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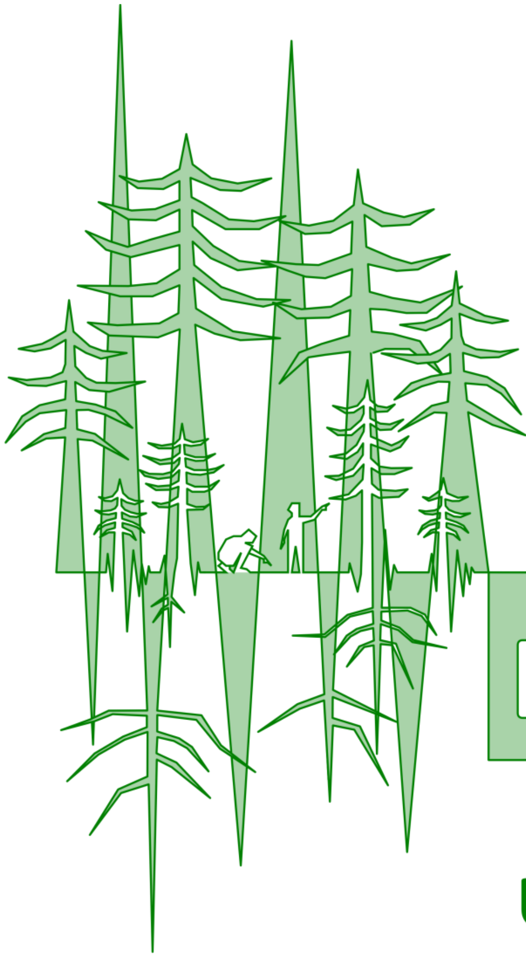

Beyond the Trees

A Systems Approach to Understanding Forest Health in the Southeastern United States

A High School Module

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Developed with the Florida Division of Forestry, Department of Agriculture and Consumer Services

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Beyond the Trees: A Systems Approach to Understanding Forest Health in the Southeastern United States

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School of Forest Resources and Conservation
University of Florida

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Developed with the Florida Division of Forestry, Department of Agriculture and Consumer Services
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The Authors

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Introduction

The forests of the Southeast are indispensible. From the Appalachian Mountains to the Floridian Peninsula and as far as the Mississippi River, the unique geography of the southeastern United States supports a diversity of forests, some found nowhere else in the world. Cypress swamps, tropical hardwoods, mangroves, scrub habitats, and pine flatwoods form a network of temperate to subtropical ecosystems that shelter animals as small as bark beetles and tree frogs to those as large as alligators and black bears.

Forests support humans in both tangible and intangible ways. Apart from being sources of aesthetic beauty and regional pride, forests provide economic resources in sectors ranging from timber and fiber production to recreation and tourism. Timber alone is a multibillion dollar industry in the South. In addition to the monetary value of these products, forests are also valued for their ecosystem services. They hold together soil and filter water, photosynthesize and produce oxygen, recycle nutrients and store carbon, and serve as a gene bank for countless organisms that may otherwise be lost.

Photo: Ricky Layson, Ricky Layson Photography, Bugwood.org

Figure 1. A Florida icon: The longleaf pine forest ecosystem.

There have been losses already. The longleaf pine forest ecosystem, once a defining characteristic of the South, has shrunk from more than 92 million acres in pre-settlement times to less than 3 million acres today (Figure 1). Heavy deforestation in the pre-1900s reshaped the land to serve agricultural, industrial, and other human needs. Despite this, southeastern forests still represent at least 30 percent of all forested land in the United States. Land conversion to timber production has been a key factor in maintaining forest cover, and since the 1980s forested land in the region has shown signs of slow but continued growth.

However, the human population in the South, which represents about 35 percent of the total population of the United States, is also growing. Thus, our conflicting demands for both land to live on and land for forest goods and services is increasing. Forests and trees are renewable resources, but are limited by the land we reserve for them. Since humans depend on forests for continued survival, it is incumbent upon us to monitor their health, encourage their growth, and manage them in a sustainable manner. With these goals, the question that arises is, "Who among us is knowledgeable and responsible for sustainable and healthy forest management?" There are two ways to answer this.

On the one hand, we may look to those who own and control forests for an answer. Forests may be owned and managed by public entities, private businesses, individuals, or families. In the South, more than 80 percent of forests are privately owned. This means that while everyone essentially has a stake in the health of forests, residents of the South are particularly engaged, because in many cases the forests here are a source of livelihood.

On the other hand, who benefits from the services that healthy forests provide? Here, the answer is much broader. Many sectors of the population can benefit from the health of forests. Forest health is a relevant issue for foresters, researchers, farmers, timber growers, hunters, hikers, urban citizens, educators, and children. Teaching youth about the significance of forests is especially critical—they are future decision makers and stewards of the planet's natural resources. Educating youth about forest health is a first step in equipping them to make informed decisions about the future of this valuable resource.

What Is Forest Health?

A healthy forest is an intricately balanced system of interacting parts. Climate influences environment, environment shapes plant growth, plants provide food for numerous other organisms, and humans intersect with this system by harvesting, planting, fragmenting, reshaping, analyzing, using, and appreciating forests for a variety of purposes.

As a result, defining forest health can be confusing because it is a subjective categorization. For those who take the utilitarian perspective, a healthy forest is a producer of tangible goods, and an unhealthy forest is one that fails to be economically valuable. On the other hand, for those with an ecosystems perspective, health is measured by quantifying different variables, such as biodiversity, a forest's capacity to provide ecosystem services, and its ability to bounce back from disruptions and disturbances. Since a forest's sustainability is the ultimate goal, some combination of the utilitarian and ecological perspectives may be used to understand forest health.

The Society of American Forests describes forest health as "the perceived condition of a forest derived from concerns about such factors as its age, structure, composition, function, vigor, presence of unusual levels of insects or disease, and resilience to disturbance." Forest health, for the purposes of *Beyond the Trees*, was additionally interpreted as a dynamic, variable characteristic that can be determined by three components: the forest's composition; the uses it serves; and its value to various stakeholders. For example, a mixed hardwood forest in a state park may be considered "healthy" to a camper who enjoys being in the outdoors while at the same time being "unhealthy" to a park ranger who is trying to restore that area to a longleaf pine ecosystem. On both geographic and temporal scales, the label "healthy" changes, depending upon the characteristics of these three components.

Historically, concerns about forest health overwhelmingly focused on the eradication of undesirable pests and disease-causing pathogens, such as insects and fungi, or environmental disruptions such as fire, which could weaken or kill trees. However, damage, decay, and destruction are essential components of healthy forests. Insects that feed upon trees are fed upon, in turn, by other animals. Fungi that rot away trees replenish the soil with nutrients that would otherwise be locked away in wood. In fire-dependent ecosystems, fires clear the undergrowth and make room for new trees to grow. So the death of individual trees in the forest is not always cause for alarm—in many cases, it is integral to the continued health of the entire ecosystem.

Photo: Chris Evans, River to River CWMA, Bugwood.org

Figure 2. Healthy urban forests: Not a place for rotting trees.

Death and decay are treated differently in more controlled ecosystems, such as plantations, parks, and urban settings. For those who depend upon certain trees for products or aesthetic value, the priority placed upon healthy individual trees may define their perspective of overall forest health (Figure 2).

Nonetheless, the general attitude toward understanding forest health has shifted from "can't see the forest for the trees" to "looking at the forest, and the trees, and beyond." In fact, the history of forests and their past treatment (and mistreatment) provides important lessons about what unhealthy forests look like. A century of fire suppression, due in part to misconceptions about the role of fire in forest ecosystems, has led to overcrowded forests choked with excessive fuels—capable of burning uncontrollably at a moment's notice. Under-harvested plantations are similarly overcrowded, potentially resulting in banks of stressed, weakened trees straining for limited nutrients, water, and room to grow.

Weakened or stressed trees in great numbers create perfect conditions for tree-feeding insects, pathogenic fungi, bacteria, viruses, and weedy plants to proliferate. Their food sources, normally limited, are in abundance, and feeding upon so many weak and dying trees can lead to explosions in their numbers. But from some perspectives, even epidemic outbreaks of native pests and pathogens are not necessarily a cause for concern. These organisms respond to existing forest conditions and management strategies in a predictable manner, as they have done for millennia. In effect, they act as a buffering system, clearing away feeble and dying trees when the forest is unhealthy. Forests eventually rebound after such attacks, as forest openings offer room for seedlings to grow and replenish the area.

But there are some unambiguous threats to forest health. Non-native or exotic pests and pathogens are problematic in any ecosystem. These organisms have the ability to eliminate species and permanently alter ecosystems. For example, in the early 1900s, American chestnuts covered 25 percent of eastern forests, but within a few decades, 3.5 billion of those trees, more than 80 percent of the existing population, were dead from a fungal pathogen that caused chestnut blight. The disease resulted in a loss of $82.5 million in 1912. In 2002, a similarly worrying fungal-insect cohort causing laurel wilt landed in Georgia. This disease is systematically killing redbay trees in the Southeast and threatens the avocado industry of south Florida.

Non-native insects such as the Asian longhorned beetle, emerald ash borer, and hemlock wooly adelgid are also wreaking havoc in the United States. The emerald ash borer has killed 15 million ash trees in the Midwest and is now found in Tennessee. The hemlock wooly adelgid, which has killed 80 percent of the hemlocks in Shenandoah National Park, has the capacity to completely remove hemlock trees from the continent. The immense voids created by these insects and disease pathogens might be filled by invasive and exotic plants. Kudzu, Chinese tallow, climbing ferns (Figure 3), cogon grass, and Chinese privet top the list of invasive plants that are changing the ecosystems of the Southeast.

Photo: Peggy Greb, USDA Agricultural Research Service, Bugwood.org

Figure 3. Overwhelming greenery: Invasive exotic Japanese climbing fern smothers a cypress stand.

All together, there have been an estimated 50,000 species of plants, microbes, and animals introduced into the country, of which 400 insects and 24 pathogens have established themselves in forests. The total damage in monetary terms is staggering. At least $97 billion dollars was lost or spent on damage caused by 79 species between 1906 and 1991. Millions of dollars are spent every year on control efforts. The permeability of geographic boundaries has resulted in accidental, misinformed, and occasionally deliberate transfer and naturalization of pests and pathogens, which hitch rides on building material, fruit crates, trucks, and ships associated with national and international trade. Even the transport of contaminated firewood from one place to another facilitates the movement of invasive species. Native ecosystems are defenseless against invasive exotics because they have not had the time to evolve protective strategies.

The situation appears even bleaker if abiotic threats to forests are also considered. Forest fragmentation by roads and development; land loss due to urban encroachment; improper fire management regimes; air pollution from ozone, sulfur dioxide, and nitrous oxides; runoff from concentrated animal feeding operations (CAFOs); and climate change are all factors that can weaken trees and forests. There are also ethical dimensions surrounding these threats to forest health. The demand for larger residential areas puts a greater strain on existing forests to provide all the goods and services we require.

Many of the problems associated with unhealthy forests originate from human actions, through mismanagement or misconceptions. This can be a source of hope, because while we may be complicit in these problems, we may accelerate solutions through increased awareness, knowledge, and a change of behaviors. Educating young people about the significance of healthy forests and the consequences of management activities is essential. Research and management are essential components of maintaining or restoring forest health, but so is an informed public. Monitoring imported goods for pathogens, managing forests through prompt harvesting and prescribed fire routines, encouraging native vegetation, creating better buffers against abiotic pollutants, and producing less and conserving more are important concepts to be understood and practiced to ensure the continued health of forests.

Teaching about Forest Health

Our conversations with teachers before developing this material revealed that while agricultural education teachers, AP biology teachers, and other environmental education practitioners understood the importance of forest health and wanted to teach their students about it, they were not equipped to do so given their existing curricula. Teachers who did cover forest health taught about forest insect pest and tree disease identification. They also addressed the role of fire in forests. Aspects that were missing from their curricula included the following:

- The beneficial roles of insect pests and tree disease pathogens in a forest.
- Management-related forest health issues.
- The impacts of exotic and invasive species.
- Forest fragmentation and urban encroachment.

This material supplements existing curricula and expands conceptual understanding beyond diagnostic and identification-based knowledge to a more in-depth understanding of the subject of forest health. It is not meant to be treated as an exhaustive compendium of forest health issues, but it does help learners:

- Consider forest health from various viewpoints.
- Understand interrelationships and feedback mechanisms in a forest system.
- Visualize spatial and temporal mechanisms of forest system functions.
- Appreciate the variety of threats to forest health.
- Consider their role as future forest stewards.

Further conversations with students and teachers during the development of this material suggest that some of the important concepts are intuitive and natural for learners, and others are quite new. We offer the following insights to help educators listen for misconceptions and develop accurate understanding in their learners.

1. Ecosystems are an easy way to launch into the study of forest health. People typically think that a healthy forest is also a healthy ecosystem, and this is a good foundation on which to start a forest health unit. What may be less intuitive is that urban forests and plantations are also ecosystems that contain similar types of biotic and abiotic influences and relationships as natural forests, albeit with heavy anthropogenic influences. One advantage of using an ecosystem approach to forest health is that learners may be better able to generalize indicators of forest health and apply them to a variety of forests rather than believing that each forest is healthy for unique reasons. Exposure to ecosystem concepts in school can help students develop this perspective.

Photo: Larry Korhnak

Figure 4. Can you name all the living things in this picture? Most of us would point out the raccoon, but few would include the oak it is perched on. Fewer still might notice the patches of lichen growing on the oak bark. Yet all these organisms are part of a healthy forest.

2. Many people mistakenly consider mammals and birds a defining feature of forest health. This may be because they are more familiar with animals than trees (Figure 4). While animal diversity is important, it is not the only important component of forest health, and some animals (or too many of a specific kind) can be a destructive force as well as a positive element.

3. Invasive exotic species are common in the Southeast and students are likely to be aware of their influence on natural ecosystems. Some species are better known than others, of course, but drawing attention to the generic strategies and influences of non-native species helps students make more robust future connections to ecosystem health.

4. Younger students typically prefer a world with clearly defined good and evil, even in forests. Young learners, therefore, may be challenged to understand that threats to forest health have both positive and negative implications. For example, insects have multiple functions in the forest. Positive roles include pollination, decomposition, and prey for other organisms, and negative roles include defoliation, vectoring of tree disease, and associated tree decline.

5. Insects, fungi, and other microorganisms are ubiquitous in forests, yet ignored as key components. This is perhaps because they are small (Figure 5) and are rarely featured on television specials, unlike larger animals. Fungi in particular are poorly understood by people of every age. Few correctly identify them as potential pathogens in forests, and their life cycles remain obscure. Yet fungi, bacteria, and other micro-organisms are essential to forest health, and this handbook attempts to give these organisms greater exposure.

Photo: Joseph O'Brien, USDA Forest Service, Bugwood.org

Figure 5. Misunderstood miniatures: This bird's nest fungus, found on the forest floor, is usually invisible but for its pencil head-sized fruiting bodies, yet it is an important decomposer of plant litter.

6. Students who have been exposed to natural or managed forests or farms may have an awareness of forest management strategies that is not always possible to duplicate in coursework. Urban students may benefit from a field trip to several types of forests to better understand the concerns and potential solutions to forest health challenges. Facilitating small group discussions and using students' experiences in class discussions enables students to share their knowledge with each other.

7. It may be tempting to use human health examples to teach about forest health, but the analogy does not transfer well. Tree health may be explained using examples from students' own lives—they are familiar with being sick, and trees can have diseases too. Tree diseases are usually caused by fungi and bacteria, while our diseases tend to be from viruses and bacteria. Likewise, broken bones heal, as do structural wounds on trees, but through different growth mechanisms. However, the analogy loses elegance when up-scaling from individual trees to the population. Forest health can be improved when weak and stressed trees die, and dead trees play an important role in returning nutrients to the forest ecosystem. But a friend or relative's illness or death is not easily recast into a statement about how this helps the human population overall.

In developing this handbook, consultation with forestry and education experts, and surveys with systems thinking experts led us to realize that forest health may be effectively taught, at least to older audiences, by using a critical thinking framework known as systems thinking. Forests exhibit many properties of systems, and their behavior and dynamics can be approached from a systems perspective. Systems thinking is relevant to teaching forest health because it encompasses the intricacies and nuances of forests as dynamic ecosystems.

Furthermore, it points to a very real issue in learning about healthy forests and how to maintain them—that this is a problem that requires increasingly creative and robust solutions. Preparing students to understand the state of forests from a systems perspective is a foundational step to empowering them with the skills to engage in problem solving, figure out their stake in forestry-related issues in the future, and take appropriate actions to protect those interests.

A Systems Thinking Framework for Forest Health

Systems thinking is a higher order thinking skill. It enables learners to view information in a multi-layered fashion, looking at phenomena in terms of interrelationships and building linkages between objects. It allows learners to dissect a large and complicated subject such as forest health into components and then put those components back together.

For instance, fungi, soil, and timber production form an interrelated system: some fungi spread through root connections between trees underground; soil properties affect the types of fungi that are able to grow there; a timber grower wants to produce a profitable crop and relies on beneficial soil fungi to promote tree growth (Figure 6), but is concerned about fungal species that might attack and weaken his trees. Systems thinking helps us realize the importance of soil characteristics when managing forest health.

In the preceding scenario, different strands of knowledge may be connected using systems thinking and connections to real world applications may also be made. In real life, there are no simple answers to complex problems. Systems thinking allows you to deconstruct an issue by looking at the causes behind the problem and the relationships of parts to the whole. An answer to the problem can then be determined that takes into consideration multiple perspectives as well as long-term consequences for a variety of actions.

In another example, the simple answer to a pest outbreak in a forest might be to use a pesticide. To reconsider this action from a systems perspective, you might ask the following questions: Why is the pest present? What features of the environment allow it to multiply rapidly? Where are its predators? If pesticide were used, would any other organisms be affected? Is there a more effective solution to the problem—not how to kill the pest, but how to prevent the population from growing?

Photo: Robert L. Anderson, USDA Forest Service, Bugwood.org

Figure 6. Know your fungi: Beneficial fungi form protective and absorptive sheathes around roots, like those of this pine seedling. Pathogenic fungi, on the other hand, may cause root rot or other diseases.

While systems thinking is a versatile and useful skill, it is not easy to learn, let alone teach. However, a foray into systems thinking can be made by becoming familiar with what systems are and how they operate. Systems are found everywhere in nature, and the dynamics of systems behavior can be seen in forest ecosystems. *Beyond the Trees* references systems behavior implicitly when it covers such things as population cycles and plant-fungi or plant-insect relationships.

Furthermore, the following systems thinking elements should expose you to some aspects of systems that are explicitly referenced in this handbook. See Table 1 for an extended description of how each activity covers forest health concepts using different teaching tools and systems thinking elements.

1. Interdependence: Variables in a system are connected and have effects upon each another. Ecosystems are rife with interdependencies—plants and pollinators are mutualists, nematodes are tree root parasites, wasps predate upon caterpillars, and so on. Concepts maps are introduced in Activity 2 as a tool to visualize interdependence within a system.

2. Feedback loops: A change in one variable results in a consequential change in another variable, which results in a further change in the first, and so on. There are positive and negative feedback loops, referring to the direction in which one variable changes relative to the other. Predator and prey populations alternate in size in a classic example of a negative feedback loop, as seen in Activity 5. Runaway sexual selection

Table 1. The six activities in *Beyond the Trees* cover various forest health concepts using teaching tools that emphasize student interactivity, hands-on learning, and creativity. In addition, systems thinking elements are embedded into each activity. Educators are encouraged to use the "Thinking in systems" section in each activity to expose their students to the value of this skill.

Activity	Forest health concepts	Tools to teach concepts	Systems thinking elements
1. A Walk in the Woods	Tree species composition characterizes forest ecosystems.	Use a map and key to identify tree composition changes in a forest.	Feedback loops: Exotic species competition negatively affects native species growth. Micro- to macro-systems: Micro- climate changes may favor an exotic invasive rather than a native seedling; the forest composition changes on a macro-level. Thinking in systems: A behavior-over-time graph explores these ideas.
	Micro-environmental conditions influence tree seedling growth.	Compare the influences of environmental conditions in light and shade upon seedling growth.	
	Exotic invasive trees compete with native ones for resources.	Use a behavior-over-time graph to contrast native and exotic invasive tree growth rates.	
2. Six Bits of Abiotics	Abiotic environmental factors affect the health of trees.	Solve a mystery in a group to identify an abiotic tree stressor.	Interdependence: Students solve the mystery through cooperation. Also, community decisions affect pollutant levels which in turn affect forest health. Inputs and outputs: Leaf gas exchange of a pollutant results in visible cell damage. Thinking in systems: Concept maps make these ideas easier to follow.
	Some abiotic environmental stressors, such as air pollutants, have anthropogenic causes.	Discuss the anthropogenic origins of an abiotic tree stressor using a concept map.	
3. How to Eat a Tree – An Insect's Guide to Finding Food in the Forest	Insects and trees use specialized offensive and defensive strategies against each other.	Read stories about insect feeding strategies and corresponding tree defense strategies.	Interdependence: Herbivorous insects depend on appropriate host trees for food. Micro- to macro-systems: The individual insect-tree relationship is expanded to the insect-tree population relationship in Activity 5. Thinking in systems: An impact triangle is used to model a basic relationship.
	Specific environmental conditions favor trees or insects to the detriment of the other.	Design posters marketing environmental conditions favored by specific trees or insects.	
	The impact triangle shows how certain environmental factors allow specific insects to attack susceptible host trees.	Use posters to match insects to host trees that would support them.	

is a positive feedback loop where extreme characteristics in a male organism lead females to choose them as mate—their male offspring have corresponding extreme features while their female offspring are increasingly predisposed to prefer those features. A behavior-over-time graph, such as the one found in Activity 1, may also be adapted to explore feedback loops in detail.

3. Inputs and outputs: As the boundaries of a system are defined, what enters and leaves that system become its inputs and outputs. If a tree is a system, some of the inputs that affect its ability to function include light, water, and nutrients; outputs include shade, oxygen, carbon dioxide and seeds. Inputs, outputs, and their effects on an ecosystem may be observed in many activities, including Activities 1 and 4.

4. Micro- to macro-systems: Every system, upon magnification, is composed of parts that are in themselves micro-systems. One landowner's cultivation of harvestable trees is a micro-component of timber production statewide, and the price of timber statewide is affected by not just local but also national and international fluctuations in the supply and demand for wood. Micro and macro-systems are seen in various activities, and particularly Activities 3 and 5.

Activity	Forest health concepts	Strategies to teach concepts	Systems thinking elements
4. Forest Travels – A Guide for Fungi	Fungi use various dispersal methods including wind and root contacts to move through the forest.	Use maps to plot fungal growth and tree colonization in a forest.	Feedback loops: As wood-rotting fungi extend their range, more stressed and dead trees are decomposed. Inputs and outputs: Wind disperses rust fungus spores from one tree stand to the next; removing co-host trees interrupts the fungus' reproductive cycle. Thinking in systems: Inputs, outputs, and system boundaries help clarify the role of fungi in a forest.
	Environmental conditions favor fungal dispersal to specific susceptible trees, according to the disease triangle.	Read stories about fungal dispersal strategies under environmental conditions that favor them.	
	Barriers including soil trenching and removal of cohost trees can prevent fungal dispersal.	Discuss possible management options to curb fungal dispersal in a forest.	
5. How to Eat a Forest – Southern Pine Beetle-Style	Southern pine beetle populations grow given specific environmental conditions.	Play a game of beetle infestation on a model forest game board.	Micro- to macro-systems: Activity 3 is expanded upon to observe the effects of southern pine beetle herbivory in a forest. Inputs and outputs: The simulation of different numbers of beetles and trees in each game round can be varied to modify outcomes. Thinking in systems: Positive and negative feedback loops can be modeled to explain population explosions.
	A southern pine beetle-vectored fungal infection can alter forest composition.	Tally and describe game board changes before and after each round of beetle infestation.	
	The impact triangle shows how beetles to attack susceptible pines under favorable conditions.	Use a worksheet to complete an impact triangle for southern pine beetles.	
6. Unhealthy Forests and the News	Forest health is a current issue in the news.	Read stories of a recent regional forest health, laurel wilt disease, issue in the news.	Interdependence: Ambrosia beetles and palamedes swallowtails rely on redbay trees; people in south Florida rely on the avocado industry. Feedback loops: The laurel wilt fungus-beetle cohort decimates redbays; avocados and palamedes swallowtails are also affected. Thinking in systems: Framing is used as a tool to understand viewpoints and bias in news reporting.
	How people determine forest health depends on stakeholder values and interests.	Compare how and why stories focus differently on stakeholder interests for the same issue.	

Good educational strategies are often experiential; students learn best when they can manipulate objects, test hypotheses, observe interactions, and model concepts. Many systems thinking researchers have capitalized on these strategies in designing educational materials. In keeping with their findings, the activities in *Beyond the Trees* employ such tools as maps, charts, and games to model and simulate real forest systems within the confines of a classroom.

Teachers from many different disciplines may find these strategies applicable to other topics besides forest health. We encourage you to adapt some of the tools and ideas found here to enrich your teaching, and hope that you will draw students' attention to how the concepts they learn from these activities are also connected to what they are learning elsewhere—such as in economics, geography, or chemistry; from hiking in the woods; or from reading the newspaper.

Using This Material

Beyond the Trees is designed for use in 9th through 12th grade classes in agricultural education, forestry, biology, environmental science, and other related classes. The dual goals of this handbook are to convey basic concepts of forest health, while exposing teachers and students to the language and tools of systems thinking.

All six activities in this handbook are correlated to the Next Generation Sunshine State Standards. They provide background information, step-by-step directions to implement each activity, extension and assessment suggestions, and student handout pages when appropriate. Unfamiliar terms are highlighted in ***bold italics*** and are defined in the glossary at the end of this handbook.

A "Thinking in systems" section in each activity encourages you and your students to maximize understanding by looking at forest health through a systems thinking lens. The points raised in this section will help you guide your students to think about systems and recognize the value of systems thinking skills, asking them questions that place them in the position of decision makers, critical thinkers, and problem solvers.

The activities suggest that educators access additional resources, photographs, and slide presentations. Many of these are available at SFRC's Extension website for educators at: http://sfrc.ufl.edu/extension/ee/foresthealth.html, including links to videos, fact sheets, and other sites that will help educators discover a host of resources.

Specific materials created to complement this guide include the following:

- ***What Is a Healthy Forest? A Supplement to Florida Project Learning Tree***
  What Is a Healthy Forest? is a supplement to the Project Learning Tree (PLT) Pre K–8 Environmental Education Activity Guide, containing modifications and extensions to thirteen existing PLT activities as well as five new activities. These activities create a module on forest health for students in grades 5 and 7. The new activities share similarities with the activities developed for this handbook and may be used to augment the concepts learned here.
- **Pocket Identification Guide to Forest Pests and Tree Diseases of the Southeastern United States**
  The *Pocket ID Guide* is a deck of flash cards with photographs and identification information of common and important insect pests, tree diseases, and miscellaneous other forest stressors. These flash cards may be used as activity supplements or as a teacher resource.
- Visual presentations and photographs are available on the SFRC Extension website for educators: http://sfrc.ufl.edu/extension/ee/foresthealth.html.

There is an electronic version of this handbook at the SFRC Extension website listed previously. These resources should enable you to build a unit that fits your teaching style, your students, and your forest ecosystem.

Conclusion

Forest health is an exciting and thought-provoking topic for biology, agriculture, current issues, and environmental science classes. Issues range from basic concepts to historic successes and calamities, and from unanswered questions to current debates. Forest health challenges affect urban and rural residents, private landowners, and public properties. Some issues are natural, while others are caused or magnified by people. Forest health is a topic that includes variety and complexity while inviting multiple opinions and new discoveries.

There is no question that forests provide important ecological services and economic resources to those who live in the Southeast. Similarly, there is no doubt that the health of our forests is contingent on the decisions we make to manage and enhance southeastern landscapes. The activities in this handbook help students rise to the challenges of managing forests for human use as well as ecosystem health, now and in the future.

Activity 1

A Walk in the Woods

Sunshine State Standards

Science (9-12): SC.912.L.17.1, SC.912.L.17.4, SC.912.L.17.5, SC.912.L.17.7, SC.912.L.17.8, SC.912.N.3.5
Social Studies (9-12): SS.912.G.5.4, SS.912.G.6.1
Mathematics (9-12): MA.912.A.2.1, MA.912.A.2.2, MA.912.A.8.2
Reading/Language Arts (9-10): LA.910.2.2.1
Reading/Language Arts (11-12): LA.1112.2.2.1

Materials

For each student
1 copy of the *Student Page* section (4 pages).

