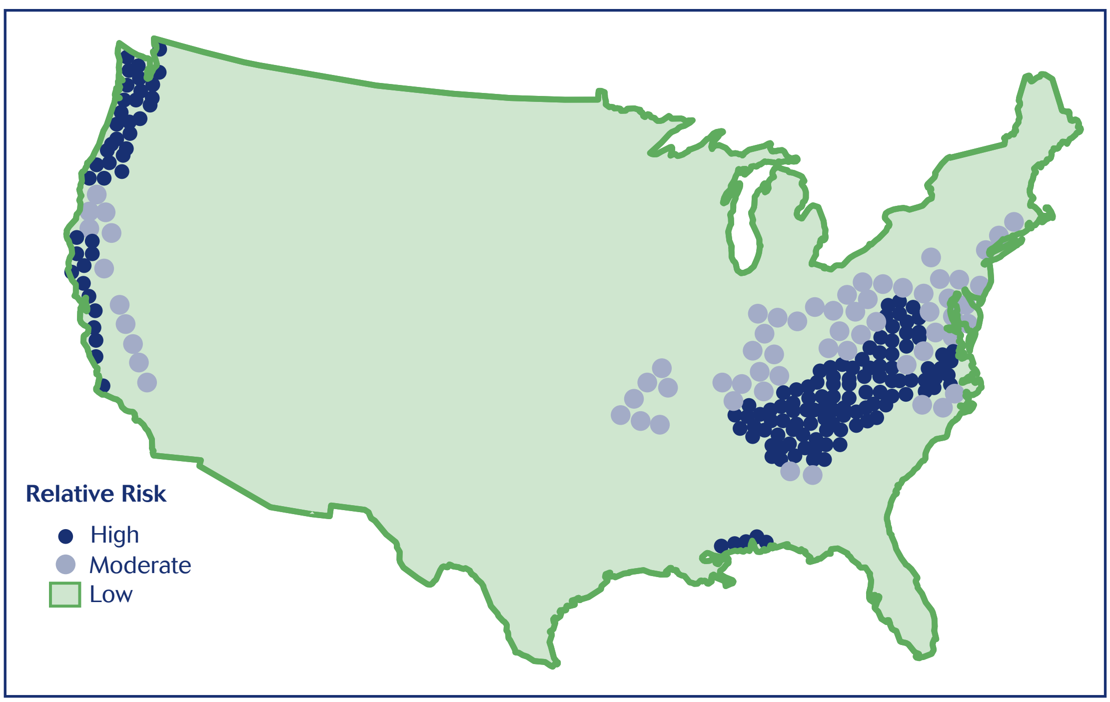


Figure 2. The location of nurseries across the United States that received plants from California nurseries that were infected with the organism that causes sudden oak death.

What is sudden oak death?

Sudden oak death is a deadly disease affecting four oak species in California and Oregon. It is caused by a fungus-like organism that produces *cankers* on the bark of oak trees. These cankers look like they are bleeding (**figure 3**). The sudden oak death organism also infects 13 other species of trees in California, including California bay laurel, coast redwood, Douglas fir, and bigleaf maple (**figures 4a–4d**). Although sudden oak death does not kill all the trees that it infects, the infection of any tree adds to the problem. When a tree is infected with the organism that causes sudden oak death, the infection enables the disease to continue to spread.

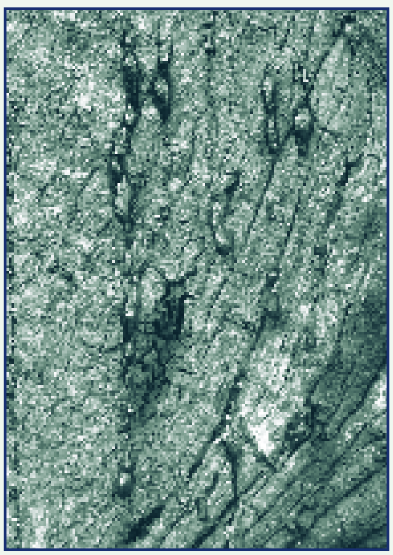


Figure 3. Canker on an oak tree caused by the sudden oak death organism. Photo by Matteo Garbelotto.

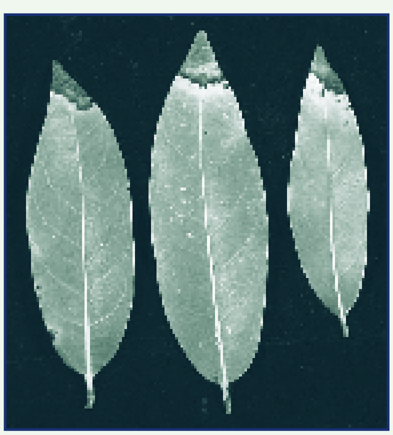


Figure 4a. The sudden oak death organism causes the death of leaf tips in bay laurels. Photo by Jeff Hall.

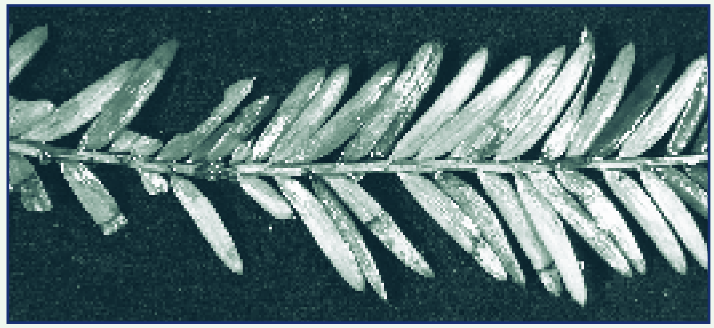


Figure 4b. The sudden oak death organism causes the death of needles on coast redwoods. Photo by Jeff Hall.

Figure 4c. The sudden oak death organism causes the stem to wilt on Douglas fir. Photo by Jenny Davidson.

Figure 4d. The sudden oak death organism causes the leaves to be scorched on bigleaf maple. Photo by Daniel Huberli.

Method

The scientists thought the organism that causes sudden oak death spreads in a manner similar to fungi (**figure 5**). This similarity includes the production of spores (**figure 6**). The scientists wanted to learn how the organism's spores move from tree to tree throughout a forest. The forest they studied contained both evergreen trees and *broadleaf* trees. The scientists knew that spores of fungi are often transported by wind and water and through soil. Within a forest, sources of water include rain and streams. Soil containing spores can be washed into streams or splashed onto the leaves of new plants.

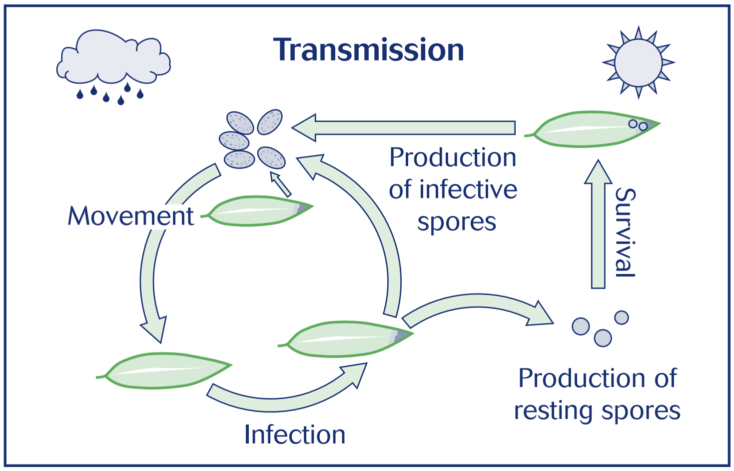


Figure 5. The cycle of reproduction of the sudden oak death organism.

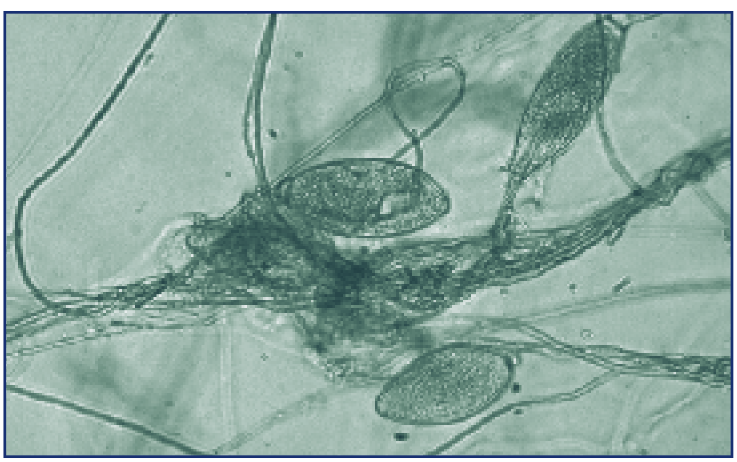


Figure 6. Spores from the organism that causes sudden oak death. Photo by David Rizzo.

Brain Crunches

Look at figures 4a–4d. Which are evergreen trees and which are broadleaf trees?

The scientists studied an area of land covering 166 hectares in California. Within this area of land, 17 percent of the coast live oak and 82 percent of the bay laurel were affected by the organism that causes sudden oak death. Sudden oak death can kill as much as 20 percent of the coast live oaks it infects in a given area (see figure 3 in the "Introduction" section).

Bay laurel trees are not killed by sudden oak death disease, but the disease still causes problems for the tree. The bay laurel tree's ability to photosynthesize is reduced and more leaves are lost from the tree. This loss is significant because bay laurel trees provide needed *habitat* and food for wildlife. Even though bay laurel trees are not killed by sudden oak death, the organism produces millions of spores while it is on the leaves. These spores may be spread to oaks, which can be killed by the organism that causes sudden oak death.

The scientists placed 30 traps to catch rainwater across the area of land (**figure 7**). They placed the traps throughout the area and collected rainwater over 2.5 years. During the rainy season, they collected the rainwater every 10 days. During the summer, when there were few rainstorms, they collected rainwater after each rain. The scientists filtered the rainwater using a very fine filter. This filter was small enough to trap the spores. The scientists performed tests to make sure the spores were the ones that cause sudden oak death. In this

Number Crunches

How many acres are equal to 166 hectares? Multiply 166 by 2.47 to find out.

Figure 7. Rainwater traps made out of a vinyl sheet were stretched over a frame and folded over to make a funnel. A 1-gallon jar placed at the end of the funnel collected the rainwater.

Figure 8. The buckets placed in a meadow near the forest edge. Photo by David Rizzo.

way, the scientists were able to estimate how many spores would be released from infected trees during a rainstorm.

To determine how far the spores travel while it is raining, the scientists put buckets in a meadow at the edge of the forest. Bay laurel trees affected by sudden oak death disease were growing at the edge of the meadow. During a rain, the scientists assumed some spores would travel away from the bay laurel trees, using windblown raindrops as their vehicles. The scientists placed buckets 0 meters, 5 meters, and 10 meters away from the trees in the meadow (**figure 8**). They collected the rainwater and filtered it in the same way they filtered the rainwater collected from the traps.

The scientists also studied how far spores could travel down a stream. The scientists placed leaves into a screen bag at three locations. They put the bags of leaves in the stream and tied them so they could not float away. If spores were present in the water, the trapped leaves would become infected. The first location was still in the study area. The second location was outside the study area but still in the forest where infected trees were growing. The leaves placed at the third location were 1 kilometer outside the forest (**figure 9**).

Number Crunches

- How many feet is zero meters? Five meters? Ten meters? Multiply the number of meters by 3.280 to find out.

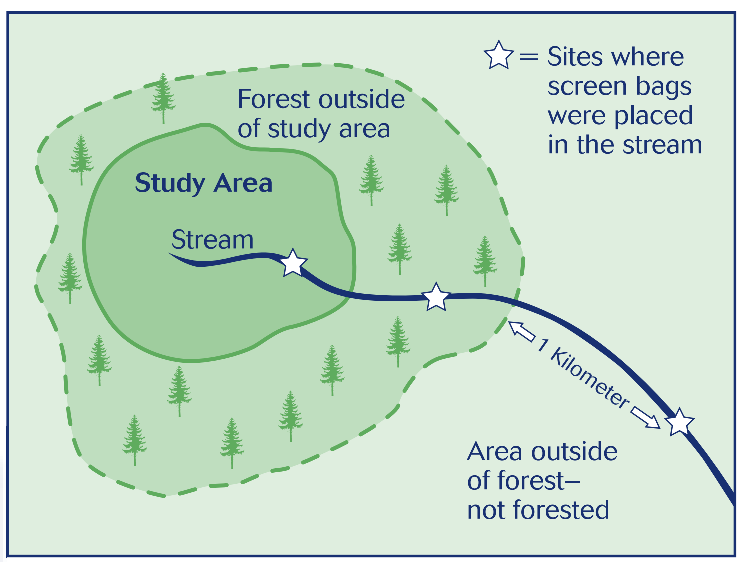


Figure 9. Locations where the trapped leaves were placed in the stream.

Finally, the scientists wanted to know whether spores could be transported on people's shoes. For this part of the study, the scientists had the help of students like you. Fifteen students hiked a trail in the study area. They hiked on 3 different days, with five students hiking each day. The scientists repeated this experiment at two different times. The distance the students hiked was 2.4 kilometers. At the end of the students' hike, the scientists scraped the soil from the students' shoes into 15 separate bowls. The scientists tested the soil in each bowl for the presence of spores. They then counted the number of students who had transported spores on their shoes.

Number Crunches

- How many miles did the students hike? Multiply the number of kilometers by .621 to find out.
- How many total students were involved in the experiment?

Reflection Section

- What would the scientists learn by comparing the number of spores found after a rain in buckets placed in increasing distances from infected bay laurel trees?
- What is the difference between the spores found in the rainwater traps and in the buckets?
- What would the scientists learn from floating leaves in the stream?
- What would the scientists learn from the students' hike?

Findings

The scientists found spores in the rain traps placed throughout the forest during the rainy season but not during the summer. At the beginning of the rainy season, the scientists found fewer spores than at the end of the season. The scientists found that the number of spores caught in the traps, however, varied from place to place and from year to year.

The scientists found that the farther away from the forest edge the buckets were placed, the fewer spores were trapped (**figure 10**).

The scientists found that the leaves floating in the stream within the study area became infected with the sudden oak death organism. During the rainy season, they also found that spores were present in the stream at both other locations, including the location 1 kilometer downstream from the forest. During the dry season, the stream dried out in the forest, and the scientists did not find any spores downstream during that time.

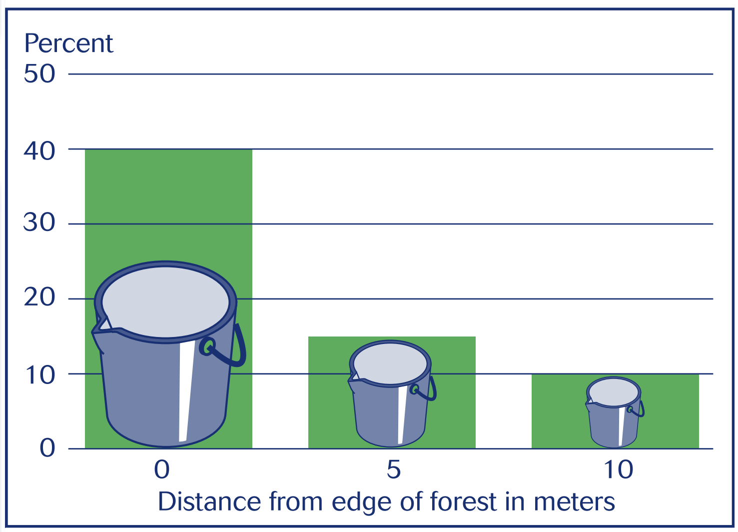


Figure 10. Percentage of times buckets were found with spores in the rainwater.

Number Crunches

- How many miles is 1 kilometer? Multiply the number of kilometers by .621 to find out.

Of the 30 students who hiked 2.4 kilometers, 12 of them picked up spores in the soil on their shoes. Forty-seven percent of the first 15 students' shoes and 33 percent of the second 15 students' shoes had spores in the soil that had clung to their shoes.

Reflection Section

- Basing your answer on the findings, would you say that sudden oak death can be transported by water? Why or why not?
- Basing your response on the findings, would you say that people can transport the spores that cause sudden oak death? Why or why not?
- Basing your answer on the findings, under what weather conditions would you say the transportation of spores is more likely to occur?

Discussion

The findings in this study are similar to research done on similar organisms. In other words, the organism that causes sudden oak death disease is transported from tree to tree in a manner similar to other fungus-like organisms. The presence of this organism is significant because when it is transported to new oak trees, it can cause the death of those trees. The scientists found that this organism is most likely transported from bay laurel trees, where the spores infect the tree but do not kill it.

This study showed how far the organism can travel through rain, streamwater, and soil. In particular, the organism can travel long distances down streams and on the shoes of hikers. Think about the possibility of transmitting the organism that causes sudden oak death across the country from nursery to nursery. If what happened in California could happen in other States, think about what might happen if the organism spread into forests across the United States. Look again at figure 2 in the "Introduction" section. Could sudden oak death get started in your State or in a State near you? The organism that causes sudden oak death is a new invasive species and not much is known about it outside California. Because it can kill oak trees, this is a disease to which we should pay attention. ■

Reflection Section

- Do oak trees live in your area? What do you think would happen if sudden oak death began to kill those trees?
- Do you think research should be done on sudden oak death outside California? Why or why not?

From: Davidson, J.M.; Wickland, A.C.; Patterson, H.A.; Falk, K.R.; Rizzo, D.M. 2005. Transmission of *Phytophthora ramorum* in mixed-evergreen forest in California. *Phytopathology.* 95(5): 587–596.

FACTivity

In this FACTivity, you will learn about the American chestnut tree and compare its story to the threat of sudden oak death disease.

The American chestnut was a large tree that grew across the Eastern United States to the Ohio Valley. American chestnut trees could grow so large that their trunks sometimes reached 5 feet across. The American chestnut was a common tree. Its nuts, which were tasty and nutritious, were used by both wildlife and people. People especially liked to eat roasted chestnuts. (Do you remember the holiday song, "Chestnuts Roasting on an Open Fire"?) The wood from American chestnuts was used for furniture and to build framing for barns. The trees were so numerous that their white blooms often made the forests look like they were snow capped.

In 1904, a fungus-like organism was brought to the United States. No one knows exactly how the organism came to the United States. Some think it may have come on nonnative chestnut trees imported from Asia. This organism enters the bark of American chestnut trees and kills everything above the place of entry. Thus, although the chestnut trees are not killed by the organism, they are reduced to nothing more than shrub-like sprouts. Within 50 years, all large American chestnut trees were gone.

Today, scientists think they will be able to bring the chestnut tree back. Even if they are able to do so, it will take years for the trees to grow. Scientists are not sure how the native forest will adapt to this new type of large chestnut tree.

In this research article, you read about the threat of sudden oak death disease. It may seem hard to believe that our Nation's big, strong oak trees could be in danger

Sudden oak death Web resources:

http://www.suddenoakdeath.org
http://www.na.fs.fed.us/sod/

American chestnut information from S.L. Anagnostakis
(e-mail: Sandra.Anagnostakis@po.state.ct.us) and
http://munic.state.ct.us/BURLINGTON/chestnuttree.htm.

because of a fungus-like organism. The American chestnut story shows that the threat of sudden oak death could be a disaster. It could change the look and ecology of our Nation's forests, parks, schoolyards, and backyards.

In this FACTivity, you will ride a time machine into the future. Imagine you are an adult with children the age that you are now. Since the time you were their age, the organism that causes sudden oak death has spread across the United States and killed all the oaks. You and your children are now living in a world without oak trees. Your children have asked you what the forests and parks were like when oak trees were alive. They want to know if you climbed oak trees, if you played under them, and what they looked like.

Write a story for your children about living with oak trees. If you have a favorite oak tree, you can write about that tree. You could tell about climbing an oak tree or building a tree house, or you could write about that one big oak tree standing alone in the park. You may include drawings with your story.

After completing your story, share your story with your classmates. You may post your stories and drawings on a display. As a class, discuss what benefits of oak trees were identified in the stories. How might your lives be different if oak trees did not exist? Basing your response on the class discussion, do you think it is important to guard against the spread of the organism that causes sudden oak death disease? Why or why not?

Extension: Students who want an extra challenge could do research to learn more about recent efforts to bring the American chestnut back to American forests.

If you are a Project Learning Tree-trained educator, you may use PLT Pre K–8th Activity Guide #77, "Trees in Trouble," as an additional activity resource. This activity teaches how to read signs and symptoms of stressed trees.

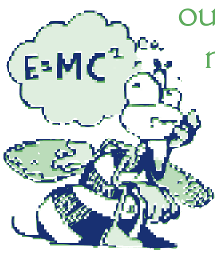
And Then There Were Nun:

Trees That Could Be Endangered by a Nun Moth Invasion

Meet the Scientist

Dr. Keena: ▼ My favorite science experience is when the mysteries of insect biology or behavior are ultimately unraveled at the end of a study.

