beetles

Science and Teaching for Field Instructors

Student Activity Guide

Bark Beetle Exploration

In forested areas, students are often intrigued by mysterious sticks covered in carved tunnels, which they often think were made by human artists or termites. After students complete this activity, they'll have the skills to identify bark beetle galleries, to make explanations about patterns, and to interpret what these tracks tell us about the life history of the organisms that made them.

In an optional discussion, students can consider outbreak levels of bark beetles that cause the death of many trees, make arguments based on evidence about possible effects on ecosystems, then brainstorm and critique possible management strategies. An optional extension for investigating student questions about bark beetles is also included.

Students will...

- **Collect bark beetle galleries from the surrounding area and study gallery features to try to make explanations that correspond to how beetles live.**
- **Use a simple field guide to identify features of bark beetle galleries.**
- ***(Optional Discussion)* Discuss bark beetle outbreaks, make explanations based on evidence about possible effects on ecosystems, compare merits of possible management strategies.**
- ***(Optional Extension)* Investigate a question they have about bark beetles through a quick study**

Grade Level:
Grades 4-8. Adaptable for younger or older students.

Timing:
50 minutes to 1.5 hours, depending on optional sections

Related Activities:
The Case of the Disappearing Log
Decomposition Mission
Tracking

Materials:
For instructor:
Small, portable examples of bark beetle galleries
Printed copies of page 16 and page 17
For students:
One copy of page 2 per pair (*Field Guide to Bark Beetle Gallery Features*)

Setting:
Scout ahead of time and choose a forested area where you know there are bark beetles. Coniferous forests usually have many galleries, as most bark beetles colonize conifers.

Tips:
To ensure a successful experience, review the teaching tips found on page 2 and throughout this guide.

NEXT GENERATION SCIENCE STANDARDS

For additional information about NGSS, see page 13 of this guide.

FEATURED PRACTICE

Constructing Explanations

FEATURED CROSSCUTTING CONCEPT

Cause and Effect

DISCIPLINARY CORE IDEAS

Interdependent Relationships in Ecosystems
Ecosystem Dynamics, Functioning, and Resilience

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

Exploration Activity

Bark Beetle Exploration

ACTIVITY OVERVIEW

Bark Beetle Exploration	Learning Cycle Stages	Estimated Time
Introducing the Activity	Invitation	7 minutes
Collecting and Studying Beetle Galleries	Exploration	15 minutes
Discussing Explanations: What Are These Beetles Doing?	Concept Invention	10 minutes
Becoming Bark Beetle Trackers	Application	10 minutes
(Optional) Discussing Effects of Bark Beetles on Ecosystems	Concept Invention, Application	(20+ minutes)
Wrapping Up	Reflection	5 minutes
(Optional) — Investigating Student Questions about Bark Beetles	Application	(15 minutes)
TOTAL		~ 50+ minutes

TEACHING TIPS

Field Card. On page 19 of this guide, you'll find a condensed, pocket-sized version of the lesson that you can carry with you in the field.

Read the Instructor Support Section. Beginning on page 10 you'll find more information about pedagogy, student misconceptions, science background, and standards.

Scout beforehand to find sticks with bark beetle evidence. It's crucial to take students to an area where you know there'll be sticks with bark beetle galleries for them to find!! Beetle galleries are present in forested areas where there are conifers. On sites where students are encouraged to pick up and use walking sticks, many sticks are removed, so consider finding an area off the trail that has not been significantly impacted or altered. Carry a few small examples of bark beetle galleries with you for students to check out before they explore to find their own. If it's not possible to carry sticks, pick up a few samples immediately before the activity.

Safety with sticks. Before students are allowed to pick up sticks, make sure they understand any necessary safety precautions, that they are mindful while they are collecting and moving sticks, and that they will return them at the end of the activity.

All materials created by BEETLES™ at The Lawrence Hall of Science.
Find the latest activities and information at http://beetlesproject.org.

Introducing the Activity—or Meet the Beetles!

1. **Lead a *Walk & Talk* about life in a different body.** On the way to the exploration site, tell students to *Walk & Talk* about these questions:
   - *Imagine you're an animal that's much, much bigger than a human. What would that be like? How might your life be different?*
   - *Now imagine you're an animal much, much smaller than a human—the size of your pinkie fingernail. What might that be like?*
   - *When I say "go," touch (or point to) the bark of a tree. What might it be like to be an animal the size of your pinkie fingernail that lives under tree bark?*
   - *What kinds of signs or pieces of evidence might an animal living under tree bark leave behind?*

2. **Students pass around & feel bark beetle galleries, with their eyes closed.** Gather students in a circle. Tell them you have some objects that were once homes to animals that lived under tree bark. Ask them to close their eyes, or use blindfolds, then hold their hands out to receive one of these objects and explore it with their sense of touch. Ask a chaperone to help you keep the sticks moving around the circle.

3. **Explain that the markings were made by bark beetles, show photo.** When all students have had a chance to feel a stick with bark beetle galleries on it, tell them to open their eyes and look at the objects. Explain that these markings were made by animals called bark beetles that live underneath the bark of trees and dig tunnels with their jaws. The markings they leave behind are called "bark beetle galleries." Show a photo of a bark beetle (one image is included on page 17 of the write-up).

Collecting and Studying Bark Beetle Galleries.

1. **Students prepare to explore & collect sticks with bark beetle markings.** Tell students they'll explore in pairs, collecting as many sticks with bark beetle galleries as possible, then bring them back to the circle. Make sure they know they should only pick up and move sticks that are on the ground.

2. **Set up safety & exploration protocols for the group.** Keeping in mind the group's energy level (and your comfort with managing their behavior), set up boundaries and rules for handling sticks. You may want to suggest that students work together to move especially large sticks, or that they just leave them and remember where they are. If students are allowed to go off-trail, make sure they are mindful of their steps and surroundings.