For the teacher
Computer and projector to display visual supplement.

Time Considerations

Part A: 10 minutes
Part B: 30 minutes
Part C: 20 minutes

Behavioral Objectives

Students should be able to do the following:

- Read a map to identify tree species composition from three forest micro-ecosystems.
- Compare environmental conditions for seedlings in different geographic locations.
- Use a graph to compare the rate of growth over time for a native and an exotic invasive tree.
- Draw rate of growth curves for native and exotic trees on a graph.
- Compare the successive growth rate curves for the native and exotic invasive species.
- Identify how the speed of growth of an invasive compared to a native tree will impact the colonization of a light gap in a forest.
- Explain the importance and impact of competition between native trees and exotic invasives.

Lesson Summary

In this activity, students learn several basic concepts about forests including the definition of a forest, the factors that determine forest composition, the environmental requirements for tree growth and reproduction, and the effect of invasive exotic competition upon native species growth. A visual presentation and discussion introduce these concepts. A worksheet that includes map reading and graph work aids students in visualizing and applying concepts.

The map simulates distribution, composition, and transition of trees in some of the natural ecosystems in Florida. Students are introduced to some of the native tree species from these microhabitats and to a common invasive exotic tree that can establish itself in a native habitat under the right environmental conditions. The graph juxtaposes the rate of growth of the invasive exotic versus a native tree species. The wrap-up discussion that follows addresses the significance of the concept outlined in the graph—the immediate effects of competition between a native and exotic invasive for the same resources as well as the potential result of such competition on overall forest composition and, subsequently, forest health.

Background

Forest Features: An Overview

This activity walks students through several basic forest features and functions. The provided visual presentation (see *Resources and References*) enables you to guide students in a virtual walk through the woods, using terminology and visuals that are later revisited in the *Student Page* section. Many of the terms, concepts and activity tools introduced here are reinforced in subsequent materials. The text in this section is a starting point for you to use with the visual presentation. You may choose to summarize or expand upon the information found here, based on your students' prior familiarity with this subject.

Take it outside

Consider arranging a visit to a real forest as a supplemental teaching tool to the virtual forest tour.

There are many factors that influence the development and ***composition*** of a forest ecosystem. Some of the most important include what type of environment the trees are growing in; which trees are producing seed; whether or not ***exotic*** species are present and if they are ***invasive***; and how the entire cohort of trees, from seedlings to mature trees, sprouts, grows and dies over the years. These aspects of forest ***dynamics*** form a baseline for assessing ***forest health***. They address typical forest properties and atypical ***disturbances***, which feature prominently in further activities as factors that contribute to unhealthy forests.

The trees in a forest do not grow randomly. Some trees need soils high in nutrients. Others may thrive in water-logged soils. Still others may need dry, well-drained soils to survive. The pattern of tree distribution in a natural forest is determined by soil type, availability of nutrients, availability of water, and so on. For instance, bald cypress trees are adapted to grow in wetlands where they can withstand long periods of root submersion in water (Figure 7), while longleaf pines are adapted to grow on dry, sandy soils despite the poor availability of nutrients.

Photo: Larry Korhnak

Figure 7. Bald cypress at the water's edge: These trees are adapted to withstand prolonged root submersion under water and thrive along riversides and lake edges and swampy areas.

The virtual forest depicted in the visual presentation has three distinct microecosystems—the riverside or riparian community dominated by cypress and other flood tolerant trees; the mixed hardwood community featuring live oak, magnolia, and other hardwood trees; and the sandhill community that is dominated by longleaf pines. These communities form a continuum of microclimates and the dominant trees support a variety of other organisms that specifically favor those particular ecosystems.

Most of the trees in this forest are native to the southeastern United States. ***Native species*** are those that have historically occurred naturally on that land. Southern magnolias, *Magnolia grandiflora*, for example, are a common native tree in Florida. Native species are well adapted to their environments and many other organisms depend on them for food and shelter.

Non-native species are called exotics—they have been introduced to an area purposefully or by accident. For instance, the Japanese mimosa, *Albizia julibrissin*, which is also found in this forest, is native to Asia, but was introduced to the United States for its ornamental flowers and its ability to grow quickly in good light conditions (Figure 8). Mimosa is a rapid colonizer—it takes advantage of landscape disturbances that produce ***light gaps*** and grows quickly from dormant seeds or underground shoots. Its ability to establish itself in a non-native environment by aggressively out-competing native species is what makes it an ***invasive*** exotic organism. See *Resources and References* for more on this concept.

Photo: James H. Miller, USDA Forest Service, Bugwood.org

Figure 8. The Japanese mimosa, or silk tree: This ornamental exotic can quickly colonize disturbed native ecosystems, becoming invasive in the process.

Different trees have different rates of growth. They may grow faster or slower depending on how favorable the environment is. The requirements for ideal growth, such as light quality, ambient temperature, water availability, shelter from wind, escape from or resistance to ***parasites***, space to grow, and nutrient availability are all specific to different tree species. For instance, magnolia seedlings may grow well in partial shade, but mimosa seedlings prefer full sun.

Competition between plants adds another dynamic to the list of environmental factors that affect seedling growth. For instance, fast-growing mimosa seedlings may quickly take up nutrients, creating poorer conditions for slower-growing magnolia seedlings, further limiting the magnolia's rate of growth.

Forests are always changing. As time passes, trees grow older, reach maturity, weaken and die, and younger trees take their place. New trees may grow in light gaps, or they may grow through the branches of older trees. There are numerous seedlings in the forest and the forest floor is littered with dormant seeds. This seed bank accumulates in many ways—dropped by the trees in the forest; carried by wind, water, or animals from other areas; and sometimes even through intentional planting by human activity. Their growth alters the structure of forests by replacing old trees with new ones. The forests' composition changes as ***succession*** patterns change—when the trees that replace the dying ones are of a different species than before. In a typical succession, fast-growing shade-intolerant species like pines are replaced over time by slower-growing shade tolerant species, typically hardwoods such as oaks.

Thinking in systems: Behavior-over-time graph

There are many tools used in this handbook that represent three-dimensional and even four-dimensional properties of a forest. In teaching students about dynamic ***systems***, one important method is to capture these dynamics in simple models on paper. This activity uses one tool—a virtual map to help students feel situated in a forest by visualizing the geographic space even if they are sitting inside a classroom. Maps, which are employed in this handbook in several other activities, help students think about how a landscape changes from one area to another.

Another tool used in this activity captures something more elusive—change that occurs over time. While the map of the virtual forest and the questions accompanying it in the *Student Page* section help students understand the composition of the forest across space, the ***behavior-over-time graph*** plots in more explicit terms *how* those changes in tree species may occur over a period of several years.

Behavior-over-time graphs are useful because they reveal information about a phenomenon. However, it is important that they are read correctly. The horizontal *x*-axis represents time. In linear fashion, occurrences are plotted against the *x*-axis to depict what happens over a period of seconds, hours, days or, in this case, years. The *y*-axis represents the behavior in question. In the case of tree growth, the *y*-axis shows how fast the tree grows from seedling to maturity.

The power of the behavior-over-time graph is that it can be used to plot behavior for more than one phenomenon, allowing for comparison in the rate of change for these phenomena. In this activity, by looking at the rate of growth for an exotic invasive tree (the Japanese mimosa) and a native tree (the southern magnolia), one can see by the shape of the curves that both trees have similar growth patterns—slow growth at first as seedlings gather nutrients, then accelerated growth as the tree is able to maximize efficiency, a plateau phase during early maturity where the tree is established in the forest, and a drop-off period in late maturity when the tree begins to die (see Figure 10 on page 6). The difference between the mimosa and the magnolia, as seen in the graph, is the *time* it takes to go through these phases—in the time it takes for one magnolia to reach reproductive age, the mimosa has already produced many generations of seeds, many of which may have the potential to reproduce as well.

You may use other examples to teach students how to read behavior-over-time graphs. For example, keeping with the central theme of trees, you might ask students to imagine how a tree's rate of growth changes during a year, rather than a lifetime. Deciduous trees shut down their vital processes in the winter, so there is no growth during the cold months, but as the days grow longer and the seasons change, the tree bursts into life—correspondingly, an accelerated rate of growth is seen during the spring and summer months. Evergreen trees, over the same yearly period, exhibit a different growth pattern—their metabolic rate may slow down in the winter, but it does not stop completely. In teaching students about trees, it helps to employ such graphic comparisons to make concepts clearer.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.
- Familiarize yourself with the visual presentation supplement for this activity, (see *Resources and References*). You may modify the presentation as necessary for use with your class.
- Prepare the supplies outlined in the *Materials* section.
  - For each student:
    - One copy of the *Student* Page section (4 pages).
  - For the teacher:
    - Computer and projector to display visual supplement.

Doing the Activity

Part A: Introduction to forests
10 minutes

1. Use the *Background* information to engage students in a preliminary discussion of these questions:

a. What defines a forest?

b. What determines which trees grow where? Are they planted or naturally growing?

c. Can every tree grow anywhere?

d. What is an exotic tree and why are there some exotics in Florida's forests?

2. Lead students in a walk through the virtual forest visual presentation.

Part B: Working on the *Student Page* section
30 minutes

3. Hand out copies of the *Student Page* section to students and instruct them to work through the answers to the questions. Conducting this activity in classrooms has revealed that younger students may find the behavior-over-time graph on *Student Page* 2 challenging. If needed, you may answer questions 4 through 8 of the worksheet together with students so they are better able to grasp how the graph works.

Part C: Discussion and reflection
20 minutes

4. Lead students in a discussion of their answers to the worksheet, using the *Answer Key* as a guide. Be sure to discuss the importance of exotics in an ecosystem. The following questions may guide discussion.

a. What did you notice about the growth of mimosa that was different from that of magnolia?

b. If mimosa trees were fast growing, but produced only 10 seeds a year, how different would that be than if they produced hundreds of seeds each year?

c. What is the difference between an exotic and an invasive?

In answering this question, Table 2 may provide further context for students. Draw a version of the table for the class and describe to students trees that match the description of both the row and the column.

An example of a non-invasive native tree in a sandhill ecosystem is the longleaf pine. Longleaf pine ecosystems have suffered from fire suppression for many years; as a result, some fast-growing oaks such as laurel oaks are beginning to dominate in that system. Laurel oaks are native to Florida, but do not belong in a healthy, fire-regulated sandhill ecosystem, so they are considered native invasives.

Exotic trees are those that have been accidentally or purposefully introduced into an area where they are not native. Some exotic ornamental trees, such as gingko, for example, are not invasive because they do not proliferate rapidly—gingko requires male and female trees in close proximity in order to reproduce, and if only male trees are planted (since the females produce smelly fruit), there is no chance of seedlings being accidentally propagated.

Exotic invasives are those trees that have the ability to aggressively get a foothold in an ecosystem in which they don't belong. Mimosa is one such invasive, because its original introduction as an ornamental plant has been superseded by its rapid production of numerous small seeds that are spread over long distances, allowing it to colonize habitats where it is not welcome.

Table 2. Some examples of natives, exotics, and invasives.

	Native	Exotic
Non-invasive	*Longleaf pine in a sandhill ecosystem*	*Gingko in a southeastern city park*
Invasive	*Laurel oak in a sandhill ecosystem*	*Japanese mimosa in a southeastern city park*

5. Exotic and invasive species removal is an important task for land owners and natural resource managers who are concerned about forest health. Lead students in a discussion and realization of why this is such a difficult problem to deal with. Ask questions such as the following to wrap up discussion.

a. How would you collect exotic invasive seeds from the forest floor before they have a chance to sprout and grab a foothold?

b. How would you prevent exotic invasive release?

c. If exotic invasives are already present and well established in an ecosystem, is it worth it at all to spend time and money eradicating them?

d. What do you think is important about this challenge in forest management?

Student Page Answer Key

The following are suggested answers to the *Student Page* section that follows. It may be used to assess students' comprehension of the activity.

1. The *Treecosystems* map on *Student Page* 4 shows three micro-ecosystems—a riverside or riparian community, a mixed hardwood community, and a sandhill community. List at least two of the common trees found in the different ecosystems, using the map key as a guide:

Riparian ecosystem	*Pond cypress and water oak*
Mixed hardwood ecosystem	*Magnolia and live oak*
Sandhill ecosystem	*Longleaf pine and turkey oak*

2. Look at the distribution of different tree species on the map. Draw lines on the map to mark the approximate boundaries between these three ecosystems.

Refer to Figure 9 for answer.

3.

Condition (A)	Light gap (B)	Tree shade (C)
Example: Light exposure	*more*	*less*
Heat exposure	*more*	*less*
Protection from predators	*less*	*less*
Water availability	*more*	*more*
Space to grow	*more*	*less*
Amount of shade	*less*	*less*
Competition from nearby plants	*less*	*more*
Availability of nutrients	*more*	*more*
Shelter from wind	*less*	*less*

Students' answers to the table may differ from the provided answers in this book. The value of discussion is that it allows students a chance to justify why particular answers were chosen.

For instance, the table suggests that plants in a light gap face less completion from nearby plants than in tree shade. This is because the light gap represents tree absence, freeing up water, nutrients and other resources that would otherwise be consumed by that tree, and allowing seedlings to grow unhindered. Some students might suggest that the reverse is true by reasoning that the light gap opens up space for seedlings to compete with each other rather than with an adult tree. In the shadow, on the other hand, decreased light creates harsher conditions and therefore allows fewer seedlings a foothold for growth and competition.

For all the environmental conditions listed in the table, it would be valuable to engage students in critical discussion of why they think their answer is the right one, allowing them to debate the plausibility of each other's reasoning.

5. Look back at the map. Are there any large mimosa or magnolia trees near the light gap? Mark these trees by coloring in the circles. These reproducing trees will have dropped seeds to the area surrounding them.

Refer to Figure 9 for answer.

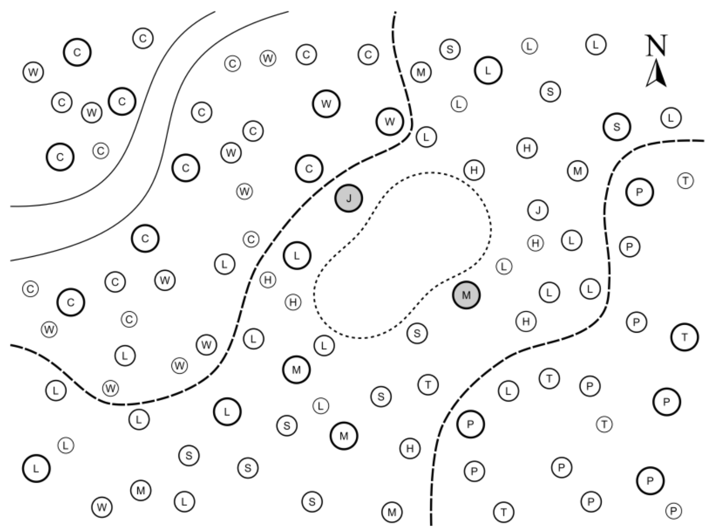


Figure 9. In students' answers to question 2, look for some approximation of the boundaries depicted by the heavy dashed lines in this figure. In students' answers to question 5, look for the shaded-in circles marked "J" and "M" adjacent to the light gap (dotted shape in the center of the map), seen here in grey.

Questions 6 through 8.

Refer to Figure 10 on the following page.

9. All other things being equal, if one magnolia and one mimosa seedling started growth now in the light gap shown on the map, what is likely to happen during the next 50 years, based on what you know about the two trees' growth rates and reproductive rates?

The light gap will likely be taken over by mimosa trees rather than magnolia.

10. What is the long-term impact of invasive trees that have short reproductive cycles in a forest? Are there any potential concerns?

Short-lived, fast-growing invasive trees reproduce faster and opportunistically take up more nutrients as they are growing. They are competitively advantageous and may choke off the growth of native trees, which take longer to grow in general. Since their seeds are so small, and the trees reach reproductive age so quickly, they have little trouble spreading through the forest. They may thus change the makeup of the forest by colonizing recently disturbed areas and choking off natural vegetation.

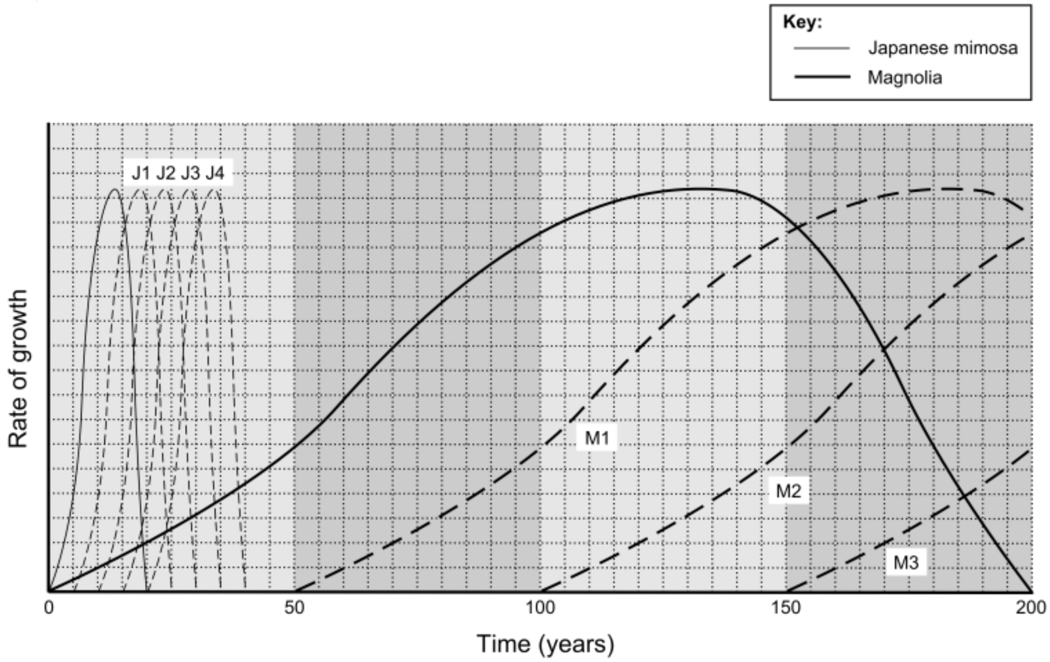


Figure 10. A behavior-over-time graph. Two hypothetical seeds of Japanese mimosa (J) and magnolia (M) sprout at the same time (T=0). In five years (T=5) the mimosa has reached reproductive age and produces seed of its own. At T=20 years, the mimosa will die. Thirty years later, at T=50, the magnolia reaches reproductive age. It will be another 150 years before it dies. At reproductive age, each tree may produce hundreds of seeds.

A hypothetical first generation seedling of mimosa (J1) could sprout at T=5 years. It will reach reproductive age in five years time, at t=10. Mimosas thus have the capacity to reproduce many times over long before magnolias produce their first offspring, and may out-compete magnolias in the process.

Assessment

Using the students' answers to the *Student Page* section, check that they can do the following:

- Read a map to identify tree species composition from three forest micro-ecosystems.
  Seen in students' answers to Student Page *question 1.*
- Compare environmental conditions for seedlings in different geographic locations.
  Seen in answers to question 3.
- Draw rate of growth curves for native and exotic trees on a graph.
  Seen in answers to questions 6 through 8.
- Identify how the speed of growth of an invasive compared to a native tree will impact the colonization of a light gap in a forest.
  Seen in answers to question 9.
- Explain the importance and impact of competition between native trees and exotic invasives.
  Seen in answers to in question 10.

Extension Ideas

- Conduct a field trip to a local state park, or from an urban center to the outskirts of a town. Ask students to keep observation journals, some noting landscape changes, and others vegetation changes. Have students create a map the next week detailing these observations. Have them identify common plants and their locations on the micro-landscape and research what sorts of environments are best suited to these plants' growth. Ask questions such as these: Do the environmental conditions at the locations on the map match the plant's specifications? What is the connection between location and vegetation growth at that location?

- Ask students to choose from an official list of regional and state invasive plants, in order to conduct further research on the plants' life cycles. Ask them to take particular note of the features that make invasive plants good colonizers. Lead the class in a follow-up discussion of their independent findings on a variety of plants. As a class, create a guide detailing the general characteristics of plants that are adaptively suited to becoming invasives—discuss what features they seem to have in common, and what features are unique to particular species.

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources.
  - A supplementary visual presentation with relevant images and figures may be adapted for use in discussion.
  - To teach more about the characteristics of successful invasive species, see *New Activity 4: Secrets of the Invasive Exotics* in *What Is a Healthy Forest?*

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- The National Invasive Species Information Center provides information and links to resources on local, regional, national, and international invasive species issues. You can search for organisms by geography or by species type.
  Visit http://www.invasivespeciesinfo.gov/

Name:

A Walk in the Woods

Instructions

In this activity, you will revisit the model forest you saw earlier in class—this time making detailed observations on what is found there. You will use two kinds of resources that are provided in this worksheet: a model map of the forest that you can draw on and a sheet of questions and directions to read information from the map.

- First, pull out the *Treecosystems* map on page 4.
- Then answer pages 1–3 of the worksheet, referring to the map when the questions ask you to.

Remember to write your name on all 4 pages of this worksheet before turning in your completed work to the teacher.

1. The *Treecosystems* map shows three micro-ecosystems—a riverside or riparian community, a mixed hardwood community, and a sandhill community. List at least two of the common trees found in the different ecosystems, using the map key as a guide:

Riparian ecosystem: ______________________________

Mixed hardwood ecosystem: ______________________________

Sandhill ecosystem: ______________________________

2. Look at the distribution of different tree species on the map. Draw lines on the map to mark the approximate boundaries between these three ecosystems.

3. There is a large light gap marked on your map with a dashed line. It was created after an old magnolia tree died. Since the old tree fell, seeds have been sprouting to recolonize the space.

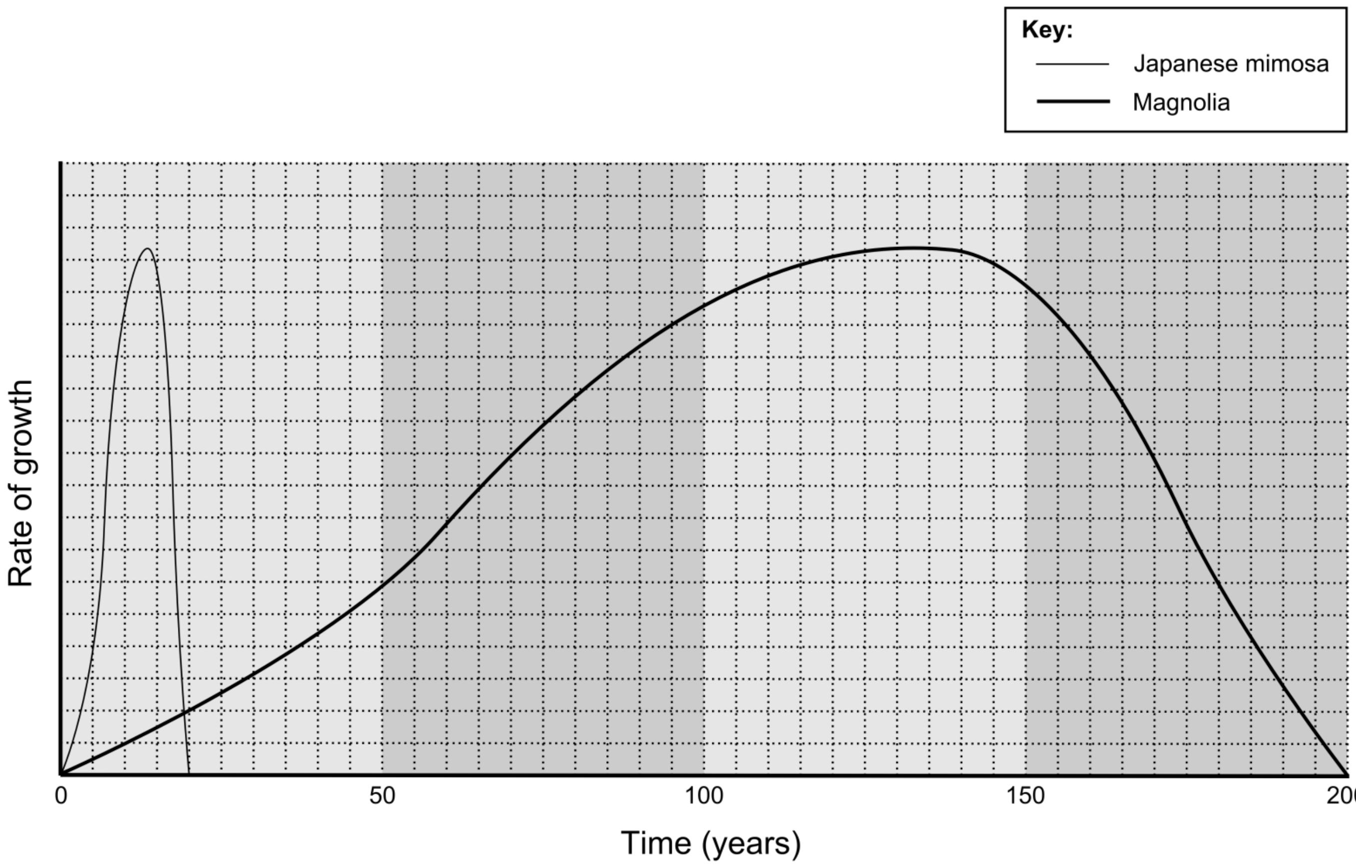
Think about the likely environmental conditions experienced by a seed or seedling growing in the shade, compared to one growing in the light gap. For example: which of the two receives more light? *The seedling in the light gap.*

The adjacent table lists a number of environmental conditions that trees experience while growing. For each condition category in the table (column A), complete information in columns B (Light gap) and C (Tree shade). Write whether you think a seedling in that location would receive “more” or “less” exposure to the environmental condition listed in relation to its position (light gap or tree shade). If you think that seedlings are equally exposed to any of the conditions, write “equal” in the respective columns.

Condition (A)	**Light gap (B)**	**Tree shade (C)**
Example: Light exposure	***more***	***less***
Heat exposure		
Protection from predators		
Water availability		
Space to grow		
Amount of shade		
Competition from nearby plants		
Availability of nutrients		
Shelter from wind		

4. Different trees species have different rates of growth. The following graph and table compare the rate of growth and lifespan of a mimosa tree with those of a magnolia.

How to read the graph and table:
On the graph, the thin line represents the rate of growth of a mimosa seedling over time. At time (T) = 0, the mimosa is a seed. From T = 0–5 years, the seed has grown into a seedling. From T = 5–15 years are the early and peak reproductive phase of the tree, where it grows from seedling to adult. This is the period when it grows the fastest and is depicted by the steepness of the growth curve. From T = 15 years onwards, the tree goes into a decline. When mature trees near death, they do not grow as fast as during their early and peak reproductive years. Although the magnolia goes through the same life phases, it does so at a much slower rate—it does not produce seeds until T = 50 years, and it is 200 years before it dies.



	Seed	Seedling	Early reproductive age	Peak reproductive age	Declining
Mimosa	0 years	1–5 years	6–10 years	11–15 years	16–20 years
Magnolia	0 years	1–50 years	51–100 years	101–150 years	151–200 years

5. Look back at the map. Are there any large mimosa or magnolia trees near the light gap? Mark these trees by coloring in the circles. These reproducing trees will have dropped seeds to the area surrounding them.

Name:

6. When the mimosa depicted on your graph first reaches reproductive age, it starts producing seeds. Draw a growth curve for the seed J1, which dropped from its mother tree when T = 5 years.

7. Similarly, draw a growth curve for seed M1, the first seed dropped by the magnolia whose growth curve is depicted on your graph by a heavy line. Remember to note when the magnolia first enters its early reproductive phase—this is the time when it produces its first seeds.

8. For the trees you have now represented as J1 and M1, repeat steps 6 and 7 and draw three more generations of seedlings (labeling them J2, J3, J4 and M2, M3 and M4), with each successive generation beginning from a seed that was produced at the earliest time its parent was able to reproduce.

9. All other things being equal, if one magnolia and one mimosa seedling started growth now in the light gap shown on the map, what is likely to happen during the next 50 years, based on what you know about the two trees' growth rates and reproductive rates?

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10. What is the long-term impact of invasive trees that have short reproductive cycles in a forest? Are there any potential concerns?