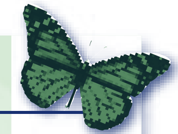
Thinking About Science



In today's world, we often think about our Nation's security. There are many different types of threats to our Nation, including biological threats from *nonnative* animal and plant *species*. In this research, the scientist studied a species of moth that has not yet been found in the United States. In Europe and Asia, this moth has done much damage to trees. The scientist wanted to know what tree species in the United States would be damaged if the moth were to come into the country.

To do her study, the scientist brought the moth eggs to the United States. When she did her experiments, she had to be certain the eggs, *larvae*, or moths did not escape into the natural environment. When scientists work with dangerous *organisms*, they must use extreme care to make sure their experiments are totally secure.

Glossary:



nonnative (nän **na** tiv): Not naturally occurring in an area.

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

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

organism (**ôr** gä niz um): Any living thing.

ancestor (**an** ses tür): An early kind of animal from which later kinds have developed.

characteristic (**ker** ik tür is tik): The special character or trait of some person or thing.

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

conifer (**kä** na für): A type of evergreen tree (pine, fir, spruce) that has cones.

broadleaf (**brôd** lef): Flat broad leaves.

crevice (**kre** vis): A narrow opening caused by a crack or a split.

incubate (***ing*** kyu bat): To keep something warm and protected so it will hatch.

pupa (**pu** pa): Intermediate stage of insect growth between larva and adult. Pupae (**pu** pe) is the plural.

native (**na** tiv): Naturally occurring in an area.

foliage (**fo** le uj): The leaves of a tree or plant.

economic (e ko **nom** ik): Having to do with managing money and resources in a home, business, or government.

Pronunciation Guide

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

Accented syllables are in **bold.**

Thinking About the Environment

Over a period of hundreds or thousands of years, organisms adapt to survive in their environment. Often, similar species living in different areas have adapted from a common *ancestor*. They may share many *characteristics*, but because they have adapted to different environments, they may also have different characteristics.

In this study, the scientist examined the preferred reproductive *habitat* of a certain type of moth. In Europe and Asia, this moth prefers to lay her eggs in particular tree species. When the eggs are laid and the larvae hatch, the larvae eat the leaves as they grow and develop. Eating the leaves damages the tree and may even kill it. The scientist wanted to know which tree species in the United States would be the preferred reproductive habitat for this moth, if it were to invade.

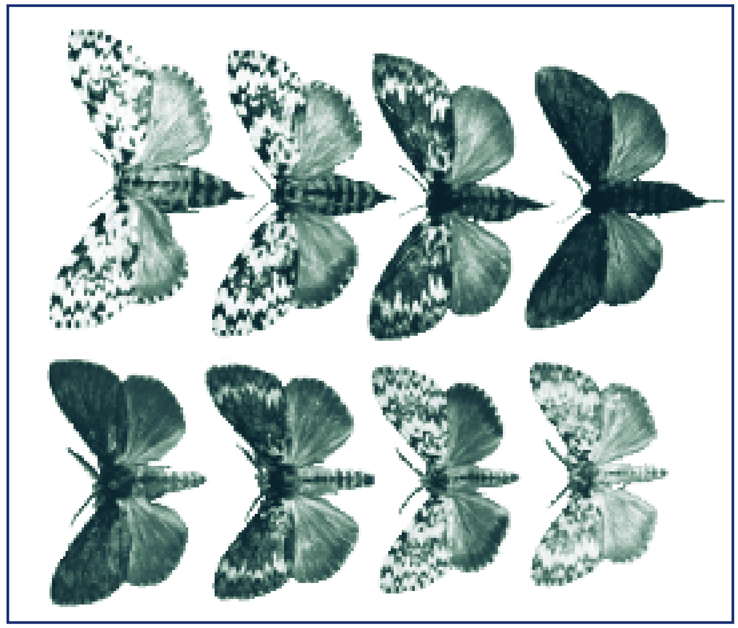


Figure 1. Nun moths.

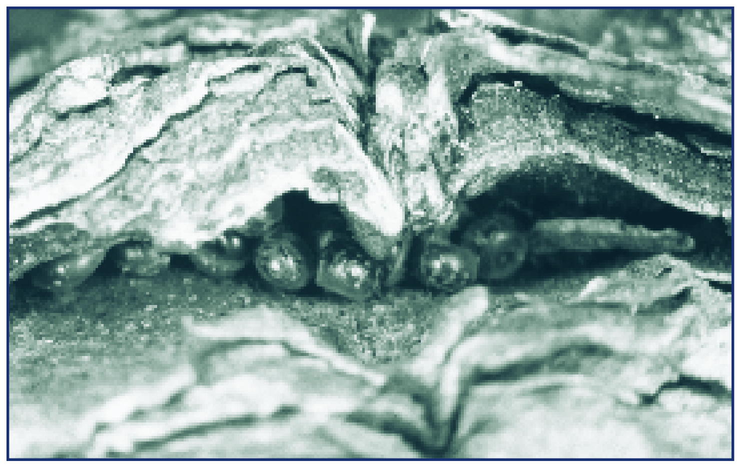


Figure 2. Nun moth eggs in the crevices of tree bark.

Introduction

The nun moth is a major pest of *conifers* and an occasional pest of *broadleaf* trees in Europe and Asia (**figure 1**). If the moth were to come to the United States, it might be a pest in the United States as well. So far, the nun moth has not been found in the United States. Insects like moths can be transported from country to country in or on the containers or vehicles that hold the goods that countries trade. For example, you might notice that your shoes were made in another country. Your shoes might have been shipped with hundreds of shoes in wooden crates when they were sent from that country to the United States.

The nun moth lays her eggs in the *crevices* of tree bark (**figure 2**). Think about what might happen if just one nun moth laid her eggs in the crevices of wooden crates that were shipped to another country. This is one way invasive species move from country to country. If the nun moth eggs or larvae were to come into the United States, they might find trees that are favorable to their growth. This situation could threaten the health of those trees and the forests they grow in.

We hope the nun moth will never invade the United States. If it does, however, it would be helpful to know which tree species would be most at risk. The scientist in this study wanted to discover which trees in the United States would be the preferred habitat of nun moths.

Reflection Section

- In your own words, state the question the scientist wanted to answer.
- What is the advantage of knowing in advance which tree species might be the preferred habitat of the nun moth?
- The scientist did this study in the Northeastern United States. Do you think she studied the moths inside or outside a laboratory? Explain your answer.

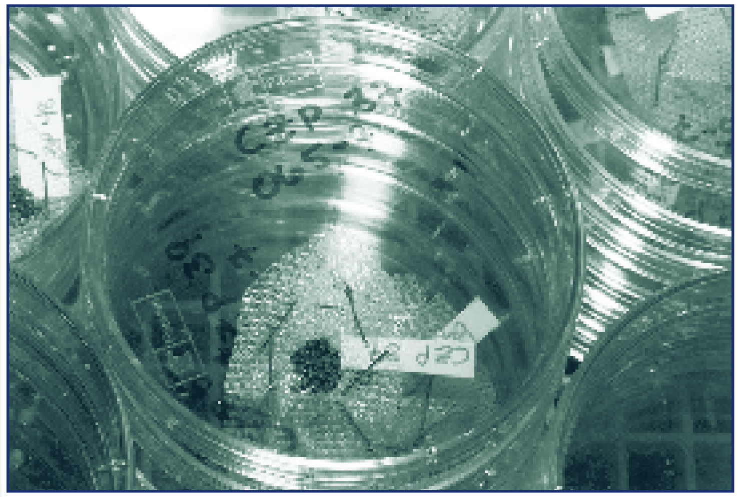


Figure 4. Nun moth eggs being incubated in a mesh packet. You can see the mesh packet and eggs inside the petri dish.

Method

The scientist used eggs that came from Eastern Europe (**figure 3**). She *incubated* the eggs (**figure 4**), which caused them to hatch into larvae (**figure 5**). She divided the larvae into two groups. The scientist observed the first group of larvae for the first 14 days of their development. She observed the second group of larvae through their development into *pupae*.

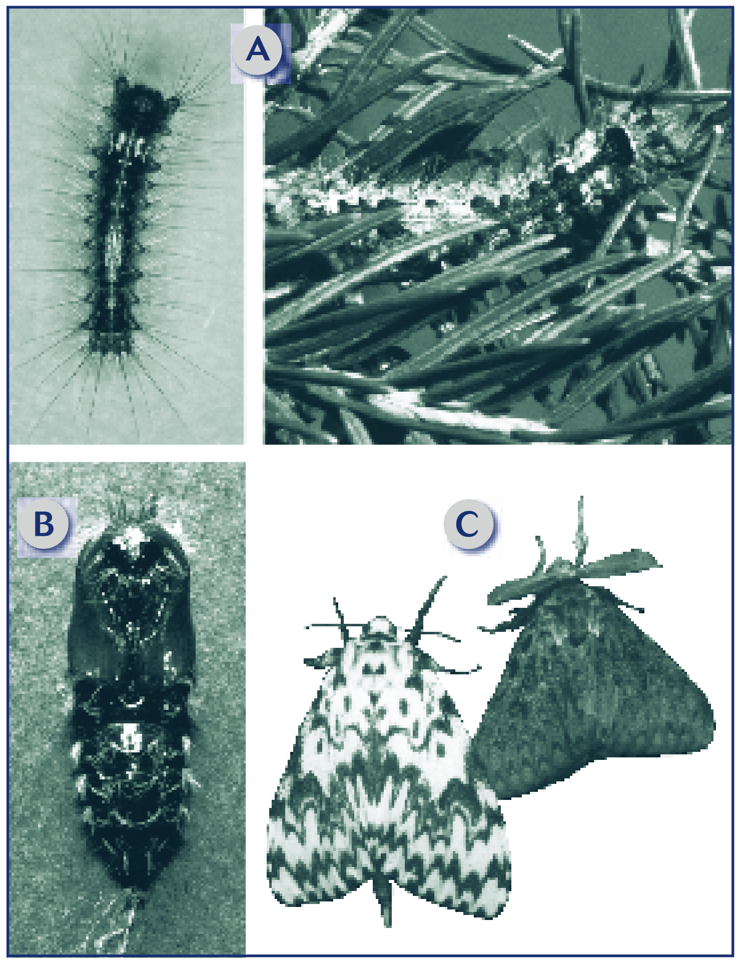


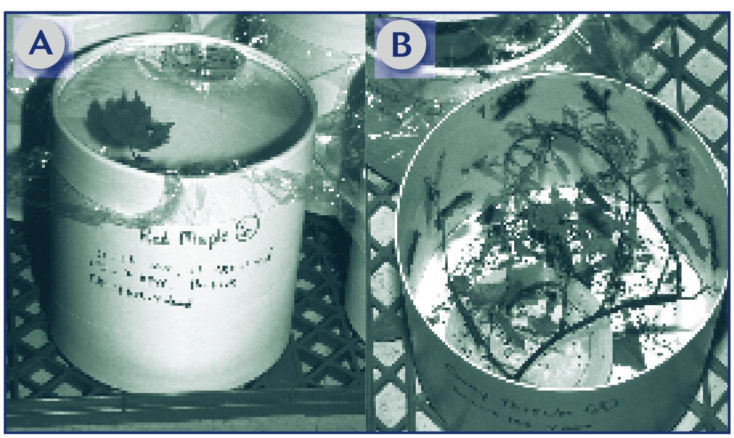
Figure 5. The life cycle of the nun moth. The eggs are shown in figure 2. Here, you can see the larva (5a), pupa (5b), and adult nun moth (5c).

Figure 3. Eastern Europe.

Within each of the two large groups, the scientist further separated the larvae into groups of 30. She allowed each group of 30 to feed on one particular tree species. The scientist used 26 tree species that are *native* to the United States and 8 tree species native to Europe or Asia. The larvae that were observed until they became pupae were allowed to feed on trees native to the United States. They also were allowed to feed on their two favorite European trees for comparison.

For each group of 30 larvae, the scientist used a container to hold the larvae. She placed the *foliage* from one tree species into a cup with water, and then placed the cup with the foliage in a container with the larvae. She covered each container with clear plastic to allow light to enter (**figures 6a and 6b**).

Because the foliage needed to remain fresh, the scientist periodically placed new foliage in the containers. Each time she changed the foliage, the scientist removed all contents of the container. She counted the number of live and dead larvae and recorded her observations. She also observed and recorded what species of foliage the larvae were eating. When the scientist put fresh foliage into the container, she placed the remaining live larvae back into the container with the fresh foliage.



Figures 6a and 6b. Containers that held larvae and foliage. There were 34 different containers, each with a different species of foliage and 30 larvae.

At the end of 14 days, the scientist removed the first group of larvae from its containers. For each container, the scientist counted the number of larvae still alive and calculated the percentage that had survived 14 days.

Number Crunches

- How was the percentage of surviving larvae calculated?

Remember that larvae from the second large group were allowed to develop into pupae. For this group, the scientist counted and recorded any pupae that had developed from larvae and then removed them from the container. Removing the pupae left only larvae in each container. The scientist removed the pupae each time she changed the foliage. She continued to do this until all the larvae should have developed into pupae, which was a total of 70 days. She then counted and recorded the number of larvae that did not develop into pupae. From this number she was able to calculate the overall percentage of larvae becoming pupae in each container.

Number Crunches

- How did the scientist calculate the percentage of larvae that had become pupae?

Reflection Section

- What did this experiment enable the scientist to discover?
- When the scientist placed fresh foliage in each container, do you think she used the same species of foliage that she had removed from that container? Why or why not?
- Why do you think the scientist wanted to discover what percentage of larvae became pupae?

Findings

The scientist compared the percentages of surviving larvae and pupae for each of the 34 types of foliage. Basing her calculations on this comparison, she rated each of the tree species as being suitable, intermediate in suitability, or poor in suitability for nun moth development. For species rated suitable, few additional larvae died after living for 14 days. The larvae ate the foliage of every conifer species. For most of the conifer species, the larvae preferred to eat the young foliage that had just emerged. Foliage that had grown in previous years was not eaten by most of the larvae until they had reached an older stage of development (**figure 7**).

The results were mixed for the broadleaf species. Some of the broadleaf species were not eaten at all. The larvae did not want to eat the small young reddish leaves of the white oak tree, but when the young leaves turned green, the larvae devoured them (**figures 8a and 8b**). The larvae also ate the foliage of gray birch, American beech, black oak, northern red oak, and California white oak. They also ate the flowers of wild cherry trees.

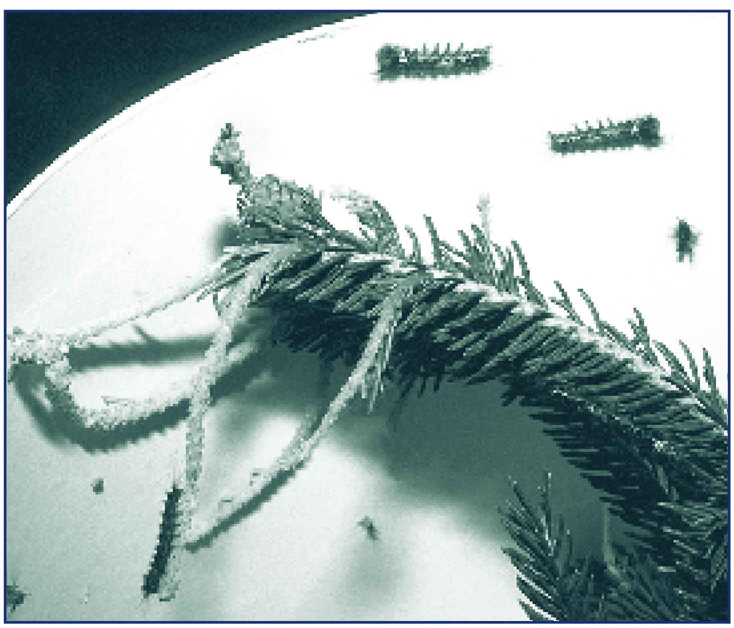


Figure 7. The larvae ate the young needles of the Norway spruce first. You can see they did not eat the older needles.

Figure 8a. The newly unfolded reddish leaves of the white oak were not eaten by the larvae.

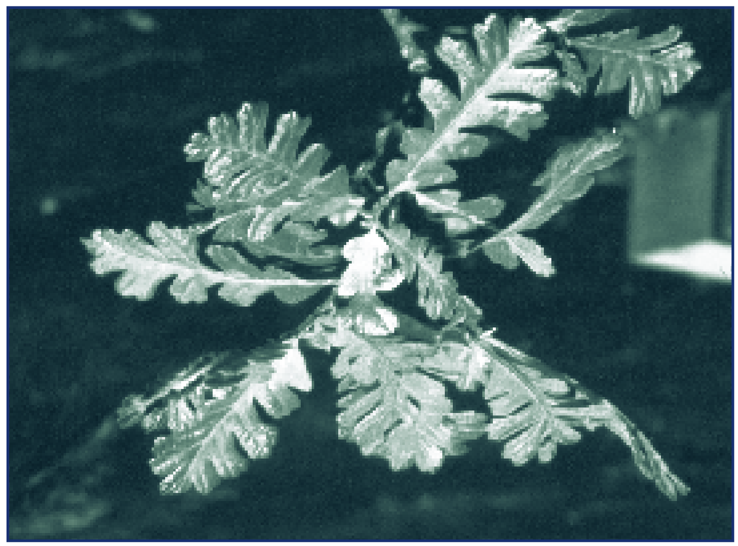


Figure 8b. After the reddish white oak leaves turned green, they became a favorite meal of nun moth larvae.

Reflection Section

- What species of trees do nun moth larvae prefer to eat?
- Do you think these findings are good news or bad news for people worried about the invasion of nun moths into the United States? Why?

Doing Research on Dangerous Insect Pests

Scientists at the U.S. Department of Agriculture (USDA) Forest Service use a secure laboratory to conduct research with insect pests such as the nun moth. The building is locked and has an alarm system. When scientists enter the building, they must change into special suits that they wear only inside the laboratory. The laboratory has no windows, and the exhaust system has very fine mesh through which no insect can escape.

Within the laboratory, scientists handle all insects inside safety cabinets, which further prevents escape. These cabinets also protect the scientists from the insects. After the scientists finish the experiments, they kill all insects and sterilize their remains before putting them into special bags. Later, specialists will burn these bags, passing the exhaust through filters. This special laboratory enables USDA Forest Service scientists to learn about insect pests without endangering people or the environment.

Discussion

If the nun moth were to invade the United States, it could cause a lot of problems for trees, forests, and people. The forests most likely to be affected are those in the Northwestern United States, the upper Midwestern United States, and the Northeastern United States. Many of the tree species preferred by nun moth larvae are *economically* important, and their damage or loss could affect people working in the forest industry. ■

Reflection Section

- Trees are important to people in forest industries, such as those using trees for wood products. Many industries that depend on forests might need the trees alive and healthy. What other forest-dependent industries could be affected by a nun moth invasion?
- In addition to economic problems, what other kind of problems might be created by the damage or loss of a large number of trees in a forest?
- What is one way we can protect trees in the United States from a possible nun moth invasion?

From: Keena, M.A. 2003. Survival and development of *Lymantria monacha* (Lepidoptera: Lymantriidae) on North American and introduced Eurasian tree species. *Journal of Economic Entomology.* 96(1): 43–52.

FACTivity

In this FACTivity, you will use the findings from this study to draw a conclusion about the possible danger from a nun moth invasion. You will answer the following question:

Could nun moths damage trees growing in your area?