3. **Circulate, troubleshoot, be a co-explorer, & pay attention to safety as students are collecting galleries.**

4. **Group gathers around sample galleries; pairs make observations & look for patterns.** When students have collected several bark beetle galleries, gather the group in a circle around the samples. Tell students each pair will choose a few galleries to study. Their challenge is to find out as much as they can about bark beetle galleries by making observations, using "I notice" statements. They will also ask questions about what they

TEACHING NOTES

See the BEETLES activity, *Walk & Talk, for logistics of this routine.*

Why have students close their eyes? In addition to the suspense and mystery created by a "blind" exploration, it also allows students to experience what sticks with bark beetle galleries actually feel like. If students don't have the chance to touch a bark beetle gallery first, they often mistake sticks that have other lines or markings on them as having bark beetle galleries. This practice also invites students to use multiple senses later, when they explore independently.

Pulling off bark. Many sticks found on the ground with the bark still attached have bark beetle galleries underneath. Encourage students to gently peel back bark on these sorts of sticks to look for the bark beetle galleries.

If you think students might need help identifying which markings are galleries—before sending them off to explore, you might show them a sample stick with some lines on it, but one that does not have actual bark beetle galleries on it, so they can be better able to notice the difference.

TEACHING NOTES

observe, make comparisons between samples, and look for any patterns and common characteristics. If they found a really large example while collecting, they can now go back to study it. Remind students that these markings were made by living beetles.

5. **Circulate, asking questions about their observations.** Encourage students to make comparisons between galleries, and to observe them from different perspectives.

Discussing Explanations: "What are these beetles doing?"

Build on student ideas. When students are sharing discoveries, help them build on their ideas. Some students may figure out different bark beetle features through their own observations and explanations. Help them build on each other's observations by asking them to expand on what the previous speaker has said or to share alternative ideas.

1. **Pairs share discoveries with other pairs, then individuals share observations & explanations with group.** Call the group back together and give pairs of students a minute to discuss and compare their discoveries and observations with another pair. Then circle up the group and call on individuals to share their observations and any possible explanations for what they saw.

2. **Help students connect the explanations they make from observations to making explanations from evidence.** Remind them that the observations they shared are the evidence that they were basing their explanations about the galleries on. Point out that scientists also use observations as evidence to support their explanations. Scientists try to come up with as many possible explanations as they can, so they can compare them with all the evidence.

Introducing more information. At this point, students are often hungry to know more about the life history of bark beetles. Consider sharing information from the *Instructor Support Section* if students are excited to find out more details about the insects that make the galleries. Try not to provide this information without also asking students to make additional observations that might corroborate these new details, or to think about whether or not the new information applies to something they've already observed.

3. **Student pairs discuss things all beetles do.** Tell students to *Turn & Talk* with a partner. Ask:
   - *What are some things that all beetles do?*

4. **As a group, generate a list of beetle behaviors.** Ask students to share their thoughts and ideas as you write them on a whiteboard. Students will usually come up with actions like eating, sleeping, pooping, dying, and moving around—growing and mating are less intuitive. After students come up with a list, add anything they missed.

5. **Point out how thinking about cause-and-effect relationships can lead to better explanations.** Say that, by thinking about what the beetles might have been doing when they made these markings, students were making a list of possible causes. They can now use that information to try to make some explanations for features they observed on the sticks. Explain:
   - *Most bark beetles engage in these behaviors underneath tree bark, so these can be causes for the markings we've seen.*
   - *When we connect a specific cause with an effect, we're making a scientific explanation for the beetle galleries.*

Pacing. If your group needs it, move to a different location, or take a high-energy break before continuing to investigate bark beetles. Just make sure you're moving them to an area that has more bark beetle galleries.

6. **Pairs discuss observations & effects & connect them to beetle behaviors that might have caused them.** Ask students to chat for a minute with their partners about some of the patterns or "effects" they observed in bark beetle galleries, and what beetle behaviors might have caused them. Provide an example:

- *If you think bark beetles pooping in their tunnels might be making the sawdust-like stuff you saw, then bark beetles pooping would be the cause, and the sawdust in the tunnels would be the effect.*

7. **Describe how scientists use cause & effect to explain things.** Say that a big part of scientists' work is making observations of the natural world and trying to come up with the best possible explanations. To do that, they sometimes try to come up with possible causes for what might have made the effects they observe–just as students are doing with the bark beetle galleries.

Becoming Bark Beetle Trackers

1. **Introduce the *Field Guide to Bark Beetle Gallery Features* on (page 2) that describes causes of some effects they've seen.** Show students the guide, and tell them it has pictures of types of markings bark beetles make while doing different things, and it describes the causes of some of the effects we're seeing.

2. **Explain:**
   - *You're going to be bark beetle trackers and make explanations for what bark beetles were doing in different places.*

3. **Tell students that being a good tracker means being a careful observer, who uses evidence left by animals to figure out what the animals were doing.** They'll get to use the field guide and their observation skills to make explanations for what the beetles might have been doing in different places on the sticks.

4. **Encourage students to remember the questions they come up with, & to make comparisons between samples.** Challenge each pair to remember any questions they come up with about the samples or about bark beetles in general, based on what they observed or noticed. Encourage them to investigate as many different samples as possible and make comparisons between them.

5. **Help, encourage, & be a co-investigator.** Move between different groups of students and help them use the field guide. Listen to their questions and encourage them to make further observations to learn more.

(Optional Discussion) Discussing Effects of Bark Beetles on Ecosystems

1. **Gather students & begin a discussion about bark beetle effects on forest ecosystems & population outbreaks.** Use the questions and information below to lead a discussion with students. Ask a question, hear responses, ask follow-up questions for clarification, evidence, and agreement or disagreement. After a few responses, move on to the next question. The notes below are NOT a script. Respond in the moment to their thoughts and ideas. Responses are shared in the order listed below, to indicate that they're meant to build student understanding incrementally. Tell them to *Turn & Talk* after a few questions to make sure they all get to discuss their ideas.

TEACHING NOTES

Journaling opportunity. Consider asking students to make diagrams of beetle galleries in their journals, and to write their observations and questions. They can also make "rubbings" of beetle galleries by placing their paper on top of a log and rubbing the side of a graphite pencil or crayon on the gallery.

On leading discussions. See *BEETLES Discussion Resources* for more information on how to support student learning during discussions.

Background information. For more information on bark beetle outbreaks and effects on forests, read the *Instructor Support* Section.