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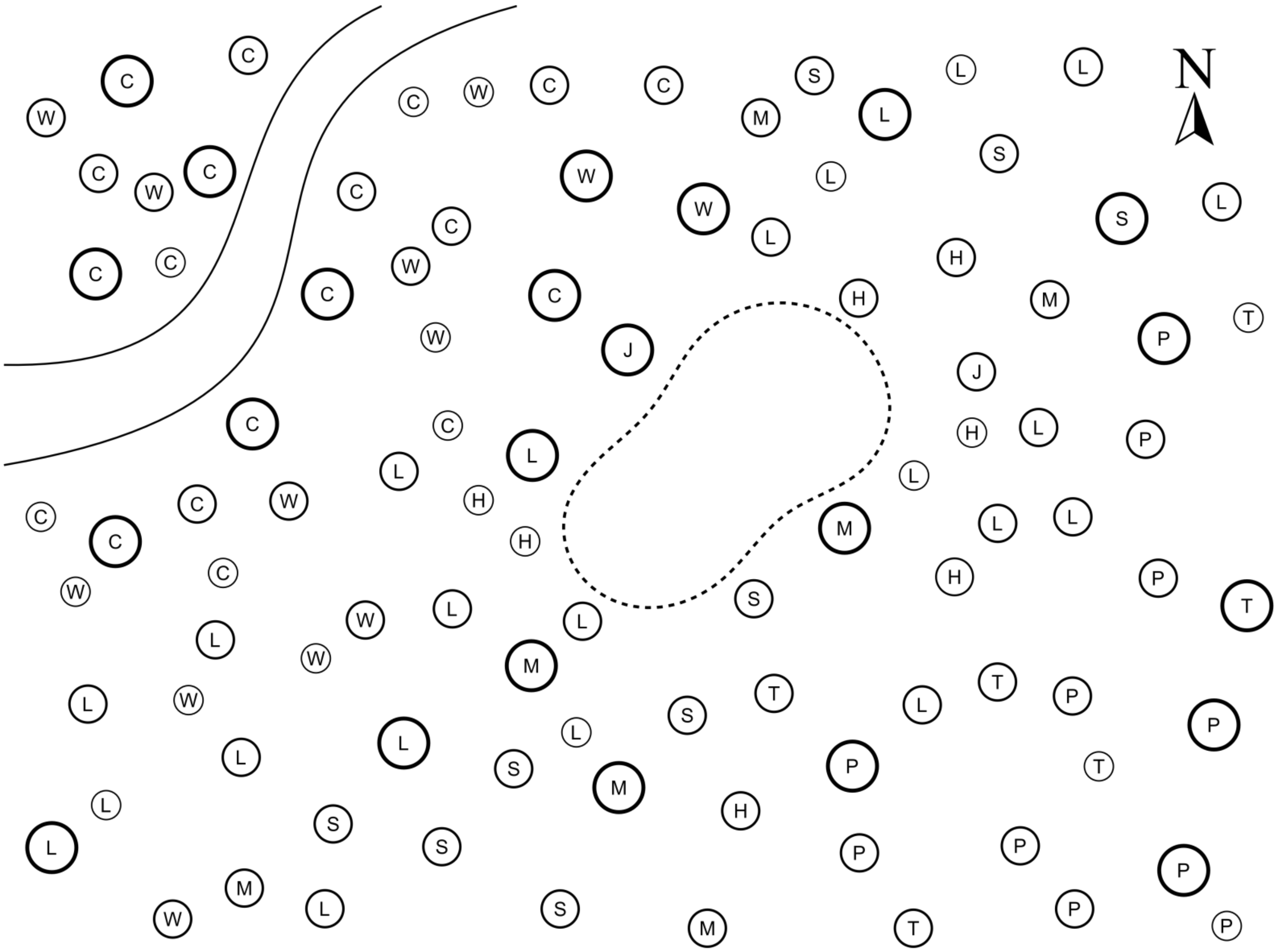
Treecosystems



Key:

Seed/Sapling	Early reproductive age tree	Late reproductive age/Mature tree
(C) Pond cypress	(L) Live oak	(S) Sweetgum
(H) Hickory	(M) Magnolia	(T) Turkey oak
(J) Japanese mimosa	(P) Longleaf pine	(W) Water oak

-------- Edge of light gap

Activity 2

Six Bits of Abiotics

Sunshine State Standards

Science (9-12): SC.912.L.17.7, SC.912.L.17.16, SC.912.L.18.11
Social Studies (9-12): SS.912.G.5.2
Reading/Language Arts (9-10): LA.910.1.7.4, LA.910.2.2.2
Reading/Language Arts (11-12): LA.1112.1.7.4, LA.1112.2.2.2

Materials

For each group of six students
1 copy of the *Student Page* (1 page).

For the teacher
1 pair of scissors.
Chalkboard, large sheets of newsprint, or other means of drawing and presenting information to the class.
Writing utensils.

Time Considerations

Part A: 10 minutes
Part B: 25 minutes
Part C: 25 minutes

Behavioral Objectives

Students should be able to do the following:

- Cooperate as a group to solve a problem.
- Describe skills that enhance cooperative work.
- Analyze the information coming from different members of each group.
- Synthesize information to solve the problem posed by a six bits activity.
- Identify the parts of an abiotic system as the nouns described in a six bits scenario.
- Form cause-effect linkages between the noun-object components identified in a concept map.
- Draw a concept map that describes the systems interactions in the six bits scenario.

Lesson Summary

In this activity students learn about abiotic environmental features and their effects on forests, and about some abiotic forest stressors. Students apply what they have learned to solve a mystery about a particular abiotic threat to urban forests—air pollution. The mystery is embedded in a collaborative learning exercise known as a six bits puzzle. Groups of six students are given six cards. Each student's card holds three seemingly unconnected snippets of information. By sharing information and working together, students put together the clues on their cards to solve the mystery.

A two-part discussion process helps students conceptualize the problem they have just solved. In the first part of the discussion, students create a concept map of the abiotic interaction represented in the six bits puzzle. The concept map shows students how various properties of an urban forest system are connected, and how a phenomenon such as pollution may affect urban forests. The second phase of the discussion session allows students to reflect on how cooperative behavior in groups helps them reach solutions. The six members of each group all have information that makes them partial experts on certain aspects of the mystery, but without acting as a group, they do not have enough information to solve the puzzle. You can help students recognize that they, too, are components of a system, able to influence each other to reach an answer that none of them can find on their own.

Background

Abiotic Interactions in a Forest

A tree is exposed to numerous environmental conditions that have an impact on its growth and overall health. These environmental factors are described as ***abiotic*** influences because they are nonliving factors. For example, if a tree with high water demands that normally grows in a swamp or floodplain is growing in a water-poor environment it becomes weakened because of limited access to water. What might cause a lack of water? It could be that the tree was planted in the wrong place and is not adapted to its environment or that water withdrawals or drought have lowered the water table. The causes of adequate, insufficient, or excessive access to water, light, nutrients, and other abiotic influences on tree growth are not restricted to just that tree—they are features of the greater environment. Just as a tree's health may be determined by environmental quality, so may the health of a forest. A drought can severely disadvantage an entire forest. It can stress water-dependent trees, but on the other hand, it may positively affect drought-tolerant trees, since they are able to thrive in the drier soils with less competition.

It is important to make the distinction between the effects of environmental conditions on individual trees—each of which may react in unique and specific ways to those conditions—and the impacts upon the entire forest, where the ***dynamics*** vastly more complex in terms of tree species, age classes, and species interactions. It is also important to understand where environmental conditions originate. A tree growing in a cubeful of soil on the side of a street with access to sun, air and water is quite different from a tree growing on the edge of a forest by a river or in the middle of a forest surrounded by weedy ***invasive*** trees.

This activity focuses on specific environmental interactions in an ***urban forest***. Development continues to be a prevailing trend of land use. Additionally, people are becoming increasingly aware of the importance of maintaining vegetation within and around their homes and workplaces; for aesthetic reasons; in order to maintain remnants of the original landscape; or to benefit from ecosystem services that trees provide, such as water purification, holding together of soil, and provision of shade. The urban forest is a particular category of forest that includes trees, other vegetation, and animals that form part of the landscape of the city. These forests often form a bridge from densely populated regions to sparser areas where farms, plantations, parks, or forest preserves may be (Figure 11).

Photo: Larry Korhnak

Figure 11. An urban forest: The trees left standing around development continue to provide ecosystem services.

Urban forests are significant because they are directly and continually influenced by anthropogenic activities. Construction activities and pedestrian and motor traffic cause ***soil compaction***, which increases pressure on roots while decreasing space for air and water to percolate. Additionally, storm water runoff is channeled along rooftops, gutters, across pavements and roads rather than directly into the soil. The water picks up and transports salts, nutrients, and contaminants between areas as it travels the city. Automobile exhausts, factory chimneys, and other sources release nitrous, sulfur, and carbon oxides; ozone; and other volatile gases. . These may combine with other molecules to fall to the ground or may dissolve in rain and travel through waterways.

These ***stressors*** are not ***infectious***—that is to say, the ***diseases*** or ***abnormalities*** they cause on trees do not spread, since the contaminants are not alive and do not reproduce. For instance, ozone intake through leaf pores (stomatas) of some trees in urban forests damages cells and causes purple spotting or stippling upon the leaves (Figure 12). The trees may weaken, but similar trees that are farther from the source of ozone will not be disturbed. Different species, and indeed different individuals within a population, have varying degrees of tolerance to abiotic stresses. But when a large area of trees succumbs to the same stressor, it may appear to the observer to be a contagious disease!

Photo: USDA Forest Service - Region 8 - Southern Archive, USDA Forest Service, Bugwood.org

Figure 12. Purple stippling on yellow poplar (*Liriodendron tulipifera*): Airborne ozone particles taken in by leaves through their breathing pores cause damage to the surrounding cells. Ozone interferes with cell processes responsible for chlorophyll production, resulting in spots of purple discoloration.

Abiotic factors that influence ***forest health*** may just as likely include dramatic events such as hurricanes, floods, or fires. While some of these may be triggered by anthropogenic activities, natural disasters also occur. Often, the way to distinguish between anthropogenic and natural abiotic stressors is to see whether the damage caused in the forest is random or follows some pattern. Pesticide misapplications cause a localized wake of damage and death. Hurricanes, on the other hand, leave wakes so large that local patterns may not be visible, and the damage caused to trees may seem massive, random, and chaotic.

Conducting a Six Bits Activity

This six bits activity operates on the principle of separating a case study or scenario into six partial "bits" of information. Students in groups of six are each given one of the six cards with unconnected facts about the scenario, such that no student knows exactly what the scenario is or what they need to do. One of the cards contains a question. Each group needs to realize that the question written on one of their cards is the key, and that putting together the pieces of information they have will allow them to answer the question. Students are not allowed to look at each others' cards; however, they are allowed to read them out loud and explain the information that they have to the other members of the group. Some of the facts on the cards are deliberately misleading red herrings that don't help answer the question, despite superficially seeming to. Only careful connection of the facts will solve the problem.

This cooperative learning activity depends upon all learners playing an integral role to answer the question. Since each group of six receives the same instructions, the discussion at the end of the activity can focus on why some groups worked well and others may have stumbled. The importance of identifying a leader and an awareness of what helps make a good leader also can be discussed. It might be interesting to have some single gender groups and some mixed groups to see how they may function differently. The actual solution to the question is only part of the value of this activity. Some teachers, after performing one six bits activity, have created others to teach various concepts to students. For more examples of six bits activities related to forest health, see *Resources and References*.

Thinking in systems: Concept maps and partnerships as problem-solving tools

A ***concept map*** is a diagrammatic representation of concepts and their linkages to one another. This useful teaching tool lays out for the observer the important items, issues, or ***component*** parts of a scenario and has lines and arrows connecting these items to each other to show how they are related. Together, the components and their ***relationships*** to each other form a ***system*** of interacting parts, so understanding the whole system is made easier by understanding how the pieces fit together. Concept maps may be representations of systems, but they may also be representations of the ways in which people think—individuals may draw conceptual understanding of a system in different ways, and this can point to differences in learning patterns as well as gaps and misconceptions in understanding. Thus, making a concept map helps students consider how a system functions.

This activity allows you to construct a version of a concept map with students, based on simple linguistic devices. A question about abiotic interactions is asked; solving the six bits activity reveals the answer. Both the question and answer can be represented as sentences. Each noun in the sentence becomes a "component" of the system of interactions that provide an explanation to the question. The students, using their six bits of information, can provide more information about each of the noun components of the initial question and answer—each of these sentences contains more nouns that represent more component parts of the system. The concept map drawn this way between nouns and facts known about those nouns can expand farther and farther past the initial starting point and may help reinforce what students learned through solving the six bits activity (see Figure 13 on page 15).

Another system is modeled through the six bits activity. The students in each group are component parts of a "system"; none of them can solve the mystery alone, and they must cooperate with each other in order to come to a solution. Pointing out to students how they functioned together in their groups allows them to reach an understanding about how the quality of interactions affects their ability to solve problems. They also learn that systems operate not just in ecosystems, chemical reactions, and biological processes, but also in everyday interpersonal relationships.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - For each group of six students:
    - 1 copy of the *Student Page* (1 page).
  - For the teacher:
    - 1 pair of scissors.
    - Chalkboard, large sheets of newsprint, or other means of drawing and displaying information to the class.
    - Writing utensils.
- Cut each *Student Page* along dotted lines to form packs of six cards for each group.

Doing the Activity

Part A: Introduction to abiotics
10 minutes

1. Prompt students to list some abiotic features of a forest and how these features might affect the ecosystem. See *Resources and References* for pictures to illustrate discussion.

Abiotic forest features include soil, water, air, sun, temperature, climate, and mineral salts—any non-organic component of the ecosystem. Abiotic features support the biotic components of a forest. Soil provides anchorage for tree roots, water transports minerals and nutrients, and so on.

2. Now ask students if they can think of any abiotic stressors to forests—non-organic features that disrupt or damage the health of trees or the whole forest.

*Answers might include drought, wildfire, flood, freeze, air pollution, etc. Natural abiotic resources are always present in a forest, but there may be fluctuations in their availability. For example, droughts and floods both affect the amount of water present in the ecosystem. Anthropogenic **disturbances** may also alter the availability or quality of abiotic resources, but sometimes they may introduce abiotic features that were never part of the environment, or they may remove features that were necessary for the ecosystem's proper function. Pollutants are abiotic additions that are not typically found in forests, and fire suppression is unnatural in a fire-dependent ecosystems.*

3. Divide the class into groups of six. Each student in a group gets one card of the six on the *Student Page*. Groups of less than six are preferred to greater than six. In two groups of five, for example, one student in each group will receive *two* cards instead of one. Instruct students in the rules of six bits.

- Each group gets a set of six cards.
- Each student in the group gets one of the six cards.
- Students are not allowed to show their card to anyone else.
- Students are not allowed to look at anyone else's cards.
- Students may tell people in their group, verbally, what is written on their cards.
- Each group is responsible for answering the question posed on one of the cards.
- The puzzle is also a race to see which group solves the mystery first.

Part B: Six bits of abiotics
25 minutes

4. Hand out a six-card set to each group. Ask them to distribute the cards, face down, one to each person. Once everyone has a card, ask the groups to turn the cards over and work together to find the solution to the puzzle.

5. Circulate throughout the room, noting how leadership develops, what causes difficulty, and the order in which groups finish. Wait for all groups to finish before starting Part C.

Part C: Discussion and reflection
25 minutes

6. Where all the students can see write the question posed by the six bits mystery: **Why do Marchwood City's linden trees have purple dots all over the leaves?**

7. Ask one team to send one of its members to the board and write underneath the question that group's solution to the problem.

8. Confirm with the rest of the class that this was the solution they all came to.

9. Ask another team to send one of their members to underline all the nouns in the question and the answer.

10. Ask another team to send one of its members to fill in a fact about one of the nouns underlined.

11. Ask a student from another group to underline the nouns in the new fact, and write in a fact of his or her own.

12. Continue in this form calling upon students from each group in turn to fill in a fact about a noun that has not yet been underlined. See Figure 13 on the next page for an example of a concept map that results from this process.

13. Explain to students that they have created a system of interacting components that together result in an outcome—in this case, the stippling of linden leaves as a result of ozone pollution. Following are some points you may touch on when describing the system that your students have created.

In the incomplete example, each noun is an object in the system of interactions that leads to ozone damage on linden trees. Each object is associated with multiple other objects, and the arrows show relationships between the components. Notice the sentences "Coal is a type of fossil fuel" and "[Enzymes] may be destroyed by ozone or SO_2." Alternately, an arrow may be drawn from "coal" to" fossil fuel" or "enzyme" to "ozone" or "SO_2" without the superfluous repetition of objects that are already represented by this system.

14. Next focus on the process that enabled each group to arrive at the correct response. Ask the first team to complete the mystery why they think they finished quickly. Ask the last to finish what bogged them down. Explore the role of leadership and what creates leaders. Sometimes it is the person who has the pencil or the question! Ask students why they were not allowed to show their cards, even though they could read them aloud.

The object of the six bits activity is to build cooperation, even when faced with a seemingly frustrating and impossible to solve problem. Some of the clues are red herrings—they don't lead to the answer, and are there to misdirect the group's participants. Likewise, minimal instructions force the group to take charge and figure out what is going on. They might start by asking each other whether they are just as clueless about what to do. One person might mention that they have a question on their card, and when the group realizes that this is unique and different from what is on all the other cards, it sets the ball rolling. What's the question? Once the group starts to share information and then make connections between the bits, they find their answer.

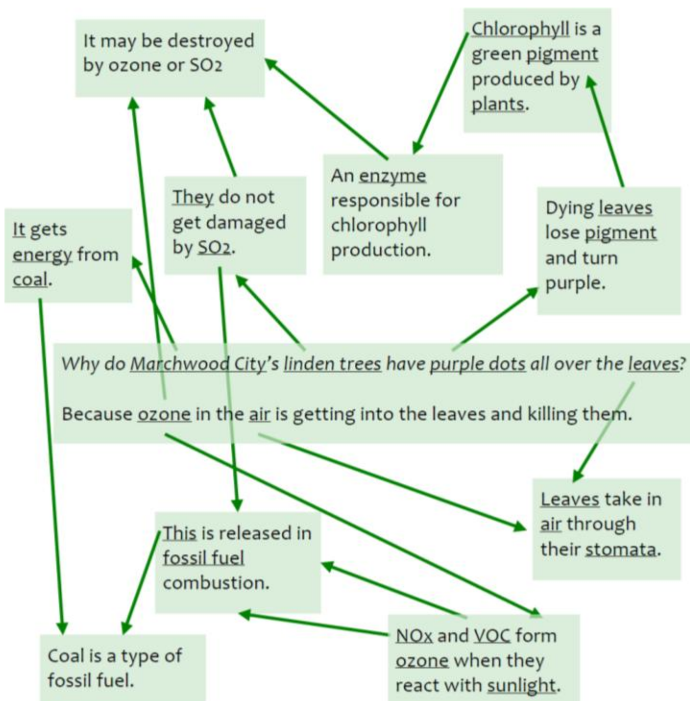


Figure 13. A partial concept map: Matching nouns to facts known about those nouns is one way to visualize the interconnections in a system.

Assessment

Using the students' answers during discussion, check that students can do the following:

- Cooperate as a group to solve a problem.
  Seen in students' successful completion of Part B as outlined in the Doing the Activity.
- Synthesize information to solve the problem posed by a six bits activity.
  Seen in successful completion of steps 1 and 2 of Part C in the Doing the Activity.
- Identify the parts of an abiotic system as the nouns described in a six bits scenario.
  Seen in successful completion of the concept map as outlined in Part C.
- Form cause-effect linkages between the noun-object components identified in a concept map.
  Seen in successful completion of the concept map as outlined in Part C.
- Draw a concept map that describes the systems interactions in the six bits scenario.
  Seen in successful completion of the concept map as outlined in Part C.

Note that these are group assessments, not individual student assessments. See *Extension Ideas* for an opportunity to assess students independently.

Extension Ideas

- The six bits scenario posed in this activity briefly mentioned high salt concentrations in water in Marchwood City. Salt is another abiotic factor that affects trees. If the question were posed: "*Why does Marchwood City have such high salt levels in the water?*" how would this system be drawn? Additional information would be required, since the causes and effects of salt accumulation in the environment are not completely discussed in the given activity. Ask students to create a hypothesis as to why salt concentrations in water might go up. Ask them to research the potential sources of salt in cities and the effects high salt concentrations have on trees. Have students individually create a hypothetical system of interactions to describe the scenario in a similar fashion to the ozone system that was discussed in class.

Resources and References

- The University of Florida's SFRC Extension website for educators includes several complementary resources.
  - A visual presentation with images relevant for this activity may be adapted for use in discussion.
  - Two other examples of six bits puzzles that teach forest health concepts are found in *New Activity 5: A Changing Forest*, in *What Is a Healthy Forest?*

  Visit http://sfrc.ufl.edu/extension/sfrc_extension/index.html

- More information on abiotic tree diseases is found at J. J. Worrall, USDA Forest Service plant pathologist's website *Forest & Shade Tree Pathology*. Specific information related to this activity is found under "Main Topics," "Abiotic diseases."
  Visit http://www.forestpathology.org/

Six Bits of Abiotics

Instructions

For each group of six students in your class, make one copy of this sheet. Cut the six cards along the dotted lines. Distribute a set of cards for each group—one card per person for each group of six, reminding students that they cannot show others their cards.

Do not show this card to anyone else. You may tell someone else verbally what is on your card.

- Excess salt taken through plant vessels travels from roots to leaf tips, where the salt is stored.
- Sulfur dioxide and ozone both form highly toxic compounds that cause enzyme damage to plant cells—these cells then die.
- Marchwood City derives its energy from a coal-fired plant just outside the city limits.

Do not show this card to anyone else. You may tell someone else verbally what is on your card.

- Tests of water runoff from Mrytle Town showed high salt concentrations.
- Why do Marchwood City's linden trees have purple dots all over the leaves?
- Marchwood City proudly boasts that nearly 60 percent of its workforce uses bicycles to commute to work.

Do not show this card to anyone else. You may tell someone else verbally what is on your card.

- It is summertime and most trees have green leaves.
- Chlorophyll is a green plant pigment produced by enzymes.
- Burning coal releases many gases: volatile organic compounds, nitrous oxides, and sulfur dioxide.

Do not show this card to anyone else. You may tell someone else verbally what is on your card.

- Patches, dots, or edges of leaf cells die when toxins accumulate in those regions.
- In autumn, deciduous leaves change color—the whole leaf may turn red, yellow, purple or brown as leaf cells die.
- Internal salt damage to plants causes leaf edges to turn yellow and then brown.

Do not show this card to anyone else. You may tell someone else verbally what is on your card.

- Ozone is a gas formed when volatile organic compounds and nitrous oxides are triggered by sunlight to react with each other.
- Chlorophyll production stops naturally in the fall and leaves eventually die, since they cannot make food without chlorophyll.
- Coal is a fossil fuel.

Do not show this card to anyone else. You may tell someone else verbally what is on your card.

- Sulfur dioxide badly damages pines and birches, but has little effect on cedar and linden.
- Individual cells lose shape and color as the enzymes inside them are broken down.
- Plants facilitate gas exchange through stomatas—breathing pores that cover the leaf surface.

Activity 3

How to Eat a Tree – An Insect's Guide to Finding Food in the Forest

Sunshine State Standards

Science (9-12): SC.912.L.14.7, SC.912.L.15.6, SC.912.L.17.1
Reading/Language Arts (9-10): A.910.1.6.2, LA.910.1.7.4, LA.910.1.7.5, LA.910.2.2.2, LA.910.2.2.3, LA.910.4.1.1
Reading/Language Arts (11-12): LA.1112.1.6.2, LA.1112.1.7.4, LA.1112.2.2.2, LA.1112.2.2.3, LA.1112.4.1.1

Materials

For every five students to share
1 copy of *Student Page A*, *B*, or *C* (2 pages).
2 sheets of 3 x 4 ft newsprint or poster paper.
2 or 3 markers.

For each student
1 copy of *Student Page D* (1 page).

For the teacher
1 roll of tape.

Time Considerations

Part A: 10 minutes
Part B: 25 minutes
Part C: 45 minutes

Behavioral Objectives

Students should be able to do the following:

- Read and obtain relevant information regarding insect-tree relationships from a text.
- Identify relevant information about defensive and offensive strategies employed by insects and trees from a text.
- Identify conditions favorable to insects but not trees, and vice versa.
- Present relevant information about insect and tree needs for survival.
- Match the correct tree host with insect causal agent using the information provided.
- Apply the impact triangle concept by connecting specific insects with the correct host trees.
- Complete an impact triangle for a particular insect-tree interaction.

Lesson Summary

Students are introduced to a basic insect-plant relationship—herbivory. They learn about three different sources of food that a tree might provide (leaves, sap, and wood); six different insects' specific approaches to eating those three parts of trees; and the defensive strategies employed by trees to prevent being eaten. The activity allows you to introduce the concept of specificity in an insect-plant relationship—a tree host may only be susceptible to damage by a particular insect predator in a particular region under the right environmental conditions. This is illustrated visually by an impact triangle, an important forest health concept.

For this activity students work in groups to read about insect interactions on one of three tree food sources and then create personal advertisements to help match trees to insects that can feed on them. The ads highlight the needs of insects and trees without identifying them by name. The entire class attempts to pair anonymous insects with trees based on the requirements specified by each organism in its ad. In the discussion that follows, you may contextualize the organism match-ups in terms of the impact triangle—unmatched trees have evolved defenses to discourage herbivory, and unmatched insects have specialized feeding requirements that preclude eating some kinds of trees. Finally, students demonstrate understanding by individually completing an impact triangle describing an insect-tree relationship not covered by their group.

Background

The Shared History of Plants and Insects

Plants ***coevolved*** with insects over millions of years. As a result, there are some very close ***symbiotic*** interactions between them. Pollination is one of the most recognizable associations, one that benefits plants (insects fertilize flowers) and insects (plants provide nutrients and food). There are other types of interactions—***mutualistic***, ***commensal***, and ***parasitic***. These relationships have developed through a history of amazing evolutionary adaptations (see *Resources and References* for some examples of symbiosis in forests).

Any aspect of a plant or insect's life cycle has unique properties, creating multiple ***niches*** for associations to occur. Feeding adaptations are one example of these specialized relationships. Since leaves are different in structure and function from roots, a ground-dwelling insect would not have the means to eat foliage. Similarly, a tiger swallowtail butterfly's coiled sipping mouthpart, adapted to sucking nectar from flower bases, would be ineffective for munching tree leaves. However, the butterflies' offspring, caterpillars, have chewing mouth parts and are efficient defoliators (see *Resources and References* for more on swallowtail feeding adaptations).

Trees have adapted to insect feeding pressures as well. For example, oak trees sequester tannins that make their leaves toxic and inedible to many insects. However, some insects are able to process these tannins, having adapted in turn to the selective pressures imposed upon them by trees. Interestingly, the ability to process plant toxins is to the insects' advantage because it also makes them less palatable to birds. In this way, coevolution results in diverse and unique solutions to problems imposed by species upon each other.

Making a Case for an Organism

Traditionally, ***forest health*** focuses on insect ***pests*** and ***pathogens*** such as bacteria and fungi. These organisms are detrimental to trees because they directly influence the quality of trees that people value for beauty, food and fiber, or for the role they play in maintaining a diverse and robust ecosystem. However, while pests and pathogens may be problematic to humans, most perform essential roles in the forest as decomposers and components of the food web and by imposing adaptive pressures on their plant ***hosts***.

In order to understand plant-insect relationships as more than just positive or negative associations, it helps to focus on the organism's specific needs. One way to visualize the needs of an organism is to characterize it—give it a voice and advertise its preferences. This activity presents the life cycles of six different types of insects that are specific feeders on different types and parts of trees. To learn about their needs, students are asked to create advertisements for insects that are looking for homes or food, and advertisements for trees that are looking for protection against unwanted tenants. Figure 14 shows some examples of ads.

These advertisements are useful to specific organisms. The *Student Page* section contains details of these organisms—the first is written for the beech scale insect, a ***parthenogenetic*** species that feeds on sap from beech trees. The second is a general advertisement for trees, focusing on the fortifications that wood provides against insect damage.

ROOMMATES WANTED

For Rent:
Apartment with hardwood floors.
Daily sap supply.
One of a kind tree suitable for one of a kind insect.
Lots of room for hundreds to join.

Applicants Must:
Have thin, needle-like mouths
Be girls. No boys allowed!
Be quiet. Hyperactive roommates attract predators.

Please Apply Within →

Calling all Trees: THE BEST PROTECTION MONEY CAN BUY

Lignified!
Strengthened Cellulose!
A kind of bark that resists all bites!

This sturdy structure lets you eat, drink, and grow in peace. Fruiting in the fall? No worries!

Come and get yours today!

Figure 14. Satisfaction guaranteed: These advertisements show some of the needs of a beech scale insect (top), and a hardwood tree (bottom).