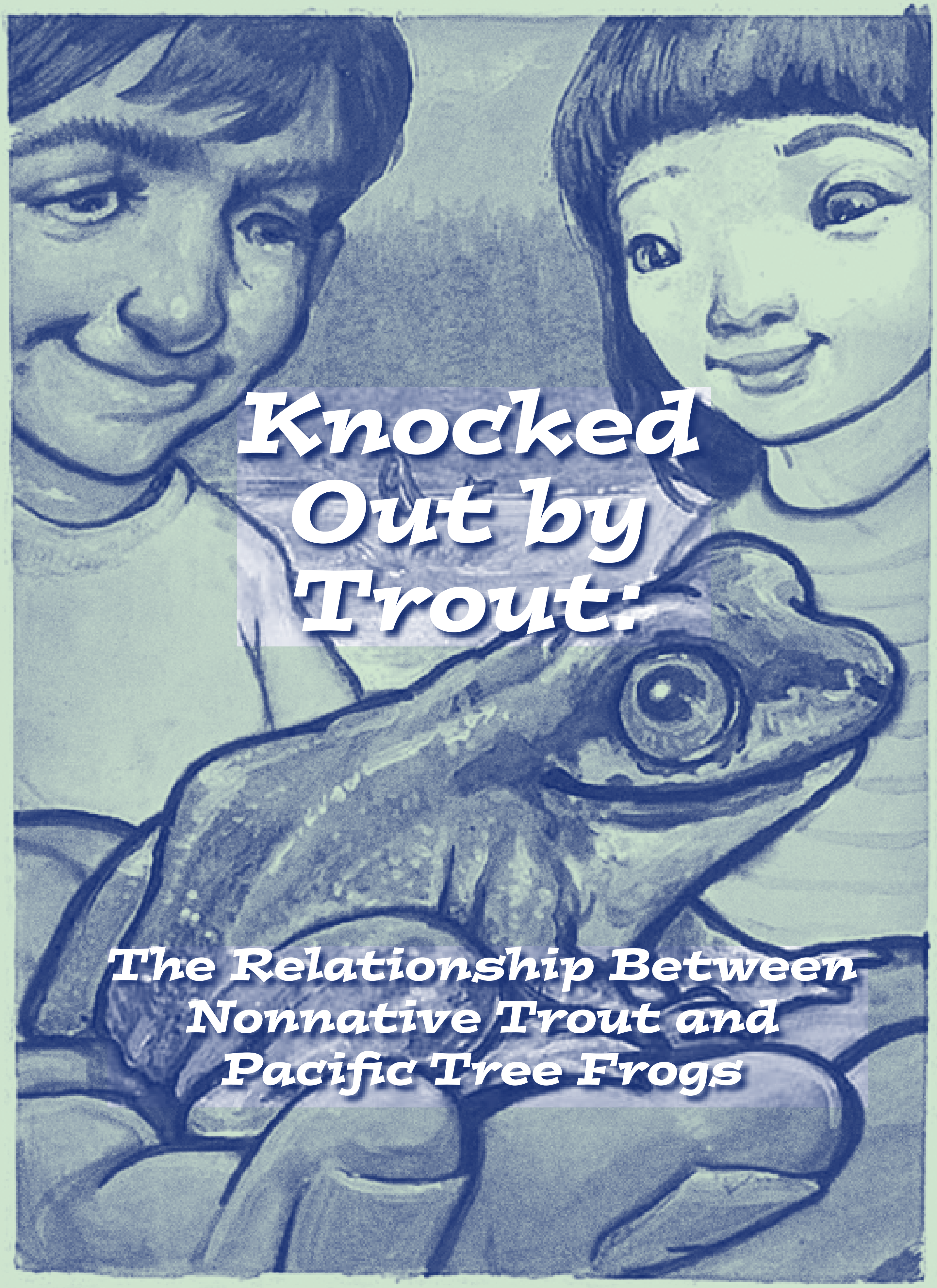
You will use the following method to answer this question:

1. Reread the "Findings" section of this article. Make a list of the types of trees nun moths like to eat.
2. Consult a guidebook to learn which trees can be found in your area. You can find books in the library or you can find this information on the Web. Usually, guidebooks will present the trees that grow in a large area, such as the Southeastern United States, or the Great Lakes area. Using the list you made in #1, identify which trees, if any, are growing in your area that the nun moth may want to eat. Do not forget that, according to this article, the nun moth likes all conifer trees.
3. Make a list of the trees growing in your area that a nun moth might like to eat.
4. Basing your conclusion on the list you made in #3, what would you conclude about the potential impact of the nun moth if it were to invade in your area?
5. Hold a class discussion about the potential impact of the nun moth in your area. Basing your thoughts on this discussion, do you think it is important to protect the United States from a possible nun moth invasion? Why or why not?

Activity extension:

Make an inventory of the trees growing in your schoolyard. If the nun moth were to invade in your schoolyard, what kind of effect would it have? How would your schoolyard look different?

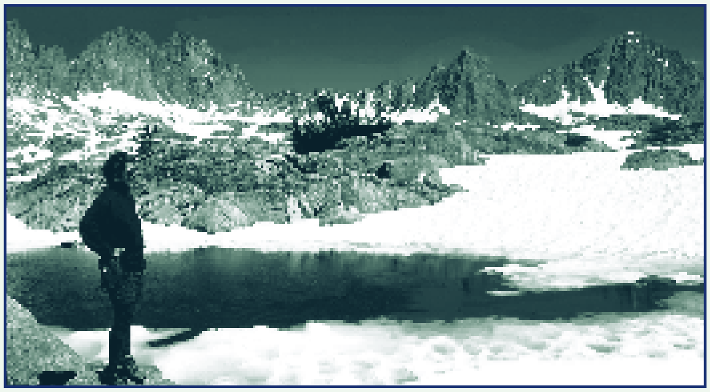
If you are a Project Learning Tree-trained educator, you may use PLT Pre K–8th Activity Guide #40, "Then and Now," and Activity Guide #3, "Peppermint Beetle," as additional activity resources. These activities teach what happens when a nonnative species is introduced and how insects use their sense of smell to find food and mates.



Knocked Out by Trout:

The Relationship Between Nonnative Trout and Pacific Tree Frogs

Meet the Scientists



Dr. Matthews: ▲ My favorite science experience was seeing the results of our research used in new *management* programs that led to increased amphibian *populations*.

Dr. Preisler: ▶ My favorite science experience is talking with scientists about a new *data* set!!!! For a statistician (**stat** uh **stish** un), happiness is a new data set! Statisticians are people who collect and arrange facts that are presented in numeric form. This photograph was taken in the Canadian Rockies.

Ms. Pope: ◀ My favorite science experience was learning about the different strategies animals use to survive in their natural environment. For example, mountain yellow-legged frogs survive the long, cold winter in the high Sierra Nevada mountains by finding pockets of water under the ice and breathing through their skin—for up to 9 months at a time.

Dr. Knapp: ▶ My favorite science experience is spending my summers in the mountains, counting frogs, catching bugs, and enjoying the most beautiful "office" in the world. This photograph was taken in the Sierra Nevada mountains, where this research was done.

Glossary:

management (**man** ij ment): Decisions and actions taken to achieve specific purposes.

population (päp yoo **la** shun): The whole number of individuals of the same type occupying an area.

data (**dat** uh): Facts or figures studied to make a conclusion.

biological (**bi** o **loj** uh kul): Having to do with plants and animals.

germination (jür mi **na** shun): The act of sprouting or beginning to grow.

nonnative (nän **na** tiv): Not naturally occurring in an area.

natural resource (**na** cha rôl **re** sôrs): A supply of something in nature that takes care of a human need, such as oil.

variable (**ver** e uh bul): Thing that can vary in number or amount.

native (**na** tiv): Naturally occurring in an area.

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

component (käm **po** nent): Any of the main parts of a whole.

fluctuation (**fluk** choo **a** shun): The act of continually changing or wavering.

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

publicly (**pub** lik le): By the government, on behalf of all citizens.

Federal (**fed** ür ul): A union of States having a central government. A reference to this central government.

metamorphosis (met uh **môr** fuh sis): The process of change in the form of some animals from an immature stage to an adult stage.

equation (e **kwa** zhun): A written statement that indicates the equality of two expressions.

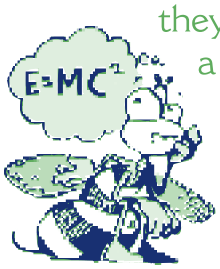
altitude (**al** tuh tud): Height; especially, the height above sea level.

Pronunciation Guide

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

Accented syllables are in **bold.**

Thinking About Science



Although all *biological* scientists collect data, they know the differences between a study done in a laboratory and one done in the natural world. One difference has to do with the concept of control. When scientists want to discover the effect something has had on something else, they try to control the things that can vary, except for the things that they want to observe. This is much easier to do in a laboratory than in the natural world. In a laboratory, for example, if a scientist wants to discover the best temperature for seed *germination*, she can control the amount of heat reaching different seeds and compare their growth.

In the natural world, this kind of control is difficult to create. In this study, the scientists found an unusual situation in the natural world that enabled them to study the effect of *nonnative* trout on a tree frog population. In this study, you will learn how past and current natural resource management action controlled one of the most important *variables*, providing an opportunity for the scientists to study the relationship between nonnative trout and tree frogs.

Thinking About the Environment

In a *native ecosystem*, the living *components* have adapted together over time. This usually results in a stable ecosystem, meaning that within certain limits of *fluctuation* and possible continuous but slow change over time, the components remain about the same. This stability is threatened when a natural or human-created disruption occurs within the ecosystem. A natural disruption is something such as a hurricane, flood, or volcano. Human-created disturbances include things such as cutting down all the trees, mining, and building roads and buildings.

Another way that humans have created disturbances within stable ecosystems is by introducing nonnative *species* into these native ecosystems. When a nonnative species is introduced into a stable native ecosystem, the relationships that have defined that ecosystem change. Often, the nonnative species has a negative effect on the native ecosystem. In this study, the scientists wanted to know how the population of Pacific tree frogs was affected by the introduction of nonnative trout into lakes that had historically had no fish living in them.

Figure 1. Location of the study sites in California.

Figure 2. A lake found within the Sierra Nevada mountains.

Introduction

This study was conducted in the Sierra Nevada mountains of California (**figure 1**). Many small and large lakes are found in these mountains (**figure 2**). Historically, no fish lived in the lakes and frogs were abundant in the areas around the lakes.

Much of the Sierra Nevada mountains is *publicly* owned. The mountain range is managed by two *Federal* Government agencies, the U.S. Department of Agriculture (USDA) Forest Service and the U.S. Department of the Interior National Park Service. You can read about the USDA Forest Service on page 81, by visiting the *Natural Inquirer* Web site (http://naturalinquirer.usda.gov), or by visiting http://fs.fed.us. The National Park Service manages the

Nation's national parks, including Yellowstone, Yosemite, and Great Smoky Mountains National Parks. You can learn more about the National Park Service by visiting http://nps.gov.

This study took place in an area the USDA Forest Service manages in the southern Sierra Nevada mountains. This area is called the John Muir Wilderness, or JMW. You can read about wilderness by visiting the *Natural Inquirer* Web site and checking out the Wilderness Benefits Edition, or by visiting http://wilderness.net. In the 1950s, the California Department of Fish and Game began stocking the fishless lakes with nonnative trout to provide fish for fishermen. This practice has continued to this day (**figure 3**).

The National Park Service manages an area immediately south of the JMW called the Kings Canyon National Park, or KCNP (**figure 4**). In 1977, the National Park Service began to phase out stocking the lakes within KCNP with nonnative trout. By 2000, fewer lakes in KCNP than in JMW had trout living in them. In the lakes with trout, scientists found almost half the number of trout living in KCNP than in JMW.

Figure 4. The location of JMW and KCNP in the Sierra Nevada mountains.

Figure 3. Stocking the lakes with fish dropped from a plane.

In earlier studies, scientists found a relationship between nonnative trout populations and a particular frog population. The scientists found that when nonnative trout are present, the population of mountain yellow-legged frogs begins to decline (**figure 5**). This change occurs because trout eat frog eggs, which the frogs lay in the water.

The scientists were interested in discovering whether the Pacific tree frog population might also be affected by the presence of nonnative trout, similar to the way these trout had affected the mountain yellow-legged frog population. The scientists wanted to compare the populations of Pacific tree frogs with the populations of nonnative trout in JMW and KCNP (**figure 6**).

Figure 5. Mountain yellow-legged frog.

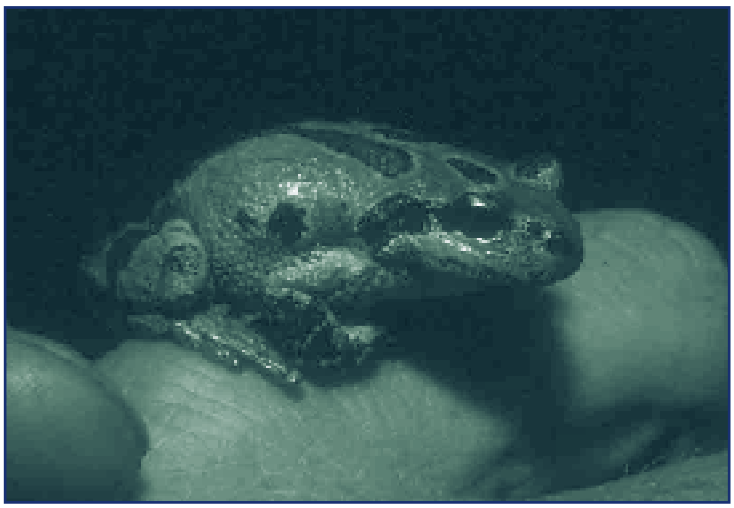
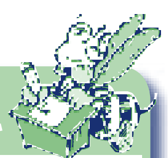


Figure 6. Pacific tree frog.



Reflection Section

- Basing your response on the information presented in the "Introduction," state in your own words what the scientists expected to find out about the population of Pacific tree frogs in JMW compared with KCNP. Then, give the reason for your statement.
- You read about the concept of experimental control in "Thinking About Science." (If you need a reminder, reread that section.) Which variable did natural resource management control, enabling the scientists to study the effect of nonnative trout on Pacific tree frog populations?

Method

In a laboratory, scientists can control most of the variables. When a change occurs or a difference is found, the scientists can be fairly sure what caused the change. In this study, the lakes in JMW and KCNP were almost identical. They had been historically fishless and are located very close to each other. The ecosystems of these lakes and the areas surrounding these lakes are very similar.

One difference is that the areas are managed by different Federal agencies. Before 1977, both agencies allowed the California Department of Fish and Game to stock the lakes with nonnative trout. Since 1977, the lakes in KCNP have not been stocked with nonnative trout and the lakes in JMW have continued to be stocked. You can see that this difference in management would be a good situation for scientists wanting to discover whether the number of nonnative trout can make a difference in the ecosystem of an area.

The scientists studied 669 lakes in JMW and 1,059 lakes in KCNP. The scientists walked the shoreline of each lake, recording the number of Pacific tree frogs that they saw (**figure 7**). The scientists recorded the existence of adult frogs, frog larvae, and frogs that had recently undergone *metamorphosis*

Figure 7. Sometimes it was difficult for the scientists to walk the shoreline and record the number of tree frogs that they saw.

(**figure 8**). The scientists also recorded the presence or absence of nonnative trout in each lake.

The scientists used an *equation* to learn the relationship between the presence of nonnative trout and the population of Pacific tree frogs. They entered the equation and their data into a computer. For each lake in JMW and KCNP, they entered the number of Pacific tree frogs found, as well as whether nonnative trout were present. The computer program was designed to tell them whether the tree frog population was about equal in each of the lakes, after considering the lake's size, *altitude*, and other considerations. The scientists did not include the presence of nonnative trout in the first calculations.

If the population of tree frogs was about equal after considering things such as size and altitude, the scientists could conclude that the presence of nonnative trout does not make a difference in the population of Pacific tree frogs. If the population of tree frogs was not equal, the scientists looked at whether nonnative trout had been found in the lakes where the tree frog populations were not equal.

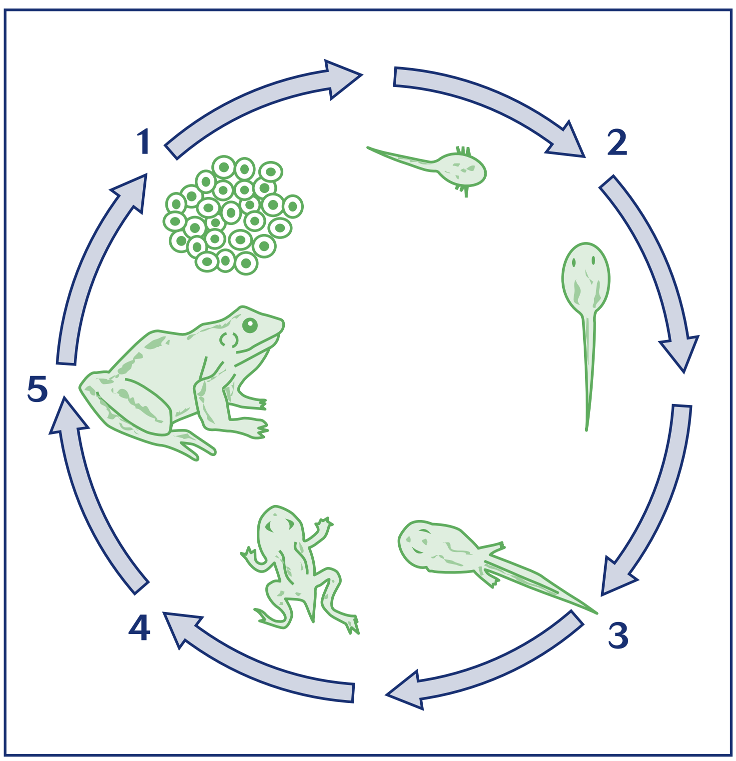


Figure 8. Frog metamorphosis.

Reflection Section

- Why did the scientists not include the presence of nonnative trout in their first calculations?
- Basing your thoughts on previous scientific findings about the presence of nonnative trout and the population of mountain yellow-legged frogs, do you think the scientists found a difference in the populations of Pacific tree frogs in JMW and KCNP? Why or why not?

Findings

The scientists found that 7 percent of lakes in JMW contained Pacific tree frogs, compared with 27 percent of lakes in KCNP. The percentage of the total water surface area containing tree frogs was almost 20 times higher in KCNP than in JMW. The lakes having the fewest nonnative trout were in the southern end of JMW and the northern and central sections of KCNP. The highest percentage of nonnative trout was found in lakes in the northern end of JMW. The scientists found this area to have the lowest percentage of lakes with tree frog populations.

The scientists considered all of the conditions that might affect the number of tree frogs present in a lake, such as its size and depth, and how much silt was in the lake. After taking these conditions into account, the scientists found that lakes with no trout were almost four times more likely to have tree frogs than lakes with trout.

Reflection Section

- Why do you think the scientists considered things such as the size and depth of the lakes and how much silt was in them?
- After reading the "Findings" section above, would you conclude that the presence of nonnative trout had an effect on the number of tree frogs in a lake? Why or why not?

Discussion

Previous research had shown a relationship between the presence of nonnative trout and a large reduction in other frog populations in the Sierra Nevada mountains. Because Pacific tree frogs are more widespread than mountain yellow-legged frogs, the scientists do not believe that nonnative trout will threaten the population of Pacific tree frogs. They do, however, believe that in high mountain areas where nonnative trout are present, the tree frog population will be reduced.

The scientists have also studied how the reduction in the tree frog population might affect the population of garter snakes in the high Sierras. Pacific tree frogs and other amphibians are a main source of food for these garter snakes. The scientists found that the continued stocking of high mountain lakes in the Sierra Nevada mountains with nonnative trout impacted garter snake populations as well. ■

Reflection Section

- Garter snakes are a source of food for skunks found in the Sierra Nevada mountains. Basing your thoughts on what you know about food webs and the results of this research, do you think it is likely or unlikely that continued stocking of nonnative trout could affect the population of skunks in the Sierra Nevada mountains? Why?

From: Matthews, K.R.; Pope, K.L.; Preisler, H.K.; Knapp, R.A. 2001. Effects of nonnative trout on Pacific tree frogs (*Hyla regilla*) in the Sierra Nevada. *Copeia*. (4): 1130–1137.

FACTivity

In this FACTivity, you will explore whether it is in society's interest to stock the Sierra Nevada lakes with fish or to stop stocking the lakes. You will use the following method:

1. Divide the class into five groups. Group 1 will consist of three students. The remaining students will be divided into four equal-sized groups. Two of those groups will be arguing in favor of continued stocking of the lakes with trout. The remaining two groups will be arguing in favor of stopping the stocking of fish.

2. Using the Internet and other sources, research the topic of stocking high mountain lakes with trout. Use search words such as:

   Sierra Nevada fish stocking
   Nonnative trout
   Sierra Nevada fishing
   Mountain yellow-legged frog

3. Prepare a list of reasons for and against fish stocking in the Sierra Nevada lakes. Depending on which side of the argument you will take, you will want to highlight your position. It is important to understand the other position as well, so do research on both sides of the argument. You may want to prepare visual aids to support your position. Each group should meet to decide on its approach to the debate. You may appoint one or two spokespersons to represent the group. The group of three students should be excused from doing this research.

4. The group of three students will function as a citizen advisory committee to the governor. While the other students are doing their research, this group will decide how they will make their decision about stocking. Will they vote? Will they insist on unanimous agreement? After listening to the arguments for and against stocking, the advisory committee will meet privately and discuss the issue. Then, the three students will make a decision about stocking and explain to the class why they made their decision.

5. Following the advisory committee's decision, hold a class discussion to review the entire exercise. How did the four groups feel about the advisory committee's decision? Did they feel that their position was fairly considered? Do all groups feel that the best interests of society have been served? Why or why not?

If you are a Project Learning Tree-trained educator, you may use PLT Pre K–8th Activity Guide #33, "Forest Consequences" or Pre K-8 Activity Guide #45, "Web of Life," as additional activity resources. These activities teach how different types of land management affect ecosystems and introduce how nonnative species change the web of life.