TEACHING NOTES

Goals of the discussion. During this discussion, students work through science concepts and apply them to an environmental issue. The goal of the first part of this discussion is for students to apply the knowledge gained through observing beetle galleries by considering how bark beetles might affect ecosystems. The goal of the second part is to consider the issue of beetle outbreaks and think about what management strategies could lessen their effects. The overall goal for students is not to agree and come to "the right answer"– it's to struggle with ideas and engage in respectful discourse about a complex issue.

Oxygen in the air. Many students think that if all the trees in a forest die due to bark beetle outbreaks, there will be no oxygen left to breathe. Although those trees do produce oxygen, about 50% of the oxygen in our atmosphere actually comes from single-celled photosynthesizing organisms (phytoplankton) in the ocean, and much of the rest of it comes from densely-packed tropical rain forests.

Introducing content. Although there is some content for the instructor to share, the students should be doing most of the talking in the discussion. The reason to offer the information provided here is so it can be used as evidence by students in making their arguments. Introduce content, ask a question, then listen and ask follow-up questions to encourage students to share their ideas about what it all means.

2. **Ask questions about what kind of wood (living or dead) they think bark beetles eat, & how living trees might protect themselves from bark beetles.**

   ▶ *During your explorations, did you find evidence of bark beetles eating wood from dead trees? From living trees? What's your evidence?*

   - Listen to student responses. Then share: scientists have found that, usually, multiple beetles eat wood from sick, weak, dying trees, but sometimes they eat the wood of healthy living trees, too.

   ▶ *How might the presence of bark beetles affect the trees, and how might a tree protect itself from bark beetles? Share why you think what you think, and what evidence supports your idea. If you disagree with someone, do it respectfully and back up your statement with evidence.*

3. **After students share their ideas, tell them beetles use chemical signals to attract other beetles, trees fight back with sap, & mostly weak trees are killed.** Let them know that scientists have observed that when beetles arrive at a tree, they send out chemical signals that attract other beetles to the location. If a tree is healthy, it can usually stop the beetles from killing it by pushing lots of sap into the areas where there are beetles. But if a tree is not healthy, it can't defend itself that well, and—as the beetles make tunnels in the tree—they destroy the tree's system for transporting fluid and nutrients, so the tree dies. Mostly, bark beetles kill trees that were sick or weak, and would likely die anyway.

4. **Turn the conversation toward the effects of bark beetles on the forest as a whole.** Ask:

   ▶ *How do trees benefit ecosystems?*

   - Listen to their ideas. If students say, "if trees die, we'll run out of oxygen," let them know that even losing a whole forest won't cause organisms to die from lack of oxygen (see sidebar). Then encourage them to brainstorm other ways trees may benefit ecosystems and other organisms.

   ▶ *How do you think bark beetles might affect a forest as a whole? What do you think might be some harmful or beneficial effects bark beetles have on forests? Think about all parts of the forest when forming your answer, not just the trees. Say why.*

   - Listen to their ideas. Mention any of the following that students have not brought up: Bark beetles are food for many other insects and for many birds. They often start the decomposition process of trees—while the tree may die, that means it also becomes a habitat for lots of other organisms such as fungi, invertebrates, and some vertebrates.

5. **Share information about bark beetle outbreaks, for students to use as evidence in the next part of the discussion.** Most species of bark beetles only kill trees that were already sick or weak, and would die anyway. A couple types of bark beetles, though, have such large populations that they're killing entire forests of healthy trees. (Show photo on page 16). Scientists have studied this phenomena, and they think a few things could be causing the outbreaks. Some causes might be connected to climate change. Longer, warmer summers and shorter winters mean bark beetles

can have LOTS more babies in a season than they used to, so this creates bigger populations of beetles. Warmer temperatures also mean that there's less water, and that trees are competing for resources–the trees are weaker and might be more likely to be killed by beetles.

6. **Ask students to consider how bark beetle population outbreaks might be affecting forests as a whole.**
   - ▶ *We talked about how bark beetles affect forests when there's just a few sick trees killed. Based on this new information about places where many, many trees are dying from bark beetle outbreaks, how do you think bark beetles affect those forests? Remember, the forest includes more than just trees. What parts of the forest might be harmed by bark beetle outbreaks? Would any parts of the forest benefit from the presence of bark beetles?*
   - Listen to their ideas. Students might disagree based on this new information. Encourage them to share why they think what they do, based on their reasoning, the information the instructor shared, their prior knowledge, or their observations.

7. **Encourage multiple students to share their perspectives, ask for evidence, & encourage respectful disagreement.**

8. **Then share that some scientists think ecosystems will work themselves out, but others think there will be worse forest fires.**
   - ▶ *Some groups of scientists think that over many years, bark beetles will cause the forests to decompose and provide food for other organisms. They predict that eventually more trees will grow, so they aren't worried. Others, like the US Forest Service, are worried that lots of dry, dead trees will burn in large forest fires, which could cause damage to forests, wildlife, and people's property.*

9. **Ask students to *Turn & Talk* about whether or not humans should try to stop bark beetle outbreaks.** Remind them to think about the problem from different perspectives, and to back up their statements with reasoning.
   - ▶ *Some think humans should try to stop the outbreaks to keep trees from dying. Do you think we should do this? Why or why not?*

10. **Ask students what strategies we might use to try to stop many trees from dying from bark beetle infestations, & to think about any possible effects of using those strategies.** Encourage them to share not only their solutions, but the other effects an outbreak might have on a forest (and the organisms in it), aside from reducing bark beetle populations. Listen to their ideas. Students may suggest: using insecticide spray, introducing a predator of the beetles, removing infected trees…
    - ▶ *If we were to decide to try to stop bark beetle outbreaks, what different strategies and actions could we use?*
    - ▶ *For each strategy, what would be the positive effects you'd want, and what might be some possible other effects?*

11. **After students share ideas, describe some management strategies that have been tried, & ask students what they think about them.**
    - The forest service has tried cutting down some trees in a forest where they think bark beetles might come later. They do this so the trees

TEACHING NOTES

If climate change questions come up. Bark beetle population explosions are a good example of what can happen as a result of climate change, but this discussion is more centered on thinking about the effects of bark beetles on forest ecosystems, and considerations for pest management in forests. If students bring up the topic of climate change, decide whether or not you want to dig into this complex but important topic. If not, you can acknowledge their comments, and redirect the discussion back to the stated purpose. You can add that climate change is a complex subject that requires more time to properly investigate and discuss.

