Activity 5
How to Eat a Forest – Southern Pine Beetle-Style

Sunshine State Standards

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).

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’ pheromonal 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...
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

- 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.

### 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.

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.

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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 tree 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.
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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](http://sfrc.ufl.edu/extension/ee/foresthealth.html)
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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 through 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.

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