Shoot! Foiled Again!

Using Chemicals To Discourage the Pine Shoot Beetle

Meet the Scientists

Dr. Poland: ◂ My favorite research experience was working in China. The experience was so different from the United States. Many local farmers and children came to help us. The area had very poor farmland with trees planted to protect the area from wind. The children were so eager to help us. They collected beetles for us and stored them in wire bicycle baskets.

Dr. De Groot: ▸ My favorite science experience is working outdoors to set up and run my experiments so that I can discover new facts about trees and forest insects.

Dr. Burke: ◂ In the 1980s, I created a special chemical in a chemistry lab. This was a powerful *pheromone* that is a very strong attractant for a particular *species* of beetle. This beetle causes severe damage to logs that will be cut into lumber. Tiny amounts of the pheromone that I made were formulated into lures, and the lures were placed in funnel traps similar to the one you see in this photo. One month later, we inspected the traps, which we had placed at lumber mills. Many traps contained more than 25,000 beetles and virtually no other insects. At one mill, we caught over 12 million beetles in 1 year. Here was science in action! It was truly amazing that the chemical, made in the sterile environment of a laboratory, could cause such a strong effect in the field. This photo was taken in China, where I was studying the pine shoot beetle. I am the person on the left.

◂ **Dr. Wakarchuk:** One of my most exciting moments as a chemist occurred when we took the first pheromone lures into the field during a beetle flight. It had taken several months of work in the laboratory to create the beetle pheromones out of chemicals. When we brought the lures out, the tiny beetles were landing on our clothing and bouncing off our heads. Chemistry really came alive when I realized that our clothing had small amounts of pheromone on it, and that the beetles were strongly attracted to this small amount of pheromone. It was very satisfying to know that all the chemistry work was done right and that the beetles weren't able to distinguish people contaminated with *synthetic* pheromone from their normal host (a freshly killed tree infested with beetles). In this photo, I am holding a multifunnel trap that is often used to trap bark beetles. A multifunnel trap was used in this research, as you will learn.

Dr. Nott: ▸ My favorite science experience had to be meeting Dr. Roberta Bondar who worked at the Great Lakes Forestry Centre when she was a student attending university. Dr. Roberta Bondar was the second Canadian and the first Canadian woman to go into space aboard the space shuttle *Discovery*. Shortly after her historic flight, she visited our Centre to give a firsthand account of her experience. It was awesome!! Here is a photo of me setting up one of the traps for the pine shoot beetle. The pine shoot beetle emerges very early in the spring so our traps had to be installed while snow was still covering the ground (and me).

Dr. Haack: ◂ My favorite science experience happened in ancient history (1975–1978) when I was working as a forester in the Peace Corps in Guatemala in Central America. There was a massive outbreak of pine-infesting bark beetles that killed millions of pine trees in Guatemala. It was that experience that made me want to study forest insects, and so after returning to the United States in 1978, I went to graduate school at the University of Wisconsin to study forest *entomology*.

Glossary:

pheromone (**fair** uh mon): A chemical given off by certain animals to attract mates, mark trails, etc.

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

synthetic (sin **theh** tik): Made by putting together chemicals rather than using natural products.

entomology (**en** to **mul** o je): The study of insects.

disperse (di **spürs**): To scatter or spread in all directions.

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

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

native (**na**t iv): Naturally occurring in an area.

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

resource (**re** sôrs): Something that takes care of a need.

phloem (**flo** em): Tissue that transports nutrients from the leaves to the rest of the plant.

larva (**lär** vuh): Wormlike feeding form that hatches from the egg of many insects.

pupa (**pu** pa): Intermediate stage of insect growth between larva and adult. Pupae (**pu** pe) is the plural.

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

population (päp yoo **la** shun): The whole number of individuals of the same type occupying an area.

broadleaf (**brôd** lef): Flat broad leaves.

control (kän **trol**): Something used for comparison when checking the results of an experiment.

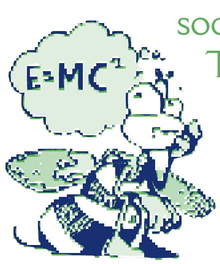
average (**av** rij): The usual kind or amount. The number obtained by dividing the sum of two or more quantities by the number of quantities added.

Pronunciation Guide

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

Accented syllables are in **bold.**

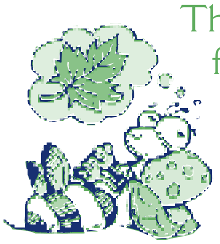
Thinking About Science



Science is a process of discovery that helps society by answering questions. The questions involve a specific problem that, when solved, will improve something that society values. Let's take this research as an example. Society places a value on healthy pine trees for a number of reasons. In this study, the scientists studied pine trees that people were going to use during the winter holiday season to decorate their homes.

When an insect attacks and damages or kills a large number of holiday pine trees, society considers this a problem. Fewer holiday trees might mean higher prices for the people who want to buy them. Trees damaged by insects might also be less attractive. The problem can be stated as a question, such as "What can be done to prevent an insect from attacking pine trees?" Scientists can ask many different questions that stem from the same problem. In your own words, develop another question that scientists could ask, based on the problem of insects attacking pine trees.

Thinking About the Environment



You know that plants have fragrances. Think about the fragrances of flowers and newly mown grass. Scientists call these fragrances volatiles (**vol** uh tīlz). They are released when a chemical inside the plant is exposed to air. When exposed to air, the chemical evaporates, which causes it to be *dispersed* in the air. Many plants have volatiles that humans cannot smell. Insects, however, can smell many of these volatiles. Most insects smell volatiles using special cells on the surface of their antennae. The volatile attracts the insects to the plant. They can then use the plant for food, as a place to lay their eggs, or as *habitat*. Name one example of an insect that uses its antennae to find food.

In this research, the scientists were interested in finding out how to prevent a particular insect from being attracted to pine trees. In this case, when the insect smells the volatile and finds the pine tree, its use of the tree damages the tree and can even kill it.

Introduction

In a healthy *ecosystem*, plants and animals have adapted together to keep the whole system healthy. Healthy ecosystems are usually made up of *native* plants and animals. When a nonnative plant or animal invades a native ecosystem, the ecosystem can be damaged. A nonnative plant or animal, called an *invasive* species, causes damage by reproducing so much that it uses too many native *resources*.

The pine shoot beetle (**figure 1**) is an invasive species in the Great Lakes region of the United States (**figure 2**). The pine shoot beetle was brought to the United States from Europe, Asia, and northern Africa. This beetle damages or kills pine trees by using the trees for reproduction and feeding. Female adult beetles bore a hole into the bark of a pine tree along the roots, where they breed with a single male. The females then bore into the *phloem* of the tree, where they lay their eggs (**figure 3**). When each egg hatches into a *larva*, the larva further tunnels in the phloem, where it becomes a *pupa*. When the pupa becomes

Figure 1. Pine shoot beetle.

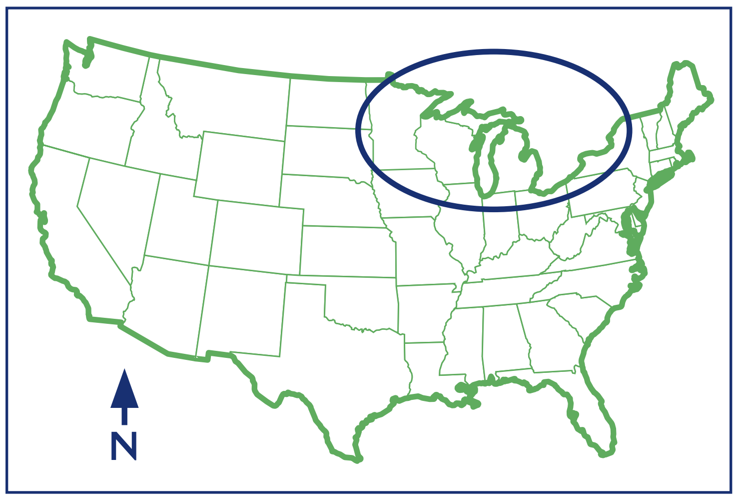


Figure 2. The Great Lakes region of the United States.

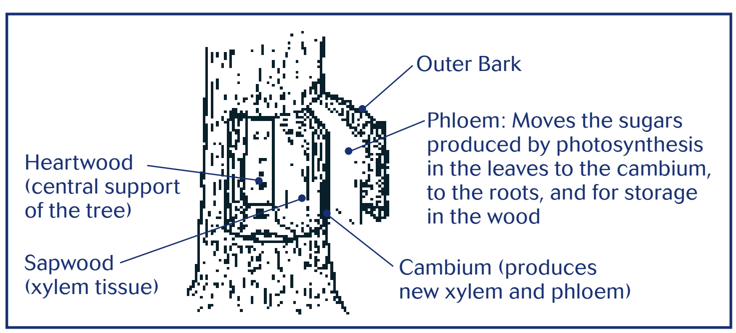


Figure 3. The phloem of a tree.

an adult, it emerges from the tree. These young adult beetles then feed on the healthy shoots of the pine tree (**figure 4**). As you can imagine, when many beetles reproduce in one tree, the tree can be damaged or killed.

As you read in "Thinking About the Environment," insects are attracted to plants such as trees by smelling their volatiles. Think about what might happen if too many pine shoot beetles are attracted to a particular pine tree. Soon, the tree would have too many beetles, and the additional beetles' needs for breeding and eating could not be met. Something interesting occurs to keep this situation from happening. The beetles *emit* a special type of pheromone that other beetles detect. This chemical, called a verbenone (**vür** buh non), tells other beetles that the area is overcrowded. As more beetles attack a tree, the rising amount of verbenone discourages other beetles from using that tree.

Unfortunately, verbenone does not discourage other beetles until so many beetles are present that the tree is damaged or killed. The rising amount of verbenone protects the beetle *population*, but it does not protect the tree. The scientists in this study wanted to find out if chemicals such as verbenone could be used to keep pine shoot beetles from attacking trees in the first place. They also wanted to know if other volatiles, such as those from *broadleaf* trees, would discourage pine shoot beetles from attacking pine trees. The scientists thought the use of broadleaf volatiles might fool the beetles into thinking the pine trees were not really pine trees, but broadleaf trees.

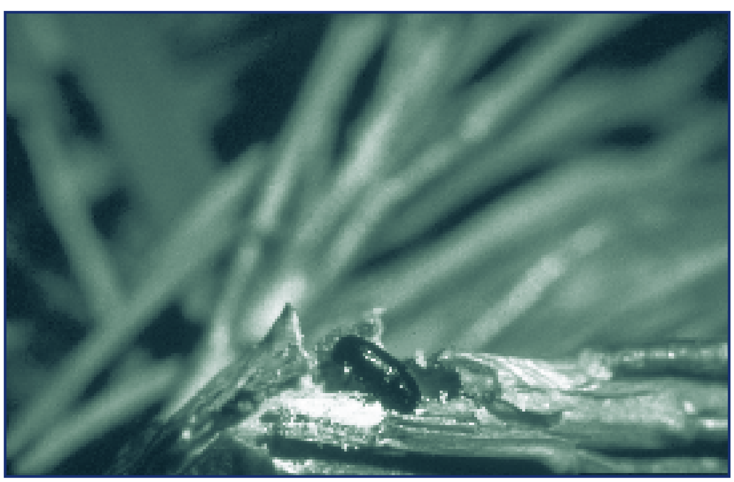


Figure 4. A young pine shoot beetle feeding on a pine shoot.

Photo courtesy of Steve Passoa, USDA Animal and Plant Health Inspection Service, http://www.forestryimages.org.

Reflection Section

- Explain in your own words how verbenone protects the beetle population but not the pine trees.
- In your own words, ask one question the scientists wanted to answer.

Method

The scientists conducted two identical experiments. One was done in southern Ontario, Canada, and the other in southern Michigan (**figure 5**). They conducted the

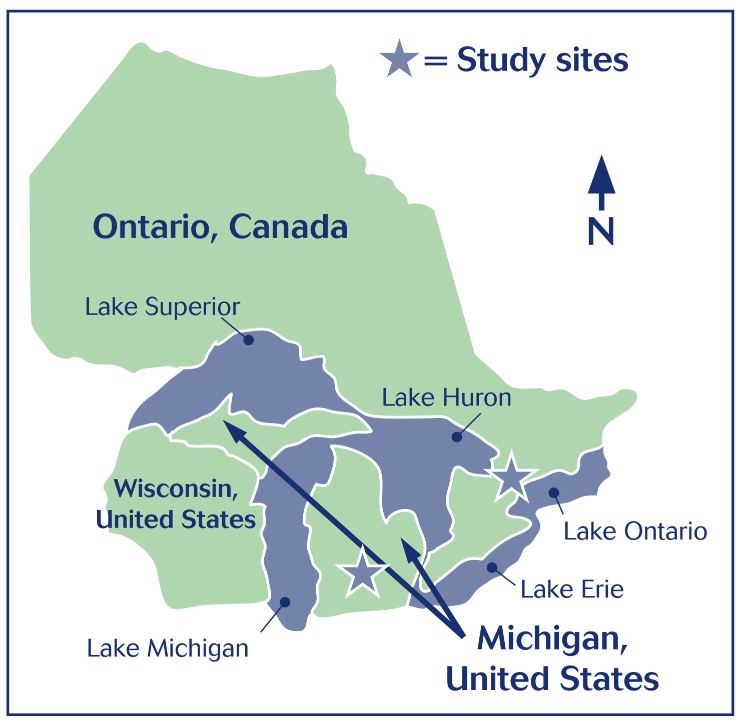


Figure 5. The study sites were in southern Ontario and southern Michigan.

experiments in holiday tree plantations of Scots pine. In these plantations, trees are planted in rows and pruned into the popular cone shape. You can see some of the trees in Dr. Nott's photo at the beginning of this article. The scientists used traps to catch the pine shoot beetles. (See the scientists' photos at the beginning of this article.) They baited all but one trap with Scots pine volatiles and also included other chemicals on some traps to discourage the beetles (**figure 6**).

Trap number	Chemicals in each trap	Purpose of trap
Traps 1–3	No chemicals	*Control*
Traps 4–6	Scots pine volatiles. The Scots pine volatiles should attract the beetles.	To attract beetles. This is a test to find out whether the Scots pine volatiles attract the beetles.
Traps 7–9	Scots pine volatiles plus broadleaf volatiles. The Scots pine volatiles should attract the beetles, and the broadleaf volatiles should discourage the beetles.	To attract and discourage beetles. This is a test to find out whether the broadleaf volatiles discourage beetles.
Traps 10–12	Scots pine volatiles plus broadleaf volatiles plus verbenone. The addition of verbenone, when compared with traps 7–9, will tell the scientists whether verbenone further detracts beetles.	To attract and discourage beetles. This is a test to find out whether the verbenone adds to the broadleaf volatiles.

Figure 6. Traps were set containing a combination of volatiles and other chemicals.

The scientists repeated the placement of the 12 traps in 10 separate areas of each of the two pine plantations.

Number Crunches

- How many total traps were set on each pine plantation? How many traps were set overall?

The scientists collected the beetles from the traps twice each week for almost 6 weeks. They identified the sex of each beetle and counted the number of beetles according to its sex. The scientists then compared the number of beetles collected in each trap.

Reflection Section

- Explain in your own words what the scientists might learn from each of the four sets of traps (from figure 6).
- Why do you think the scientists repeated the experiment 10 times on each plantation?

Findings

The results of the experiment are shown in **table 1**.

As you can see, there were differences in the average number of beetles captured in Michigan and in Ontario. The pattern for each set of traps, however, is similar. In both Michigan and Ontario, the number of beetles being trapped was much higher when the Scots pine volatile was used than when it was not used. (Compare the first and second set of traps for each place.) Regardless of the chemicals used, the average number of beetles trapped was much lower than when no chemicals except the volatiles were used. (Compare the second set of traps in each place with the third and fourth sets.) When

Traps	Average number of male pine shoot beetles captured	Average number of female pine shoot beetles captured
Michigan: No chemicals	1	1
Michigan: Scots pine volatiles	77	91
Michigan: Scots pine volatiles plus broadleaf volatiles	25	24
Michigan: Scots pine volatiles plus broadleaf volatiles plus verbenone	21	18
Ontario: No chemicals	0	0
Ontario: Scots pine volatiles	22	21
Ontario: Scots pine volatiles plus broadleaf volatiles	7	8
Ontario: Scots pine volatiles plus broadleaf volatiles plus verbenone	5	6

Table 1. The *average* number of beetles caught in each set of traps.

the scientists compared the third and fourth set of traps, they found that the addition of verbenone made only a small difference in the average number of beetles trapped.

Reflection Section

- Look at table 1. Would you say the Scots pine volatiles attracted pine shoot beetles to the traps? Why or why not?
- If you were one of the scientists, what would you tell people who manage holiday tree plantations about the use of chemicals to discourage pine shoot beetle damage?

Discussion

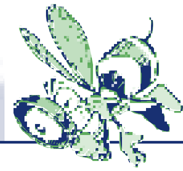
The scientists found that pine shoot beetles can be discouraged from entering a trap that contains a combination of broadleaf volatiles and verbenone. The scientists suggest that the number of pine shoot beetle attacks on trees can be reduced by placing these chemical traps around the edges of holiday pine tree plantations and throughout the plantations. ■

Reflection Section

- Why do you think the broadleaf volatiles discourage the pine shoot beetle from attack?
- Do you think these findings are important to people who grow holiday pine trees for sale during the winter holiday season? Why or why not?

From: Poland, T.M.; De Groot, P.; Burke, S.; Wakarchuk, D.; Haack, R.A.; Nott, R. 2004. Semiochemical disruption of the pine shoot beetle, *Tomicus piniperda* (Coleoptera: Scolytidae). *Environmental Entomology.* 33(2).

FACTivity



A beetle's sense of smell is tremendous. The beetle uses smell to attract him to something or repel him from something. In this FACTivity, we want you to think about what scents you really like and what scents you really do not like. First, make copies of the Scent Chart, then take about 5 minutes to list some scents that you like and some scents that you do not like. Think about why you like the scent or why you do not like the scent. Does the scent remind you of something? Or does it make you hungry? Or does it make you feel sick? After 5 minutes, share your likes and dislikes with the class. See if there are any scents that the whole class likes or the whole class dislikes. If there are such scents, why do you think the whole class feels this way about them? Also discuss why a sense of smell is important for humans and compare the use of this sense of smell for humans with the beetle's use of smell. Are there similarities? Differences?

Scent Chart

Scent	Like	Dislike	Why?
Freshly cut grass	✓		Reminds me of springtime and gardening

If you are a Project Learning Tree-trained educator, you may use PLT Pre K–8th Activity Guide #3, "Peppermint Beetles," Activity Guide #22, "Trees As Habitats," and Activity Guide #77, "Trees In Trouble," as additional activity resources. These activities show how insects use scent for communication, how insects use different parts of trees, and how trees express stress.

Tag, You're It!

Using Harmonic Radar To Track the Flight of Beetles

Meet the Scientist

Dr. Williams: ▼ One of my most interesting science experiences was placing tags on Asian long-horned beetles. Because the beetles eat through wood in their early life stages, they have very strong jaws. It takes two people to tie a tag on them, and you have to be very careful because when they bite they draw blood! In this photograph, Mr. Liu is helping me place a tag on a beetle.

Glossary:

entomologist (**en** to **mul** o jist): A scientist who studies insects.

native (**na** tiv): Naturally occurring in an area.

nonnative (nän **na** tiv): Not naturally occurring in an area.

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

import (**im** port): To bring goods into one country from another.

larva (**lär** vuh): Wormlike feeding form that hatches from the egg of many insects.

pupa (**pyü** puh): Intermediate stage of insect growth between larva and adult.

manager (**ma** ni jür): A skilled person who directs or manages something.

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

antenna (an **ten** uh): A set of wires used to send and receive signals.

speculate (**spek** u lat): To think about or make guesses.

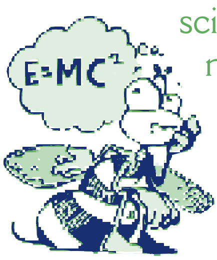
habitat (**hab** uh tat): Environment where a plant or animal naturally grows and lives.

Pronunciation Guide

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

Accented syllables are in **bold.**

Thinking About Science



Technology is giving environmental scientists new ways to study the natural world. For *entomologists*, technology has enabled them to track the movements of flying insects. To track the movement of animals larger than insects, scientists use a transmitter placed on the animal that sends a signal to a receiver. For small flying insects, these transmitters are too heavy because they require a battery.

Entomologists are now using technology called harmonic radar. The scientist attaches a small metal tag to an insect. The tag reflects an electronic signal coming from a hand-held transceiver. (Transceiver is a combination of the words "transmitter" and "receiver" because the transmitter also receives the signal that is reflected off the tag.) This signal enables the scientist to locate the tag and, in this case, the insect to which the tag is attached. The reflected signal is the same for all tags, so the scientists must also mark the insects so that they can identify individuals. In this study, the scientist followed the flight of a beetle *native* to China.