The Curse of the Cane Toad. Often students suggest that humans should introduce a predator of bark beetles. Consider sharing the story of the Cane Toad, a species introduced in Australia to try to control the crop pest cane beetles. Cane toad populations exploded and have harmed the health of other organisms because they eat other amphibians, carry diseases, and compete for resources. After sharing this story, ask students if they can think of any ways introducing a predator of bark beetles could backfire, and harm the ecosystem.

TEACHING NOTES:

left behind aren't competing for as many resources, like sunlight and water, are stronger, and hopefully have a better chance of surviving a bark beetle attack. Logging companies cut the trees and the wood is used for building. But there's no evidence this works to reduce the number of trees killed by beetles.

- *What do you think about this solution? What are some positive or negative effects this solution might lead to?*
- *What other groups of people might have different ideas about this solution? What do you think their opinions might be?*

12. **Wrap up the discussion by briefly summarizing the main things the group talked about & any ideas they agreed or disagreed on.**

13. **Remind them that scientists think about connections between causes & effects to try to explain the natural world.** Explain there are often many causes that contribute to patterns we see in nature on a large and small scale. Scientists observe, or look at the "effects," and to try to figure out what has caused them in order to try to understand how the world works.
    - *An important job of science is to try to find the best possible explanations about the natural world.*
    - *The more we understand, the better we can predict what might happen in the future, and make decisions about how to protect the environment, while also thinking about effects our actions might have.*
    - *Thinking about cause and effect is something all scientists do—it's something you can think about when you're exploring nature, or looking at any other part of the world.*

14. **Tell students these issues are complex, & the discussion they just had might be similar to those environmental policy makers or scientists might have.** Let them know that these types of issues are complex and there's rarely a simple answer about what to do.

15. **Call out what students did well during the discussion.** If students did a good job backing up their statements with evidence and reasoning, or disagreeing respectfully, or considering multiple perspectives, point this out to them and let them know they can use those skills in the future.

Wrapping Up

1. **Students reflect in pairs or in journals.** Provide a structured environment for reflection, like *Walk & Talk*, *Turn & Talk*, or journal time, and invite students to reflect with some of these questions:
    - *What was it like to be a bark beetle tracker?*
    - *Where could we look for more bark beetle galleries in the future?*
    - *What advantages or disadvantages does living underneath tree bark provide? What body structures do you think beetles need to survive in their habitat?*
    - *How might beetles affect the trees they're on?*
    - *If you were going to explain bark beetle galleries to a friend or relative, what would you say?*

Multiple options for following up. Once students have finished the bulk of this activity, you can head in one of many directions. Following student questions or having a discussion are just a couple of the options. Students could also look for other invertebrate evidence, or could think about bark beetle adaptations. Many other possible connections exist. Extend the activity in a way that's meaningful given your site, interests, themes, and students.

- *What's something that surprised you today?*
- *What helped you to learn about bark beetles today?*
- *Did any of your ideas or opinions change as we discussed bark beetles?*

(Optional Extension) Investigating Student Questions

1. **Collect student questions.** If your students are eager to go into more depth with bark beetle galleries, bring them together after they've had a chance to identify gallery features and develop some questions. Ask them to share any questions they had about bark beetles or their individual samples.

2. **Find a question to follow.** Once a few students have shared, ask the group to think about which questions could be answered through further observation, given the available tools, time, and resources. Some examples of these types of questions include:
   - Based on the number of egg notches that have tunnels coming out from them, can we figure out about how many eggs are laid on average, and how many beetle babies hatch from them? If we choose to investigate this, what assumptions are we making?
   - Since different styles of bark beetle gallery markings are usually from different species of bark beetles, how many different species can we find evidence for in this area?

3. **Set up investigation norms, discuss bias, & let students investigate the question.** Once the group agrees on a question, give students the chance to gather information. Set up norms based on student suggestions that will help give the question a "fair test," and prevent redundancy or inaccuracy in the study. Tell students to be aware of and guard against bias—a very human tendency to favor information that confirms what we think to be true. Remind them to be careful and honest when they're investigating.

4. **Interpret the results.** Ask students to share what they found and discuss any intriguing findings or ideas.

5. **Reflect on the scientific process.** Ask students to talk about the accuracy of their data, and what they might change about their investigation if they had more time to complete a more accurate study.

TEACHING NOTES:

A more in depth study. A study doesn't need to be a full-blown investigation to be useful. Quick studies like this one can be engaging, and quite informative even though they aren't conclusive. Should you wish to have students engage with their questions a bit more deeply, try BEETLES activity *Exploratory Investigation,* with a focus on bark beetles.

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Instructor Support

Teaching Knowledge

Engaging students in discussion. In order for students to be able to engage in discussion, it's important to set up a culture of discourse in your group, and to give students opportunities to discuss in pairs and small groups before participating in a whole group discussion like the one in the optional section. To establish a culture of discourse, create and nurture an atmosphere of respect and intellectual curiosity by responding equitably to students' ideas as a facilitator and facilitating—not dominating–the discussion. When you respond to students, do so in a neutral, accepting manner, then probe their thinking with follow-up questions. Encourage respectful agreement and disagreement, and establish that, when there is disagreement about ideas, students will not be ridiculed for having the "wrong" answer. Emphasize that sharing ideas as a group is an important part of the learning process.

"Scientific inquiry shouldn't stop just because a reasonable explanation has apparently been found."

-Neil deGrasse Tyson

On teaching about climate change. Climate change is the environmental issue of our generation, and many environmental educators are eager to engage students with the topic. If you live in an area where population explosions of bark beetles are killing off forests, it's an opportunity for students to directly witness evidence of global warming/climate change. It serves as an illustrative example of how even a slight change in temperatures can affect ecosystems around the world in drastic ways. But the main goal of the *Bark Beetle Exploration* activity is not to teach about climate change.