The Impact Triangle through a Microscope

In forest health, the ***impact triangle*** is a useful concept used to understand the damages and ***diseases*** sustained by trees. Traditionally, this concept is referred to as "the disease triangle" and applies specifically to tree diseases, but the concept may be modified to understand other biotic impacts upon trees as well (see *Resources and References* for more on the disease triangle). In the case of insect herbivory upon trees, direct disease is not the result; however, insects do *damage* trees as they feed. The impact triangle helps delineate what conditions are necessary for significant damage to occur on trees, which initially is seen through the "microscopic" lens of one insect on one location on the tree. In later activities the impact triangle is revisited on a macroscopic scale.

Three factors are necessary precursors to biotic damage on a tree. First, the host, the tree itself, is typically vulnerable, stressed, or weakened so that it becomes susceptible to damage-causing agents. Second, damage-causing agents must be present and able to break through the tree's defensive networks. Trees and insects are coevolved and share specific relationships; the right kind of host is only susceptible to the right kind of insect, otherwise there is typically no impact on the tree. Third, the environment in which host and causal agent exist is conducive to both to the spread of the agent and the susceptibility of its host.

This idea is diagrammatically represented by the following impact triangle (Figure 15), which includes these three ***components*** represented by the three sides of the triangle: a host tree, a damage-causing agent, and local conditions in the environment that allow the host-agent interaction to occur.

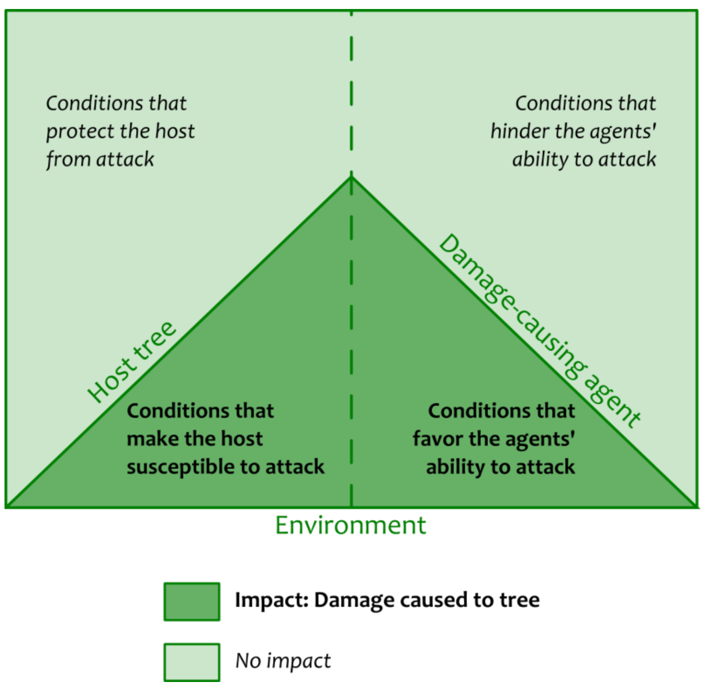


Figure 15. A basic impact triangle: This diagram is similar in some ways to a Venn diagram— conditions that are jointly met by different elements result in specific consequences for a tree.

To read this diagram, imagine the rectangular box represents all potential environmental conditions that the tree may be subjected to, or in the case of this particular activity, all specific environmental conditions that may be experienced at a specific tree location. On the left are conditions that affect the host tree. On the right are conditions that affect the causal agent (the insect pest). The dashed line in between shows that while there are specific conditions that may favor either host or agent, sometimes the same condition might affect both equally.

The text in italics, conditions that protect the host tree from attack and conditions that hinder the agent's ability to attack, result in "no impact" upon the tree. The text in bold, inside the impact triangle, represents conditions that make the host susceptible to attack and conditions favoring the agent's ability to attack. If the right host tree and the right insect are found in an environment that is amenable to the host being attacked and overwhelmed by the insect—then tree damage (impact) occurs.

The importance of the impact triangle is that it describes the unique set of factors necessary to cause a tree to weaken or die. However, on a microscopic level the impact triangle concept may also be applied to a *part* of a tree, which is a specific feeding ground, rather than the whole tree or the whole tree stand. For example, consider the impact triangle in a scenario involving eastern tent caterpillars on a cherry tree (Figure 16).

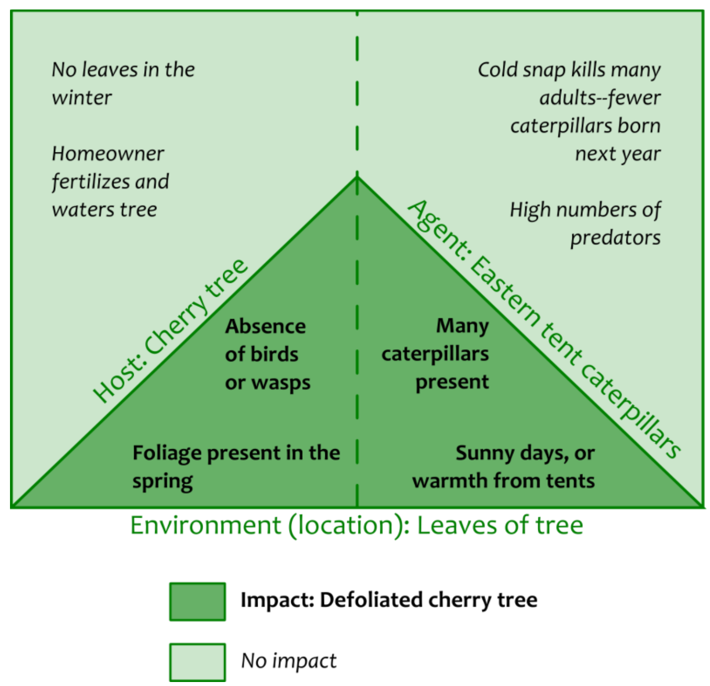


Figure 16. An impact triangle for eastern tent caterpillars on a cherry tree.

The impact, defoliation, occurs only on the leaves and only if environmental conditions on the host side and the agent side apply. For example, an absence of bird or wasp predators would be a disadvantage for the cherry tree if there were many caterpillars present; however, if there were few caterpillars present, then defoliation would not occur, regardless of the fact that the lack of predators would make it a safe environment for the caterpillars to feed and grow.

Thinking in systems: Transporting the triangle

This activity introduces the impact triangle, an important concept that is also part of activities 4 and 5. The impact triangle is a powerful model that can be applied in multiple contexts. Here, we look at a simple, three part ***system*** through a very tiny lens—one tree species, one insect, and one part of the tree where conditions must be ripe for an observable impact to occur.

However, the real power in using the impact triangle is the ability to scale it upward. The impact triangle, more traditionally known as the disease triangle, may be applied to fungi, bacteria, and other tree pathogens (Activity 4). It may also be applied to large-scale populations of trees and insects—the impact of an epidemic number of insect agents causes damage on the scale of a forest (Activity 5) rather than just the tips of the leaves of a single tree. In teaching this concept, keep in mind that the analogy may be transported to other scenarios as well. For instance, the impact triangle may also be used to describe the specific epidemiology of diseases in human populations.

For forest health management, as for human health management, understanding the mechanisms of disease perpetuation in populations is the first step to combating and controlling their spread. The impact triangle is one tool that facilitates comprehension.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - For every five students to share:
    - 1 copy of *Student Page A, B*, or *C* (2 pages).
    - 2 sheets of 3 by 4 foot newsprint or poster paper.
    - 2 or 3 markers.

    Plan to divide your class into at least three groups, so you can distribute at least one copy *Student Page A*, *B*, and *C* to each group.
  - For each student:
    - 1 copy of *Student Page D*.
  - For the teacher:
    - 1 roll of tape.

Doing the Activity

Part A: Introduction to insect-tree feeding relationships
10 minutes

1. Introduce students to an impact triangle using Figure 15 as a visual guide (see *Resources and References* for more visuals). Explain that insects have specific food preferences for different trees and even different parts of a tree. Trees in turn have various defensive mechanisms that work against different insects and at different locations. The impact triangle helps contextualize insect adaptations against those of trees.

2. Inform students that they will be exploring different feeding grounds for insects. Split the class into at least three groups. Hand out one copy of *Student Page A*, *B*, or *C* to each group. Tell students that each group will work in secret, and they cannot share handouts with other groups.

3. Ask each group to read the handout, using a note-taker to underline or circle the following:
- What are the trees' defensive strategies?
- What are the insects' offensive strategies?
- What environmental conditions might favor the insects but not the trees?
- What environmental conditions might favor the trees but not the insects?

Part B: Advertising premium locations
25 minutes

4. Instruct groups to work on creating advertisements for trees and insects. The goal is to attract the right insects to host trees that will support them, or the right strategies to defend trees against an insect invasion. Read the two ads from Figure 14 out loud and explain that they are examples of ads for specific organisms.

Each group should do the followin:
- Pick an insect from the *Student Page* and create an ad promoting housing, food, or roommates that would be attractive to that insect.
- Pick a tree from the *Student Page* and create an ad selling defenses against unwanted tenants that the tree would find interesting.
- Make sure not to give away the insect or tree's name on the ads.
- Write in pencil on the *backs* of each ad the names of the tree and insect for which it was written.

5. Distribute two sheets of newsprint and some markers to each group. Remind students again that they are working in secret, and encourage them to be creative (Figure 17).

Photos: Amanda Burnett

Figure 17. Poster play: When conducting this activity, youth have shown appreciation and eagerness for having a chance to get creative while learning new things.

Part C: Discussion and reflection
45 minutes

6. Collect all groups' ads and reorder them so matched trees and insects (those made by the same group) are not near each other. Use the roll of tape to post the ads on the walls of the classroom. Allow students to walk around and read the ads.

7. Ask students to see if any of the advertisements by insects might be matched with a suitable tree. Have them focus on matching pairs from other ads than those made by their own group. Collect pairs of matched ads and re-position them. You can leave unmatched pairs hanging as well. Anticipate a portion of unmatched ads, since some insects are species-specific herbivores (they feed only on beech trees, for example), while others are generalists (they feed on many hardwood species, for example).

8. Lead students in a discussion of why they picked the pairs that they did and why they left some advertisements alone. Then ask groups to reveal the identities and some details of the organisms. For example: If an ad for an *Ips* engraver beetle was correctly matched with an ad for a pine tree, ask those who made the ads to describe to the other groups what conditions the *Ips* engraver beetle would be happy with, and what conditions would keep the pine tree healthy.

Keep in mind that some advertisements may seem to be more generic than they actually are, depending on how much detail students provide. This is especially so in the case of trees—while most insects in the *Student Pages* have been identified to genus or species level, some of the trees may be broadly referred to as "conifers" or "hardwoods" even though there are many species within these groups. As a result, you may find some unintentional match-ups in the ads. Use these opportunities to discuss species-specific interactions, or to have students provide more details about their organisms.

Some matches may have been made between insects and trees covered by different *Student Pages*. For instance, the examples used in Figure 14 take an insect from *Student Page B* and a tree defense from *Student Page C*. There are specific conditions under which this match would work. Only beech trees are susceptible to the beach scale insect, a fact that is not provided in Figure 14. The ad for tree bark reinforcements likewise does not specify which species it applies to. Clarify these ambiguities with students when they offer more details about their ads.

For ads which remain unmatched, ask students what made that tree so impenetrable, and what made the insect unable to find its preferred food.

9. Next give students copies of *Student Page D*. Remind them about the impact triangle discussed in the beginning of class. Ask them to focus on a particular location or environment on a particular tree of their choice, and find an insect that specializes in eating that part of that tree. Ask them to pick a host tree, insect agent, and environment (or tree location) from the information on the handout or from what they learned in class, and to fill in *Student Page D* accordingly. Have them specify on the triangles what the impact would be for the tree if all three components of the triangle were satisfied. The page can be completed in class or turned in as homework.

Assessment

The following are group assessments. Using the students' advertisements, check that they can do the following:

- Identify relevant information about defensive and offensive strategies employed by insects and trees from a text.
  Seen in ads made during Part B of the Doing the Activity *section.*
- Present relevant information about insect and tree needs for survival.
  Seen in ads made during Part B.
- Apply the impact triangle concept by connecting specific insects with the correct host trees.
  Seen in students' match-ups during in Part C.

For individual assessment, use the answers to *Student Page D* to check that students can do the following:

- Complete an impact triangle for a particular insect-tree interaction.
  Seen in students' answers to Student Page D.

Extension Ideas

- Some of the insects introduced in the activity are social, while others feed alone. Sometimes, the effect of the insects' herbivory is devastating to the plant, while other times, it may have little effect on its overall health. For each pair of insects introduced—leaf eating, sap sucking, or stem boring, ask students to define what type of relationship exists between: a) individual insects (such as between one eastern tent caterpillar and another), b) individual insects and the tree, c) a group of insects and a tree, and d) a group of insects and the forest. What is the level of impact upon the individual tree if just one insect were feeding on it versus a group of insects? What is the level of impact upon the forest if just one tree were being fed upon, versus all the trees of that species? Ask students to turn in a report with their conclusions.

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources.
  - Images and figures used in this activity, including those of the impact triangle, are found in a visual presentation online.
  - Flash cards from the *Pocket ID Guide* provide more information about insect pests. You may use the flash cards to assess students' understanding of the impact triangle. The flash cards mentioned below correspond either to the species on the *Student Pages* or to related species with similar life cycles and behaviors.
    - *Student Page A*: Eastern Tent Caterpillar, Pine Sawflies.
    - *Student Page B*: Scale Insects, Sycamore Lace Bugs.
    - *Student Page C*: Twig Girdler, *Ips* Engraver Beetles.
  - The impact triangle for pathogens such as fungi is known as the disease triangle. This concept is taught by means of a game in *New Activity 3: The Disease Triangle*, in *What Is a Healthy Forest?*
  - There are many symbiotic relationships that contribute to the health, good or bad, of a forest. Some of these relationships are covered in *Extension to PLT Activity 26: Dynamic Duos*, in *What Is a Healthy Forest?*
  - Feeding relationships can determine survival and extinction in a forest. Two species of swallowtail butterflies are used to teach about generalist and specialist diets and their affects on populations in *Extension to PLT Activity 45: Web of Life*.

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- More information about pine sawflies, leafhoppers, and *Ips* engraver beetles may be found at the University of Florida's Department of Entomology and Nematology Extension website, *Featured Creatures*.
  Visit http://entnemdept.ifas.ufl.edu/creatures/

- More information about the beech scale insect may be found in the USDA Forest Service Forest Insect and Disease Leaflet 75, "Beech Bark Disease," Houston, D. R. and J. T. O'Brien, 1983.
  Visit http://www.na.fs.fed.us/spfo/pubs/fidls/beechbark/fidl-beech.htm

- More information about eastern tent caterpillars and twig girdlers may be found at Auburn University's Department of Entomology and Nematology's *Web Publications*.
  Visit http://www.ag.auburn.edu/enpl/webpub.htm

- Extensive picture resources may be found at the University of Georgia's Center for Invasive Species and Ecosystem Health's website, *Insect Images.*
  Visit http://www.insectimages.org/

How to Eat a Tree –
An Insect's Guide to Finding Food in the Forest

Instructions

Shhh! Your group is working in secret. Read the following text and work as a team to identify the answers to the following questions. Circle or underline the answers in the text.

- What are the trees' defensive strategies?
- What are the insects' offensive strategies?
- What conditions might favor the insects but not the trees?
- What conditions might favor the trees but not the insects?

When you are finished, wait for your teacher to provide you with materials and instructions to complete the second part of this activity.

Leaf-Eating Insects

The most visible and easily accessible part of a tree is the leaf. Many animals focus on leaf feeding, either stripping down the soft tissues in between veins, or chewing the whole leaf down to the base of the stem. Since leaves are a tree's primary food production organs, defoliation, depending on the age and health of a tree, can cause weakening, slower growth, and even death. Leaves may be protected from herbivores by bristles, spines, tough coats of wax, or toxins in the leaf cells, but even so, some insects have evolved strategies around these defenses.

Eastern tent caterpillars

Eastern tent caterpillars are the larval form of a moth, *Malacosoma americanum*. As caterpillars they are known for being highly social tent builders. They hatch in the hundreds in early spring and build their tents in the crooks of tree branches. These tents are used for shelter from predators and for temperature regulation, since they cannot feed unless they are warm. As the caterpillars grow and molt, they expand the size of their tent, layer by layer, and search farther along the branches for leaves to eat. When a caterpillar locates fresh foliage, it marks its trail back to the tent for its tent-mates to follow. This makes the tent caterpillars a very efficient defoliating colony, and large groups of them can strip an entire tree of its leaves.

Eastern tent caterpillars are eaten by numerous predators and parasites, including wasps and birds, and their populations are usually kept in check by these animals. However, if predator populations are low, the eastern tent caterpillars can attack trees unhindered. Caterpillars feed on numerous broadleaf species, but prefer species from the Rosaceae family, such as cherry, apple, and hawthorn trees.

Photo: Robert L. Anderson, USDA Forest Service, Bugwood.org

Eastern tent caterpillars make communal tents.

Pine sawflies

Photo: Albert (Bud) Mayfield, USDA Forest Service, Bugwood.org

Redheaded pine sawflies defoliating a longleaf pine (*P. palustris*).

Pine sawflies, *Neodiprion* species, are not "true flies" despite their name. They are related to wasps, bees, and ants. There are several species of sawflies whose larvae feed on conifers, particularly pines (*Pinus* species). The adult females use their saw-shaped ovipositors to cut slits into pine needles and lay their eggs. The newly hatched larvae feed only on the outer needle tissues, but older larvae chew up entire needles, leaving only little stubs behind.

Pine sawflies can attack pine trees of all ages and may move from one tree to the next as they defoliate them. When outbreaks occur, this can severely affect the growth of pines. Some species, such as the redheaded pine sawfly, *Neodiprion lecontei*, have multiple generations of young per year, and feed on both old needles and new growth. Others, such as the European pine sawfly (*Neodiprion sertifer*), have only one generation of larvae that feed only on needles from the previous year. All southern pine species are hosts for pine sawflies. Natural sawfly predators include several species of birds and insects, such as ground beetles and parasitic wasps, which feed on sawfly larvae and pupae.

Photo: G. Keith Douce, University of Georgia, Bugwood.org

Eastern tent caterpillars have completely defoliated these black cherry trees (*Prunus serotina*).

Photo: Albert (Bud) Mayfield, USDA Forest Service, Bugwood.org

Extensive damage of planted longleaf pines by the redheaded pine sawfly.

How to Eat a Tree – An Insect's Guide to Finding Food in the Forest

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- What are the trees' defensive strategies?
- What are the insects' offensive strategies?
- What conditions might favor the insects but not the trees?
- What conditions might favor the trees but not the insects?

When you are finished, wait for your teacher to provide you with materials and instructions to complete the second part of this activity.

Sap-Sucking Insects

The internal transportation structures of trees are xylem and phloem tubes, which run like veins from roots to leaves, carrying water, minerals, nutrients, sugars, and starches. Sap contains nutrients that nourish the cells of the tree, and insects that feed on sap extract the same minerals and nutrients for their own growth and development. Sap-sucking insects may be found in the root system of trees, as well as the stems, branches, and tree trunk, but they can be stopped by thick bark. Once a sap sucker has gained entry to the xylem or phloem, it must also have the ability to process toxins produced by the tree for protection.

Beech scale

Beech scale (*Cryptococcus fagisuga*) is a tiny scale insect, related to aphids, leaf hoppers, cicadas, and other "true bugs." It is an entirely female species, producing young by parthenogenesis. In the early summer, adults lay a few eggs and die. Their young nymphs have feelers and legs, and are able to crawl in search of beech trees (*Fagus grandifolia*), their preferred food source. Since they are so small, they may also be transported by wind, water, or other animals.

The scale insect, like all sap-sucking true bugs, has a specialized needle-like mouthpart which it injects into the tree. Once attached, it sucks on tree sap while morphing into a legless, immobile adult, producing a waxy scale covering for protection in the process. In large numbers, the insects can deplete beech trees of much needed water and nutrients, but the more serious consequence of their work is the number of wounds they leave behind as they feed. These wounds become entry points for woody tissue-digesting fungi, the most famous being the *Nectria* species, which can kill beech trees.

Photo: Joseph O'Brien, USDA Forest Service, Bugwood.org

A tiny, crawling beech scale nymph will become an immobile, waxy-coated adult.

Leafhoppers

Leaf hoppers (Cicadellidae) are tiny, winged "true bugs," related to scale insects and cicadas. Like scale insects, leafhoppers also have a needle-like feeding apparatus that they use to suck out sap from xylem tubes. One of the most diverse of all insect families, leafhopper bugs have specialized associations with many plants and trees. The young nymphs are expert jumpers and the adults can fly, allowing them to move great distances in search of food.

Many species of leafhoppers are considered pests of some commercially important crops, such as grape, peach, and plum, as well as ecologically significant trees such as palms. This is because their feeding methods create wounds on plants and trees and deplete them of resources. Most importantly, leafhoppers may also transmit viral and bacterial diseases from one tree to the next, much as mosquitoes carry malaria to people. They are preyed upon by fast-moving animals such as dragonflies and damselflies, mantids, spiders, lizards, and birds.

Photo: Whitney Cranshaw, Colorado State University, Bugwood.org

Adult and nymph leafhoppers feeding on *Yucca* stem.

Photo: Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org

A beech scale infestation can spread and cover tree bark in a white coating.

Photo: USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org

Leafhopper damage on red maple (*Acer rubrum*) leaves, which are discolored.

How to Eat a Tree – An Insect's Guide to Finding Food in the Forest

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- What are the trees' defensive strategies?
- What are the insects' offensive strategies?
- What conditions might favor the insects but not the trees?
- What conditions might favor the trees but not the insects?

When you are finished, wait for your teacher to provide you with materials and instructions to complete the second part of this activity.

Stem-Boring Insects

Woody trunks, branches, and twigs combined are the most abundant tissue structures found on a tree. That's a lot of food! However, woody tissue is not a free meal. The xylem, which provides structural support to trees, is hard-to-digest cellulose and lignin. The inner bark, phloem, is nutritious but protected by the outer bark. Coniferous trees additionally produce resin, which they maintain under pressure inside the trunk. A successful stem borer must be able to resist being flushed out by this resin as the insect drills through the wood, as well as resist the aromatic compounds that the tree releases, which act as a further deterrent. For this reason, stem-boring insects often focus on finding dead or dying trees rather than live ones, and often partner with other organisms, such as fungi, to aid in the work of weakening the trees for their mutual benefit.

Twig girdler

In the early fall, female twig girdler beetles, *Onicideres singulata*, are ready to lay eggs. They do so by selecting small branches of trees and chewing a groove around the circumference. This "girdling" process kills the branch tip past the groove by cutting off nutrient flow. The female makes a notch in the branch above the girdling point to lay single eggs. Hatched larvae burrow into the twigs to feed on the dead inner bark (phloem) and wood beneath. They pupate inside the branch as well, and emerge as adults the next fall.

Girdled branches often break off due to mechanical stresses such as the wind, and this may give trees an uneven look. The twig girdlers are otherwise harmless, since the health of the whole tree is not compromised. Twig girdler beetles attack numerous broadleaf nut-bearing and fruit-bearing trees, including pecans, walnut, elm, and citrus. In orchards, twig girdler damage may reduce nut and fruit yield and cause stem deformities on the trees.

Photo: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

A twig girdler chews around a pecan (*Carya illinoinensis*) twig.

Ips engraver beetle

There are three species of *Ips* engraver beetles that feed on southern pines. Males seek out weakened, stressed, or dying pines (*Pinus* species) preferentially, since these trees are easier to colonize. Once a male locates a suitable host tree it tunnels in and releases pheromones to attract females and other males. A mass attack on a pine can completely overwhelm its defenses, if the pine is unable to flush out the beetles with sticky resin. Adults tunnel and feed in the inner bark (phloem) and lay their eggs. Hatched larvae make feeding tunnels through the phloem tissue and pupate.

Emerging adults can fly as far as four miles in search of new trees to colonize. Apart from the damage the beetles cause through their feeding activities, they also introduce a blue stain fungus into the trees. This fungus colonizes and blocks the xylem tissues, further weakening the pines and hastening their death. *Ips* engraver beetles in large numbers can kill healthy trees, but these outbreaks tend to be relatively small and short-lived.

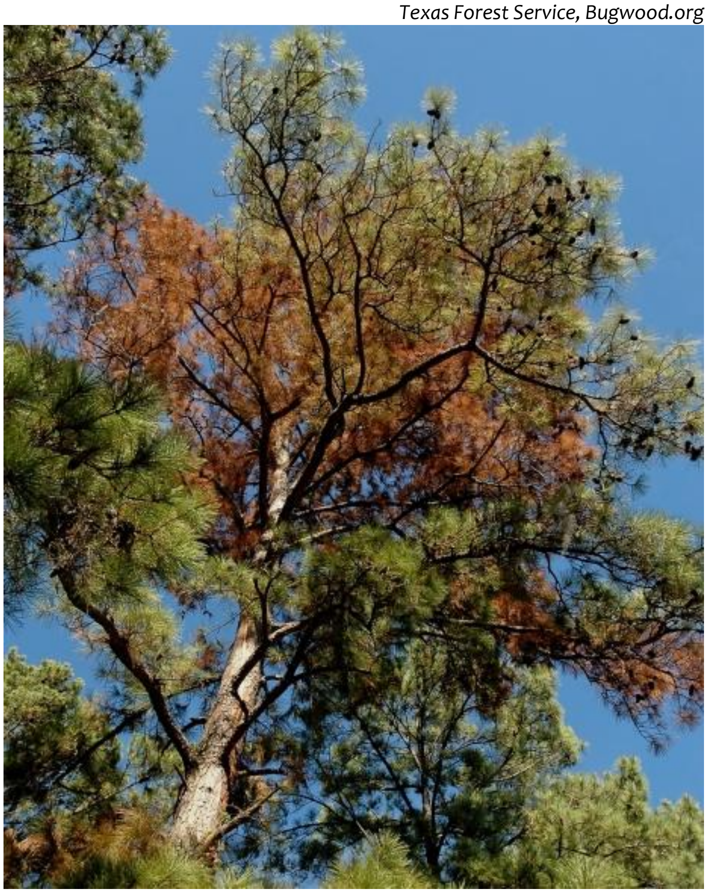
Photo: G. Keith Douce, University of Georgia, Bugwood.org

***Ips* engraver beetles tunneling through inner bark**

Photo: Lacy L. Hyche, Auburn University, Bugwood.org

A twig girdler larva gets ready to pupate within a twig. It has fed on phloem, and sealed off the tunnel behind it with wood chips.

Photo: Ronald F. Billings, Texas Forest Service, Bugwood.org



***Ips* engraver beetle damage on a loblolly pine (*P. taeda*). The tree's needles are dying and discolored.**

Student Page D

Name:

How to Eat a Tree – An Insect's Guide to Finding Food in the Forest

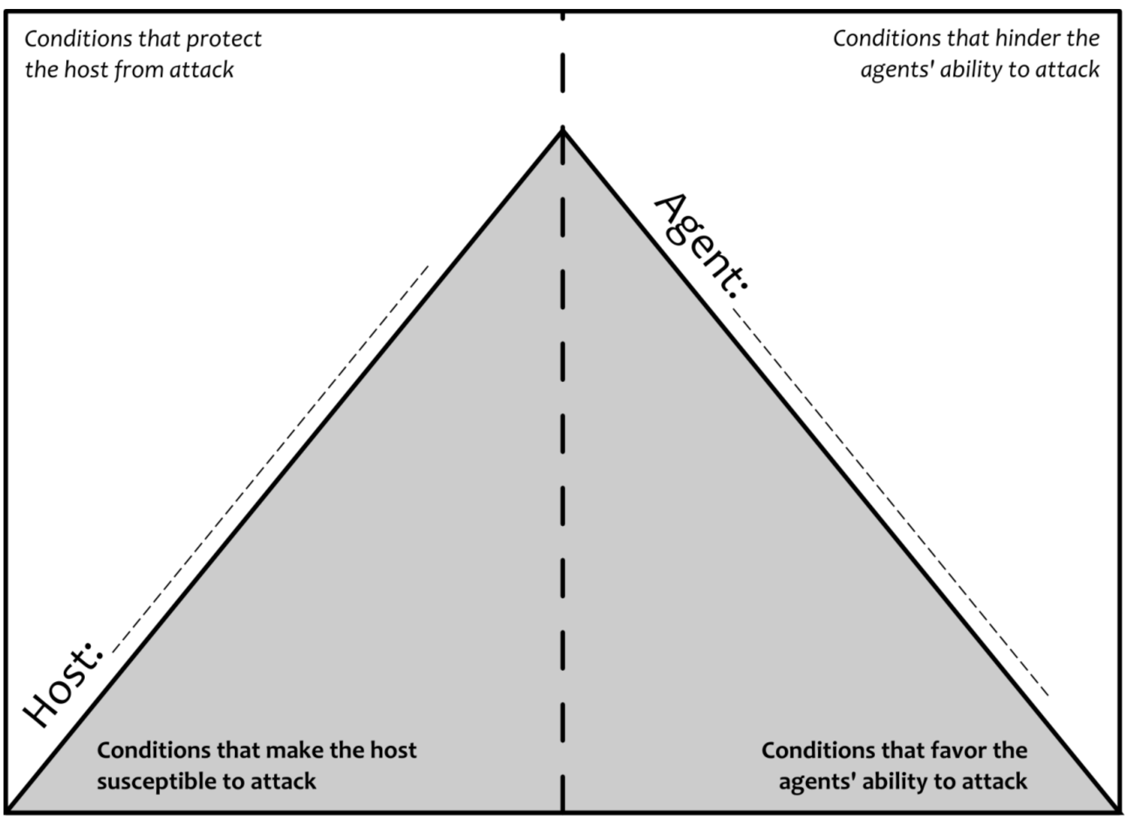
Instructions

The following diagram represents a system with three components, represented by the three sides of the triangle. The components are a host tree, an insect agent, and environmental conditions at a particular location on the tree. Under specific conditions, represented by the area inside the triangle, these components interact to cause an impact on the tree. Conditions found in the area outside the triangle will not result in any impact.