Thinking About the Environment

All animals move. Sometimes movement results in animals placing more distance between themselves and other animals. When animal movement results in more distance between individual animals, scientists call this dispersal (dis **pür** sul). For insects, dispersal is often the result of short flights, usually made when an insect is searching for food or new breeding sites for laying eggs. When the insect is a *nonnative* pest with eating or breeding behavior that can damage or kill plants, it is important to understand its dispersal.

In this study, the scientist traveled to China to study the dispersal of an insect pest that had recently been found in the United States. By observing the insect's dispersal in its native *habitat*, the scientist was able to better understand how its dispersal might occur in the United States.

Introduction

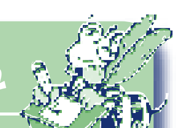
The Asian long-horned beetle is an insect pest that was discovered in New York in 1996 and Chicago in 1998 (**figure 1**). It arrived in the United States on wood packing material that was being used to *import* goods from Asia. The beetle lays its eggs under the bark of trees. As the *larva* and *pupa* develop, they use the tree for food. These activities can kill the trees. Fortunately, the beetle was quickly identified and destroyed in New York and Chicago.

Unfortunately, thousands of trees had to be removed from New York and Chicago to destroy the Asian long-horned beetle. Scientists estimate that if the Asian long-horned beetle had been allowed to disperse, it might have cost the United States more than $600 billion. The United States could have lost millions of trees if the Asian long-horned beetle had dispersed across the country.

Figure 1. Asian long-horned beetle. This beetle has been painted with a number so it can be identified for this study. What is this beetle's number?

One key to destroying the Asian long-horned beetle is to remove the trees. After removal, the trees are cut into small chips and then burned. To be successful in removing the trees to destroy the beetles, forest *managers* must know about how far the insect moves every day. As you read in "Thinking About the Environment," flying insects fly in search of food or places to lay their eggs. The scientist in this study wanted to know about how far an Asian long-horned beetle can fly every day.

Reflection Section



- State in your own words the question the scientist wanted to answer through this research.
- If the Asian long-horned beetle were found again in the United States, how would forest managers use the scientist's information to help them destroy the insects?
- If a different insect pest were found in the United States, should forest managers use this information about the Asian long-horned beetle to tell them how far the insect might fly? Explain.

Method

The scientist traveled to China to study the Asian long-horned beetle. The area studied was located at latitude 39°23´ N. longitude 117°00´ E. The study site was about 80 kilometers southeast of Beijing (**figure 2**).

Number Crunches

- How many miles southeast of Beijing was the study site? Multiply 80 by .621 to find out.

The scientist conducted his study on a row of existing trees. He found a row of 200 willow trees that were growing along a four-lane highway. Agricultural fields were on both sides of the highway. The trees covered a straight-line area of almost 1,000 meters. The *average* height of the trees was 5.1 meters.

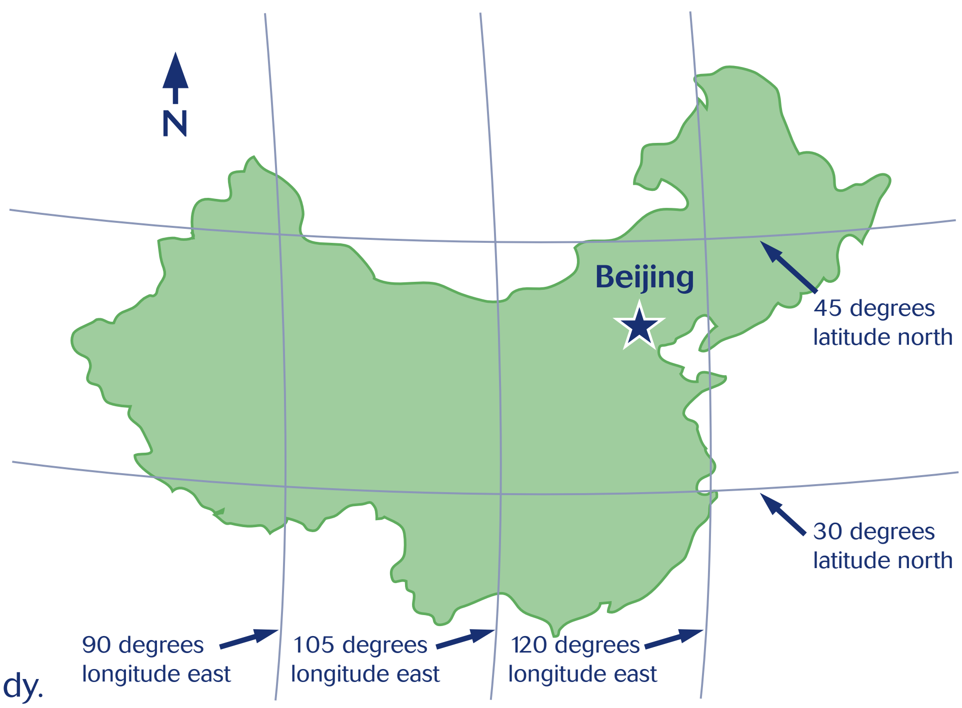
Number Crunches

- To calculate how many feet 1,000 meters are equal to, multiply 1,000 by 3.280.
- What was the average tree height in feet?

The scientist planned to release Asian long-horned beetles onto the trees and then track their dispersal over 16 days. Before releasing the beetles, the scientist placed a metal tag on each one (**figure 3**). The tag was tied onto the beetle with dental floss. The tag included

Figure 3. Asian long-horned beetle released on a tree. Can you see the two wires that served as antennas? Is this the same beetle or a different beetle than the one shown in figure 1? How do you know?

Figure 2. ▸ Map of China with lines of latitude and longitude. Latitude and longitude are imaginary lines drawn over the surface of Earth so places can be precisely located. Latitude lines mark the distance north and south from the equator. Longitude lines mark the distance east and west from the prime meridian, an imaginary line running through Europe and western Africa. Examine this map to see if you can locate the approximate location of this study.



two small wires that served as *antennas*. Each beetle was also marked with a number so it could be identified. If you have not done so, read "Thinking About Science" above. This section explains that the scientist used a technology called harmonic radar to track the dispersal of the beetles.

The scientist placed between 7 and 12 beetles on the willow tree trunks every day for the first 5 days of the study. He released 55 beetles overall. Almost equal numbers of male and female beetles were released. The scientist used different willow trees each day for releasing the beetles. He recorded each beetle's number and on which tree it was released.

The scientist searched for the beetles from the 2nd day of the experiment through the last day. He used the transceiver to search for beetles in the tree canopy (**figures 4 and 5**). He also used binoculars and the naked eye to search for beetles (**figure 6**). When the scientist found a beetle, he recorded its number, sex, and location.

To determine how far a beetle traveled, the scientist summed the straight-line distance measured each time each beetle was identified **(figure 7**). Remember that the scientist also recorded the sex of each beetle so he could compare the movement of males and females.

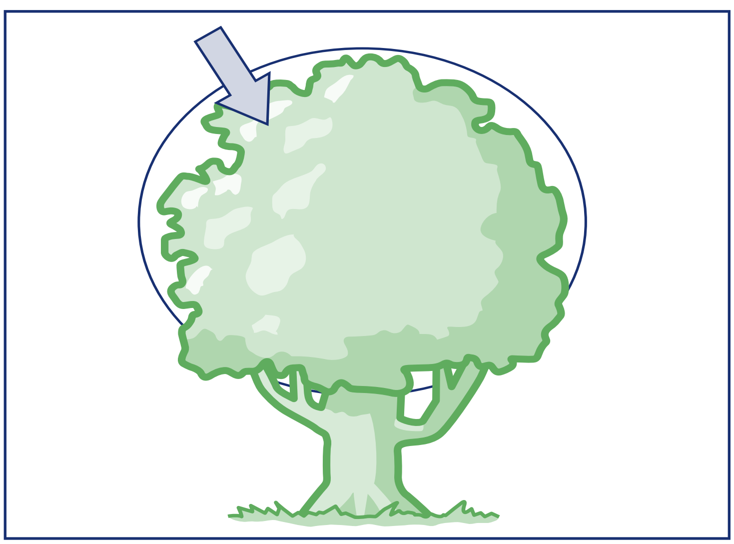


Figure 4. Tree canopy.

Reflection Section

- Do you think the scientist should have done this study in the United States? Why or why not?
- What would have happened if the scientist had forgotten to paint a number on each beetle?

Figure 5. Scientist using the transceiver.

Figure 6. Scientists searching for beetles using binoculars and the transceiver.

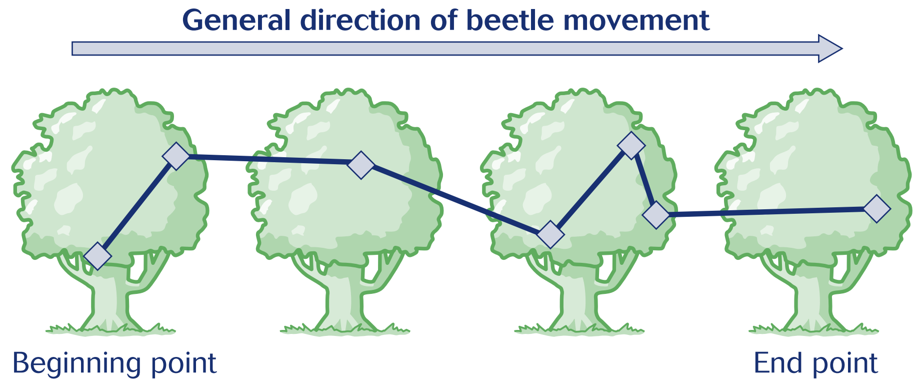


Figure 7. Example of how the total distance traveled was recorded. The total distance traveled by one beetle was the sum of the distances between the grey diamonds. The diamonds represent the place where the beetle was found each day. As you can see, the beetles moved both within and between trees.

Findings

Male beetles traveled more than six times the distance of female beetles and moved twice as fast. Most females did not move from the tree on which they were released. Overall, the beetles that moved went equally in both directions (east or west) from their place of release. After they began moving in a direction, most beetles continued moving in the same direction. Of those that moved, the average distance traveled over the 16 days was about 22 meters (**table 1**).

Number Crunches

- Calculate the number of feet the beetles moved by multiplying the distance in meters by 3.280.

	Gender	
	Male	Female
Average number of meters traveled per day	3.7	1.9

Table 1. Average number of meters traveled per day by male and female beetles.

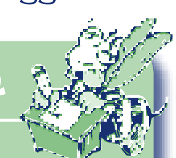
The findings in this study are different from what other scientists had found about the dispersal of Asian long-horned beetles. In this study, the beetles did not travel as far as the distance other scientists had found. The scientist in this study *speculated* on the reasons for the different distances. First, the daily air temperature during this study was extremely high compared with other studies. The daily high temperature averaged 33.6 degrees Celsius.

Number Crunches

- To calculate the temperature in Fahrenheit, multiply the temperature by 9/5 then add 32.

In earlier research, other scientists found that females traveled farther than males. In this study, a high percentage of female beetles did not travel at all. The scientist speculated that the female beetles in this study did not travel because they were sexually mature and ready to lay their eggs. They probably found the willow tree that they were released on was a suitable habitat for laying their eggs.

Reflection Section



- Why do you think the beetles moved only either east or west and did not move north or south? (Hint: Reread the second paragraph in "Method" above.)
- Do you think this study completely answers the question of how far Asian long-horned beetles travel? Why or why not?

Discussion

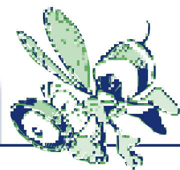
The scientist thinks more studies are needed to better understand the dispersal of Asian long-horned beetles. Although he found that most females did not move from the tree that they were released on, one of the females traveled more than 30 meters in a little more than a week's time. If the female beetles are not ready to lay their eggs as they probably were in this study, they may travel longer distances. As a dangerous pest of American trees, even just a few females traveling 30 meters in a week's time could pose a threat. ■

Reflection Section

- In what way could a few female beetles traveling 30 meters pose a threat to American trees?
- From the results of this study, what might you conclude about the dispersal of Asian long-horned beetles?

From Williams, D.W.; Li, G.; Gao, R. 2004. Tracking movements of individual *Anoplophora glabripennis* (Coleoptera: Cerambycidae) adults: application of harmonic radar. *Environmental Entomology*. 33(3): 644–649.

FACTivity



In this FACTivity, you will participate in a "rapid response" exercise. You will pretend you are scientists responding to the news of an Asian long-horned beetle invasion in your town. The method you will use is as follows:

Students will work in pairs. Each pair represents a team of entomologists who are studying the Asian long-horned beetle. Your team has just been contacted by the Department of Homeland Security. A citizen has called with a report of an Asian long-horned beetle. After doing some research, the Department of Homeland Security has traced the beetle to a shipment of goods from China. The beetle arrived in a shipping crate. It is unknown how many other beetles might be loose in your town. All that is known is that the shipment of goods from China arrived in your community 15 days ago.

Your team has been asked to help stop the spread of the Asian long-horned beetle. Using the data from this study, develop a plan for stopping the spread of the beetle. To refresh your memory, reread the "Thinking About the Environment" and "Introduction" sections. Also, you may want to review the "Findings" and "Discussion" sections.

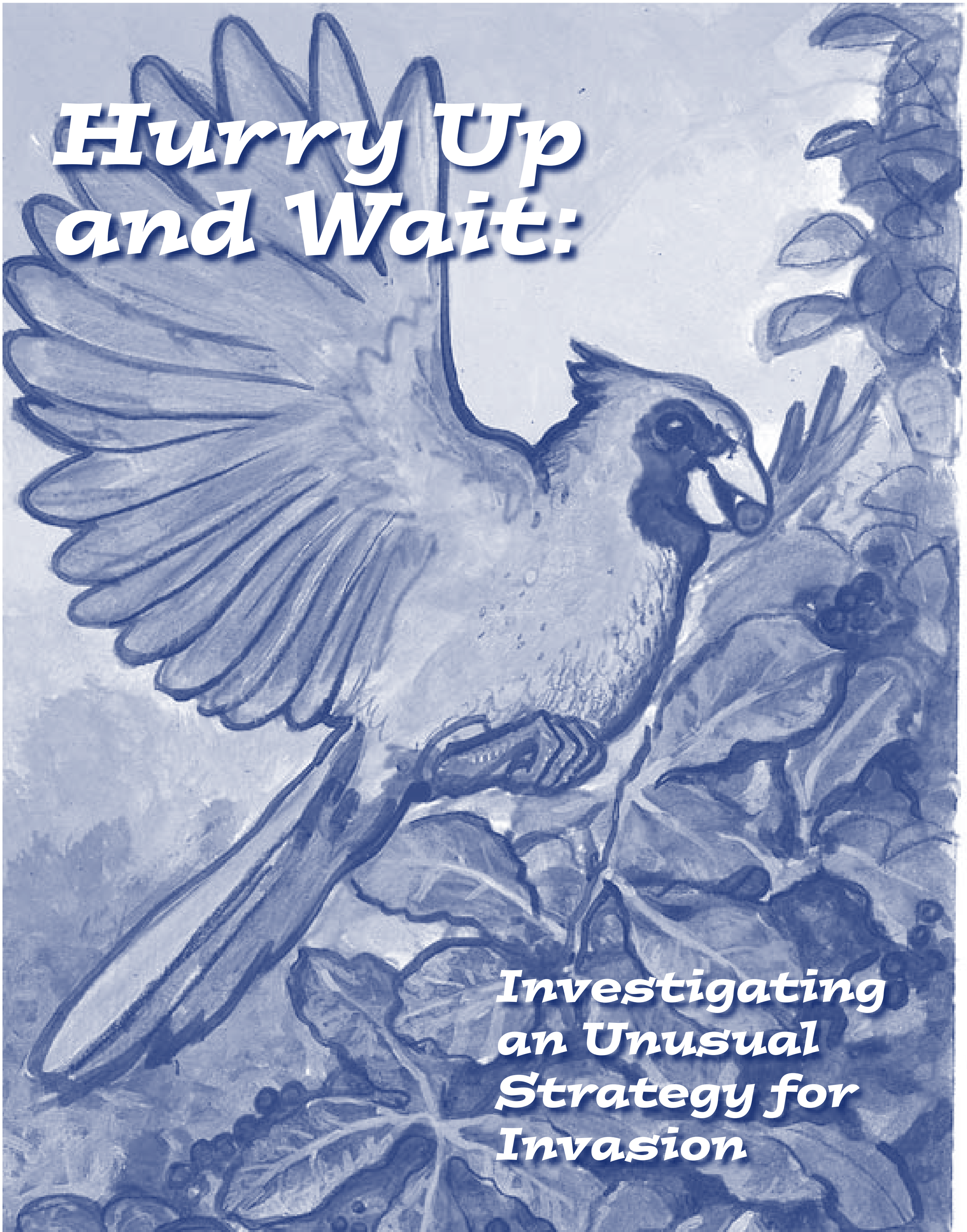
Each team should develop a written plan for destroying the Asian long-horned beetle. You may want to use visual aids as well. Each plan should include reasons for each action based on information from this article or from other sources about the Asian long-horned beetle. Each team should present its plan to the class.

Following the presentations, hold a class discussion about the various plans. How were they similar? How were they different? The class may want to vote on the best plan for destroying the Asian long-horned beetle.

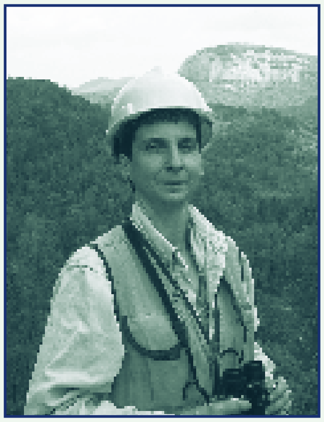
If you are a Project Learning Tree-trained educator, you may use PLT Pre K–8th Activity Guide #8, "Forest of S.T. Shrew," and Activity Guide #22, "Trees As Habitats," as additional activity resources. These activities guide the study of microhabitats and introduce trees as insect habitat.

Hurry Up and Wait:

Investigating an Unusual Strategy for Invasion



Meet the Scientists



◂ Dr. Greenberg: My favorite science experience is learning how animals need plants for food and *habitat* and how many plants also need animals to *disperse* their seeds to new places.

Ms. Moody: ▸ My favorite science experience occurred when I was teaching high school. I taught Earth/ environmental science and did a stream study on our campus with each class. I loved seeing the students get really excited about the bugs we were catching and getting into the data we were collecting about the health of their stream. My students always told me the stream study was one of their favorite activities of the semester.

Glossary:

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

disperse (di **spürs**): To scatter or spread in all directions.

native (**na** tiv): Naturally occurring in an area.

diversity (duh **vür** suh te): The quality of being different or varied.

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

nonnative (nän **na** tiv) Not naturally occurring in an area.

defecate (**def** uh kat): To get rid of waste matter from the bowels.

resource (**re** sôrs): Something that takes care of a need.

relationship (re **la** shun ship): When two or more things are connected in some fashion.

germination (jür mi **na** shun): The act of sprouting or beginning to grow.

hypothesis (hi **paw** thuh sis): An unproven idea that is accepted for the time being and is often tested during a scientific study. Plural is hypotheses (hi **paw** thuh ses).

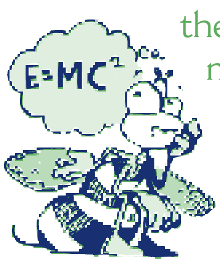
density (**den** suh ti): The condition of a substance having its parts close together.

Pronunciation Guide

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

Accented syllables are in **bold.**

Thinking About Science



When scientists complete their research, they communicate the scientific method they used and their findings with other scientists by submitting a writeup of their research to a scientific journal. Other scientists evaluate the writeup and make suggestions about how the scientists can improve the writeup. The writeup may be accepted or rejected by the journal based on these evaluations.

If your teacher asks you to write a paper and then gives you feedback on how your paper can be improved, he or she is doing something similar to what scientists do. There are two major differences, however. When your teacher gives you feedback, you know who is making the suggestions for improvement. When scientists review and evaluate the writeups of other scientists, the identity of the reviewers is kept secret. This method is called a blind review. A blind review gives the reviewers more freedom to make suggestions. The other difference is that the reviewers do not know who wrote the paper they are reviewing. What is one advantage of keeping the author's identity a secret?

Thinking About the Environment

When plants are introduced into an area where they are not *native*, they sometimes reproduce to the point of disrupting or destroying the native vegetation. When this change happens, plant *diversity* is reduced and normal *ecosystem* processes are changed. *Nonnative* plants that damage a native ecosystem are called invasive plants.