In general, when leading any environmental issue discussion, it's important for an instructor to try to be a neutral facilitator of different student ideas, encouraging them to use evidence and reasoning. The goal should not to be to convince students of a particular perspective, but to take the long view, and coach students on how to engage in evidence-based discussion in an open-minded manner. The idea is to help them be better critical thinkers and listeners in the future. That said, it's definitely appropriate for instructors to insert accurate evidence into the discussion, such as the fact that average global temperatures have been rising over the past 50+ years. If students say that scientists don't agree on the *cause* of the global temperature rise, you might want to use this as an opportunity for teaching about the nature of science as a discipline. You can point out that this sort of disagreement about the possible mechanisms for a phenomena is encouraged in science and seen as a strength of the process. Unfortunately, the reasons behind a scientific disagreement can be grossly misunderstood by the general public (see Instructor Support for the BEETLES student activity: *What Scientists Do*), as is the case with discussions about the cause of climate change.

This issue has been greatly politicized, and many outdoor educators feel the need to tread carefully so they don't offend parents, teachers, and school administrators. Instructors can understandably feel uncomfortable with leading a potentially loaded discussion about climate change, and it also requires a solid understanding of the science behind the causes and mechanisms, as well as the potential solutions and remediations of its effects. However, some classroom teachers are currently addressing this topic extensively with their middle school and high school students. It would

be worthwhile to find out if students have already had some exposure to the topic that you might be able to build upon. Instructors should be sure to discuss this with their program leaders—how your particular program has decided to deal with this important environmental issue.

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Conceptual Knowledge

Bark Beetle Life History

"Bark beetle" is a general term that is used to describe any one of around 6,000 species of beetles found in the U.S. These organisms spend most of their life cycle under the bark of trees, where they ingest wood and leave behind tunnels. Bark beetles also leave behind different kinds of tunnels associated with different behaviors or stages in their life cycle. When breeding, adults make one long tunnel and lay eggs along the side. Sometimes these egg tunnels have one notch or hole per egg; in other species, the eggs are deposited in the center of the tunnel. Larvae hatch from eggs and eat their way through tunnels that radiate out from the center tunnel. In some species, these larval galleries are straight, while others twist and curve. When they first hatch, their tunnels may be so thin as to be hard to even see, but as they grow, their tunnels often gradually become wider. The tunnels they leave behind are evidence of their growing body size. As beetles bore, they create "frass," a sawdust-like dust that is a by-product of boring combined with beetle waste. Some adult beetles clear frass out of tunnels, larvae don't clear frass out of larval galleries (those messy kids!).

Bark beetle species often specialize in one species of tree, or even specifically on the canopy or base of one type of tree. Each species of bark beetle carves a distinct shape for their gallery, so the beetle species can often be identified based on the host plant and the gallery shape alone. This can be a cool fact to share with students if they're really "into it"–particularly if you ask them to make observations to try to figure out how many beetle species are in the area based on evidence. Although each bark beetle species differs in the patterns of galleries they make, there are consistent features associated with certain life stages and behaviors of beetles in general (i.e., eating, waste, and egg tunnels), so they can be recognized almost anywhere.

Bark Beetle Effects on Individual Trees

Typically, a few adult beetles enter a tree through the bark, then send out pheromones (chemical signals) to attract other beetles to the area. When a tree is attacked by even a few bark beetles it will emit chemical-filled sap that kills or immobilizes the insects. Early signs of bark beetle infestations are pitch tubes, cylindrical formations of resin that appear outside tree bark; this means a few individuals are beginning to occupy the tree. Sometimes a healthy tree can emit enough sap to fend off a beetle infestation, but often, as more and more beetles bore holes into the bark, their tunneling causes a disturbance in the trees' fluid and nutrient transport system. If the tree can't transport water and nutrients, it starves and dies. A later sign of bark beetle infestation in conifers is their needles changing from green to orange.

Bark Beetle Effects on Ecosystems

The long-term effects of bark beetle outbreaks on forests are not entirely

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known, and the possible management strategies are not agreed upon. From some studies, scientists think forests killed by bark beetles will be more at risk to forest fires because the dry, dead trees will be more flammable. While this may be true, other scientists are making the argument that many of the forests in western North America, which are thickly wooded due to years of fire suppression by humans, will be naturally thinned by the presence of bark beetles and will, ultimately, recover and regain some sort of balance.

There are differing opinions on whether it is necessary to try to mitigate the effects of bark beetle outbreaks, and on the management strategies that could be used. These large swaths of dead trees cause issues for forest management, timber use, and fire suppression. Only a few species of bark beetles have this sort of "outbreak" potential. The US Forest Service and other similar organizations have advocated for some management strategies. One strategy for not-yet-infested forests is to thin patches of trees in the hope that reducing the competition for resources in an area will lead the trees left behind to be more able to ward off beetle attacks. But there's no evidence that this approach actually works. Other management strategies have included using spray pesticides, some of which have been tested, and some of which have been shown to be harmful to other organisms. Currently, there is not a uniform consensus on how to manage these outbreaks. The issue is nuanced and complex and the discussion of this topic should follow suit.

Common Relevant Misconceptions

Misconception. All bark beetles are "pests" and kill entire forests.

More accurate information.

There are thousands of species of bark beetles, and most of them target sick or weakened trees, or dying branches on healthy trees.

Most species of bark beetles don't have "outbreak-sized" populations, are a natural part of forest ecosystems, and help recycle resources in otherwise decay-resistant wood. They are also food for organisms like woodpeckers, other birds, and different insects.

There are a few species, including the native Mountain Pine Beetle and Spruce Beetle, that currently have massive populations, and are causing the death of entire stands of trees. The specific causes of these outbreaks have been studied by scientists, but are still not completely known. Research suggests that the trees in these forests are not sick, but are thought to be weakened due to competition for resources—especially water. This makes them less able to defend themselves by emitting sap, and more susceptible to being overwhelmed by beetle attacks. Additionally, due to global warming, the warmer, longer summers and shorter winters have made it possible for bark beetles to have many more generations of young in one breeding season than in the past, which has led to massive population explosions of beetles.