You have seen many examples of insect-tree interactions. Pick an insect-tree pair and complete the following gaps in the diagram:

- What is the host tree, insect agent, and tree location (environment)?
- What environmental conditions go inside the triangle, resulting in damage to the tree?
- What environmental conditions go outside the triangle, resulting in no effect to the tree?
- What is the impact on the tree if conditions within the grey triangle are right?

The Impact Triangle



Environment (location): ______________________________

What is the impact on the tree if conditions within the grey triangle are right? ______________________________

Activity 4

Forest Travels – A Guide for Fungi

Lesson Summary

In this activity, students explore the specific reproduction and colonization patterns of two kinds of tree-feeding fungi, one of which primarily moves vegetatively through root networks and the other mostly through wind-borne dispersal. Students read about the two fungi and then use maps and worksheets to document and observe their movement across the forest through time.

The activity includes a discussion of students' observations on how these two different fungi operate, what types of trees are best suited for their colonization, and what sorts of conditions favor fungal transport. You may use a provided visual presentation to animate the maps that the students used and prompt them to think of methods to control the fungi from spreading to other trees. Students are asked think about the importance that fungi play in the forest—how they change the land, how they may be beneficial to the forest, how they might be detrimental, and the consequences of fungal colonization to people who are maintaining trees for forest products.

Background

The Secret Life of Fungi

Frequent images triggered by the words "fungus" or "fungi" are mushrooms or toadstools. However, fungi are a much more complex group of organisms, going through numerous life stages that are largely invisible to the casual observer. Tree-infecting fungi often go completely unnoticed except for when they reproduce—when their fruiting bodies appear not just as mushrooms but a variety of other shapes. Puff balls, crusty or velvety sheets, cups, bracket-like or hoof-shaped "conk" structures, blisters, rusts, and even microscopic structures are formed around tree bases, on stem swellings, and leaf surfaces. The fruiting bodies produce and disseminate ***spores*** (Figure 18.e), important propagules of the fungus analogous to seeds produced by plants.

But fungi are not ***autotrophs***, as plants are. They do not possess chlorophyll and therefore cannot photosynthesize to manufacture their own food energy. Instead, they exist by acquiring food as ***saprophytes***—obtaining food from dead organic material (Figure 18.b), or as ***parasites***—feeding on tissues of living organisms. The body of the fungus is a vast

Sunshine State Standards

Science (9-12): SC.912.L.14.9, SC.912.L.15.6, SC.912.L.17.1, SC.912.L.17.4, SC.912.L.17.5, SC.912.N.3.5
Social Studies (9-12): SS.912.G.1.3, SS.912.G.5.6, SS.912.G.6.4
Reading/Language Arts (9-10): A.910.1.6.2, LA.910.1.7.4, LA.910.1.7.5, LA.910.2.2.2
Reading/Language Arts (11-12): LA.1112.1.6.2, LA.1112.1.7.4, LA.1112.2.2.2

Materials

For each student
1 copy of the *Student Page* section (7 pages).
1 ruler, or index cards with markings for an approximation of inch-scale distance.

For the teacher
Computer and projector to display visual supplement (see *Resources and References*).

Time Considerations

Part A: 10 minutes
Part B: 30 minutes
Part C: 20 minutes

Behavioral Objectives

Students should be able to do the following:
- Read and understand key points about two kinds of fungi and their methods of growth and dispersal in the forest.
- Plot geographic movement of fungi in a forest over time.
- Name specific tree hosts that favor the spread of a particular fungal species.
- Name specific environmental conditions that favor the spread of a particular fungal species.
- Identify particular times or places where fungal movement through the forest can be stopped.

network of crisscrossing microscopic filaments known as ***hyphae*** (*sing.* hypha) (Figure 18.a). Masses of hyphae belonging to an individual fungus form vegetative structures called ***mycelia*** (*sing.* mycelium). Mycelia may occur as invisible nets, ropey branch- or root-like structures, distinctive sheets (Figure 18.c) or even small globular clusters of cells. When moisture and temperatures are favorable, they produce fruiting bodies (Figure 18.d).

Fungal interactions with plants are among the most important relationships in a forest. Reciprocal associations between highly specialized fungi and some plant and tree roots result in ***mutualistic*** "fungus-roots" or ***mycorrhizae***. Mycorrhizae increase the absorptive capacity of plant roots and provide necessary nutrients for the fungus. Fungi may also be ***pathogens*** that affect the ***host*** plant's physiology by causing ***disease*** or ***parasites*** that colonize and digest plant tissues. Saprophytic fungi are important processors of dead plant and tree tissue, releasing and recycling nutrients into the ecosystem that are used by other living organisms.

Armillaria Root Rot and Fusiform Rust

Understanding tree health and ***forest health*** is aided by recognizing how fungi operate in a forest ecosystem. Two fungi with distinctively different life cycles and relationships to their host trees are used in this activity to illustrate aspects of tree disease development within selected forest situations.

The *Armillaria* species, which are members of a common genus of mushroom-producing fungi, cause root disease and spread through forest systems via two pathways. The mushrooms release airborne spores to facilitate long-range dissemination. Local spread occurs via vegetative growth from colonized dead trees and rotting stumps to the root systems of susceptible neighboring trees (Figure 19). Many *Armillaria* species are opportunistic pathogens, lingering within dead matter until environmental conditions facilitate their ability to attack living but weakened trees.

The fusiform rust fungus, a species of *Cronartium*, affects certain southern pines and has a complex life cycle. Like many rust fungi, fusiform rust requires two distinctly different host species in order to complete its life cycle; in this case pines and oaks. It produces several different types of spores at different times of the year. Some are produced on oak leaves and disseminated by the wind to infect pine tissues; others are produced on pine stems and windborne to re-infect oaks (Figure 20).

The fusiform rust fungus is highly damaging to its host pines, but causes inconsequential damage—only tiny leaf spots—on oaks. *Armillaria* species, on the other hand, often kill their

Photos: Fred Brooks, University of Hawaii at Manoa, Bugwood.org

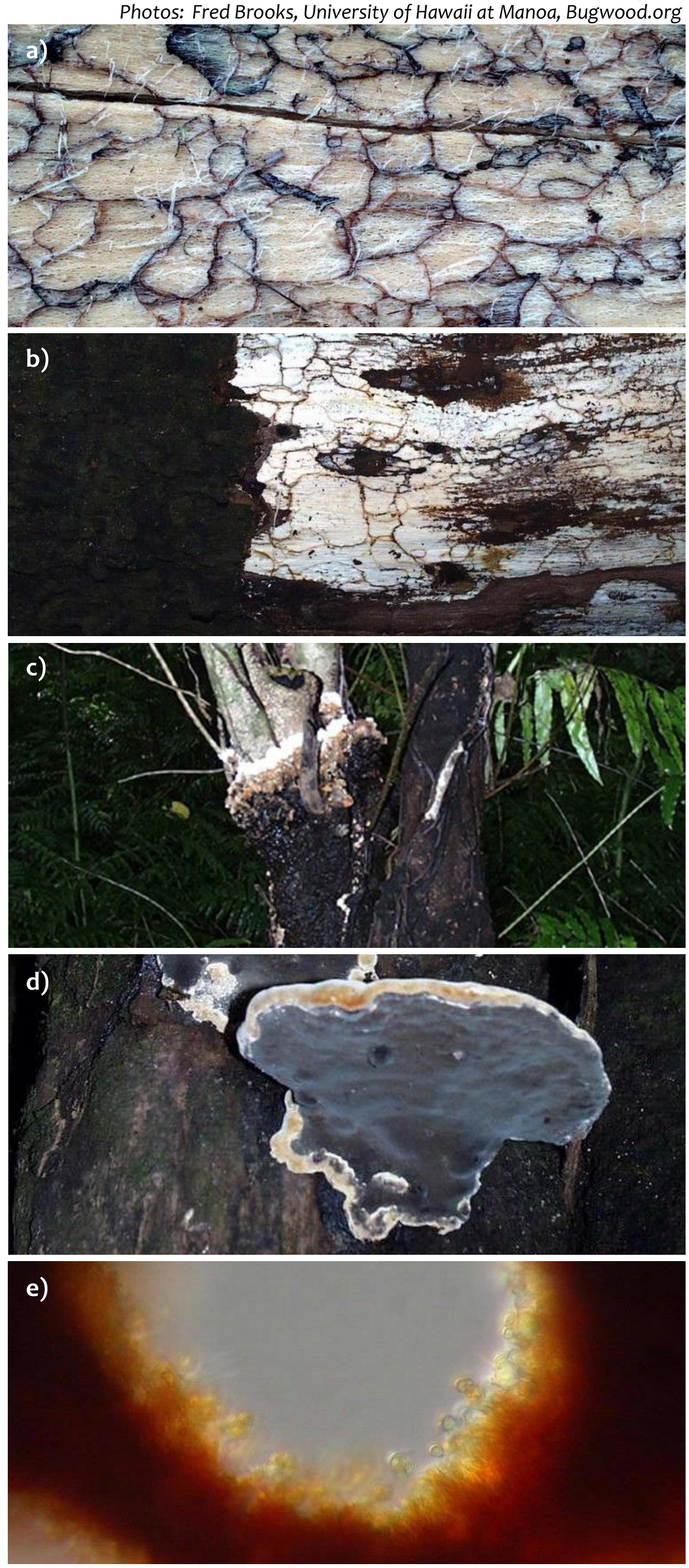


Figure 18. Parts of a wood-rotting *Phellinus* fungus: a) Threads of hyphae digest lignin and cellulose; b) Decomposing wood turns white as it is broken down; c) A crusty black mat of mycelia develops up the tree trunk from rotting roots; d) Mycelia form porous fruiting bodies (conks); e) A pore reveals sexual spores ready to be released.

host trees over time. The distinct life cycles and patterns of spread of these two tree pathogens result in differing patterns of disease development. Consequently, different strategies for management or control are required, appropriate to the fungi's particular characteristics. See *Resources and References* for more information on these fungi.

Image adapted from: HortFACT – Grapevine diseases in New Zealand, hortnet.co.nz

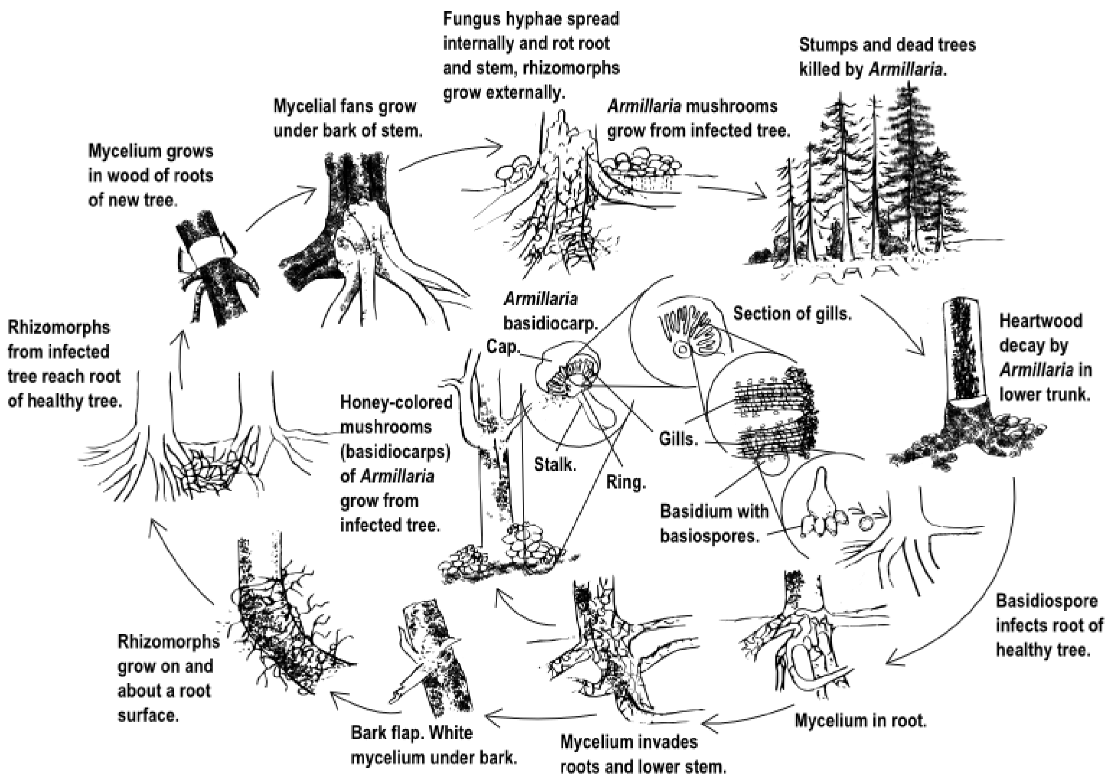


Figure 19. Life cycle of an *Armillaria* fungus. It can spread vegetatively through root contacts or by airborne sexual spores.

Image: Cooperative Extension Service, University of Georgia College of Agricultural and Environmental Sciences, Circular 440, Fusiform Rust on Pines

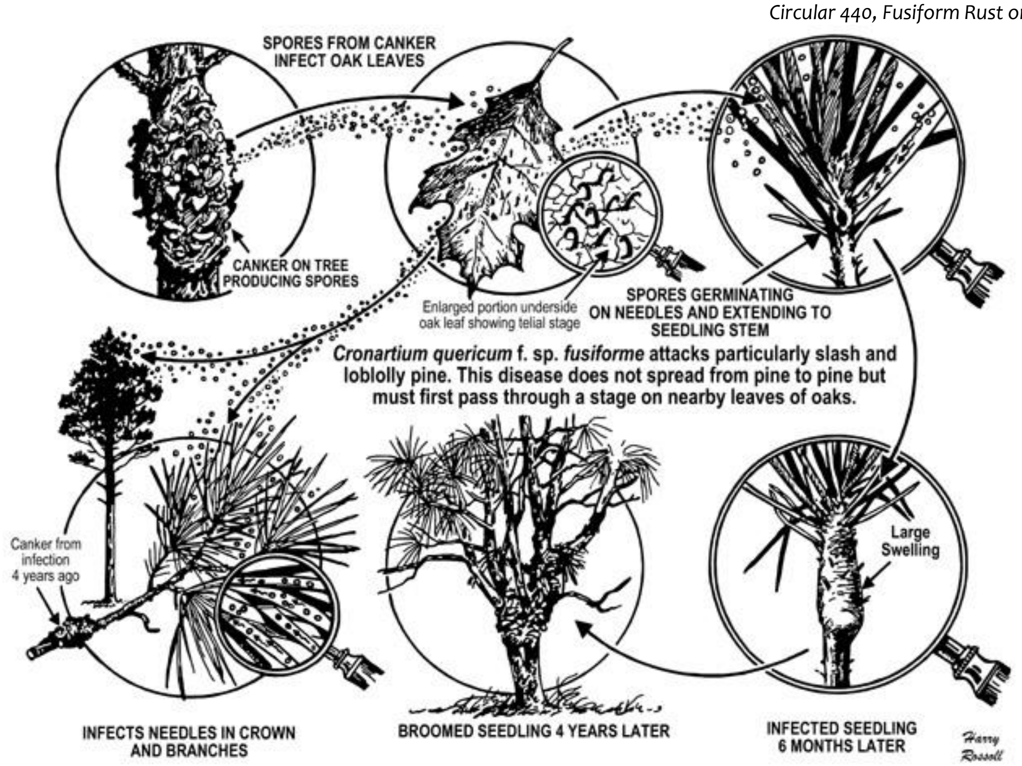


Figure 20. The life cycle of the fusiform rust fungus. Fusiform rust produces five different types of spores which infect pines or oaks at specific times during its life cycle.

Thinking in systems: Inputs, outputs, and their influences

This activity reintroduces the use of maps as a visual aid to explore the ***dynamics*** of a forest ecosystem (as in Activity 1). Additionally, the ***impact triangle*** concept described in Activity 3 may be revisited here: fungal interactions with trees are successful if they occur with specific environmental conditions, appropriate hosts, and specific pathogens. Consider bringing up the impact triangle again with students to reinforce this concept and reapply it to the diseases caused by fungi, rather than the damage caused by insects.

Further observations may be made on how these ecosystems operate and how fungi impact the forest. Some of the following questions may be asked. What ***inputs*** influence fungal activity? What ***outputs*** result from fungal activity? What are the ***boundaries*** of the ***system*** in which the fungi operate? In other words, if there are inputs and outputs, from where are they originating?

For example, in looking at the two forest maps used in this activity, you can see that the fungi present in the system spread because of external environmental influences as well as internal propagation. For the *Armillaria* fungi, the presence of dead wood favors colony expansion—more weak, stressed or dying trees are an "input" that results in *Armillaria* growth. Likewise, wind contributes as an input in the spread of the fusiform rust fungus. From a management perspective, removing an input source reduces the impact of the phenomenon—in the case of both *Armillaria* and fusiform rust, removal of dying trees, cutting trenches to prevent root propogation, and removing co-host trees are all physical means of disrupting the fungi's lifecycles. Managers are not likely to remove wind, however.

Another issue regarding inputs and outputs to the system is origination of the fungi. Both *Armillaria* and fusiform rust are ***native*** fungi in the southeastern United States. However, they are considered problematic in areas where the land has been converted from natural use to serve another purpose—timber production artificially sets new boundaries and defines a new "ecosystem," one where fungal parasites may not be desired. In exploring forest health issues in connection with "unwanted" organisms such as fungi, historic and current demands upon the ecosystem define exactly how disastrous those organisms can be. Why expend energy and effort to control a native organism? What is to be gained in doing so? What would be lost if the fungi were left to their own devices? On the one hand, losing harvestable trees is an economic loss. However, the loss of native fungi may have ecosystem repercussions as well.

Getting Ready

- Read the *Background*, *Doing the Activity*, and *Student Page* sections to familiarize yourself with the material.
- Familiarize yourself with the visual presentation supplement for this activity (see *Resources and References*). You may modify the presentation as necessary for use with your class.
- Prepare the supplies outlined in the *Materials* section.
  - For each student:
    - 1 copy of the *Student Page* section (7 pages).
    - 1 ruler, or index cards with markings for an approximation of inch-scale distance.
  - For the teacher:
    - Computer and projector to display visual supplement.

Doing the Activity

Part A: Introduction to fungi
10 minutes

1. Use the *Background* information to introduce students to fungi and their importance in an ecosystem.

2. Ask students if they recognize either the honey mushroom or the fusiform rust fungus, which are both common to Florida. Tell them that they will be working in pairs to learn more about these two fungi by using maps to track their movement.

Part B: Working on the *Student Page* section
30 minutes

3. Hand out copies of the *Student Page* section to students and ask them to work in pairs to answer the questions. For younger students, you may wish to answer some of the questions as a class, particularly to help them read and use the maps properly.

Part C: Discussion and reflection
20 minutes

4. After the *Student Pages* are completed, discuss the following questions with students. Some potential answers to the questions are provided.

a. What happened after two years of the *Armillaria* fungus infection? How far did it travel?

Armillaria *primarily moves through root networks, and in two years, the infection center expanded from a few dead trees to neighboring dead or weakened trees, because these are easier to colonize.*

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b. How far did the fusiform rust fungus travel in two years? Why is there a difference in the rate of spread for these two fungi?

Since fusiform rust is an airborne traveler, the spores, especially the hardier ones that are spread from the pine trees, travel long distances. Within two years, all the trees on the small plot of land depicted on the map were infected.

c. Looking at the maps, which of the two fungi do you think has a colonization center? If you were trying to manage the spread of that fungus, what is one thing you could do to stop the fungus from traveling?

Armillaria *fungi are limited by the extent to which their mycelia and rhizomorphs can spread. Mechanical isolation of infection centers from healthy trees is a way to curb the fungus' growth. Forest managers and land owners dig trenches that are one-foot deep and two-feet wide to break tree-to-tree root connections in a channel around a fungal colony. The trees within the infection center may be colonized, but the disruption of their root connections to healthy neighbors prevents further growth of* Armillaria.

d. Looking at fusiform rust, what aspect of its life cycle makes it hard to manage trees against infection? What aspect of its life cycle allows for relatively easy management?

Fusiform rust has windborne spores that travel long distances. Mechanical obstruction cannot contain such dispersal so other methods must be sought. Apart from using fungicides and growing trees resistant to the rust, its life cycle provides an alternate form of control. Since the fungus cannot complete its life cycle without two alternate host trees, removing oaks from an area that contains valuable pine species can protect the pines from infection.

5. Use the visual presentation to animate the yearly expansion of the fungal territories. The following questions allow you to discuss fungal colonization and potential management strategies.

a. What conditions facilitate the *Armillaria* colony's growth?

Dead trees, cut stumps, and weakened trees are easiest for Armillaria *to colonize. The fungus cannot spread, as seen in the colony on the left of the map, if there are no suitable trees.*

b. How has the forest changed after three years of *Armillaria* expansion?

There are more dead trees after three years of colony expansion. There are fewer weak trees.

c. What use does the *Armillaria* serve by killing weakened trees? Is there any reason why this might not be desirable?

Armillaria *serves an important function in forests by breaking down and recycling nutrients from weakened and dead trees. However, if commercially valuable trees are killed, or those in a park that are valued for their beauty, allowing the trees to die would not be desirable.*

d. What would be the best way to prevent fusiform spread?

Initially only two oaks were infected. It would be easiest to manage fusiform rust by removing these oaks in the first year.

e. Which year would be the best to remove pine trees? Is there any reason why someone may not want to cut down those trees?

In the first year, very few pines showed signs of fusiform rust, and this would be the best time for removing colonized trees. Since pines are sometimes grown for timber, prematurely cutting trees would mean that less money could be made from selling the trees.

6. Ask students to consider the past and the future states of both forests, beyond the time period of the activity. Point out that hundreds of years ago, there was little question of managing for fungi because people did not manage forests as is done today. What has changed since then? How might the forest look fifty years from now? Will the dead trees be replaced by new trees? Will new trees have to be planted? Ask students to consider two scenarios—the forests they looked at without humans, and the same forests with humans playing a role in how they function. In comparing the two scenarios, how severe does the magnitude of fungal spread appear to be?

The makeup of the forest is one thing, the purposes it serves is another. Forests managed to produce goods such as timber and fruit puts new demands on the same system, and where once fungi were unnoticed, now they are an undesirable or threatening feature. They are a problem because humans perceive them as one. In a natural forest, ***succession*** *patterns allow dormant seeds and saplings to take over once old trees have died. In planted forests, on the other hand, new trees—desirable stock—are often planted. Landowners often find that removal of old and dead trees is not enough to ensure the successful growth of new ones, because fungi can lie dormant in the soil, or be spread from nearby trees via wind or water. Managing for healthy forests requires understanding threats from fungi and how they might be reduced.*

Student Page Answer Key

The following are suggested answers to the *Student Page* section. The visual supplement details the progression of *Armillaria* and fusiform rust in the forest. Figures 21 and 22 respectively show the extent of *Armillaria* and fusiform spread at the end of the time periods specified in the *Student Pages*.

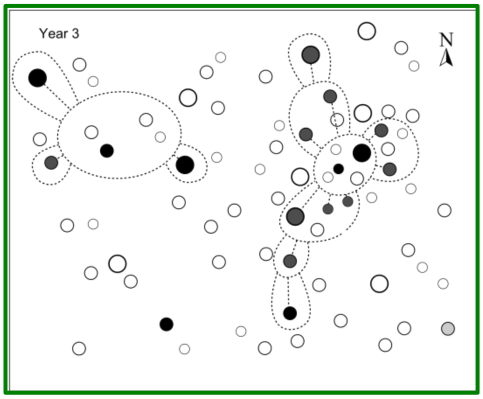

Figure 21. *Armillaria* progression over three years.

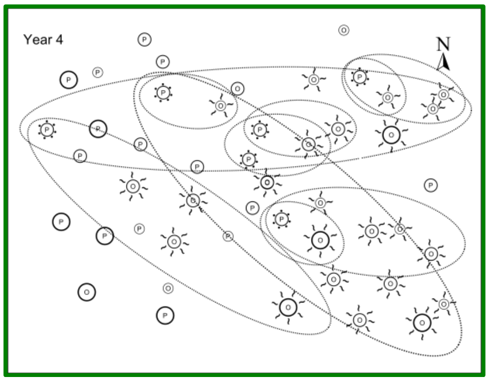

Figure 22. Fusiform progression over four years.

2. The grey circles are weak or stressed trees. Look at their pattern of distribution on the map. Can you think of one reason why these trees might be stressed?

These trees are spaced very close together. The high density of trees means increased competition for resources and more weakened or stressed trees.

4. Draw a dashed line surrounding the new range of the *Armillaria* fungus. Mark this range as Year 1of the colony's growth. Repeat the same steps until you have three years of *Armillaria* traveling through the root network. Can you describe how the pattern of the fungus's range has changed in those three years?

The colony has spread using weak or dying trees as its new colonial outposts. In places where there are no weak or dying trees, or if the space between the root networks is too large, the colony has stopped growing in that direction.

5. The oak spores are delicate, and easily destroyed, but they can be carried by the wind a few hundred feet under the right conditions. Which tree species are these spores going to infect?

The oak spores will infect the pine trees.

7. The pine spores are hardy, and can travel for a hundred miles. Which species of trees are these spores going to infect?

The pine spores will infect the oak trees.

Assessment

Using students' answers to the *Student Page* section, check that they can do the following:

- Plot geographic movement of fungi in a forest over time.
  Seen in students' successful completion of the tree colonization maps.
- Name specific environmental conditions that favor the spread of a particular fungal species.
  Seen in answers to question 2.
- Name specific tree hosts that favor the spread of a particular fungal species.
  Seen in answers to question 5 and 7.

Extension Ideas

- Ask students to research either "the role of fungi in forests" or "fungal diseases in forests." Have them present findings on both topics and lead a discussion on the way fungi were depicted given the initial search queries. The "role of fungi in forests" is a neutral term; "fungal diseases in forests" connotes unhealthiness. Were the research results positive, neutral, or negative? Did it make a difference if fungi were discussed in terms of their roles in the ecosystem or industry?

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources.
  - A visual presentation includes images and figures used in this activity.
  - Flash cards for Armillaria Root Rot and Fusiform Rust in the *Pocket ID Guide* provide more information about the fungi in this activity.
  - A game is used to teach about fungal dissemination in *New Activity 3: The Disease Triangle*, in *What Is a Healthy Forest?*

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

- The textbook *Biology* (Sixth Edition or higher), by N. A. Campbell, and J. B. Reece includes an informative chapter on fungi. Illustrations from the Sixth Edition are found at the following website.
  Visit http://sharon-taxonomy2010-p6.wikispaces.com/Fungi

- More information on fungi structure, function, and pathology is found at J. J. Worrall, USDA Forest Service plant pathologist's website *Forest & Shade Tree Pathology*. Specific information related to this activity is found under "Main Topics," "Fungi."
  Visit http://www.forestpathology.org/

Student Page

Name:

Forest Travels – A Guide for Fungi

Instructions

In this activity, you will learn about two common Florida fungi, the honey mushrooms, an *Armillaria* species; and the fusiform rust fungus, a species of *Cronartium*. Both have exciting life styles and interesting travel habits.

For each fungus, first read about its life cycle, then use the accompanying map and questions to model how the fungus travels through a forest. You may draw directly onto the maps to show how the fungus moves each year.