Invasive plants have certain characteristics that help them invade and take over the native ecosystem. For example, they often produce lots of seeds that are dispersed far and wide by wind or animals. They can also spread by underground roots called suckers. In this study, the scientists studied a plant with some of these traits called the Oriental bittersweet (**figure 1**). Oriental is a term that used to refer to areas east of the Mediterranean Sea. The region known now as Asia, therefore, used to be called the Orient.

Figure 1. Oriental bittersweet. Photo by Henry McNab.

Introduction

The Oriental bittersweet is a vine that was transported to the United States from Asia in 1860. Oriental bittersweet is attractive, partly because it produces lots of bright orange berries (**figure 2**). Unfortunately, birds eat the berries and then fly away from the plant. When the birds *defecate*, they deposit the seeds deep in the forest, often far from where the seeds were eaten. Oriental bittersweet escaped from gardens and has spread into natural areas where it is not native. When the vine takes over natural areas, native vegetation cannot compete with it for the *resources* they need. These resources include space, water, and sunlight (**figure 3**).

Figure 2. Oriental bittersweet berries.

Figure 3. Oriental bittersweet taking over resources in an open area within a forest. Photo by Henry McNab.

Oriental bittersweet, like many invasive plants, grows well in an area with a lot of sunlight. Often, invasive plants cannot grow well in a forest. This lack of growth happens because the leaves overhead create a shade so deep that invasive plants cannot become established. Oriental bittersweet is different. It seems as if Oriental bittersweet is able to become established in deep shade. Then, it just sits and waits for an opportunity to grow.

At some time in the future, something might happen in the forest to disturb the deep shade. An old tree could fall over on a windy day, or a wildland fire could burn an area of forest. When sunlight hits the small Oriental bittersweet, it reacts by growing and reproducing quickly. Soon, Oriental bittersweet has reproduced so much that it has grown over the native plants (see figure 3).

The scientists in this study wanted to learn more about the *relationship* between different amounts of sunlight and the *germination* and growth of Oriental bittersweet. They wanted to test the *hypothesis* that the amount of sunlight reaching the ground will affect the percentage of seeds that germinate and the rate at which the seedlings grow.

Reflection Section

- What human actions caused the problem we now have with Oriental bittersweet? What actions might be taken today to help solve the problem?
- If you were the scientist, how would you set up an experiment to compare the amount of seed germination and growth under different amounts of shade and sunlight?

Method

The scientists conducted their experiments in a greenhouse (**figure 4**). The scientists planted an Oriental bittersweet seed in each of 100 identical containers using the same kind of potting soil. They divided the 100 containers into 5 groups of 20 containers in each group. They exposed each of the five groups to a different amount of sunlight (**figure 5**).

Figure 4. The greenhouse where the scientists conducted their experiments.

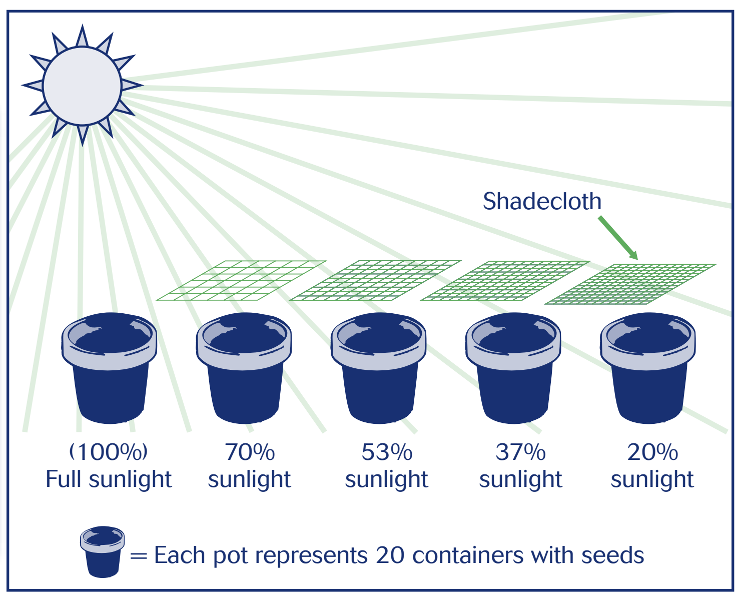


Figure 5. Each group of containers received a different percentage of sunlight by covering the containers with different densities of shadecloth.

The scientists controlled the amount of sunlight reaching each group of containers by using shadecloth. Shadecloth is like a screen but is more flexible. Shadecloth can be purchased at different *densities*. The denser the weave of the shadecloth, the less the amount of sunlight that can shine through it. The scientists used a piece of equipment called a quantum sensor (**figure 6**) to measure the amount of sunlight reaching each group of containers.

The scientists covered all but the "full sunlight" containers with increasing densities of shadecloth in the greenhouse (**figure 7**).

The scientists watered and observed the containers every day. They recorded the date of seed germination. After 100 days, they counted the number of leaves and measured the lengths of the plant stems and the roots in each container. Then they compared the germination and growth of the five groups of Oriental bittersweet vines.

Figure 7. The scientists covered the containers with shadecloth that allowed different amounts of sunlight to reach the pots. This photograph shows another experiment that is similar to the study of Oriental bittersweet, except that the pots contain oak seedlings.

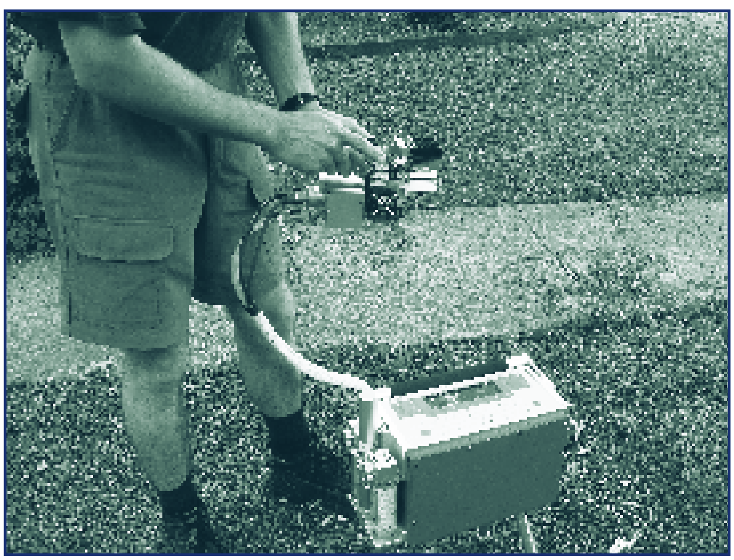


Figure 6. The scientists used a quantum sensor to measure the amount of sunlight reaching each group of containers. Here, the scientist is pointing to the part of the equipment that senses light. The box on the ground records and displays the information.

Reflection Section

- What is the reason the scientists used shadecloth to cover the four groups of containers and a quantum sensor to measure the amount of sunlight reaching them?
- Why did the scientists count the number of leaves and measure the roots and stems of each plant?

Findings

The scientists found no large differences among the different groups of containers (**table 2**). About the same percentage of seeds germinated in each group, with an average of 55 percent of the seeds germinating.

Even though the differences were not very great, the scientists found that the plants in containers with 100 percent and 70 percent sunlight grew a greater number of leaves and had longer stems and roots than the plants receiving a smaller percentage of sunlight. Look at table 2 and see if you can find the one exception to this finding.

Discussion

This study shows that Oriental bittersweet can become established under a wide range of sunlight conditions. Even in heavily shaded areas, the seeds will germinate and grow. Because of this pattern, Oriental bittersweet seeds do not need to be transported to a sunlit area to reproduce. Once the plants become established in a shaded area, they remain alive but do not grow very large. By being able to wait until something happens to open a shaded area to sunlight, Oriental bittersweet has been able to survive and spread across most of the United States. ■

Reflection Section

- Basing your answer on what you know about plant germination, does it surprise you that Oriental bittersweet germinated and grew at about the same rate, regardless of the amount of sunlight? Why or why not?
- Reread the second paragraph in the "Introduction." What do you think would happen to the plants in the five groups if the scientists had let the plants grow for another 100 days before measuring them?

Reflection Section

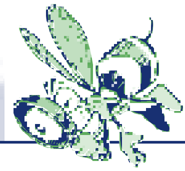
- Do you think Oriental bittersweet could become a bigger threat to native forests in the future? Why or why not?

From Greenberg, C., H.; Smith, L.M.; Levey, D.J. 2001. Fruit fate, seed germination, and growth of an invasive vine—an experimental test of 'sit and wait' strategy. *Biological Invasions.* 3: 363–372.

Percentage of sunlight	100	70	53	37	20
Number of leaves	19	18	13	16	13
Days until germination	16	15	13	15	14
Stem length in centimeters	8.1	8.2	7.0	8.2	7.5
Root length in centimeters	27.8	27.8	25.6	26.5	25.2

Table 2. No large differences exist among the groups of containers.

FACTivity



In this FACTivity, you will examine how different amounts of light affect another type of seed's germination. You will compare this seed's germination pattern with the germination pattern of Oriental bittersweet. You will answer the following question:

How does the amount of light affect the germination of lima bean seeds compared with the amount of light affecting the germination of Oriental bittersweet seeds?

You will use the following method to answer this question:

1. Get 16 pieces of screening, like the screening you might find on a screen door. Each piece should be about 4 inches square.
2. Get 12 lima beans from a seed store. Put potting soil in 12 plastic cups and then plant seeds about 3/4ths of an inch to 1 inch below the surface of the soil. Water the soil until it is moist. Number each cup from 1 to 12.
3. Place cups 1–4 in direct sunlight. They will receive 100 percent sunlight.
4. Cover cups 5–8 with one layer of screening. Cover cups 9–12 with four layers of screening. Cups 5–8 will receive 50 percent sunlight, and cups 9–12 will receive 10 percent sunlight.
5. Place cups 5–12 near the cups in direct sunlight.
6. Note that the screening will provide different amounts of shade for the cups.
7. Water the seeds every day and replace the coverings. Count the number of days until each seed germinates. Use the chart below to record your data.
8. After all the seeds have germinated, look for a pattern in the germination of the seeds. Is the pattern similar to or different from the pattern of Oriental bittersweet germination (from table 2 in the "Findings" section)? How is it similar or different? Now answer the question posed at the beginning of this FACTivity.
9. Continue to water the seeds for 2 weeks and record their progress. At the end of 2 weeks, measure and record the length of the stems. Compare your findings with the findings in table 2. How are your findings similar or different?
10. Basing your conclusion on the findings in the study of Oriental bittersweet, what might you conclude about the ability of lima bean seeds to survive in the same manner as Oriental bittersweet? What would you need to do to be certain of your conclusion?

Alternative Method of Seed Germination

Use three 9- by 11-inch trays. Place four to five moist (not soaked) paper towels on the bottom of each tray. Place 10–12 lima bean seeds on the paper towels in each tray. Cover the trays with plastic wrap and place them in direct sunlight. Cover one of the trays with a double layer of screening and another with four layers of screening. Keep the paper towels moist. Observe and record the germination of the seeds using a chart similar to the one shown below. This method of germination will enable students to see the seeds germinate.

Cups	Cup 1 Full sun	Cup 2 Full sun	Cup 3 Full sun	Cup 4 Full sun	Cup 5 Med. shade	Cup 6 Med. shade	Cup 7 Med. shade	Cup 8 Med. shade	Cup 9 Most shade	Cup 10 Most shade	Cup 11 Most shade	Cup 12 Most shade
Days until germination												

If you are a Project Learning Tree-trained educator, you may use PLT Pre K–8th Activity Guide #27, "Every Tree For Itself," and Activity Guide #41, "How Plants Grow," as additional activity resources. These activities teach plant growth requirements and competition for resources, and they investigate various conditions for plant growth.

Goll-ly! Don't Take a Knapweed!

The Impact of Nonnative Plants and Animals on Deer Mice

Meet the Scientists

Dr. Ortega: ◀ I grew up in southern California in a big city. My first biology job took me all the way to the wilds of Alaska. That convinced me that I was on the right career path. On the first day of work, our boat was approaching a rugged shore in Princess Bay where we were to set up our bird banding station. We noticed a figure on the beach. As we got closer, we realized that it was a brown bear, standing on its back legs! It did not seem afraid of us or our boat and, in fact, was letting us know whose beach it was! We got the picture and turned around. But we returned to that beach in Princess Bay all summer long to band birds, never again seeing the bear, but always paying our respects to her by calling out, "Hey Princess!"

Dr. Pearson: ▶ My favorite science experience is when I can prove a scientific *hypothesis*. I work in a special scientific area called community *ecology*. Community ecology addresses the *relationships* of different kinds of communities within an *ecosystem*, such as plant communities and communities of animals. You have to examine many things at once, and these examinations make the research very complex. When you make a hypothesis about what is happening in a complex system and through careful experimentation are able to show that your hypothesis is correct, it is very satisfying. In this photograph, I am holding a Lynx kitten.

Dr. McKelvey: ◀ My favorite science experience was not in the outdoors, but while sitting at a computer. I had just finished building a map-based computer model of how spotted owls move across the land. The model could draw land areas of different sizes and shapes. I was surprised to see that large areas of irregularly shaped land behaved like networks of smaller areas. Shape was as important as size to providing good *habitat* for the spotted owl. As I pondered this finding, I realized that many scientists were dismissing the importance of the size and shape of land areas for wildlife habitat. This realization has shaped my career as a scientist. Here is a picture of me handling a 1-year-old wolverine. I was placing radio collars on wolverines to track them as they moved across the land.

Glossary:

hypothesis (hi **paw** thuh sis): An unproven idea that is accepted for the time being and is often tested during a scientific study. Plural is hypotheses (hi **paw** thuh ses).

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

relationship (re **la** shun ship): When two or more things are connected in some fashion.

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

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

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

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

nonnative (nän **na** tiv): Not naturally occurring in an area.

larval (**lär** väl): Relating to the wormlike feeding form that hatches from the egg of many insects or animals that changes form when it becomes an adult.

native (**na** tiv): Naturally occurring in an area.

mammal (**ma** mul): Any warm-blooded animal with a backbone and glands to produce milk for feeding their young.

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

arid (**air** id): Dry.

prey (pra): An animal hunted for food by another animal.

livestock (**liv** stawk): Animals kept or raised on farms or on rangelands.

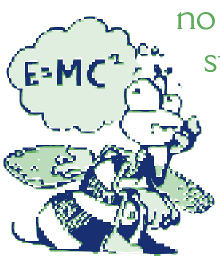
population (päp yoo **la** shun): The whole number of individuals of the same type occupying an area.

Pronunciation Guide

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

Accented syllables are in **bold.**

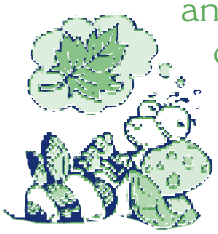
Thinking About Science



In environmental science, scientists see no end to the problems they could study. Scientists often identify new problems to study from the findings of earlier research. When research is done, more questions always emerge at the end of a study. Scientists spend a lot of time reading and thinking about the results of previous research. They may also observe on their own what is happening. They then think about what information is missing. Often, scientists compare what they know with what is missing to develop hypotheses or predictions. This method of comparison is one way that science progresses.

In this study, previous research had discovered information about the relationship between an *invasive* plant *species* and *nonnative* insects that might help to control it. Part of the insect's life cycle includes a *larval* stage. The scientists observed that a *native mammal* enjoyed eating these insect *larvae*. The scientists wondered if the substitution of the mammal's usual food with a nonnative food might affect the ecology of the whole area.

Thinking About the Environment



An ecosystem is a community of plants and animals that interact with each other and with the nonliving environment. An ecosystem is not a specific size area. It can be any size one wishes to study. For the purposes of research, scientists often define an ecosystem by the plant or animal communities that live in a particular area. In this research, the scientists were interested in the ecosystem defined as an *arid* grassland (**figure 1**).

One animal living within this arid grassland ecosystem is the deer mouse (**figure 2**). In an arid grassland ecosystem, deer mice usually breed and raise their young in the summer when food is most easily found. Deer mice eat a lot of different foods, including fruits, small nuts, insects, and spiders. Deer mice are *prey* for a wide variety of other animals, including snakes and owls. During the day, deer mice hide under rocks, in burrows, and use the thick grasses for protection. Using the deer mouse as an example, you can see that in an ecosystem many different plants and animals interact with and depend on each other.

Figure 1. Arid grassland with bluebunch wheatgrass and balsamroot.

Figure 2. Deer mouse being measured during this study.

Introduction

One risk to a native ecosystem is an invasion of nonnative plants or animals. In the Western United States, spotted knapweed is one of the most widely found nonnative plants (**figures 3a and 3b**). Spotted knapweed was brought to the United States from Eastern Europe in the early 1900s. When spotted knapweed spreads into an area, it takes over and native plants cannot compete with it. This change reduces the amount of food available to animals that eat the native plants, such as *livestock* and other hoofed animals.

To control the spread of spotted knapweed, two types of gall flies have been released into

Figures 3a and 3b. Spotted knapweed.

areas with spotted knapweed (**figure 4**). Gall flies lay their eggs on the flowerhead of the spotted knapweed. When the eggs hatch and become larvae, the larvae burrow into the flowerhead to feed on the plant (**figure 5**). This feeding destroys the developing seeds and helps control the reproduction of spotted knapweed.

Unfortunately, these gall flies are not native to the arid grassland ecosystem. The scientists in this study observed that deer mice prefer eating gall fly larvae more than they prefer native foods. The scientists thought that this preference could cause a problem for the ecosystem overall.

Figure 4. Gall fly.

Figure 5. Cross-section of a spotted knapweed flowerhead showing a gall fly larva (on the right).

Gall fly larvae are available to deer mice from September through May of every year. They become unavailable in the summer when the adult gall flies emerge. This change means that deer mice, which usually do not reproduce in the winter when native food is scarce, might be reproducing into the winter months because gall fly larvae are available to eat. More importantly, the scientists thought that the availability of gall fly larvae in the winter might help more mice to survive the cold winters.

Usually, deer mice reproduce during the summer when native foods are available. Because knapweed overtakes native plants, native foods are less available to the deer mice. You can see that the presence of spotted knapweed and gall flies are changing the habits of deer mice. Because gall fly larvae are available to eat throughout the winter, the *population* of deer mice might be growing beyond its normal size.

The scientists wanted to study the effect of spotted knapweed and gall flies on the population of deer mice in arid grassland ecosystems. They predicted that they would find an overall increase in the population of deer mice within these ecosystems.

Reflection Section

- In your own words, state how spotted knapweed and gall flies have changed some things for deer mice living in the arid grassland in this study.
- What question did the scientists want to answer?

Method

The scientists selected two large areas to study in the Lolo National Forest in Montana (**figure 6**). The large areas were similar in many ways, except that one had mostly native plants and the other had been invaded by spotted knapweed. In the area with knapweed, gall flies had been released and were living throughout the area. Within the two large areas, the scientists selected four smaller areas. Then within each of those four areas, they identified four even smaller sites to study.

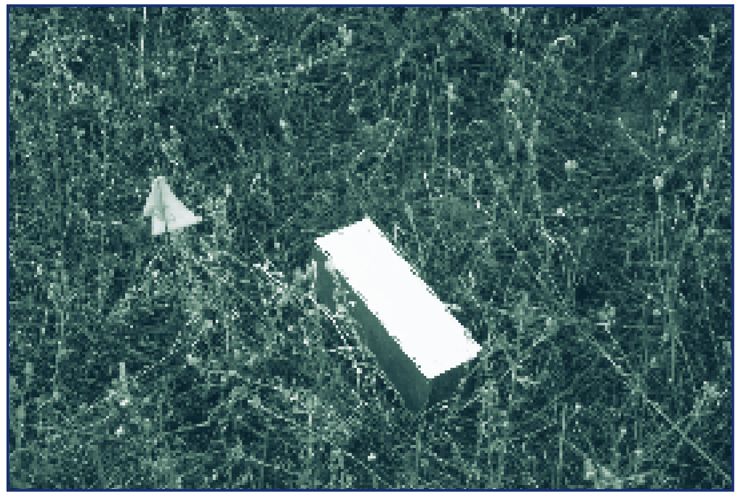


Figure 7. A live trap in the knapweed.

Number Crunches

- How many total sites did the scientists study?
- How many total areas with spotted knapweed did they study?

The scientists trapped deer mice using live traps at each of the 32 study areas (**figure 7**). Live traps enable scientists to trap animals unharmed and then release them back into the environment. They baited the traps with peanut butter and oats. The scientists checked each trap two times every morning for 4 days.