Connections to *Next Generation Science Standards (NGSS)*

BEETLES student activities are designed to provide opportunities for the "three-dimensional" learning called for in the *NGSS*. To experience three-dimensional learning, students need to engage in scientific practices to learn important science concepts (Disciplinary Core Ideas) and make connections to the big ideas in science (Crosscutting Concepts). In short, students should be using the tools of science to explore and investigate rich phenomena, trying to figure out how the natural world works.

In *Bark Beetle Exploration,* students take part in the practice *of Constructing Explanations* as they build a foundation for understanding disciplinary core ideas related to *Ecosystem Dynamics, Functioning, and Resilience,* and to *Human Impacts on Earth Systems*—and relate those ideas to the crosscutting concept of *Cause and Effect.*

Featured Science and Engineering Practices

Engaging students in Constructing Explanations. According to the National Research Council's *A Framework for K–12 Science Education*, a major goal of science is to deepen human understanding of the world through making explanations about it, and students should develop their understanding of science concepts through making their own explanations about natural phenomena. Students begin to engage in this practice when they look at the markings left by bark beetles and construct alternate explanations for what beetle behaviors may have caused them. For students to be fully engaged in this practice, they need to go beyond just making explanations as described above. They also need to consciously use tentative language ("I think that…"), base their explanations on evidence, and consider alternate explanations based on that evidence.

The optional discussion focuses on how bark beetle outbreaks affect ecosystems, and the merits of possible management strategies. The conversation begins with more general ideas about how moderate populations of bark beetles affect trees and ecosystems, which is important for giving students the chance to connect the content of the discussion to what they've already learned about bark beetles in the activity. This allows students to build their understanding of bark beetles' different roles in ecosystems, and use that information as evidence later in the discussion of overpopulation of bark beetles. The instructor offers new information throughout the discussion, but refrains from offering their own opinions and solutions. The goal is for students to create arguments for and against different solutions so the group can move toward the best possible ideas.

Featured Crosscutting Concepts

Learning science through the lens of cause and effect. When scientists make explanations for how or why something happens, they're thinking about the connection between cause and effect. What we can observe of the natural world are the "effects" of many potential "causes." Understanding relationships between cause and effect leads to a deeper understanding of the world, which is helpful in making predictions and explanations about what might happen in similar conditions in the future.

NOTES:

About the Next Generation Science Standards (NGSS) The development of the Next Generation Science Standards followed closely on the movement to adopt nationwide English language arts and mathematics Common Core standards. In the case of the science standards, the National Research Council (NRC) first wrote a *Framework for K-12 Science Education* that beautifully describes an updated and comprehensive vision for proficiency in science across our nation. The *Framework*–validated by science researchers, educators and cognitive scientists–was then the basis for the development of the NGSS. As our understanding of how children learn has grown dramatically since the last science standards were published, the NGSS has pushed the science education community further towards engaging students in the practices used by scientists and engineers, and using the "big ideas" of science to actively learn about the natural world. Research shows that teaching science as a process of inquiry and explanation helps students to form a deeper understanding of science concepts and better recognize how science applies to everyday life. In order to emphasize these important aspects of science, the NGSS are organized into three dimensions of learning: Science and Engineering Practices, Crosscutting Concepts and Disciplinary Core Ideas (DCI's). The DCI's are divided into four disciplines: Life Science (LS), Physical Science (PS), Earth and Space Science (ESS) and Engineering, Technology and Applied Science (ETS).

Read more About the *Next Generation Science Standards* at http://www.nextgenscience.org/ and http://ngss.nsta.org/

NOTES:

Why teach science practices? "Engaging in the practices of science helps students understand how scientific knowledge develops... It can also pique students' curiosity, capture their interest, and motivate their continued study..." (National Research Council F*ramework for K–12 Science Education*). Focusing on these science practices will help to ensure a more scientifically literate public who will be better able to make thoughtful decisions.

In discussing solutions for environmental issues, students are engaging in some engineering practices. Engineers ask: What can be done to address a particular human need or want? How can the need be better specified? What tools and technologies are available, or could be developed, for addressing this need? Engineers make decisions based on evidence that a given design will work. The process of developing a design is iterative and systematic.

— Adapted from *A Framework for K–12 Science Education*

In *Bark Beetles*, students start by looking at the different features of bark beetle galleries and making explanations about which beetle behaviors may have caused them. In the optional discussion, students go a little deeper into thinking about cause and effect when they use their own observations as evidence for how bark beetles might affect trees and forests. Then, they apply the concept in a different way when they consider possible future effects of outbreak-levels of bark beetles and possible effects of different environmental management strategies. Make sure students know that thinking about cause and effect is a major part of all of science, and that it's a useful way of looking at the designed world, in addition to what can be found in nature. Try to give students opportunities to think about cause and effect in different contexts during their field experiences. Encourage them to use this lens to explain things they see in nature, or to examine something in the designed world where they can try to make connections between causes and effects.

Featured Disciplinary Core Ideas

Building a foundation for understanding Disciplinary Core Ideas. The *NGSS* make it clear that students need multiple learning experiences to build their understanding of disciplinary core ideas in science. *Bark Beetle Exploration* provides students with an opportunity to develop understanding of some disciplinary core ideas related to LS2.A *Interdependent Relationships in Ecosystems*, and LS2.C *Ecosystem Dynamics, Functioning* and *Resilience.*

When students examine evidence of how bark beetles interact with wood as they eat, protect themselves, and reproduce, they build understanding of the idea that organisms are dependent on their environmental interactions with living and nonliving factors, and that organisms survive where their needs are met (LS2-A). In the optional discussion where students discuss the effects of temperature differences on bark beetle populations and the implications of bark beetle outbreaks on the rest of the ecosystem, students can develop understanding of the idea that ecosystem characteristics can change over time and that disruptions can lead to shifts in organism populations (LS2-C).

Performance Expectations to Work Toward

When examined closely, it's clear that the *NGSS* represent complex knowledge and multifaceted thinking abilities for students. No single activity can adequately prepare someone for an *NGSS* performance expectation. Performance expectations are examples of things students should be able to do, after engaging in multiple learning experiences or long-term instructional units, to demonstrate their understanding of important core ideas and science practices, as well as their ability to apply the crosscutting concepts. As such, they do not represent a "curriculum" to be taught to students. Below are some of the performance expectations that this activity can help students work toward if you do lead the optional discussion about the effects of bark beetle populations on ecosystems.