Honey Mushrooms and the Underground Network

Fruiting bodies of *Armillaria* fungi are often honey-yellow in color, hence the common name, "honey mushrooms." However, the main body of the fungus is a vast and mostly invisible network of thread-like filaments called hyphae. The hyphae of *Armillaria* are dispersed through the tissues of their colonized hosts, the soil, and decaying organic matter. The individual filaments clump together to form sturdier cords called mycelia, which are sometimes bioluminescent so they glow in the dark. These fungi are widespread through much of the world and colonize and parasitize a wide variety of hardwood species, conifers, and even palm trees.

Photo: Sturgis McKeever, Georgia Southern University, Bugwood.org

***Armillaria* fruiting bodies growing from oak (*Quercus* species)**

Armillaria, like all living organisms, are dependent on certain environmental conditions for their survival and spread. In forest systems, *Armillaria* compete with other organisms for their habitat and food sources. They may exist as saprophytic fungi, feeding on decomposing tissues of stumps and dead trees; or they may colonize and parasitize living trees if the trees are subjected to sufficient stress from, for example, insect defoliation, mechanical injury, or drought. *Armillaria* are considered pathogens and problematic if they colonize and degrade or kill trees of high value.

Photo: Joseph O'Brien, USDA Forest Service, Bugwood.org

***Armillaria* mycelia under tree bark of pine (*Pinus* species)**

Armillaria species spread through forest ecosystems in many ways. Airborne spores produced by the fruiting mushrooms provide for long distance dispersal. Local and more efficient spread is accomplished by vegetative growth of the fungus through its hyphal network. Microscopic hyphae grow from stumps to roots and root to root via root contacts or grafts. Hyphae also aggregate to form visible, root-like structures called rhizomorphs that grow through the soil "searching" for new woody food sources.

The map on page 4 shows dashed circles marking the ranges of two *Armillaria* colonies. They are feeding on and recycling nutrients from all the trees within their range, and they are also expanding their mycelial network, traveling through the root connections to find new trees. You will need a ruler and a pencil to map out the travel pattern of the fungus. (0.5 inches on the map equals 15 feet on the ground.)

Student Page

Name:

1. The black circles on the map represent dead trees or tree stumps, the easiest wood to colonize. Look for dead trees that are near the *Armillaria* colonies. If they are within 15 feet (0.5 inches on the map) of the colony, then the tree root systems and the mycelia overlap and the *Armillaria* can colonize these trees as well. Mark all the tree stumps the *Armillaria* colony can reach in this manner by drawing a line from edge of their range to the nearest un-colonized dead tree.

2. The grey circles are weak or stressed trees. Look at their pattern of distribution on the map. Can you think of one reason why these trees might be stressed?

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3. The *Armillaria* can also colonize weak or stressed trees through the tree networks. Again, using your ruler to determine how far away they are, draw lines from colonized trees to the nearest weak trees. Blacken in the grey circles, because the fungus will eventually kill these weak trees.

4. Draw a dashed line surrounding the new range of the *Armillaria* fungus (15-foot radius around each colonized tree). Mark this range as Year 1 of the colony's growth. Repeat the same steps again until you have three years of *Armillaria* travels through the root network. Can you describe how the pattern of the fungus's range has changed in those three years?

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Air Travel for the Rust Fungus – A Two Tree Story

The fusiform rust fungus, a species of the genus *Cronartium*, has a complex life cycle involving five types of fruiting bodies, three of which grow on oaks (*Quercus* species), and the other two on pines (*Pinus* species). The fungus needs both host trees for its survival. Its fruiting bodies do not look like mushrooms—rather, they are individually small and appear as small blister-like clusters on oak leaves; and as large, swollen, gall-shaped clusters on pines branches. The oaks and pines are alternate hosts for the fungus, meaning that the fungus colonizes each tree species in turn during its life cycle, forming spores to travel from one to the other species.

Photo: Robert L. Anderson, USDA Forest Service, Bugwood.org

Fusiform fruiting bodies on underside of oak leaf.

One spore type is produced in clusters of hairy bumps or blisters on the undersides of oak leaves. These spores, carried by the wind, land on succulent growth on pines—new needles or stems—and the germinating fungus produces microscopic, thread-like hyphae that

Name:

grow into the leaf, stem, and branch tissues of the pine. As the fungus grows, the infected woody tissue swells into fusiform (spindle-shaped) galls on the stems and branches. A year or more after infection, the galls develop masses of yellow-orange blisters that release powdery spores into the wind to infect newly emerging oak leaves the next spring.

Photo: Robert L. Anderson, USDA Forest Service, Bugwood.org

Fusiform gall with yellow fruiting bodies on pine.

The fusiform rust fungus is detrimental to commercial pine tree operations because it causes deformed pine stems, trees unsuitable for timber harvesting, and also pine mortality due to wind breakage of limbs and stems where the galls form. Loblolly and slash pines are the most seriously affected pines in southern forests, although there is growing concern that the fungus may cause significant damage to longleaf pines as well. Although the fusiform rust also affects oaks, it does not damage the commercially valuable portion of the tree.

On the map on page 5 are some pines with dotted lines around them, and some oaks with squiggled lines around them. These are infected trees; the dots and squiggles represent the different spores of the fusiform fungus.

5. The oak spores are delicate, and easily destroyed, but they can be carried by the wind a few hundred feet under the right conditions. Which species of trees are these spores going to infect?

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6. On the day the oak spores are ready to be released the dominant wind direction is to the northwest. Using your ruler, locate all pine trees that are within 20 feet (1 inch on the map) of the infected oaks, and mark them with dotted circles to show that they are now infected. Draw a dashed-line circle around the oaks and all trees they infect and mark this as Year 1 of the infection cycle.

7. The pine spores are hardy, and can travel up to a hundred miles. Which species of trees are these spores going to infect?

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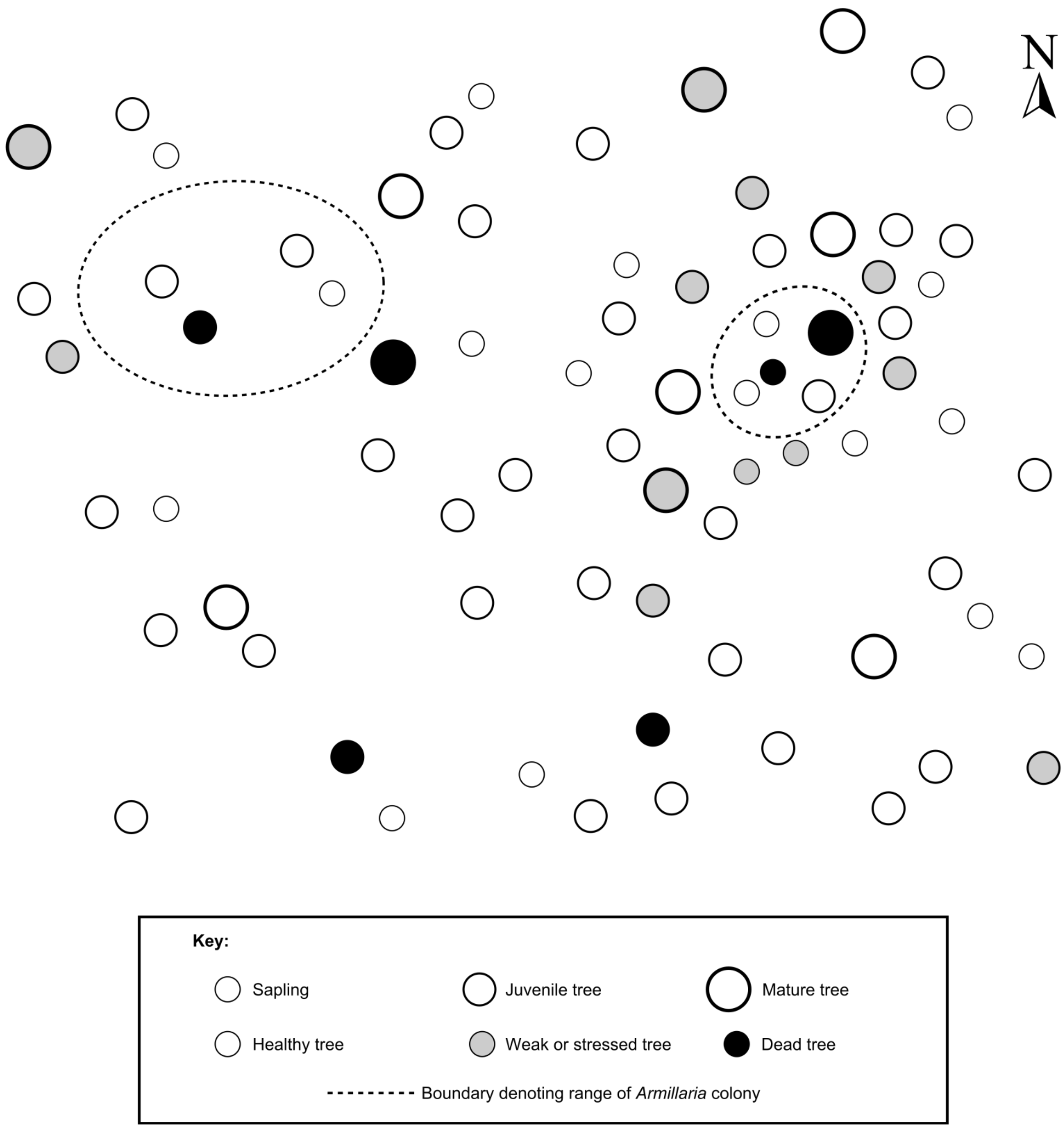
8. On the day the pine spores are ready to be released the wind has shifted to the east. Locate all trees within 500 feet of the pines that are likely to be infected, and mark them with the appropriate symbol. Draw a dashed-line circle around these pines and the trees they infect as [Year 2] of the infection cycle. Mark this area as Year 2.

9. In the third year, the cycle repeats and infected oaks release spores to infect pines again. The dominant wind blows west. Mark how many more pines are infected and draw new dashed-line circles to note the expansion of the range of infected pines. Mark this area as Year 3.

10. In the fourth year, when the spores on the pines germinate, the wind blows them southeast. Repeat the steps to mark the infected oaks, draw the expanded range of infection, and mark it as Year 4.

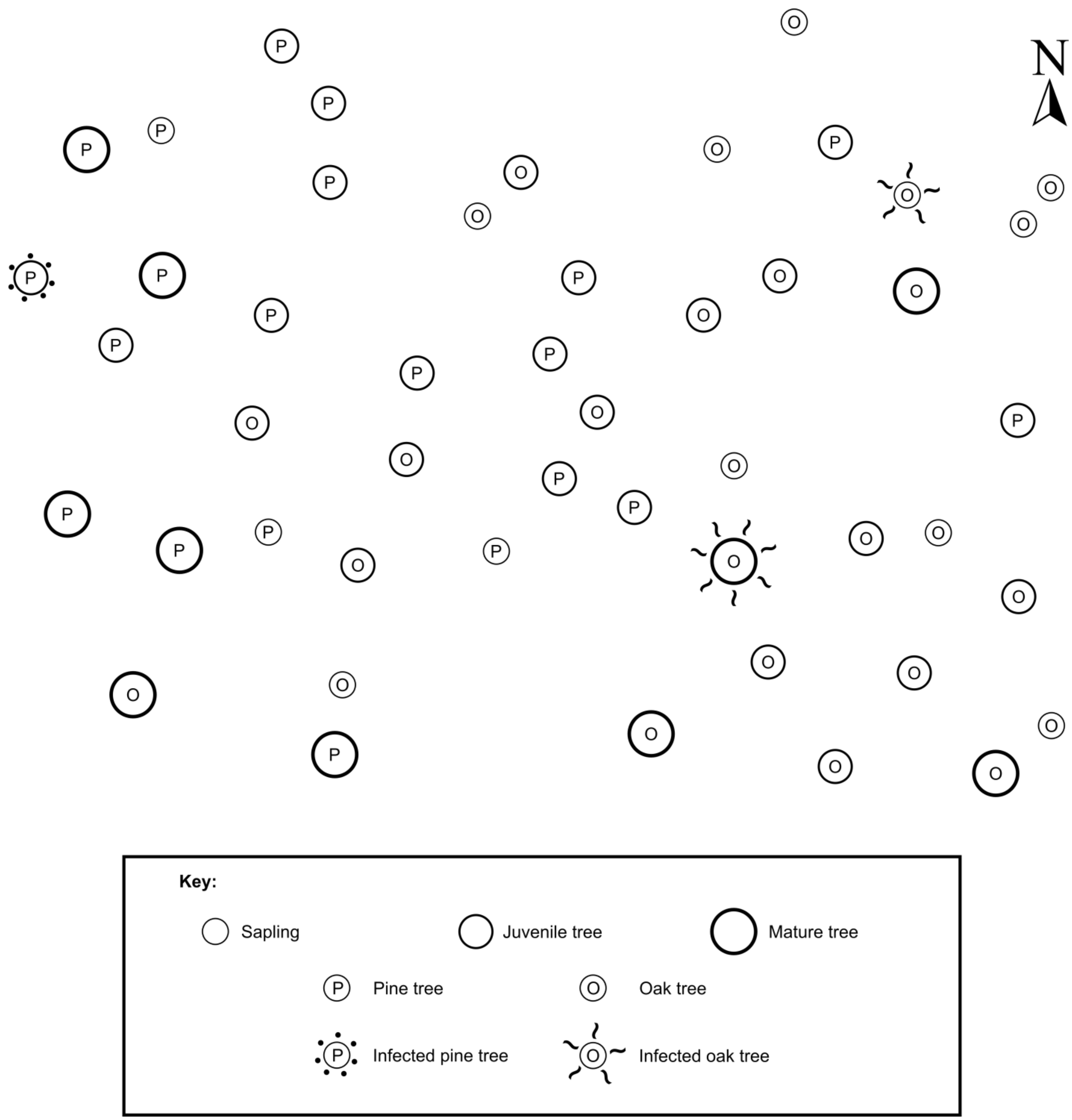
Tree Colonization by *Armillaria*

0.5 inches on the map = 15 feet on the ground



Tree Colonization by Fusiform Rust

1 inch on the map = 20 feet on the ground



Activity 5

How to Eat a Forest – Southern Pine Beetle-Style

Sunshine State Standards

Science (9-12): SC.912.L.14.6, SC.912.L.17.1, SC.912.L.17.4, SC.912.L.17.5, SC.912.N.3.5
Social Sciences (9-12): SS.912.G.5.6, SS.912.C.2.10

Materials

For every 10 students
1 copy of the *Student Page* section (2 pages).
1 sheet of 3 x 4 ft newsprint or poster paper.
15 red, 15 white, 10 blue poker chips, or other playing pieces representing three kinds of trees.
1 cup of black beans, or similar sized playing pieces such as beads or dark-colored paper punch-hole clippings representing beetles.

For the teacher
1 marker.
1 ruler.
1 coin to flip.

Time Considerations

Part A: 10 minutes
Part B: 30 minutes
Part C: 20 minutes

Behavioral Objectives

Students should be able to do the following:

- Model beetle movement and population growth in a simulated version of a forest.
- Predict outcomes of a model simulation.
- Document forest changes by contrasting number and location of beetles, and number and condition of trees on a game board before and after a model simulation.
- Describe an impact triangle specific to the southern pine beetles.
- Manipulate the model board game to favor specific species—either saving the trees or encouraging the growth of the beetle population.

Lesson Summary

In this activity, students play a board game that simulates the feeding and reproductive patterns of pine beetles in a forest. Students are introduced to the life cycle of the insect, the specific host it feeds on, and the environmental conditions that favor the spread of the beetles through the forest. This activity is another application of the impact triangle concept, where the three factors of host tree, insect causal agent, and appropriate environmental conditions must be present for trees to be damaged by beetles.

Following simulations for several different forest conditions, you may engage students in a discussion of the dynamics of this insect-tree relationship and its effects on the forest. Topics and questions include the following: What changes to the forest would occur given the density of trees and beetles? Is an epidemic attack of beetles inevitable or could it be prevented? How could trees be planted to reduce the risk of a beetle population explosion? What is the difference between the natural role of beetles in a forest versus their potential danger in a forest where trees are valued for industry.

Background

Forest Ecosystem Life Cycles: The Case of the Southern Pine Beetles

Many bark beetle species have specific associations with ***host*** trees. They bore into the trunks for food; they also lay their eggs within the tree so that their young may feed and become adults in relative safety under layers of bark. In addition, some bark beetles carry and introduce a fungus into trees in ***spore*** form. The fungus is specific to both the insect and to the host tree. Under the right conditions, spores germinate within the host and the growing fungus can overwhelm tree defenses by feeding on the woody tissues. The beetles can feed on the fungus in turn.

The southern pine beetle, *Dendroctonus frontalis*, is well recognized in the United States because it plagues several commercially and ecologically important pine trees. It can infest any pine species within its range, but it prefers loblolly (*Pinus taeda*), shortleaf (*P. echinata*), Virginia (*P. virginiana*), pond (*P. serotina*), and pitch pines (*P. rigida*). Loblolly is very common in the southeastern United States, where it is cultivated for timber. As a result the beetle can be particularly problematic to this commercially valuable crop because the beetle's preferred food source is abundant in plantations. Longleaf (*P. palustris*) and slash pines (*P. elliottii*) are fairly resistant to southern pine beetles.

Female southern pine beetles find suitable trees—typically those that are dying or stressed due to drought, fire, injury, or poor environmental conditions—and bore under the bark into the ***phloem*** to lay their eggs. During that process they often introduce a fungus that plugs up the tree's ***xylem*** tubes. Larvae feed on phloem for several weeks, pupate, and emerge to attack new trees (Figure 23).

Figure 23. Life cycle of a southern pine beetle: The developmental stages consist of egg, larva, pupa, and adult; the life cycle lasts 4–6 weeks within the tree and a few days outside.

A healthy tree is able to resist the beetle by producing pine resin, stored under pressure in ***resin canals*** beneath the bark. When the female beetle tries to bore into the wood, she ruptures the resin canals and resin is pushed out, sticking to the beetle and preventing it boring farther. Stressed or dying trees cannot produce enough resin or maintain it under high pressure inside the resin canals so the beetle can more easily bore into the wood of weakened trees. A single successful adult beetle releases ***pheromones*** attracting others to the tree. Beetles are also attracted to the smell of resin seeping from newly opened wounds. The tree is typically overwhelmed and killed by beetles that congregate in response to the aromatic compounds in the tree's sap and beetles' pheromononal cues.

Southern pine beetles are a ***native*** insect, normally performing an essential role by helping to recycle dying trees. Epidemic level outbreaks are a result of environmental conditions (such as drought or fire) or anthropogenic conditions that promote tree stress and favor the growth of beetle populations. Some examples follow.

- Densely planted stands, such as loblollies for timber production, make trees compete for scarce resources while facilitating the beetles' movement.
- Fire suppression allows the development of dense undergrowth that increases resource competition for pines.
- Monocultures of susceptible trees as opposed to diverse tree stands make it easier for beetles to spread through the forest.
- Mechanical injury, such as of roots through ***soil compaction*** during construction, weakens trees and makes them less able to resist beetle attacks.
- Imbalances in nutrient or water requirements, such as through excessive irrigation or fertilizer runoff from farms, stress and weaken trees, making them more susceptible to attack.

The Impact Triangle and Southern Pine Beetles

Southern pine beetles are treated as significant ***pests*** because their activities, in large numbers, can cause apparently healthy trees to weaken and die. Diseased and dead trees in large numbers create unhealthy conditions in a forest because epidemic level outbreaks affect not just individuals but entire populations. Since pine trees form an essential part of many natural southeastern ecosystems, pine mortality can result in corollary affects upon other species. Organisms that depend on pines for their growth will be compromised, and those whose growth was once held in check by pine competition gain the opportunity to proliferate. Meanwhile, in areas where pines are planted commercially an outbreak can mean economic ruin. Thus, understanding how to manage beetles is an important concern to many.

The ***impact triangle*** is a concept used to describe conditions that provide opportunities for an organism to have a damaging effect on its host—the right host tree and the right kind of insect must be present in an environment where the conditions are amenable to both the host's susceptibility and the insect's ability to attack the host (See Activity 3 for more details).

An impact triangle specifically for the southern pine beetles involves these three ***components***:

- Host tree: numerous pine species, but especially loblolly pine and shortleaf pine.
- Damage-causing agent: southern pine beetle.
- Environment: land dominated by dead or dying trees, drought-stressed trees, high tree density, heavily impacted ground, etc.

In Activity 3, the impact triangle was used to describe localized criteria for damage to occur on one tree. While the southern pine beetle can cause such damage on a small scale, the purpose of this activity is to zoom out from the tree to look at a whole forest. Figure 24 is an impact triangle showing the potential impact of southern pine beetles upon a forest.

The impact triangle in the figure below describes the cumulative effects necessary for insects such as the southern pine beetle to affect the *forest*, not just individual trees. The mere presence of southern pine beetles in a forest does not mean that an epidemic of pine death will occur; the beetle is native to the southeastern United States and has been here for millennia. Likewise, a forest of oaks and pines and maples would not necessarily be threatened by disease, since the beetles need to travel farther between the mixed species to find the preferred food source, the pines. In other words, ***forest health*** is dependent on a perfect storm of appropriate conditions, just as the health of an individual tree is.

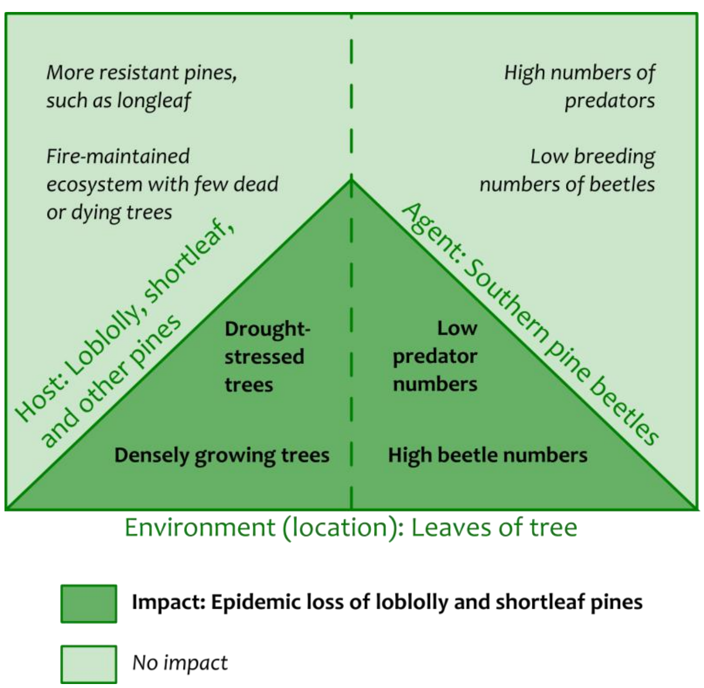


Figure 24. The southern pine beetle impact triangle: The diagram lists potential conditions for host, insect agent, and environment. All three conditions must be present for epidemic pine loss to occur. See Figure 15 in Activity 3 for more on how to read an impact triangle.

Thinking in systems: Games as models of systems behavior

The following activity uses a game to simulate beetles moving through a forest of pine trees. Each iteration of the game can be set to model different conditions, such as loblollies planted close to each other, a few weakened pines in the midst of a vast oak forest, and so on. Playing the game under different conditions enables students to predict whether an epidemic is likely.

After playing the game, discuss with students the ***dynamics*** of the ***system*** they just witnessed—the components of the impact triangle and the interplay between these components which may or may not have caused destruction in the forest. Discussion should lead them to reflect on causes and effects of specific conditions that they modeled, such as if planting pine trees further apart decreased the likelihood of all trees being wiped out, or if beetles working together to bring down trees were more effective than beetles working as individuals. You might challenge them to create a forest on the game board that could withstand beetles, and then discuss how landowners might manage for such conditions in real life.

To do all this, it is useful to keep in mind the power of the activity as a simulation as well as a teaching tool. Games are excellent models of systems because playing the game is analogous to watching the real system in action. In this case, converting the beetle-forest dynamics into a game helps students visualize otherwise intangible concepts, such as how fast a population of insects might explode, or how the ***composition*** of a forest may change over time, as old trees die and new ones grow in its place. By simplifying and illustrating these phenomena in an engaging, experiential format, the game allows students to use their imaginations to predict what might happen when the game board is laid out differently, or if their control over the beetles could be fine-tuned. Expanding on the existing rules of the game to illustrate other forest-based behavior might be a good next step. For instance, what might happen if a flock of beetle-eating birds was introduced to the system?

The game presents an opportunity to discuss ***positive*** and ***negative feedback loops***. A positive feedback loop is a destabilizing interaction in the system. For example, when many weak trees, a preferred beetle food source, are present in the forest the beetle population shoots up. With more beetles, even healthy trees can be brought down, further increasing the number of weak trees. This again favors beetle population growth, to the point where the population explodes. After an epidemic outbreak, the

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forest is decimated. The beetles, having over-consumed their food source, now experience a population crash and are decimated as well.

The negative feedback loop helps maintain system equilibrium. Greater numbers of healthy trees mean that there is less food for beetles to eat. Their numbers drop. The system remains unthreatened. Predator-prey population fluctuations are a classic example of negative feedback loops—with more beetle predators, beetle numbers drop, and with less beetles to consume, predator numbers drop. When predator numbers fall, the beetle population rises again. When their population rises, the predators pick up speed as well.

Given this example, consider again the impact of a beetle outbreak in the forest. As with predator-prey interactions, population fluxes happen when a food source is in limited supply. During an epidemic, beetles eat beyond their means, and the next season they will starve. In a sense, they eliminate themselves from the system. What happens next? The trees have a chance to regenerate, free from the threat of beetles. Whether the trees that subsequently grow are the same species as the ones that were killed is a question that determines whether the forest is recycling itself, or if it is transforming into something new—an oak forest perhaps, instead of a pine forest. If the forest regenerates, is an epidemic really a case of system crash, or a system renewal? And if so, were the beetles part of a short term *positive* feedback loop, or a long term *negative* one?

Getting Ready

- Read the *Background* and *Doing the Activity* sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - For every 10 students:
    - 1 copy of the *Student Page* section (2 pages).
    - 1 sheet of 3 x 4 ft sheets of newsprint/poster paper.
    - 15 red, 15 white, and 10 blue poker chips or other playing pieces representing three kinds of trees.
    - 1 cup of black beans, or similarly sized playing pieces like beads or dark-colored paper punch-hole clippings representing beetles.
  - For the teacher:
    - 1 marker.
    - 1 ruler.
    - 1 coin to flip.
- Use the marker and ruler to prepare 3 x 4 foot game boards on newsprint by marking a 23 x 17 inch dot matrix with dots 2 inches apart from each other, as shown in Figure 25. Alternately, see *Resources and References* for a pre-made game board.

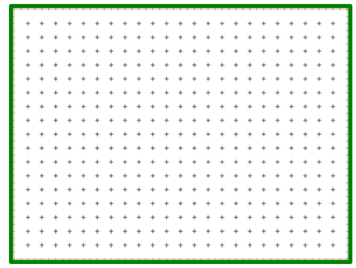

Figure 25. Activity game board.

Doing the Activity

Part A: Introduction to southern pine beetles in the forest
10 minutes

1. Ask students if they have heard of southern pine beetles, and if they can guess what the beetles like to feed on.

Answers might include southern pine trees, but specifically loblolly, shortleaf, pond, and pitch pines. Explain that there are many kinds of pine tree species, some more resistant to southern pine beetles than others. Longleaf pines, for example, are fairly resistant.

2. Briefly describe southern pine beetles and the specific trees they prefer. For example, they are a native, wood-boring insect; they like to feed on loblollies, shortleaf pines, and so on. You may use the *Background* section and visuals from the *Resources and References* section to illustrate your presentation.

3. Briefly describe how pine trees can defend themselves against beetles by pushing them out with resin, which is held under pressure in a healthy pine tree. The pine trees' resin defense system can be compromised by drought or other stresses.

4. Ask students if they can think of any reasons why trees would not be able to defend themselves.

Drought will reduce the amount of resin produced and the reduced water pressure in the bark makes it harder to pump resin out.

5. Compare trees to humans and ask students what would make people vulnerable to attack by ***disease***-causing agents. What would make trees vulnerable to attack?

People may become vulnerable due to lack of sleep, lack of nutrients, lack of water, etc. Tree health may be compromised by drought, overcrowding, etc.

6. Tell students that they will be playing a game where each of them becomes a southern pine beetle, looking for food in the forest. The objective is to successfully reproduce. They do that by colonizing pine trees.