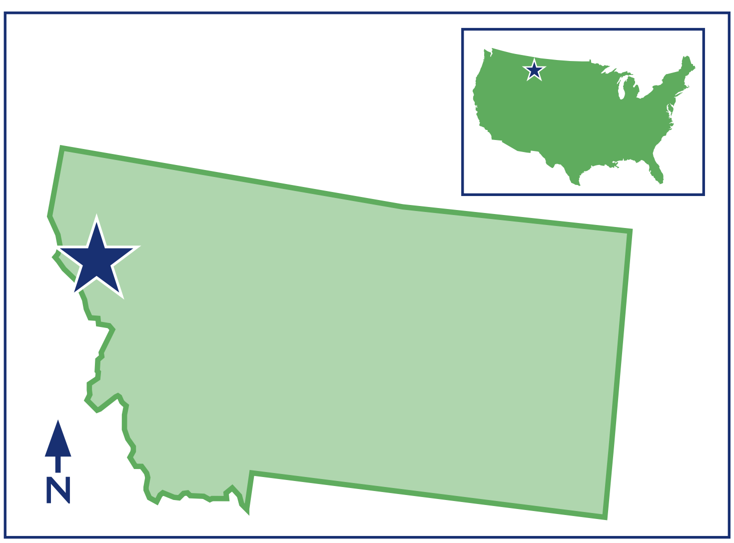


Figure 6. The location of the Lolo National Forest in Montana.

When a mouse was trapped, the scientists weighed it and recorded its sex. They gave each mouse a different number and placed an ear tag on it. The scientists then released the mouse back into the environment.

The scientists repeated the trapping and recording of mice for 3 years. They trapped mice for 4 days each in May (spring), July (summer), and September (fall) of each year.

The scientists then counted the number of different individual mice trapped at each site in each of the seasons. They compared the number of mice trapped in the spring with the number trapped the previous fall. The difference between the two numbers would give them an estimate of the number of mice that had lived throughout the winter.

Reflection Section

- Why did the scientists select two large areas to study—one ecosystem with nonnative knapweed and the other a native ecosystem without knapweed?
- Why was each deer mouse given a different number?
- Why did the scientists collect information over 3 years?

Findings

Throughout the 3 years, the scientists checked the traps 21,760 times. They trapped 583 individual deer mice. If they counted the deer mice they trapped more than once, in total they trapped deer mice 913 times.

Number Crunches

- What percentage of deer mice were trapped more than once? (Hint: Divide 583 by 913 then subtract that number from 100.)
- What percentage of the time did the scientists trap deer mice? (Hint: Divide 913 by 21,760.)

In all 3 years, the scientists trapped more deer mice in the knapweed sites than in the native grassland sites (**figure 8**).

In 1999 and 2000, the number of deer mice was larger in every season, except for the summer of 2000 (**figure 9**). Look closely at figure 9. Do you see a difference between 1999, 2000, and 2001? The 2001 numbers show a large decline in the number of mice found at knapweed sites. This decline probably happened because of the drought that occurred over the spring and summer of that year. Because the number of knapweed plants decreased, the scientists expect that the number of gall flies was reduced as well.

The scientists found that in the sites with knapweed plants, 80 percent of the spring population of deer mice trapped were adults. This finding told the scientists that the winter availability of gall fly larvae helped to keep deer mouse adults alive over the winter months.

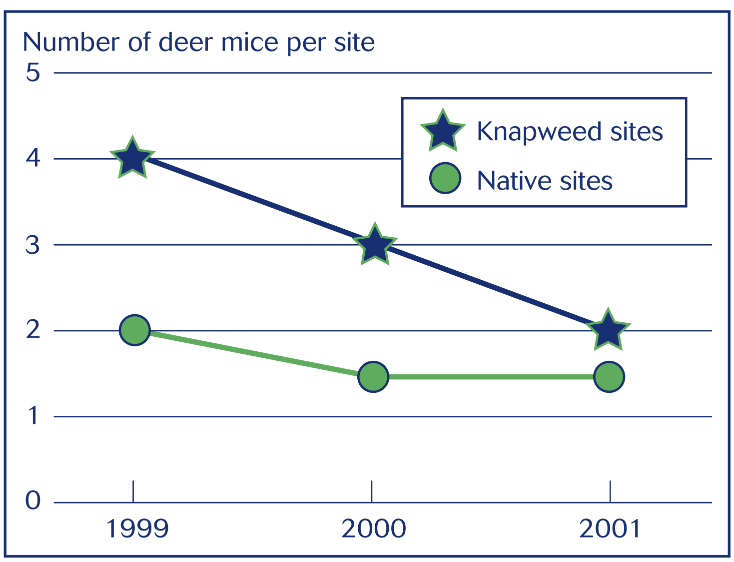


Figure 8. The average number of deer mice trapped per site.

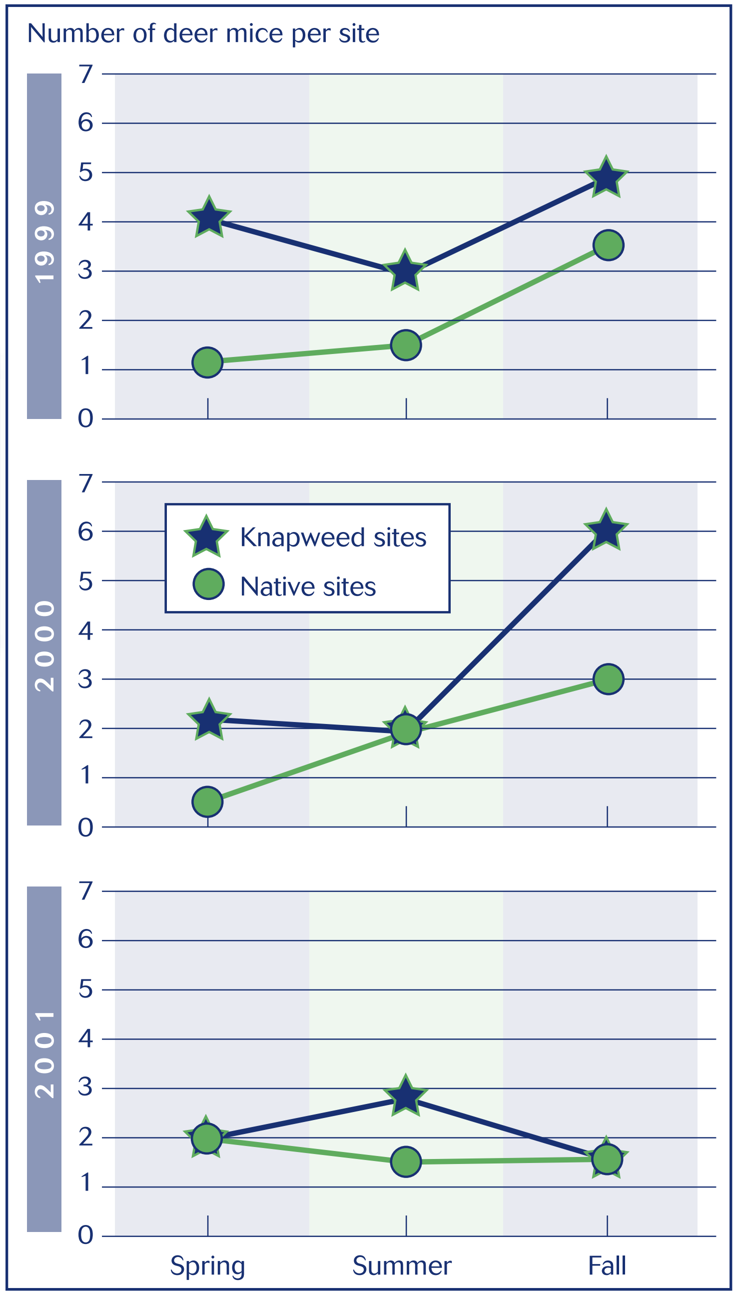


Figure 9. The average number of deer mice trapped per site by season of the year.

Reflection Section

- Reread the last paragraph in the "Introduction" section. Was the scientists' prediction correct? What is the evidence?
- During the summer when gall fly larvae are not available, the population of deer mice living in areas with spotted knapweed eats more native seeds and insects than it normally would eat simply because the total number of individuals is higher. How might an overall increase in the number of deer mice affect the native seeds and insects?
- Do you think the introduction of invasive species can upset the ecology of any area? Using this study as an example, explain your answer.

Discussion

In this study, the invasive plant species knapweed was supposed to be controlled by the nonnative gall fly. Unfortunately, the knapweed population is still getting larger. In addition to not solving the knapweed problem, the introduction of gall flies has affected the population of other animals in the ecosystem. ■

Reflection Section

- Basing your response on the findings and implications of this study, what would you conclude about using nonnative species to control invasive ones?
- Purple loostrife is an invasive plant. Scientists recently found that Galerucella beetles, native to Europe and Asia, help control purple loostrife by eating its leaves. How does this information change your answer to the question above?

From: Ortega, Y.K.; Pearson, D.E.; McKelvey, K.S. 2004. Effects of biological control agents and exotic plant invasion on deer mouse populations. *Ecological Applications.* 14(1): 241–253.

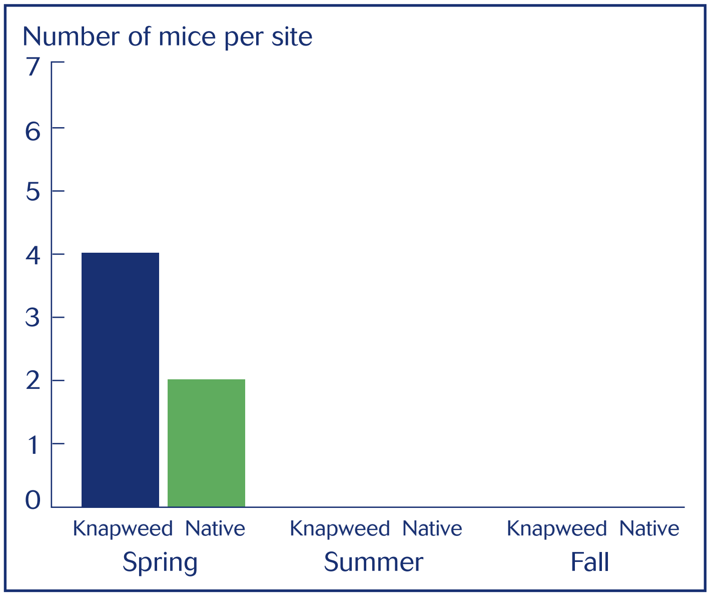
FACTivity

In this FACTivity, you will compare different ways of displaying research findings. You will answer the following questions in this FACTivity:

1. Which of two methods of displaying results is easier for you to understand?
2. Can the use of pie charts, rather than tables, help you better understand the results of an experiment?

You will use the following method to answer these questions:

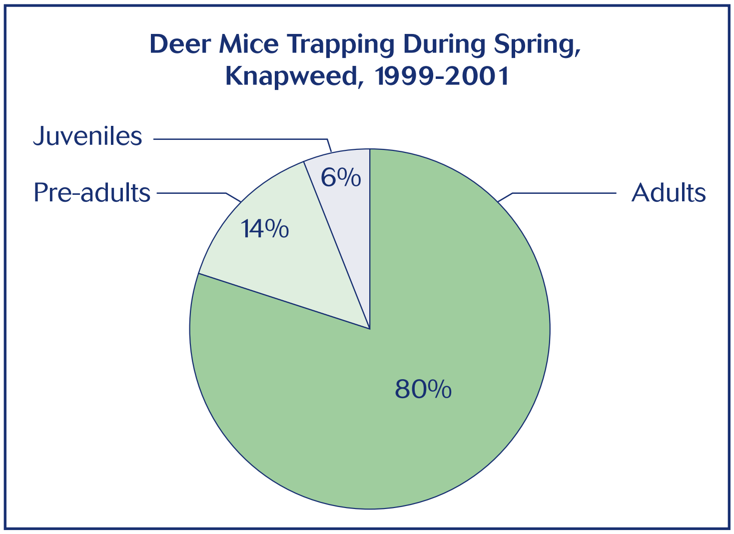
1. Look at figures 8 and 9 in the article. You will be using these figures to create bar charts (also called histograms).
2. Create four bar charts using the information from figures 8 and 9. See the example below, taken from figure 8.
3. Compare your bar charts with the figures shown in this article. Hold a class discussion about the different forms. Are the bar charts easier to read? More difficult? Discuss how the same information can be shown in different forms. Can you think of any other ways to display this same information? Answer the first question of this FACTivity.
4. Examine the table on page 67.
5. After looking at the table, can you determine any patterns in the number of deer mice trapped by age class and season? If so, what are the patterns?
6. Complete the table by adding up the numbers in each of the two columns marked "Knapweed" and "Native" for each season. Total knapweed trappings in the spring is done as an example.
7. Using the total number as the denominator, determine the percentage of each age class for each season. For example, in the spring for knapweed trappings, the total of 106, 19, and 8 is 133. This number has been placed in the table for you. The denominator, therefore, is 133, and the numerators are 106, 19, and 8. To calculate the percentage represented by 106, divide 106 by 133. The answer is .796, or .80. You can see that .80 has been placed in the column next to 106. The other percentages have also been calculated for spring knapweed trappings. Fill in the shaded areas of the table with your calculations, like the example for knapweed trappings in the spring.
8. Create six pie charts based on the calculated percentages. Label each of your pie charts. See the example on page 67. This pie chart shows the information for spring knapweed trappings. To create the pie charts, you can use a computer program, such as Excel, or you can use a protractor.



Season and age class	Knapweed	Percentage	Native	Percentage
Spring				
Adult	106	.80	51	
Pre-adult	19	.14	7	
Juvenile	8	.06	3	
Total	133	1.00		
Summer				
Adult	83		45	
Pre-adult	26		19	
Juvenile	12		15	
Total				
Fall				
Adult	81		44	
Pre-adult	40		39	
Juvenile	25		19	
Total				

Number of deer mice trapped in knapweed and native grasslands by age class and season, 1999–2001.

9. After you complete and label your pie charts, revisit the question asked in #5, above. This time, use the pie charts rather than the table to describe the patterns.



10. Hold a class discussion about whether the pie charts helped you understand the findings of this research. What are the advantages of using charts and graphs over tables? What are the disadvantages? Reread the first paragraph of this FACTivity. What is the answer to question #2?

If you are a Project Learning Tree-trained educator, you may use PLT Forest Ecology Secondary Module #4, "Home Sweet Home," Pre K–8th Activity Guide #45, "Web of Life," and Activity Guide #43, "Seeds Will Travel," as additional activity resources. These activities introduce how nonnative insect control affects the web of life and how seed dispersal varies.

Reflection Section Possible Answers

The following section provides a guide to possible answers to the reflection questions found in each section of the articles. Reflection Sections are meant to stimulate critical thinking about the article, not to test knowledge. Use the answers below as a guide to stimulate critical thinking and discussion in your classroom.

Moving Spore-adically

Introduction

- **What is the problem the scientists wanted to study?** The problem is that sudden oak death, a disease that can damage or kill trees, is spread from tree to tree within a forest. The scientists wanted to know how sudden oak death is spread from tree to tree in order to try to stop it.
- **Which type of tree would you guess is most often killed by the organism that causes sudden oak death?** Oak.

Method

- **What would the scientists learn by comparing the number of spores found after a rain in buckets placed in increasing distances from infected bay laurel trees?** They would learn about how far the spores travel from affected trees across open spaces during a rain.
- **What is the difference between the spores found in the rainwater traps and in the buckets?** The rainwater traps would tell the scientists how many spores can travel from infected trees in the forest through rain to the ground. The bucket traps would tell the scientists how far spores can travel from infected trees across open spaces during a rain.
- **What would the scientists learn from floating leaves in the stream?** The floating leaves would become infected with sudden oak death if spores were in the stream. This part of the experiment would tell the scientists if spores were in the stream within the forest and, if so, if the spores could survive in the water 1 kilometer downstream of the forest.
- **What would the scientists learn from the students' hike?** The scientists would learn whether spores from infected trees would get in the soil and then onto the students' shoes. They would learn whether the spores would remain on the shoes after a 2.4-kilometer walk. This finding would tell the scientists whether hikers can transport sudden oak death if they walk through a forest with infected trees.

Findings

- **Basing your answer on the findings, would you say sudden oak death can be transported by water? Why or why not?** Yes. The evidence indicates that the spores that cause sudden oak death are transported by rainwater and down streams.
- **Basing your response on the findings, would you say that people can transport the spores that cause sudden oak death? Why or why not?** Yes. The student hiking experiment showed that spores are in the soil and can be transported after the soil gets onto hikers' shoes.
- **Basing your answer on the findings, under what weather conditions would you say the transportation of spores is more likely to occur?** During the rainy season, or when it rains.

Discussion

- **Do oak trees live in your area? What do you think would happen if sudden oak death began to kill those trees?** These questions are for individuals and each student should come up with his or her own ideas. Some potential answers include: (1) Animals that use oak trees for food and habitat would no longer have a place to live, (2) the beauty of oak trees, including what they contribute to the area, would be lost, and (3) the ecology of forests with a lot of oak trees would be changed.

- **Do you think research should be done on sudden oak death outside California? Why or why not?** Yes. Because sudden oak death can kill oak trees and is easily transported from tree to tree in California, it would be best to know how it might be transported in areas outside California and which trees might be affected.

And Then There Were Nun

Introduction

- **In your own words, state the question the scientist wanted to answer.** Which tree species in the United States are most likely to be the preferred habitat of the nun moth?
- **What is the advantage of knowing in advance which tree species might be the preferred habitat of the nun moth?** If the nun moth were found in the United States, people would already know which tree species the moths prefer as habitat. People could stop the spread of the nun moth by cutting down those trees within the area where the moths were found, or by otherwise controlling the moths before they spread.
- **The scientist did this study in the Northeastern United States. Do you think she studied the moths inside or outside a laboratory? Explain your answer.** The scientist had to do her study inside a laboratory because she did not want any eggs, larvae, or moths to escape into the outside environment.

Method

- **What did this experiment enable the scientist to discover?** The scientist discovered which species of foliage kept larvae alive and which species of foliage supported the development of larvae into pupae.
- **When the scientist placed fresh foliage in each container, do you think she used the same species of foliage that she had removed from that container? Why or why not?** Yes. If she used foliage from a different tree species, she would have no way of knowing which species of foliage supported the larvae's development.
- **Why do you think the scientist wanted to discover what percentage of larvae became pupae?** If the scientist had stopped the entire experiment at 14 days, she might have overestimated the percentage of healthy larvae. Some larvae may have lived but might never have become pupae.

Findings

- **What species of trees do nun moth larvae prefer to eat?** Most conifer species and many oak species appear to be preferred by nun moth larvae.
- **Do you think these findings are good news or bad news for people worried about the invasion of nun moths into the United States? Why?** These findings would be bad news for people worried about a possible nun moth invasion because nun moth larvae appear to survive on a wide variety of tree species that are found in the United States.

Discussion

- **Trees are important to people in forest industries, such as those using trees for wood products. Many industries that depend on forests might need the trees alive and healthy. What other forest-dependent industries could be affected by a nun moth invasion?** You may need to encourage your students to think outside the box. One forest industry that encompasses many different businesses is the tourism industry. If many trees are damaged or die from a nun moth invasion, people may not want to visit the forest for recreational activities such as hiking, bird watching, camping, and boating. This lack of visitors could affect businesses such as hotels, stores, restaurants, and recreation guides. Your students may think of other industries that could be affected.

- **In addition to economic problems, what other kind of problems might be created by the damage or loss of a large number of trees in a forest?** It would cause a lot of environmental damage, which could include the loss of habitat for animals, increased erosion that results in loss of soil and in water siltation, and a loss of tree diversity.
- **What is one way we can protect trees in the United States from a possible nun moth invasion?** Your students may come up with a variety of suggestions. Some obvious ones include: (1) Carefully inspect wooden packing crates for nun moth larvae before allowing them into United States ports, and (2) teach people how to identify nun moths so that if they do come into the United States, they can be dealt with before they spread.

Knocked Out by Trout

Introduction

- **Basing your response on the information presented in the "Introduction," state in your own words what the scientists expected to find out about the population of Pacific tree frogs in JMW compared with KCNP. Then, give the reason for your statement.** Your students may state it differently, but in essence, they should state that the scientists expected that the population of Pacific tree frogs would be lower in JMW than in KCNP. The reason for this expected answer is the higher population of nonnative trout found in JMW compared with KCNP.
- **You read about the concept of experimental control in "Thinking About Science." (If you need a reminder, reread that section.) Which variable did natural resource management control, enabling the scientists to study the effect of nonnative trout on Pacific tree frog populations?** The number of nonnative trout living in the lakes in JMW and KCNP was controlled by the natural resource managers.

Method

- **Why did the scientists not include the presence of nonnative trout in their first calculations?** If the number of tree frogs was about the same between JMW and KCNP, then the number of nonnative trout did not affect the population of tree frogs, and the scientists would have no reason to count their presence or absence.
- **Basing your thoughts on previous scientific findings about the presence of nonnative trout and the population of mountain yellow-legged frogs, do you think the scientists found a difference in the populations of Pacific tree frogs in JMW and KCNP? Why or why not?** Yes. One would expect to find a difference based on the previous research. The previous research indicated that when nonnative trout are present, the population of frogs is lower than in areas where nonnative trout are not present.