3-LS4-4: Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Activity Connections and Additional Ideas

This is an exploration activity and combines well with others, such as *Spider Exploration* or *Lichen Exploration*. The concepts explored here would also support ideas from *The Case of the Disappearing Log* and *Decomposition Mission*, and could serve as an invitation to motivate students to think about matter and energy flow. *Bark Beetles* could also be used as part of a "tracking" theme in conjunction with the activities *Tracking* and *Bird Language Exploration.*

NOTES:

Translating the codes used in the NGSS: Each standard in the *NGSS* is organized as a collection of performance expectations (PE) for a particular science topic. Each PE has a specific code, provided here so that they can be easily referenced in the *NGSS* documents. The first number or initial refers to the grade level: K - kindergarten, 1 - first, 2 - second,etc...MS - middle school, and HS - high school. The next letters in the code refer to the science discipline for the standard: LS, PS, ESS, ETS. The number following the discipline denotes the specific core idea within the discipline that is addressed by the PE, and the last digit identifies the number of the PE itself.

So...3-LS4-4 means it's a third grade standard for life science, addressing the fourth core idea (Biological Evolution: Unity and Diversity) within the life science standards. It's also the fourth PE that makes up the complete LS4 standard at this grade level.

Example Of Tree Death Due To Bark Beetles

(Dead trees are those that have turned orange)

"Seclusion, Grand Lake" by Don Graham, via flickr.com, Creative Commons

Adult Bark Beetle

"Dendroctonus micans" by Gilles San Martin, via flick.com, Creative Commons

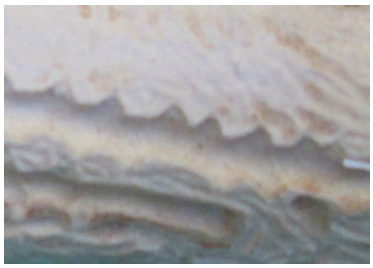
Field Guide to Bark Beetle Gallery Features

This is a guide to markings bark beetles make as they eat, grow, make waste, have young, and carve tunnels. Different species (or types) of bark beetles make slightly differently-shaped markings, so the egg gallery, waste, or tunnel you find might not look exactly like the ones pictured here.

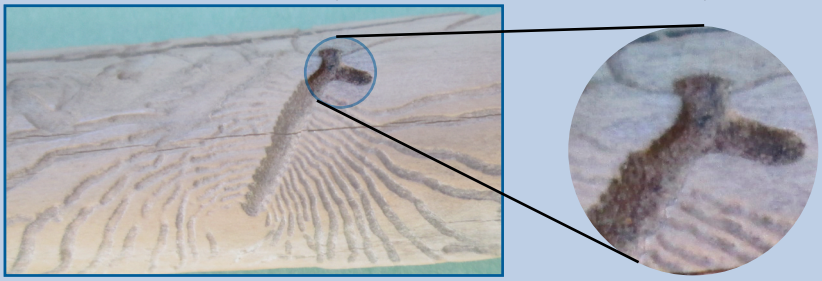
Egg Galleries

When bark beetles lay eggs, they carve one long tunnel and lay one egg at each notch in the egg tunnel.

When the eggs hatch, the larvae (baby beetles) eat wood and carve tunnels of their own that spread away from the egg tunnel.



Mating Chambers



Some bark beetles mate first in mating chambers, like these. Others mate outside the tree, and don't make chambers.

Evidence of Beetle Growth

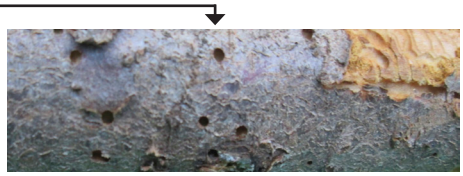
As young beetles grow, the tunnels they carve get bigger.

Evidence of Beetle Waste

The sawdust-like material in bark beetle galleries is a mix of beetle poop and parts of the wood beetles don't eat.

Exit and Entry Holes

Round or oval-shaped holes in tree bark are places where young beetles exited, or where adult beetles entered to mate and lay eggs.



Boring Holes

Some species (or types) of bark beetles eat through all the outer soft, sweeter wood of a tree first, then tunnel into the branch or trunk to find more food, or to change into adults in a safer place. Other kinds of beetles bore (or carve tunnels) deep into the wood and spend most of their life cycle there.

FIELD CARD

Cut out along outer lines, & fold along the centerline. This makes a handy reference card that will fit in your pocket.

Bark Beetle Exploration

Introducing the Activity - Meet the Beetles

1. Lead a *Walk & Talk* about life in a different body.
   - *Imagine you're an animal that's much bigger than a human. What would that be like? How might your life be different?*
   - *Now imagine you're an animal much, smaller than a human–the size of your pinkie fingernail. What might that be like?*
   - *When I say "go," touch (or point to) the bark of a tree. What might it be like to be an animal the size of your pinkie fingernail, that lives under tree bark?*
   - *What kinds of signs or pieces of evidence might an animal living under tree bark leave behind?*
2. Students pass around & feel bark beetle galleries, with their eyes closed.
3. Explain that markings were made by bark beetles & show photo.

Collecting and Studying Bark Beetle Galleries

1. Students prepare to explore & collect sticks with bark beetle markings.
2. Set up safety & exploration protocols for the group.
3. Circulate, troubleshoot, be a co-explorer, & pay attention to safety as students are collecting galleries.
4. Group gathers around sample galleries; pairs make observations & look for patterns.
5. Circulate, ask students questions about their observations, & encourage them to make comparisons between galleries, & from different perspectives.

Discussing Explanations - What are these beetles doing?