Take it outside

Consider conducting this activity outdoors since it requires space to move. Youth have shown interest in being outdoors while learning new things, and if you can point to examples of southern pines, it can enrich the learning experience.

Part B: Playing the game
30 minutes

7. Hand out one game board per ten students in the class. Hand out one bean to each student, explaining that the beans represent beetles, and that they are all southern pine beetles and the game board is the forest in which they must find food. Remind them that loblollies are the southern pine beetles' favorite food. Note that they can feed most successfully on weak trees because these don't have the pressure to push the beetles out with resin.

8. Randomly spread out ten red and four white poker chips on the game board. The chips need not lie directly on or between the dots; any approximation will do (see Figure 26). Explain to students that the red chips represent healthy loblolly pines, and the white chips represent weak loblolly pines.

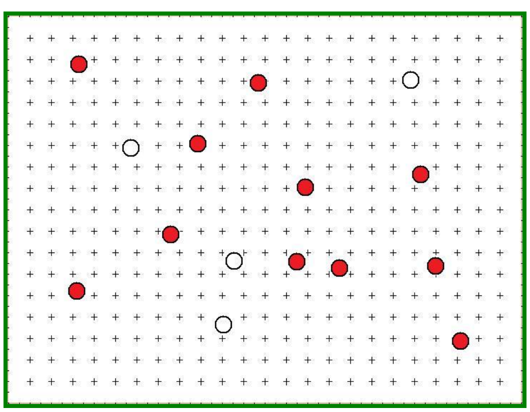

Figure 26. Red circles are healthy loblolly pines; white circles are weak ones.

9. Explain the rules of the game.

- The object of the game is for each beetle to find enough food for itself so it can lay eggs and produce the next generation of beetles.
- Students take turns with the various tasks including making observations and taking notes on the number on and location of beetles, the number and type of trees, the layout of the game board, and what has changed after each round of the game. These roles (beetle counter, tree counter, note taker) are outlined in the *Student Page* section as well.
- Each student picks a dot on the edge of the grid for their beetle's starting position. As students begin to play they will realize the starting position is key to quickly reaching a weak tree, or to reach a tree with other beetles.
- Flip the coin and call out "one step" for heads and "three steps" for tails.
- Each beetle can move from dot to dot in any direction for the number of steps called out. Diagonal movement is not allowed.
- If a beetle lands on a white chip or weak tree, it feeds, lays eggs and kills the tree. This student receives three additional beetles to move in the next round. The dead tree chip should be removed from the board.
- If a beetle lands on a red chip or healthy tree, it must wait for two more beetles to join it on the tree before the tree is weakened. If no others are in the vicinity, the beetle may decide to move on in the next round.
- After each coin flip, if three beetles make it to a red chip, each of those students is given three more beetles, and the red chip is replaced with a white chip—that tree is now weakened.
- Students can move each of their new beetles independently, in different directions, either one or three steps depending on the coin flip.
- After five coin flips, the round ends. If a beetle has not found a tree in that time, it dies, and the bean is returned.

10. Ask students from different "forests" to describe what happened on their game board at the end of the round.

11. Reset the game board to play a new round, with different variations of trees (see Figure 27 on the following page for examples). Describe the new forest for each new round of the game and ask students to predict what might happen. Some game board variations include the following.

a. Host trees are mostly unhealthy (many more white chips on the board) (Figure 27.a).

b. Mixed forest of loblollies (red), and a more resistant pine species like longleaf (blue). Six beetles need to attack a longleaf before it succumbs and the beetles can reproduce (Figure 27.b).

c. Host trees are stressed from overcrowding (densely packed red chips, or red and white chips mixed) (Figure 27.c).

d. Tree chips in rows, such as on a plantation.

Cont'd on next page.

Cont'd from previous page.

e. Gaps between tree stands, meaning beetles must move farther before finding host trees (Figure 27.c).

f. Mixed forest of pines (red), and trees that southern pine beetles cannot attack, such as oaks (blue).

g. Very few dead trees, but many beetles (each student gets three beans at the beginning of the game, rather than one).

h. Thanks to a strong wind, beetles start their attack from the center of the game board rather than from the edges.

i. Beetles communicate with each other, via chemical signals, calling more beetles to the trees under attack.

12. Break off the game for reflection after four or five rounds have been played.

Part C: Discussion and reflection
20 minutes

13. Ask students the following reflection questions, depending on the game board variations used. The answers given here are suggestions for where the discussion could lead.

a. How do the beetles change the forest when there are very few weak trees present?

Weak trees are the easiest for southern pine beetles to colonize. If there are very few weakened trees in the forest, fewer beetles will reproduce due to a lack of food. Soon all the weak trees will be colonized by the existing beetle population, causing the trees to die. The remaining trees are mostly healthy ones. Beetle populations may never reach outbreak conditions because there aren't enough weak trees to sustain them.

b. How do the beetles change the forest when there are very few healthy trees present, or very many closely packed trees?

Epidemic level outbreaks of southern pine beetles typically occur when trees are very stressed, closely packed, or unhealthy. This makes the entire forest easily navigable for the beetles, because their preferred feeding and breeding grounds are everywhere. The forest can change dramatically after such an outbreak. If an outbreak occurs on a plantation, the entire timber crop could be lost. If it occurs in a mixed forest, the loss of pines would alter the forest's composition.

c. What role does the southern pine beetle play in the forest?

Southern pine beetles are essential in southeastern forests. They are a native species and their actions influence pine populations by hastening the death of weak trees. Southern pine beetles also create ***niches*** *for other dying or dead tree colonizers; including other decomposing insects and fungi, and cavity nesters such as woodpeckers. Likewise, the beetles are a source of food for birds, mammals, and other insects.*

In forests with mixed trees, southern pine beetles preferentially attack dying over live trees, loblollies over longleaf pines, and any pine trees over other tree species. They can influence the dynamics of a forest's composition—such as would have been observed in the pine/oak variation or the loblolly/longleaf variations of the game. Other organisms dependent on certain forest types may have to adapt or move if the ecosystem changes after a beetle attack.

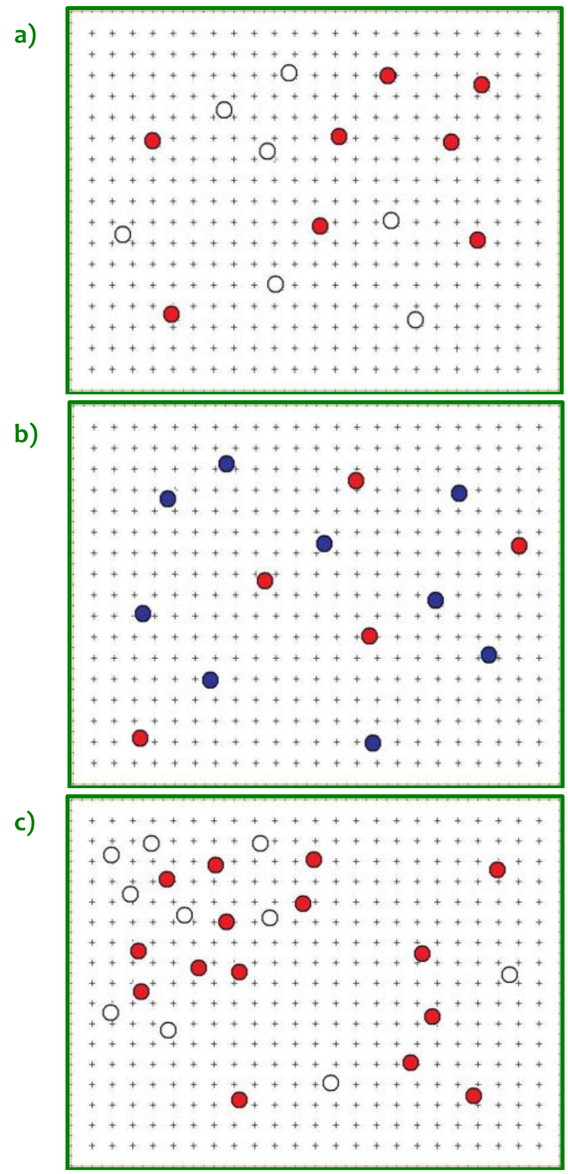

Figure 27. Game board variations: a) Equal numbers of healthy and weak pines; b) Two different pine species, one resistant to attack, the other not; c) A cluster of closely spaced trees separate from another stand that is sparsely populated.

14. Prompt students in a discussion of the southern pine beetle-forest dynamics. The following questions can guide students towards thinking of how they could hypothetically influence trees and forests through the perspectives of trees, beetles, or forest managers.

a. What stresses trees?

If trees are planted very close to each other, they are all competing for the same limited resources. Likewise, drought, flooding, or nutrient imbalances make it difficult for trees to function normally. Drought stress is a particular concern for pine trees during southern pine beetle outbreaks. Drought-stressed trees produce and store less defensive resin, which under normal conditions seeps through the bore holes that beetles make, flushing them out. The less water available to the trees, the less able they are to resist the beetles' attack.

Furthermore, when more than one beetle attacks a tree, it triggers a positive feedback loop: the tree pushes out resin, which causes more beetles to flock to the it because of the smell of the resin or the pheromone odor of the first wave of beetles; this further stresses the tree and triggers more resin efflux to the point where the tree can no longer defend itself. Environmental ***stressors*** *favor the beetles, and negatively influence the trees; the beetles, in high numbers, become tree stressors too.*

b. If the students could control their own forest—if they could lay out the game board according to their own wishes—how would the trees be planted? Ask students to think about this twice—once from a perspective favoring the southern pine beetles and again from the perspective favoring tree survival.

The variations of the game board that favor insects include rounds where the beetles could communicate, teaming up in groups to bring down healthy trees faster or jointly targeting clusters of trees. Variations that favor trees are those with large gaps between trees, a variety of species of trees, or no weakened trees. Students might be prompted to remember which layouts of the forest favored beetle survival and reproduction, or tree survival and beetle death.

A "healthy" forest is described as such based on the perspective of the person making the diagnosis. Forest managers have a different perspective from either beetles or trees, depending on whether they think southern pine beetles are a pest or an essential part of the ecosystem. Forests may be used for many purposes, for instance, loblolly production, recreation, and longleaf pine reintroduction. A forest manager's goal is determined by the forest's purpose.

c. If all beetles started from the edge of the game board, how did they get there? Where do beetles come from and how might they spread from forest to forest?

Southern pine beetles are a native insect and exist in low numbers in forests. Since they particularly favor dying or dead trees (such as lightning-struck pines) or loblolly pine stands, these might be where local pockets of southern pine beetles exist in higher numbers than throughout the forest.
They get from tree to tree when they fly in search of new feeding and breeding grounds. Additionally, they may be transported in cut logs from urban to rural places, or from forests into cities, and so on. Beetles may hitchhike longer distances through trade routes and transport of wood across state or national borders, or they may be carried by strong winds to colonize new areas where host trees are present.

15. Discuss with students the impact of positive and negative feedback loops, both of which occur in the game. An epidemic outbreak of beetles is the result of a positive feedback loop where greater numbers of weak or dead trees promote larger beetle numbers, which in turn result in even more weak or dead trees. Positive feedback loops tip the system out of balance—what happens when there are so many beetles that there is no food for them anymore?

Negative feedback loops are system stabilizers. If most of the trees are healthy, fewer beetles survive to reproduce. Likewise, as beetle predator populations increase, beetle numbers go down. The system remains in equilibrium—most trees are healthy. Ask students to list other positive (destabilizing) and negative (stabilizing) loops to make the concept clearer.

16. As a follow-up to the previous question, ask students to think about the consequences of system destabilization. Consider a post-outbreak forest, with most trees dead. Is this the end? Or will trees eventually regenerate? How would the forest composition change?

Assessment

The following are group assessments. Using the students' answers during discussion and their responses to the *Student Page* section, check that they can do the following:

- Predict outcomes of a model simulation.
  Seen in students' answers to the Student Pages, *and step 12 of* Doing the Activity.
- Document forest changes by contrasting number and location of beetles, and number and condition of trees on a game board before and after a model simulation.
  Seen in answers to the Student Pages.

For individual assessment, use the answers to *Student Page D* of Activity 3 (page 29)

- Describe an impact triangle specific to the southern pine beetles.
  Seen in students' answers to Student Page D.

Extension Ideas

- Instruct students to modify the game to depict forests more realistically. There are several scales at which this modification can occur, and each depends on how many additional variables are introduced. The simplest is predation. Ask students to find out if southern pine beetles have any natural predators. The predator can be included as another game piece, and students can be given the opportunity to build rules to depict the predator's movement.

  To guide students into thinking about how they would design the game modifications, ask them how fast the predator would need to move in order to eat the beetles. How many moves can it make in each round? How many beetles does it need to eat before it can reproduce? How many offspring does it have each year? To stimulate reflection, keep a chart similar to the Student Page used in the activity to count not just beetle and tree numbers, but also predator numbers. Plot these numbers on the blackboard to show population fluctuations.

- A further modification of the game can be to make the forest larger, with subsections of land falling under different management plans. The groups' game boards can be combined to form a much larger one on the floor. Students can be assigned to quadrants where they can choose what type of forest they have and its characteristics. For instance, it could be a pine forest, in the middle of the city, have a river running through it, and so on.

  Have students use markers to draw a more complex landscape. Then ask students on each quadrant to develop independent rules for how the trees in that forest are managed. Do the people of the city want to cut down pine trees and plant other trees instead? Are people transporting logs from one area to the next? Does a forester practice extensive burning to clear the undergrowth. Are pesticides used to control beetle populations? Each of the quadrants is responsible for enforcing the rules on that piece of land.

  When the simulation is run, if an epidemic outbreak occurs, which of the game rules (or management roles) need to be negotiated and changed in order to keep down beetle populations in the next round? Ask students to reflect upon the game experience and write about what they think is important when people manage real forest health issues.

Resources and References

- The University of Florida's SFRC Extension website for educators includes several related resources.
  - A visual presentation contains images to supplement your discussion on southern pine beetles in forests.
  - An 8.5 x 11 inch matrix with dots is available for printing. Multiple copies can be taped together to create a larger game board.
  - The Southern Pine Beetle flash card in the *Pocket ID Guide* provides more information about this organism.

  Visit http://sfrc.ufl.edu/extension/ee/foresthealth.html

Student Page

Team Name:

How to Eat a Forest – Southern Pine Beetle-Style

Instructions

Pick a team name and write it at the top of the page. In this game you control southern pine beetles. Your objective as a team is to make sure your beetles survive and reproduce as they move though the forest eating pines. Your teacher will read out the game rules and call out the number of times you may move in each round.

Appoint three team members to collect notes on what happens before and after game play during each round. At the end of each round, let the person to your left take over your counting or note-taking duties.

- **Tree counter** – Counts and identifies the types of trees and reports information to note taker.
- **Beetle counter** – Counts beetles and observes their general location and reports information to note taker.
- **Note taker** – Takes down information provided by tree counter and beetle counter. Draws or describes the forest layout before and after each round. Notes what happened to the forest after each round.

Round 1	**Before game play**	**After game play**
Forest layout on game board		
Number and types of trees		
Number and location of beetles		
What happened?		

Round 2	**Before game play**	**After game play**
Forest layout on game board		
Number and types of trees		
Number and location of beetles		
What happened?		

Student Page

Team Name:

Round 3	Before game play	After game play
Forest layout on game board		
Number and types of trees		
Number and location of beetles		
What happened?		

Round 4	Before game play	After game play
Forest layout on game board		
Number and types of trees		
Number and location of beetles		
What happened?		

Round 5	Before game play	After game play
Forest layout on game board		
Number and types of trees		
Number and location of beetles		
What happened?		

Activity 6

Unhealthy Forests and the News

Sunshine State Standards

Science (9-12): SC.912.L.17.8, SC.912.N.4.2
Social Studies (9-12): SS.912.A.1.5, SS.912.G.5.4
Reading/Language Arts (9-10): A.910.1.6.2, LA.910.1.7.3, LA.910.1.7.4, LA.910.1.7.5, LA.910.2.2.2
Reading/Language Arts (11-12): LA.1112.1.6.2, LA.1112.1.7.3, LA.1112.1.7.4, LA.1112.1.7.5, LA.1112.2.2.2

Materials

For each student
1 copy of the *Student Page* section (6 pages).

For the teacher
Scratch paper.
Pen or pencil.

Time Considerations

Part A: 10 minutes
Part B: 30 minutes
Part C: 20 minutes

Behavioral Objectives

Students should be able to do the following:

- Critically read a news report-style article.
- Identify the key issues and stakeholders in a news article.
- Use the information in the text to answer questions about the article's purpose.
- State their opinion on reading about issues from multiple perspectives.

Lesson Summary

In this activity, students read, critically analyze, and compare two articles covering a national forest health issue. The articles are written in the style of news reports. While both articles cover the same story, they are told from different perspectives. While the articles were written for this exercise, the data are factual and the concerns expressed are representative of how this particular issue has been conveyed in various news media articles.

Following the activity, students discuss who determines the values by which a forest is judged as healthy and how a phenomenon in a forest—such as a disease epidemic—should be reported.

Background

What is Forest Health, Really?

A definition of ***forest health*** includes many interrelated factors. ***Composition*** plays a role, such as the type and number of trees and their ages, or the diversity of the flora and fauna. The health of a forest may also be determined by how well it serves its purpose. Is it a buffer against soil erosion? A source of timber and other forest products? A place for hikers and campers? Or an oxygen pump for the planet? Forest health may also be ascertained by what is out of place in the ecosystem—fire suppression, unseasonal drought, presence of pollutants or ***invasive exotic*** species, and so on.

The Society of American Foresters (SAF) provides a definition of forest health that attempts to take the aforementioned variables into account. It defines forest health as *"the perceived condition of a forest derived from concerns about such factors as its age, structure, composition, function, vigor, presence of unusual levels of insects or disease, and resilience to disturbance."* It further mentions that the *"perception and interpretation of forest health are influenced by individual and cultural viewpoints, land management objectives, spatial and temporal scales, the relative health of the stands that comprise the forest, and the appearance of the forest at a point in time."*

By this definition, those who manage forests need to look at more than the current state of forest health; they must also consider causes and future effects of management decisions.

The SAF definition draws attention to the fact that while forest health may be described in terms of a forest's ***component*** properties, it is also defined by ***stakeholder interests*** and ***values***. Longleaf pine forest restoration, for example, is a goal that is of specific value to many ecologists in the Southeast who would like to see the return of this once abundant endemic ecosystem. Meanwhile, those who see the economic value of forests managed for timber and other products have a different set of criteria for forest growth and management.

The general public also has opinions and ideas about what forest health is and what it should be. Their opinions may be informed by personal experiences, what they are taught in schools, and what they read about in the papers. The public's stake in forest health rests twofold in its reliance on forests for ecosystem and economic services, and its ability to influence management decisions by voting and voicing opinions on how this natural resource may be used.

Public opinion can be influential, for good and for bad, but public education about forest health is complicated by the complexity of the topic—what may be the right thing to do in one scenario may not be appropriate in others. Prominently in the United States, the Smokey Bear campaigns educated the public about the dangers of accidentally lighting forest fires; however, this led to misunderstandings about the essential role of fire in a forest. Decades of suppression of natural fires resulted in dangerously overgrown forests that are greater fire risks than in the past. The trees in such forests are less resilient to insects and tree ***diseases*** as a result of overcrowding. Public education in the Southeast now focuses on the significance of naturally occurring fire in the ecosystem and the importance of prescribed fire as a tool for healthy forest management.

Framing Forest Health in the Media

Forest health issues are not widely discussed in the public sphere, often because they require special understanding of ecological and management contexts. However, forest health invariably appears in the media when forests experience changes that affect people's access to forest products or that alter their quality of life (Figure 28). For this reason, when tree diseases, fire threats, or other forest health issues make the news, they introduce the public to important consequences of ecological and environmental processes.

However, public education based on media information comes with certain caveats; news articles simplify complexities and report issues from various viewpoints and angles, ***framing*** the issues in such ways that they may both capture and influence public opinion.


The Christian Science Monitor

Raging wildfires: Climate changes to blame for record season?

Many scientists suggest that climate changes could be causing certain kinds of wildfires for which the West's forests are not well adapted. This year could help researchers better understand and fight the trend.

The New York Times

November 18, 2008

Bark Beetles Kill Millions of Acres of Trees in West

By JIM ROBBINS

HELENA, Mont. — On the side of a mountain on the outskirts of Montana's capital city, loggers are racing against a beetle grub the size of a grain of rice.

From New Mexico to British Columbia ...

npr

Fungal Disease Spreads Through Pacific Northwest

by RICHARD KNOX

April 23, 2010

A rare and dangerous fungal infection named *Cryptococcus gattii* has been quietly spreading from British Columbia southward to the U.S. Pacific Northwest. And it's changing as it goes.

Researchers have discovered that a unique strain of the bug has emerged recently in Oregon and already spread widely there, sickening humans and animals.

So far, over the past 11 years there have been about 220 cases reported in British Columbia. Since ... Washington and Oregon have reported about 50 cases. Among the total 270 cases, ...

Figure 28. Forest health makes the news: The state of forests is an economic, ecological, and even emotional concern.

A "frame" in this context is a way to look at the world and a way to represent it. A person's perspective, agenda, or biases may influence the way they frame a report. The person may deliberately or unintentionally use subjective language, pick some facts over the other, represent certain voices while omitting others, or otherwise skew a narrative away from the whole story. Furthermore, while frames may be constructed by the writer of an article, the audience too may bring preconceived notions while reading it. Readers make framing choices such as what to read, what to believe, and how to interpret the facts presented before them.

An extreme example of framing forest health is taken from an early 1900s news article covering chestnut blight, a fungal disease of American chestnut trees:

"Enemies now attack this tree on every side, and it is very poor forestry to favor a tree against which nature has so definitely set her hand. The chestnut has been practically exterminated over whole sections where formerly it was common, and in many others it is now being destroyed by the wholesale. Its enemies bid fair to destroy it as a commercial tree, perhaps to push it to the borders of extinction."

In the preceding text, framing devices such as the word choices of "enemies," "practically exterminated," and "destroy," sensationalize chestnut blight. The threats against chestnut trees are humanized—they are enemies with purpose, rather than non-motivated biological ***stressors***. In fact, if the word "tree" were replaced with "person" or "country," the paragraph would read much like a war zone report. Language is used to cause alarm and raise the dramatic impact of the disease.

Framing devices used to grab attention and get people to care about issues may lead to misunderstandings if taken at face value. A key skill in reading news reports is to think critically about objectivity, motivations, and potential sources of bias within the story. Reading from multiple sources is a way to broaden ones understanding of a subject. And of course, keeping in mind one's own preconceptions is important when trying to understand an issue.

The fictional news articles in this activity are more contemporary and less dramatic than the chestnut blight example seen previously. However, since there are multiple stakeholder values to consider, the concept of framing provides a useful methodology for looking at how forest threats have both real and potentially media-constructed impact upon the readers' perceptions of the issue.

Thinking in systems: Using critical thinking to understand frames

Careful, critical reading of newspaper articles provides a useful opportunity to practice visualizing ***systems***. The framing technique used to present information in newspapers is similar in many ways to a snapshot view of the world, one which turns systems into objects. A systems view combines several snapshots, so to use systems thinking is to see multiple points of view.

The two news articles in this activity present a forest health case that is a concern in the southeastern United States—the epidemic of laurel wilt that is decimating redbay trees in the region (See *Resources and References* for more information on this disease). However, neither article by itself tells the whole story. There are two snapshots, one with a slant toward economic impacts, and the other with a slant toward ecology. The causes of the epidemic are variously attributed to accidental overseas transportation, beetles, or freak weather events. The implications of the epidemic are serious to humans in different ways. However, a complete picture is not formed unless both articles are read and compared.

The framing techniques used in this activity present the case of laurel wilt from the perspective of landowners, foresters, teachers, and farmers. Reading the text and asking questions about the positions included in the articles reveals aspects of the problem. Asking questions about biases toward particular values and interests provides clues about the other issues. Critical reading also reveals missing information and raises additional questions that the articles may not address.

Encourage students to think about the significance of looking at issues from multiple perspectives. Critical thinking asks readers to think beyond what is in the text, to look past the snapshot to the whole story. As a systems thinking skill, it encourages learners to address problems by taking into context the various variables involved. In the case of forest health management, it may mean listening to many stakeholders with different interests so that solutions to problems are satisfactory to as many people as possible.

Getting Ready

- Read the *Background*, *Doing the Activity*, *Student Page*, and *Answer Key* sections sections to familiarize yourself with the material.
- Prepare the supplies outlined in the *Materials* section.
  - For each student:
    - 1 copy of the *Student Page* section (6 pages).
  - For the teacher:
    - Scratch paper.
    - Pen or pencil.

Doing the Activity

Part A: Introduction to laurel wilt
10 minutes

1. Introduce students to the laurel wilt disease by asking if anyone has heard of the beetle, fungus, or the tree ***host***. Figure 29 on the following page depicts the laurel wilt disease cycle. See *Resources and References* for more information on laurel wilt.

2. Ask students if they can think of any reasons why laurel wilt might make the news. Broaden the discussion to things that tend to make news, such as famous people, current events, something that impacts many people, local events, or natural and human-caused disasters. Make notes of students' answers to use for discussion later.

Image: M. Hughes, and A.E. Mayfield,
University of Florida Institute of Food and Agricultural Sciences, Department of Plant Pathology,
Florida Department of Agriculture and Consumer Services, Division of Forestry

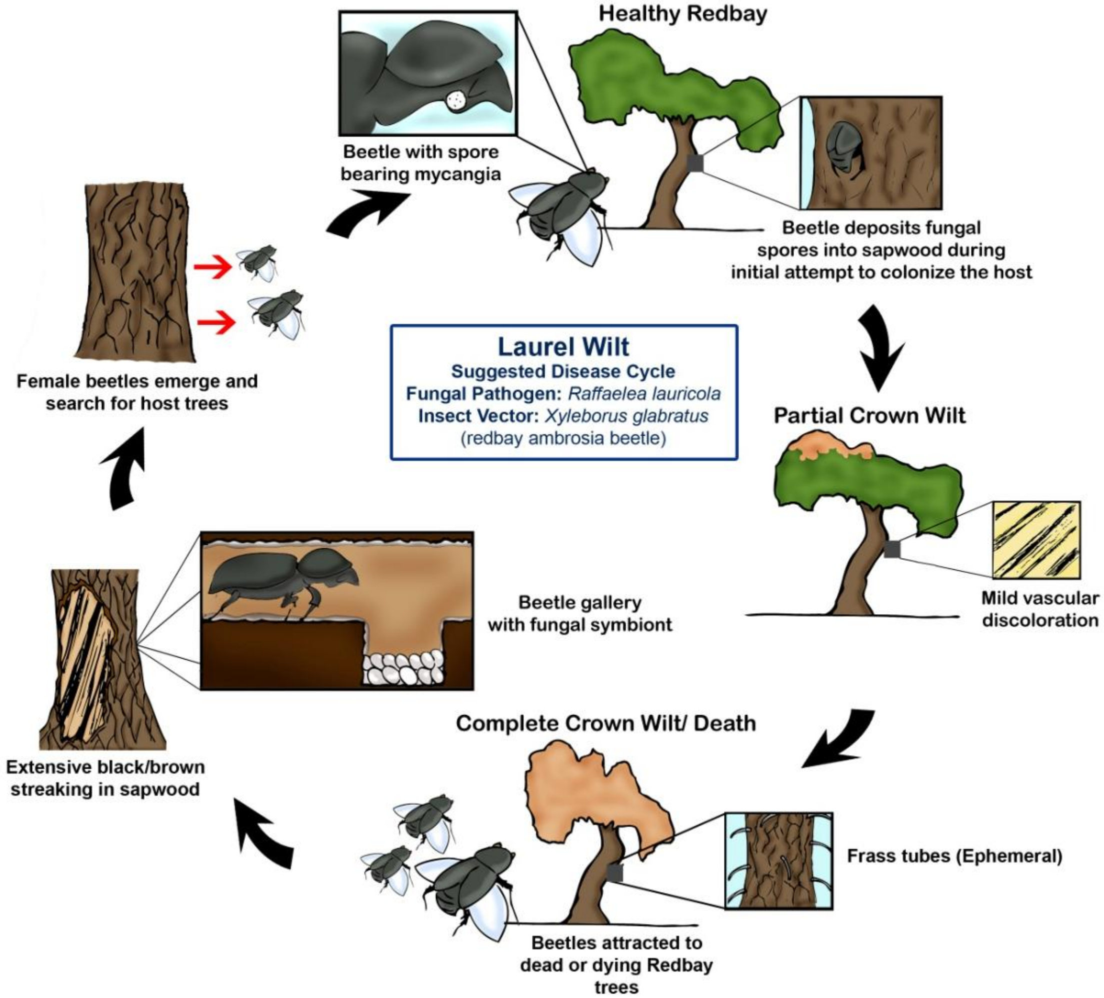

Figure 29. Laurel wilt disease cycle.