Findings

- **Why do you think the scientists considered things such as the size and depth of the lakes and how much silt was in them?** The scientists considered that these other things could also influence the presence and number of tree frogs in a lake. If they did not consider these things, they would not know for sure whether the number of tree frogs in a lake was due to the lake's characteristics or whether it was due to the presence and number of nonnative trout.

- **After reading the "Findings" section above, would you conclude that the presence of nonnative trout had an effect on the number of tree frogs in a lake? Why or why not?** Yes. The evidence shows that after considering the characteristics of the lakes, the presence and number of nonnative trout had the strongest relationship with a lower number of tree frogs.

Discussion

- **Garter snakes are a source of food for skunks found in the Sierra Nevada mountains. Basing your thoughts on what you know about food webs and the results of this research, do you think it is likely or unlikely that continued stocking of nonnative trout could affect the population of skunks in the Sierra Nevada mountains? Why?** It seems likely that a reduction in an animal population's food source would affect its numbers. If fewer tree frogs are available as food and the population of garter snakes is therefore reduced, it seems likely that the population of skunks could be affected as well. Your students might have different explanations, such as the skunks finding a new food source. Above all, the students should be able to support their answers.

Shoot! Foiled Again!

Introduction

- **Explain in your own words how verbenone protects the beetle population but not the pine trees.** The verbenone is emitted from individual beetles as they reproduce, eat, and grow. When a large number of beetles is on a tree, the combined amount of verbenone tells other beetles that many beetles are already present. This message discourages more beetles from attacking the tree and, therefore, encourages them to find new trees. The number of beetles present at this point is already high enough to damage or kill the tree.
- **In your own words, ask one question the scientists wanted to answer.** (1) Can verbenone be used to discourage pine shoot beetles from attacking pine trees? (2) Can other volatiles, such as those from broadleaf trees, be used to discourage pine shoot beetles from attacking pine trees? Your students may state these questions a little differently.

Method

- **Explain in your own words what the scientists might learn from each of the four sets of traps (from figure 6).** The first set of traps is a control. With no chemicals, it provided a way to equally compare each of the other traps. The second set contained the chemical that attracts pine shoot beetles to Scots pine. This set of traps told the scientists how many beetles would be attracted in the absence of any repelling chemical. The third set of traps contained the attractant and the broadleaf chemicals that might discourage beetles. This set of traps, when compared with the second set, told the scientists how many beetles might be discouraged from Scots pine trees when using chemicals from broadleaf trees. The fourth set of traps contained the attractant, the broadleaf chemicals for discouraging beetles, and the verbenone, which should also discourage beetles. This set of traps, when compared with the third set, told the scientists how many more beetles might be discouraged from Scots pine trees with the addition of verbenone to the broadleaf chemicals.
- **Why do you think the scientists repeated the experiment 10 times on each plantation?** The more traps that could be set and compared, the more confidence the

scientists could have in their results. If the traps set in different areas of the plantation showed different results, then the scientists might suspect that something more than the chemicals was affecting the behavior of the beetles. If the results were similar across all experiments, then the scientists could assume that the beetles' behavior was the result of the different chemicals in the traps.

Findings

- **Look at table 1. Would you say the Scots pine volatiles attracted pine shoot beetles to the traps? Why or why not?** Yes. The average number of beetles caught was much higher than in the control, which contained no attractant.
- **If you were one of the scientists, what would you tell people who manage holiday tree plantations about the use of chemicals to discourage pine shoot beetle damage?** I would tell them they can discourage the pine shoot beetle by using broadleaf volatiles or a combination of broadleaf volatiles and verbenones.

Discussion

- **Why do you think the broadleaf volatiles discourage the pine shoot beetle from attack?** Because the broadleaf volatiles smell like a broadleaf tree to the beetle. Broadleaf trees are not the preferred habitat of the beetle. The beetle is fooled into thinking the tree is a broadleaf, not a pine.
- **Do you think these findings are important to people who grow holiday pine trees for sale during the winter holiday season? Why or why not?** Yes. If the pine shoot beetle damages or kills too many holiday trees, the trees will not be available for sale. If the people who grow these trees cannot sell them, they will lose money.

Tag, You're It!

Introduction

- **State in your own words the question the scientist wanted to answer through this research.** About how far do Asian long-horned beetles fly in a day's time?
- **If the Asian long-horned beetle were found again in the United States, how would forest managers use the scientist's information to help them destroy the insects?** They could determine approximately how far and how fast the insects would disperse. This information would help them determine how large an area they would need from which to remove and burn the trees.
- **If a different insect pest were found in the United States, should forest managers use this information about the Asian long-horned beetle to tell them how far the insect might fly? Explain.** If the insect pest were similar to the Asian long-horned beetle, the information learned in this study could be used as a guide, if no other information were available. Different insect species behave differently, however, and it could be disastrous to use information learned about one insect and apply it to the behavior of another.

Method

- **Do you think the scientist should have done this study in the United States? Why or why not?** No. The Asian long-horned beetle is an insect pest in the United States. It might be disastrous to do this study in the United States. Beetles would likely escape from the study area and destroy trees.
- **What would have happened if the scientist had forgotten to paint a number on each beetle?** The scientist would have no idea how far each beetle had dispersed, because he would have no way of knowing which beetle was which.

Findings

- **Why do you think the beetles moved only either east or west and did not move north or south? (Hint: Reread the second paragraph in the "Method" section.)** The study site was a row of willow trees growing along a highway with agricultural land on either side. Therefore, the beetles were most likely to fly from tree to tree, which were lined up east to west.
- **Do you think this study completely answers the question of how far Asian long-horned beetles travel? Why or why not?** The study does not completely answer the question because its findings were different from other findings. It gives a clue about the relationship between distance traveled and air temperature. It also provides a clue as to the relationship between the sexual maturity of females and whether and how far they will travel.

Discussion

- **In what way could a few female beetles traveling 30 meters pose a threat to American trees?** If the females laid eggs, those eggs could hatch and the population of Asian long-horned beetles would increase. To control the beetle population, forest managers might have to cut down hundreds or thousands of trees.
- **From the results of this study, what might you conclude about the dispersal of Asian long-horned beetles?** You might conclude that higher air temperatures slow the dispersal of beetles. You might also conclude that after a beetle begins to move, he will most likely continue to move in the same direction. You might also conclude that female beetles that are ready to lay eggs will be less likely to travel than female beetles that are not yet ready to lay eggs.

Hurry Up and Wait

Introduction

- **What human actions caused the problem we now have with Oriental bittersweet? What actions might be taken today to help solve the problem?** On the surface, the answer would be that we imported Oriental bittersweet as an ornamental plant, and this action certainly started the problem. You can challenge your students, however, to consider other actions that have expanded the current problem. Other actions include gardeners being careless with the plant and allowing it to escape from gardens. They also include using the plants for indoor arrangements, then discarding the plants outdoors along with their seeds. Actions that might help solve the problem include educating people about the danger posed by Oriental bittersweet and helping people identify the plant. People could also learn how to remove or destroy the plant when they find it.
- **If you were the scientist, how would you set up an experiment to compare the amount of seed germination and growth under different amounts of shade and sunlight?** You could take the seeds and plant them in containers. Then you could place them under different amounts of sunlight and shade and compare their germination and growth. You can ask your students to be as specific as possible as they think about how they would do this experiment.

Method

- **What is the reason the scientists used shadecloth to cover the four groups of containers and a quantum sensor to measure the amount of sunlight reaching them?** By using shadecloth, the scientists could control the amount of sunlight reaching the containers. By using the quantum sensor, they could know exactly what percentage of sunlight was reaching each group of containers.

- **Why did the scientists count the number of leaves and measure the roots and stems of each plant?** The scientists needed a way to compare the growth rate of the plants. By counting and measuring, the scientists could compare the plants' growth. Counting and measuring provided a way to compare the plants without introducing personal opinion or evaluation into the process.

Findings

- **Basing your answer on what you know about plant germination, does it surprise you that Oriental bittersweet germinated and grew at about the same rate, regardless of the amount of sunlight? Why or why not?** Students should know that most plants will germinate better either in more sunlight or in less sunlight, depending on the unique needs of the plant. It is unusual for a plant to germinate and grow almost equally regardless of the amount of sunlight it receives. Students should be able to back up their answers with their own evidence or knowledge.
- **Reread the second paragraph in the "Introduction." What do you think would happen to the plants in the five groups if the scientists had let the plants grow for another 100 days before measuring them?** The Oriental bittersweet plants growing in 100 percent and 70 percent sunlight should grow much faster and have more leaves than the plants in the more shaded conditions.

Discussion

- **Do you think Oriental bittersweet could become a bigger threat to native forests in the future? Why or why not?** Oriental bittersweet will likely become a bigger threat in the future. The reasons are that it can germinate and grow in shaded conditions, and it can sit and wait until an area is open to sunlight before it grows quickly and further reproduces. Regardless of the answers your students give, they should be able to back up their answers with observations, knowledge, or logic.

Goll-ly! Don't Take a Knapweed!

Introduction

- **In your own words, state how spotted knapweed and gall flies have changed some things for deer mice living in the arid grassland in this study.** The spotted knapweed has reproduced so much that native grasses and other native plants are overtaken and choked out. The addition of gall flies has caused the feeding cycle of deer mice to change. They now can eat as much as they want from September to May. Then in the summer, their food source is reduced. This situation is the opposite of their natural cycle. This change may also be causing the population of deer mice to increase because of the wide availability of food for much of the year.
- **What question did the scientists want to answer?** Is the population of deer mice higher in areas where spotted knapweed has overtaken native plants and gall flies have been released to control it?

Method

- **Why did the scientists select two large areas to study—one ecosystem with nonnative knapweed and the other a native ecosystem without knapweed?** The question the scientists wanted to answer required them to compare a native ecosystem with a grassland area that had been overtaken by nonnative knapweed.
- **Why was each deer mouse given a different number?** Each deer mouse was

given a different number so the scientists could tell if they had trapped the same mouse twice. Also, when recording the weight and sex of each mouse, the number helped to identify it as an individual.

- **Why did the scientists collect information over 3 years?** The only way the scientists could compare fall and spring populations was to collect information over more than 1 year. In addition, the more times and the more different conditions under which the scientists were able to compare the numbers of mice, the more confidence they could have in their findings.

Findings

- **Reread the last paragraph in the "Introduction" section. Was the scientists' prediction correct? What is the evidence?** Yes, the scientists' prediction of a larger population of deer mice in spotted knapweed sites was correct. The evidence is shown in figures 8 and 9, which indicates that, overall, larger numbers of deer mice were in spotted knapweed sites.
- **During the summer when gall fly larvae are not available, the population of deer mice living in areas with spotted knapweed eats more native seeds and insects than it normally would eat simply because the total number of individuals is higher. How might an overall increase in the number of deer mice affect the native seeds and insects?** As predators of insects and seed eaters, an increase in the number of deer mice, along with a decrease in other food, would cause the number of insects and seeds to be reduced.
- **Do you think the introduction of invasive species can upset the ecology of any area? Using this study as an example, explain your answer.** Yes. In this study two nonnative species have been introduced. The introduction of these two species has caused a change in the number of deer mice, which ultimately will have an impact on other plants and animals in the ecosystem.

Discussion

- **Basing your response on the findings and implications of this study, what would you conclude about using nonnative species to control invasive ones?** You might conclude that before using nonnative species to control invasive species, you should give careful thought to the problem and do research to predict and protect against any harmful results that might happen to other plants and animals in the ecosystem.
- **Purple loostrife is an invasive plant. Scientists recently found that Galerucella beetles, native to Europe and Asia, help control purple loostrife by eating its leaves. How does this information change your answer to the question above?** If you concluded that nonnative species should not be used to control invasive species, this information will help you see that, in some cases, using nonnative species may be the best approach to controlling invasive species.

Invasive Species Lesson Plan

Subjects Covered
- Science: Life science and environmental science
- Reading: Comprehension
- Writing: Summarization

Science Skills
- Comparing, recording, analyzing, classifying

Science Education Standards Addressed
- Science as Inquiry
- Regulation and Behavior
- Population and Ecosystems
- Diversity and Adaptation of Organisms

Objectives
- Students will be able to describe the difference between a nonnative and an invasive species.
- Students will be able to read and explain research about invasive species using the *Natural Inquirer*.
- Students will be able to identify a specific problem with invasive species using the *Natural Inquirer*.
- Students will be able to explain the findings and implications from a scientific study using the *Natural Inquirer*.
- Students will be able to compare and contrast different types of invasive species.
- Students will be able to explain why invasive species may be harmful to an ecosystem.

Estimated Time for Lesson
- Two class periods

Materials
- Invasive Species Edition of the *Natural Inquirer* journal
- Notebook
- Pencils

Procedures
1. Begin the lesson by engaging students in a brief discussion about nonnative and invasive species and the reasons why invasive species may be harmful to an ecosystem.
2. Divide the class into groups of three or four and assign each group a *Natural Inquirer* article to read.
3. As the groups read their article, have them take notes about the article. They should at least answer the following questions:
   a. What is the name of the invasive species?
   b. What type of organism is the invasive species (animal, plant, etc.)?
   c. Why is the invasive species a problem?
   d. What problem did the scientists study?
   e. What are the findings from the study?
   f. What are the implications of the study?
4. After students have finished reading and taking notes on their article, ask each group to present the information to the class.

Assessment

After students have presented their information to the class, ask students to compare and contrast the different invasive species that they heard about during the presentations. Note: You may want to encourage students to take notes while listening to other groups' presentations. Have students also discuss questions such as: How can students help control the spread of invasive species? Teachers may also want to assess students by collecting the notes from the groups and by considering class discussion and presentations.

Modifications

For students who want an extra challenge after finishing this activity, ask the student to research an invasive species in the area where the student lives and prepare a report for the class on the invasive species and how it can be controlled.

For students who have difficulty reading or writing, try pairing them with a reading buddy. In addition, it may be helpful for students to create a word wall of science vocabulary words for the journal before they begin reading the article. To create the word wall, ask students to use the glossary at the beginning of each article and create word and definition cards to put on the wall. Students may want to include drawings that represent the word to help them remember the word.

PLEASE COPY THIS FORM BEFORE COMPLETING!

STUDENTS—Tell Us What You Think About The *Natural Inquirer*

1. The article I read was entitled: ____________________

Circle the answer that best describes how you feel about the article you just read.

2. The article was: Easy to understand Hard to understand Very hard to understand

3. The article was: Very interesting to read Somewhat interesting to read Not interesting to read

4. Did you learn something from reading the article? Yes No

5. Did you try to answer the Reflection Questions? Yes No Some of them
   If you read and tried to answer any of the Reflection Questions, did they help you to think about the article? Yes No

6. Would you like to read another article? Yes No

7. How old are you? 9 10 11 12 13 Other age: __________

8. What grade are you in? 4th 5th 6th 7th 8th 9th

9. Are you a girl or a boy? Girl Boy

Now write in your answer:

10. What did you learn from reading the article? ____________________

____

____

____

11. What is your favorite subject in school? ____________________

Along with your class or by yourself, please send this form to:
Dr. Barbara McDonald • Forest Service • 320 Green St. • Athens, GA 30602-2044

Thank You!

PLEASE COPY THIS FORM BEFORE COMPLETING.

The Natural Inquirer
Teacher's Evaluation

For each article that you read, please answer the following:
Name of Article:_______________________________

1. Would this article help you meet any of the required statewide science curriculum standards?
   ❑ Yes ❑ No

2. How close to the appropriate reading and comprehension level for your students is this article written?
   ❑ Very close ❑ Somewhat close ❑ Not close

3. If the article is somewhat close or not close to the appropriate reading and comprehension level, is it:
   ❑ Too hard ❑ Too easy

4. Would or did you use this article in your classroom as an educational resource?
   ❑ Yes ❑ No

Why or why not? _______________________________

____

____

5. Please rate the article sections on a scale of 1 to 5. The number 1 means the section was not useful at all. The number 5 means the section was very useful.

	Not useful				Very useful
FACTivity	1	2	3	4	5
Glossary	1	2	3	4	5
Introduction	1	2	3	4	5
Methods	1	2	3	4	5
Results	1	2	3	4	5
Graphs, figures, photos	1	2	3	4	5
Reflection Questions	1	2	3	4	5

For any of the sections you rated with either a 1 or a 2 in question 5, please indicate why the section was not useful or how it can be improved:

FACTivity_______________________________________

Glossary____

Introduction ____________________________________

Methods ____

Results ____

Graphs, figures, photos __________________________

Reflection Questions _____________________________

6. Was the "Note to Educators" useful to you?
   ❑ Yes ❑ No ❑ Somewhat

7. What grade(s) do you teach? _________________

8. What subject(s) do you teach? ________________

9. Other comments or suggestions: ______________

____

____

____

Please send this evaluation, along with your students' evaluations, to
Dr. Barbara McDonald
Forest Service
320 Green St.
Athens, GA 30602-2044

Thank you! Your evaluations will help us to continually improve The *Natural Inquirer*.

National Science Education Standards for Invasive Species Edition of the *Natural Inquirer*

	Moving Spore-adically!	And Then There Were Nun	Knocked Out by Trout	Shoot! Foiled Again!	Tag, You're It!	Hurry Up and Wait	Goll-ly! Don't Take a Knapweed!
Science as Inquiry							
Abilities Necessary To Do Scientific Inquiry	✓	✓	✓	✓	✓	✓	✓
Understandings About Scientific Inquiry	✓	✓	✓	✓	✓	✓	✓
Life Science							
Reproduction and Heredity		✓		✓			
Regulation and Behavior	✓	✓	✓	✓	✓	✓	✓
Populations and Ecosystems	✓	✓	✓	✓	✓	✓	✓
Diversity and Adaptations of Organisms	✓	✓	✓	✓	✓	✓	✓
Science and Technology							
Understanding About Science and Technology		✓			✓	✓	
Science in Personal and Social Perspectives							
Risks and Benefits	✓	✓	✓	✓	✓	✓	✓
Science & Technology in Society	✓	✓	✓	✓	✓	✓	✓
History and Nature of Science							
History of Science			✓				
Science as a Human Endeavor	✓	✓	✓	✓	✓	✓	✓
Nature of Science	✓	✓	✓	✓	✓	✓	✓

National Research Council, Content Standards, Grades 5-8.

Student's Notes

What Is the USDA Forest Service?

The Forest Service is a part of the U.S. 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 more than 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 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 USDA Forest Service are scientists, whose work is presented in the journal. USDA Forest Service 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.

What Is Ag in the Classroom?

Agriculture in the Classroom is a grassroots program coordinated by the USDA's Cooperative State Research, Education, and Extension Service (CSREES). The goal of Agriculture in the Classroom is to help students and teachers gain a greater awareness of the role of agriculture in the economy and in society. The program is carried out in each State, according to State needs and interests. People involved at the State level represent farm organizations, agricultural businesses, education, and government. The mission of the CSREES is to advance knowledge for agriculture, the environment, human health and well-being, and communities. The CSREES provides leadership to identify, develop, and manage programs to support university-based and other institutional research, education, and extension.

Visit These Web Sites for More Information

USDA Forest Service
http://www.fs.fed.us

The *Natural Inquirer*
http://www.naturalinquirer.usda.gov

Conservation Education
http://na.fs.fed.us/spfo/ce/index.cfm

Cooperative State Research, Education, and Extension Service
http://www.csrees.usda.gov

USDA Kid's Page
http://www.usda.gov/news/usdakids/

Agriculture in the Classroom
http://www.agclassroom.org

NatureWatch
http://www.fs.fed.us/outdoors/naturewatch/

Woodsy Owl:
http://www.fs.fed.us/spf/woodsy

Smokey Bear:
http://www.smokeybear.com

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

National Forests by Map:
http://www.fs.fed.us/recreation/map/finder.shtml

National Forests by State:
http://www.fs.fed.us/recreation/map/state_list.shtml

United States Department of Agriculture

Forest Service

FS-837
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Photo courtesy of Steve Passoa, USDA Animal and Plant Health Inspection Service, http://www.forestryimages.org.

Visit These Web Sites for More Information About Invasive Species

USDA Forest Service Invasive Species Information and Management
http://www.fs.fed.us/foresthealth/programs/invasive_species_mgmt.shtml

Invasive Species: A Gateway to Federal and State Invasive Species Programs
http://www.invasivespeciesinfo.gov/

Invasive and Exotic Species
http://www.invasive.org/

Animal and Plant Health Inspection Service's Invasive Species Page
http://www.aphis.usda.gov/oa/invasive/invasive.html

Invasive Species Forecasting System
http://bp.gsfc.nasa.gov/

The Invasive Species Initiative—The Nature Conservancy
http://tncweeds.ucdavis.edu/index.html

Natural Inquirer editorial review board members.