1. Pairs share discoveries with other pairs, then individuals share observations & explanations with group.
2. Help students connect the explanations they make from observations to making explanations from evidence.
3. Student pairs discuss things all beetles do. Ask:
   - *What are some things that all beetles do?*
4. As a group, generate a list of beetle behaviors.
5. Point out how thinking about cause & effect relationships can lead to better explanations. Explain:
   - *Most bark beetles do all these things underneath tree bark, so these can be causes for the markings we've seen.*
   - *When we connect a specific cause with an effect, we're making a scientific explanation for the beetle galleries.*
6. Pairs discuss observations (effects) & connect them to beetle behaviors that might have caused them.
7. Describe how scientists use cause & effect to explain things.

Becoming Bark Beetle Trackers

1. Introduce the *Field Guide to Bark Beetle Gallery Features* that describes causes of some effects they've seen.
2. Explain:
   - *You're going to be bark beetle trackers & make explanations for what bark beetles were doing in different places.*
3. Tell students that being a good tracker means being a careful observer, who uses evidence left by animals to figure out what they were doing.
4. Encourage students to remember the questions they come up with & to make comparisons between samples.
5. Help, encourage, & be a co-investigator.

(For Optional Discussion about bark beetle infestations, see second field card)

Wrapping Up

1. *Walk & Talk, Turn & Talk,* or journal reflection:
   - What was it like to be a bark beetle tracker?
   - Where could we look for more bark beetle galleries in the future?
   - What advantages or disadvantages does living underneath tree bark provide? What body structures do you think beetles need to survive in their habitat?
   - How might beetles affect the trees they're on?
   - If you were going to explain bark beetle galleries to a friend or relative, what would you say?
   - What's something that surprised you today?
   - Did any of your ideas or opinions change as we discussed bark beetles? Why?

(For Optional Extension — Investigating student questions, see second field card)

FIELD CARD

Cut out along outer lines, & fold along the centerline. This makes a handy reference card that will fit in your pocket.

Bark Beetle Exploration--Optional Sections

***(Optional)* Discussion: Beneficial & Harmful Effects of Bark Beetles**

1. Gather students & begin a discussion about bark beetle effects on forest ecosystems & population outbreaks.
2. Ask students questions about what kind of wood (living or dead) they think bark beetles eat, & how living trees might protect themselves from bark beetles.
   - *During your explorations, did you find evidence of bark beetles eating wood from dead trees? From living trees? What's your evidence?*
3. Listen, then share: scientists have found that usually, multiple beetles eat wood from sick, weak dying trees, but sometimes they eat the wood of healthy living trees, too.
   - *How might the presence of bark beetles affect the trees, and how might a tree protect itself from bark beetles?*
   - Listen, then share: scientists have observed that when beetles arrive at a tree, they send out chemical signals that attract other beetles to the location, trees fight back with sap, & mostly weak trees are killed.
4. Turn the conversation toward bark beetle effects on the forest as a whole. Ask:
   - *How do trees benefit ecosystems?*
   - *How do you think bark beetles might affect a forest as a whole? What do you think might be some harmful or beneficial effects bark beetles have on forests?*
5. Listen, then share (if not brought up already): bark beetles are food for many other insects & for many birds.
6. Share: Most species of bark beetles only kill trees that were already sick or weak, but some species of bark beetles are having population explosions and are killing all the trees in certain forests.
7. Ask students to consider how bark beetle population outbreaks might affect forests as a whole (all parts of the forest, not just the trees).
8. Encourage multiple students to share their perspectives, ask for evidence, & encourage respectful disagreement.
   - *Some groups of scientists think that, over many years, bark beetles will help these forests decompose and provide food for other organisms, so they aren't worried. Others, like the US Forest Service, are worried that lots of dry, dead trees will burn in large forest fires, which could cause damage to forests, wildlife, and people's property.*
9. Ask students to Turn & Talk about whether or not humans should try to stop bark beetle outbreaks.
   - *Some think we should try to stop the outbreaks to stop trees from dying. Do you think humans should do this? Why or why not?*
   - *If we were to decide to try to stop bark beetle outbreaks, what different strategies and actions could we use? For each strategy, what would be the positive effects you'd want, and what might be some possible negative effects?*
10. Share: The forest service has tried cutting down some trees in a forest where they think bark beetles might come later—they do this so trees left behind aren't competing for as many resources, like sunlight and water, and hopefully have a better chance of surviving a bark beetle attack. Logging companies cut the trees and the wood is used for building. But there's no evidence this works to reduce the number of trees killed by beetles.
    - *What do you, personally, think of this solution? What are some positive or negative effects this solution might lead to?*
    - *What other groups of people might have different ideas about this solution? What do you think their opinions might be?*
11. Wrap up the discussion by briefly summarizing the main things the group talked about, & any ideas they agreed or disagreed on.
12. Explain that there are often many causes that contribute to patterns we see in nature on a large & small scale.
    - *One job of science is to notice patterns in nature, and try to figure out what causes them. There are often many causes, and if we understand these better, we're better prepared to notice their effects, to predict what might happen in the future, and to make decisions about how to protect the environment while thinking about what effects our actions might have.*
13. Tell students the discussion they just had might be similar to those environmental policymakers or scientists might have. Let them know that these types of issues are complex—and there's rarely a simple answer about what to do.
14. Call out what students did well during the discussion.

***Optional:* Questions for Further Study**

1. Hear student questions.
2. Find a question to follow, e.g.:
   - Based on the number of egg notches that have tunnels coming out from them, can we figure out about how many eggs are laid on average, & how many beetle babies hatch from them? If we choose to investigate this, what assumptions are we making?
   - Since different styles of bark beetle gallery markings are usually from different species of bark beetles, how many different species can we find evidence for in this area?
3. Set up investigation norms, discuss bias & fair test, and let students investigate the question.
4. Interpret the results.
5. Reflect on the scientific process.

ABOUT BEETLES™

BEETLES™ (Better Environmental Education Teaching, Learning, and Expertise Sharing) is a program of The Lawrence Hall of Science at the University of California, Berkeley, that provides professional learning sessions, student activities, and supporting resources for outdoor science program leaders and their staff. The goal is to infuse outdoor science programs everywhere with research-based approaches and tools to science teaching and learning that help them continually improve their programs.

www.beetlesproject.org

The Lawrence Hall of Science is the public science center of the University of California, Berkeley. *www.lawrencehallofscience.org*

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