A beetle carries fungal spores in specialized structures on its body called mycangia. The spores are deposited within redbay trees, where the fungus germinates and grows through the tree's vascular tissues, killing the tree in the process.

Meanwhile, the beetle lays eggs that hatch and develop within the tree. New beetles catch spores off the fungus in their mycangia as they exit the dead redbay to infest other trees.

Part B: Critical reading
30 minutes

3. Hand out copies of the *Student Page* section to each student. Explain to students that they will be working in pairs and need to pick one of the two articles to read, making sure that their partner is reading the other one. It is important for partners to read different articles so that they can compare notes. Advise students to read the article twice, once briefly, to get a sense of the topic, and then again closely, to pick up specific details.

4. The *Student Pages* include questions that follow the two articles. Ask students to fill in the answers after they have read the articles. The last three questions require that they work in pairs to discuss the different stories.

Part C: Discussion and reflection
20 minutes

5. Using the *Answer Key* that follows, go over the *Student Page* questions, asking students to volunteer answers.

6. Ask students what their perceptions were of the ways in which the articles were written? For each article ask the following:

- What makes it news?
- Who would find this article relevant?
- How does the article suggest dealing with the forest health issue?

7. Wrap up the discussion by asking students to consider the importance of critical reading in the context of media and forest health. The following questions may guide your discussion.

a. What would happen if all the news we read came from only one perspective?

As students will have seen when comparing notes about laurel wilt in the Southeast, not all repercussions of the disease are revealed in either story. For various reasons, hearing the news from just one source may mean that some voices are not heard, and some issues don't come to light.

b. What clues are there within a text to suggest that only part of the story is being told?

You might ask students to point out examples of subjective versus objective writing in the text. Dialogue has a tendency to be subjective, and there are differences between expressing opinions and stating facts. You may also ask students about linguistic choices—are there words being used in the articles to create emotional responses such as fear, worry, or anger?

Additionally, ask students to consider what it was that each author wanted to address. In the first article, the goal is report on the economic repercussions of laurel wilt on Florida's avocado industry. In the second report, the goal is to discuss the ecological consequences of laurel wilt, especially with regard to the palamedes swallowtail butterfly. Would it be possible to write either article while also paying attention to the key points of the other?

c. What is the significance of newspapers and other media as a form of public communication?

Newspapers are a source of information and can be an educational tool for the general public. But there is only so much space within a news article to provide a) facts that are important to know, and b) reasons why these facts are important. It often happens that the news is framed using alarm, fear, and other emotional hooks to capture the reader's attention.

Careful reading of newspapers can help separate fact from opinion. Reading widely can help flesh out the details of news stories to provide other angles and views of what is important.

d. In your opinion, which of the two articles is the more newsworthy story, and why?

There are no right answers to this question, but the argument may be made that both articles express realities about laurel wilt disease that will occur whether or not they are reported.

However, public awareness of the issue, from either perspective, could lead to increased pressure to allocate funds to combat the disease or a push for educational resources to prevent the disease ***pathogen*** *from spreading. Ultimately, news articles focus on stakeholder issues. In this case, it is stakeholders who are aware of current events that can decide what is important, and how to take action.*

Student Page Answer Key

The following are suggested answers to the *Student Page* section. You may consider other student answers that fit the questions as well.

1. Summarize the main point of the news article you read. In other words, why is it important and what makes it news?

Those who read the first article may summarize the main issue as a crisis of redbay extinction that could likely have economic implications to Florida's avocado industry as well. Those who read the second article might summarize the issue as an extinction crisis for a ***native*** *species (the palamedes swallowtail butterfly) at the expense of exotic invasives.*

2. List at least three stakeholders mentioned in the article, including those who are interviewed and those who will be affected by the issue. Stakeholders are those people who have some relationship to the issue at hand—they will either benefit or have something to lose because of the issue.

Some stakeholders include residents who live around or in these forests, hikers, avocado growers, the timber industry, forestry experts.

3. For the stakeholders you identified in question 2, describe their interests as explained the article. Interests are the things people care about, value, or think are important.

Examples: Residents have psychological attachment to their homes and the trees on their land, and they rely on a living forest to provide other ecosystem benefits. Hikers enjoy recreating in forests. Avocado growers see the potential threat of laurel wilt to their livelihood. The timber industry may not be affected by this particular issue. Forestry experts are concerned with epidemic outbreaks and the impacts and consequences on the forest ecosystem.

4. How do you think the laurel wilt epidemic will affect the stakeholders you identified?

For those who appreciate forests for their ecosystem benefits, or for recreators who enjoy hiking in the woods, the presence of so many dead redbays may indicate an unhealthy forest. Butterfly fanciers and ecologists may be concerned about the loss of the palamedes swallowtail butterfly. Avocado growers may find their livelihood at risk. Forestry experts must expend time and money to find a solution to the laurel wilt problem before it escalates.

5. How do you think the laurel wilt epidemic will affect the forests of the Southeast?

The disease is causing a local extinction of redbay trees—more than 90 percent of them are now dead. This is consequently affecting all the organisms that depend on *redbays, such as the palamedes swallowtail. Related trees from the Lauraceae family, such as sassafrass and the economically important avocado, may also become infected. The forests that contain the redbay ambrosia beetle serve as a reservoir for the disease to move to new locations.*

Laurel wilt, being a non-native disease, is problematic to southeastern forests because none of the native species have evolved defenses against it. The disease is robbing the palamedes swallowtails of a food source, and indirectly altering the dependencies of many other forest organisms. It is yet to be seen whether the dead redbays will be replaced, and if so, whether by more redbays, or some other organism.

6. Your partner read another article on the laurel wilt epidemic. Turn to her/him and discuss both of your answers to question 1. Now write a combined response to question 1.

Refer to question 1.

7. If your answers were different, discuss the reasons. To help, compare each other's answers to the questions on stakeholders, their values, how laurel wilt affects the stakeholders, and how it affects the forest (questions 2–5). How does a different emphasis on an issue affect the story that is told?

The first article discusses the laurel wilt epidemic in terms of its effects on southeastern ecosystems, and quotes an avocado grower whose livelihood may be threatened by the disease. The second article also discusses the laurel wilt epidemic, but this time in the context of an endemic organism—the palamedes swallowtail. It quotes a butterfly enthusiast/teacher who is concerned about the loss of the butterfly in the context of its ecological value rather than its economic one.

Both points of view address relevant consequences of laurel wilt, but neither article provides the whole picture. In reading both articles, it emerges that research for a solution to laurel wilt is hampered by lack of funding. Resources might only be allocated to finding a solution if an economic species, such as the avocado, is threatened.

8. In your opinion, is there any significance to reading more than one perspective on an issue? For example, in the case of the laurel wilt epidemic, are the perspectives presented in your article more, less, or of equal value to the ones presented in your partner's article? Why do you think so?

Read students' responses with an eye for how they justify *their opinion, since there are many right answers to this question. Encourage students to discuss why one perspective may offer incomplete information.*

Assessment

Using the students' answers to the *Student Page* section, check that they can do the following:

- Identify the key issues and stakeholders in a news article. *Seen in students' answers to all questions in the worksheet, but particularly questions 1, 2, and 6.*

Extension Ideas

- Ask each student to select a news article that covers an issue of natural resource use, misuse, destruction, or preservation. It can be a local, national, or international issue. Ask them to apply the concepts learned in this activity to read and identify the issue and whose voices are represented by the article and whose voices are not. Ask them to prepare and turn in a one-page summary and critique of the article. Alternately, ask them prepare a short, presentation of their findings that they can share in class.

- Find three resources for students to read: an op-ed, a news article, and a scientific report that all address the same natural resource issue. Ask students to compare how data sources, interviewees, and the author's own language frame each of these three texts, and discuss the implications of objective versus subjective news writing.

Resources and References

- The University of Florida's SFRC Extension website for educators includes several complementary resources.
  - The *Pocket ID Guide* provides technical information about laurel wilt and its beetle vector. Look for flash cards on Laurel Wilt and Ambrosia Beetles.
  - Images and illustrations used in this activity are found in a visual presentation online.

  Visit http://sfrc.ufl.edu/extension/sfrc_extension/index.html

- The latest information on laurel wilt identification, spread, and control options is found at the USDA Forest Service website for Forest Health Protection, Southern Region. The laurel wilt webpage includes information on the pathogen's distribution, the disease cycle, identification of vectors and hosts, disease history, and management.
  Visit
  http://www.fs.fed.us/r8/foresthealth/laurelwilt/index.shtml

Unhealthy Forests and the News

Instructions

You will be working with a partner. There are two articles presented in this worksheet: a) *A Deadly Menace Moves Closer to Home* (page 1) and b) *A New Wave of Extinction Hits the Southeast* (page 3). Both articles discuss the same forest health issue, but they are written from different perspectives. The articles are written in the style of news reports. They describe a current forest health issue in the Southeast, and while the characters in the articles are fictional, the issues they describe are real.

Each of you will read one of the articles and later compare notes on what the other person has read. Carefully read the article you selected and answer the questions that follow. The last three questions on this sheet are to be completed when you discuss and compare notes with your partner. You may consult with your partner to clarify doubts, but you must write your own answers independently on your worksheet. Turn in the last two pages to your teacher when you are finished.

A Deadly Menace Moves Closer to Home

Photo: Ronald F. Billings, Texas Forest Service, Bugwood.org

A redbay swansong: The central tree has put out a last flush of leaves directly from its trunk. Its canopy has succumbed to laurel wilt. The neighboring redbays are also dead.

There are rust-colored ghosts in the Southeast. They are redbay trees—long dead from a fungal disease carried by a beetle smaller than the tip of a pencil.

North and South Carolina, Georgia, Florida, and Mississippi have all been invaded, and the disease shows no signs of abating as it moves farther inland as well as north and south along the east coast of the United States. To a casual observer, the forests seem fine, but a closer look reveals the destruction within. Nearly every redbay tree in the region is a corpse, with wilted brown leaves still attached to dead branches. It has been a selective and so far unstoppable epidemic.

"If you look at the history and the pattern of infection," said Burt Smythe, of the Georgia Forestry Commission in Savannah, Georgia, "it's very much like watching a slow earthquake. You have the disease center here, in Port Wentworth, Georgia, in 2002. Every year since then, more redbays have caught the disease, and it has been spreading outward, almost like a wave." In 2005, the disease had just entered northern Florida. By 2011, it was in Miami-Dade County in the far south.

Forest health specialists speculate that the disease, known as laurel wilt, was most likely introduced to the United States accidentally on wooden shipping crates from East Asia. Hidden in the wood were tiny black ambrosia beetles carrying even tinier shipment of their own, some fungal spores in a special storage area under their jaws.
A native of Asia, the ambrosia beetle is a beneficial insect in its home environment, inoculating dying and dead trees

Name:

with a fungus that speeds up the trees' decay, in the process recycling nutrients back into the environment. But here in the United States, it's a different story. The beetle, with no natural predators, has moved unchecked. The trees it bores into are healthy and alive, not sickly or dead. Redbays and related trees such as sassafras and avocado of the family Lauraceae have not evolved defenses against either the beetle or the deadly fungus it carries.

Xyleborus glabratus, the scientific name of the redbay ambrosia beetle, roughly translates from the Latin to mean "smooth-bodied xylem borer." The beetle, as its name suggests, burrows into the water-carrying xylem tubes of redbay trees. There it transfers spores of *Raffaelea lauricola*, the laurel wilt fungus, from its jaws into the xylem. The fungus grows through the tree's tissues and becomes food, or "ambrosia," for the beetle. As it grows the fungus leaves a dark stain on the inner woody tissue and essentially chokes the tree to death by cutting off its water supply. The leaves wilt and turn brown, and the tree dies soon after.

Photo: James Johnson, Georgia Forestry Commission, Bugwood.org

Beetle burrowing activity in a redbay cross-section, showing white growth of laurel wilt fungus.

Within a few years, redbay mortality has gone from 10 percent to more than 90 percent in all affected areas, from forest preserves to landowners' backyards. "I've been getting calls every week from people wanting to know how to save their trees," said James Greggson, a forestry consultant. "Many landowners have redbays in their yards. There have been hikers in the woods who've noticed the dead trees amid healthy oaks and pines and sweetgum. Everyone who's seen how fast this has happened is concerned."

In Miami-Dade County, Florida, there's another worry—this is avocado country. The avocado tree is a close relative of redbay, and there is a lot at stake if laurel wilt reaches the orchards.

About 90 percent of Florida's crop comes from Miami-Dade, and Florida's avocado industry is worth more than $50 million annually. Paul O'Conner, a local farmer, said, "I'm very worried about it. There are thousands of people depending on this industry. We make our living off avocados. We can't afford to lose our crop and our livelihood."

While it is yet to be seen whether the trees in orchards will show signs of the disease, researchers have shown that avocado can become infected by laurel wilt in the lab.

"In a way, it's almost a good thing that laurel wilt is threatening avocado country," said Mr. Smythe. "At least now more people are taking notice. Frankly, research on how to stop the disease is limited by funding. Our hands are tied until enough people realize what's at stake for them." Smythe believes that the more people who are aware and concerned about the disease, the more opportunities there are for money being allocated to solve the problem.

Forest pathologists in Georgia and Florida are working to find solutions to the laurel wilt problem. There has been limited success with chemical scent traps for the beetles, fungicide applications on redbays, and immediate containment and destruction of beetle-infested trees and wood. For some healthy, mature trees, a fungicidal application can help protect against infection. However, this is a costly procedure, and only effective if repeated every year or two.

Pathologists are also hoping to find redbays with natural resistance to laurel wilt. But it remains to be seen whether genetic resistance in these trees can be successfully identified, and if so, whether the improved genotypes of redbays can be reintroduced to the forests of the Southeast.

Until then, stopping the scourge of laurel wilt must continue to happen at the frontline—preventing the beetles from spreading any farther than the forests they've already claimed. "I wish that were easy to do," said Smythe. "Because how are you going to control an insect that's smaller than a grain of rice? Put up a fence?"

A New Wave of Extinction Hits the Southeast

Photo: Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org

The palamedes swallowtail: On its way out.

A moment of silence for the palamedes swallowtail butterfly, for we may be the last generation to see it alive.

Its death may be a drop in the bucket compared to the worldwide epidemic of species extinction, but this time it is happening in our own backyards. Anyone in the Southeast who has a redbay tree on their property will see why, because the redbays are dying as well.

From South Carolina through Georgia and halfway into Florida, more than 90 percent of the coastal redbay trees have been wiped out by a fungus-carrying beetle accidentally introduced to the United States in 2002. The destruction has been so swift and thorough that within nine years the disease complex known as laurel wilt has brought redbay trees to the brink of extinction in the Southeast.

The palamedes swallowtail, a showy, large butterfly that lays its eggs primarily on redbay leaves, has essentially been starved to death by the loss of its only food source. "I saw just one last year," said Sandra Leeds, butterfly enthusiast and high school biology teacher in Gainesville, Florida. "I don't know what she laid her eggs on, but there was surely nothing for her caterpillars to feed on when they hatched."

The beetle responsible, meanwhile, continues to spread, claiming more redbays every year in an outbreak that forestry experts are describing as "unstoppable" and "catastrophic."

"It takes just one beetle to kill a tree," said Iona Brennan, a Forest Service entomologist. "That's why it's such a problem." The female redbay ambrosia beetle, *Xyeleborous glabratus*, burrows under the bark of a redbay and deposits spores of the *Raffaelea lauricola* fungus into the tree's xylem. The fungus feeds on the tree, killing it, and the beetle feeds on the fungus. It also lays its eggs under the safety of the bark.

Each beetle that inoculates a tree may potentially lay dozens of eggs. New beetles emerging from the dead tree all carry the laurel wilt fungus on them. "You can imagine what happens next," said Brennan. "Dozens more dead redbays, each a nursery for the next generation. Pretty soon, we were dealing with an outbreak of exponential proportions."

The beetle can fly several kilometers in search of its preferred host tree. It may also be aided by the wind. "Primarily though, this is a people problem," said Sandy Gleeson of the Alabama Division of Forestry. "It likely started with contaminated wood shipment, and it continues to spread by human-aided transport." Firewood and timber moved out of forests may carry the beetle, and it may even hitchhike on off-road vehicles. There have recently been isolated reports of laurel wilt in Mississippi and North Carolina, and it seems likely that laurel wilt will make more geographic advances in the years that follow.

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"We can't stop this pest, but we're hoping we can contain its spread," said Gleeson. He is calling on people to learn to identify redbay, sassafrass, and related laurel family trees, and signs of the beetle or laurel wilt, so they may report cases to their county officer or local extension office. This way, the infested trees may be destroyed to prevent more beetles from spreading.

"The ambrosia beetles make toothpick-sized frass tubes as they burrow into the trees, and you can see these tubes on the bark of infected trees," said Gleeson. "We don't want laurel wilt in Alabama, but we fear that it'll invade anyway. The most we can ask for right now is for people to be vigilant. And not to transfer potentially contaminated wood."

Photo: James Johnson, Georgia Forestry Commission, Bugwood.org

Frass tubes: These toothpick-sized tubes of sawdust are extruded from within redbay trees as the beetles burrow.

"Don't transport contaminated wood," seems like a useful maxim, but in practice it is hard to follow. *Xyleborous glabratus* is not the only ambrosia beetle in the United States, but one of several related species. Maura Wilson, a University of Florida forest pathologist, said, "There are at least 50 to 100 other species of exotic ambrosia beetles in North America, and it's thought that most of them were introduced in the exact same way, on wooden shipping crates from elsewhere."

Once here, the beetles escape and often become aggressive invasives. "There's really nothing here that's adapted to resist them," said Wilson. "Each successful invasive does more than just knock out its new food source—it alters an ecosystem niche that other organisms can exploit and fill up. So if the redbays are gone, all the organisms dependent on those trees need to find new sources of food and shelter, or perish. New trees, possibly opportunistic invasive ones, will grow in the spaces once occupied by live redbays. There's a cascading effect that interferes with the lives of many other native organisms."

Natives such as the palamedes swallowtail are just the first wave of organisms that have been affected by laurel wilt. It is yet to be seen how the butterfly's extinction will affect birds that ate this species, for example, or flowers that were pollinated by it.

If there is a lesson to be learned from the laurel wilt epidemic, it is a not a new one—this has happened countless times before. Ecosystems continue to be bombarded by exotic invasives as people move from state to state and country to country, opening up channels of transport for more than just goods and services. If there is anything to be done to stop invasives, it is to prevent them from entering rather than trying to control them after they have established themselves.

In the case of laurel wilt the situation looks bleak. Ms. Leeds said, "As a teacher, I want to share my fascination for the natural world with my students. Part of that sharing is also sharing solutions, but in the case of the butterfly, there's nothing I can say but, 'It's too late.'"

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Questions

1. Summarize the main point of the news article you read. In other words, why is it important and what makes it news?

2. List at least three stakeholders mentioned in the article, including those who are interviewed and those who will be affected by the issue. Stakeholders are those people who have some relationship to the issue at hand—they will either benefit or have something to lose because of the issue.

3. For the stakeholders you identified in question 2, describe their interests as explained the article. Interests are the things people care about, value, or think are important.

4. How do you think the laurel wilt epidemic will affect the stakeholders you identified?

Name:

5. How do you think the laurel wilt epidemic will affect the forests of the Southeast?

6. Your partner read another article on the laurel wilt epidemic. Turn to her/him and discuss both of your answers to Question 1. Now write a combined response to question 1.

7. If your answers were different, discuss the reasons. To help, compare each other's answers to the questions on stakeholders, their values, how laurel wilt affects the stakeholders, and how it affects the forest (questions 2–5). How does a different emphasis on an issue affect the story that is told?

8. In your opinion, is there any significance to reading more than one perspective on an issue? For example, in the case of the laurel wilt epidemic, are the perspectives presented in your article more, less, or of equal value to the ones presented in your partner's article? Why do you think so?

Glossary

Abiotic
A feature of the environment that is not alive, or biotic. Wind, soil, water, and atmospheric gases are abiotic environmental factors.

Abnormalities
Unnatural structural features on an organism. For example, mutations can cause trees to develop swellings (galls) on leaves or twigs that are not normally found there. Abnormalities do not necessarily affect the health of the tree.

Autotrophs
An organism that makes its own food is an autotroph. Plants, algae and many bacteria are autotrophs, forming the base of the food web that all other organisms rely upon for survival.

Behavior-over-time graph
A graph that plots the variable change of a phenomenon on the *y*-axis against a period of time on the *x*-axis. It reveals how a phenomenon might be expected to change over a chronological period.

Boundaries
The limits drawn around a system; the boundaries may be physical or abstract.

Coevolved
Coevolved species are unrelated organisms that influence each other's survival, resulting in complementary and often unique adaptations to each other. For example, the structural adaptations of the ghost orchid make it inaccessible to any other species but the sphinx moth, which is the only insect with feeding apparatus long enough to reach into the flower's depths.

Commensal
A relationship between two different species where one organism benefits from support provided by the other, it's host, without being detrimental to the host organism itself. Lichen growing upon a tree trunk is an example of commensalism. *See* Symbiotic.

Component
One of the "parts" of a system, components may be physical objects such as trees, or abstract entities such as the cost of an ecosystem service.

Composition
The makeup or characteristics of a forest, referring to the types of trees species and age classes of trees found there, as well as other environmental characteristics such as the type of soil, the microclimate in the region, biotic elements, and so on.

Concept map
A diagram representing how we think about a system of interacting components. The diagram consists of items and the descriptive linkages between them.

Disease
An abnormality that has disruptive effects on an organism, compromising its ability to function normally, and sometimes affecting its ability to survive. Diseases may be caused by nutritional deficiencies, environmental stressors, or biotic organisms (pathogens) such as fungi and bacteria. *See* Impact triangle.

Disturbances
Factors that disrupt or halt normal growth in a forest. Natural disturbances include lightning or hurricane damage. Anthropogenic or man-made disturbances include deforestation or fire suppression.

Dynamics
Systems are never in stasis. Parts continually influence each other and the results of these interactions cause the system to function. In a forest, processes including weather changes, species reproduction, and nutrient turn over constitute the dynamics of the ecosystem.

Exotic
An exotic species occurs outside of its native geographic range, either by accidental or deliberate introduction to a new ecosystem.

Forest health
The state of a forest, dependent on many factors including its composition, functional properties and uses, and the reasons for which it is valued. Typically, it has an appropriate degree of diversity and is able to withstand disturbances and continue to flourish.

Framing
A way of representing a story, through specific choices of language, viewpoints, values, and biases. Frames are embedded in content and may color the way a reader understands a story. Frames are also ways of viewing the world, so a reader might take only some pieces of information from a story while neglecting others, thereby creating a frame with respect to him or herself.

Host
An organism upon which another species can live. A host may support species that cause no harm to the organism, such as lichen on tree bark, or they may support parasites and pathogens such as mistletoes and root fungi, which grow into a tree to steal its resources.

Glossary

Hyphae (singular: hypha)
Microscopic hairs that form the bulk of the fungus body, and exist as a crisscrossing network underground or within the tissues of other organisms. *See* Mycelia.

Impact triangle
A concept used to describe how the right kind of host and the right kind of causal agent (pest or pathogen) both need to be present in an environment under conditions that favor the causal agent's ability to impact the host and the host's susceptibility to impact. If these three conditions are not met, no impact (damage or disease) occurs. Causal agents may include insect pests and tree pathogens such as fungi, insect-transmitted microbes, viruses, bacteria, and nematodes. The impact triangle concept is more commonly encountered as the "disease triangle," where the causal agent is specifically a disease pathogen rather than a pest. *See* Disease.

Infectious
An infectious disease is one that can be spread from one organism to another by biotic vectors such as insects, or abiotic agents such as wind and rain.

Inputs
The components, physical or abstract, that enter a system. Increasing or decreasing an input variably affects the resulting outputs or outcomes produced by the system. *See* Outputs.

Interests
Those particulars that people consider important or of value. Interests differ depending on personal perspective or culture.

Invasive
A species that aggressively thrives and reproduces in an environment where it should not naturally occur. Native invasives are those organisms that are present in the ecosystem, but in reduced number until a disturbance allows for their unchecked growth. Exotic invasives are those introduced organisms that become successful colonizers. In both cases the invasive out-competes naturally occurring organisms in the area.

Light gap
The space created in a forest after a tree falls; the opening in the canopy allows light to stream down to the forest floor where there was previously shade.

Mutualistic
A relationship between two organisms that benefits both species. *See* Symbiotic.

Mycelia (singular: mycelium)
The thickened mass of hyphal hairs, mycelia form the physical, vegetative parts of the fungus and can take many forms, ranging from sheets to ropes to globular clusters. *See* Hyphae.

Mycorrhizae
These highly specialized fungi form symbiotic associations with plant roots. The mycorrhizae increase the absorptive surface area of plant roots by enveloping them in a sheath that helps absorb water and minerals such as phosphorus from the soil. In exchange for supplying limiting resources to their plant hosts, the fungi receive sugar and other nutrient essentials from the plants.

Native
An organism that is naturally found in the ecosystem is a native species. It has evolved to fit an ecosystem niche specific to that region.

Negative feedback loop
A stabilizing interaction in a system. It occurs when two components have opposing effects upon in each other—an increase in one causes a decrease in the other, and vice versa. *See* Positive feedback loop.

Niche
An ecological niche is the space occupied by a species in response to its environment. The food it eats, the territory it lives on, the influences it has on other organisms and on the landscape all are characteristics of that organism's niche.

Outputs
The resultant outcomes, either physical or abstract, that are produced by a functioning system. *See* Inputs.

Parasite
A parasitic organism lives off a host species, to the detriment of the host. *See* Symbiotic.

Parthenogenetic
A species that has the ability to reproduce asexually, that is, the females can produce offspring without the genetic input of males.

Pathogen
An organism such as a bacterium, fungus, or virus, that causes disease.

Pest
A nuisance organism. The term is typically used to describe destructive plant-feeding, stem or root-boring insects, usually in the context of the damage they cause to economically valuable trees.

Glossary

Pheromones
Aromatic signaling compounds released by organisms to communicate their location to others.

Phloem
One of the living tissue layers found within plants, this circulatory system transports sugars throughout the plant through a series of tubes that run from leaf edge to root tip.

Positive feedback loop
A destabilizing interaction in a system characterized by two components having similar quantitative effects on each other, so that an increase in one leads to an increase in the other, leading to a further increase in the first, and so on. Likewise, decreasing the value of one component starts a spiral of depreciation in both components. *See* Negative feedback loop.

Relationship
In the context of a system, the interaction that occurs between two or more component parts of that system. Relationships affect system properties, determining how the system functions and what it does.

Resin canals
A defensive feature of some trees, particularly pines. This tissue system produces and stores resin, held under pressure within its cells. The resin canals of a healthy pine tree can flush out beetles that attempt to drill into the bark.

Saprophyte
An organism that feeds on dead tissues of other organisms. Many fungi, bacteria, and insects are saprophytes.

Soil compaction
When pressure on surface soil packs it densely, it decreases the soil's ability to hold air and water and restricts tree root growth. Compaction occurs naturally, such as under the weight of glaciers, and anthropogenically, such as with foot or automobile traffic.

Spores
Microscopic reproductive units that function much like seeds, spores are a primary means of fungal reproduction and dissemination.

Stakeholder
A person who has some involvement or connection to a particular issue or situation, such that the outcome would influence his or her interests.

Stressor
A factor that affects the healthy functioning of organisms; for example, tree stressors affect a tree's ability to grow and reproduce at peak capacity. Severe stressors can compromise a tree's ability to survive or resist attack by certain insects and pathogens.

Succession
The process by which populations replace each other. Plant succession in an ecosystem typically involves turnover from grassland and shrubs to trees, or from fast growing, short-lived trees to slow growing, long-lived trees, as long as there is no disturbance that disrupts the chain of events.

Symbiotic
A symbiotic relationship is a close interaction between two different species where either one or both species profits from the association.

System
A set of components that interact with each other in various ways resulting in changes to the collective whole. The whole system displays emergent properties and behaviors as a result of the relationships among its parts.

Urban forest
A type of forest found within and/or surrounding areas where people work, live, and recreate. Urban forests are either those trees that are retained after building construction in cities, or planted after, to re-vegetate the land. They can be in cities, villages, suburban areas, parks or cemeteries.

Values
Those criteria by which people judge things as worthy.

Xylem
Another of the plant tissue layers, this system of tubes transports water and minerals through the plant. In addition, xylem tubes being made of dead, woody cells, provide structural support to the plant.