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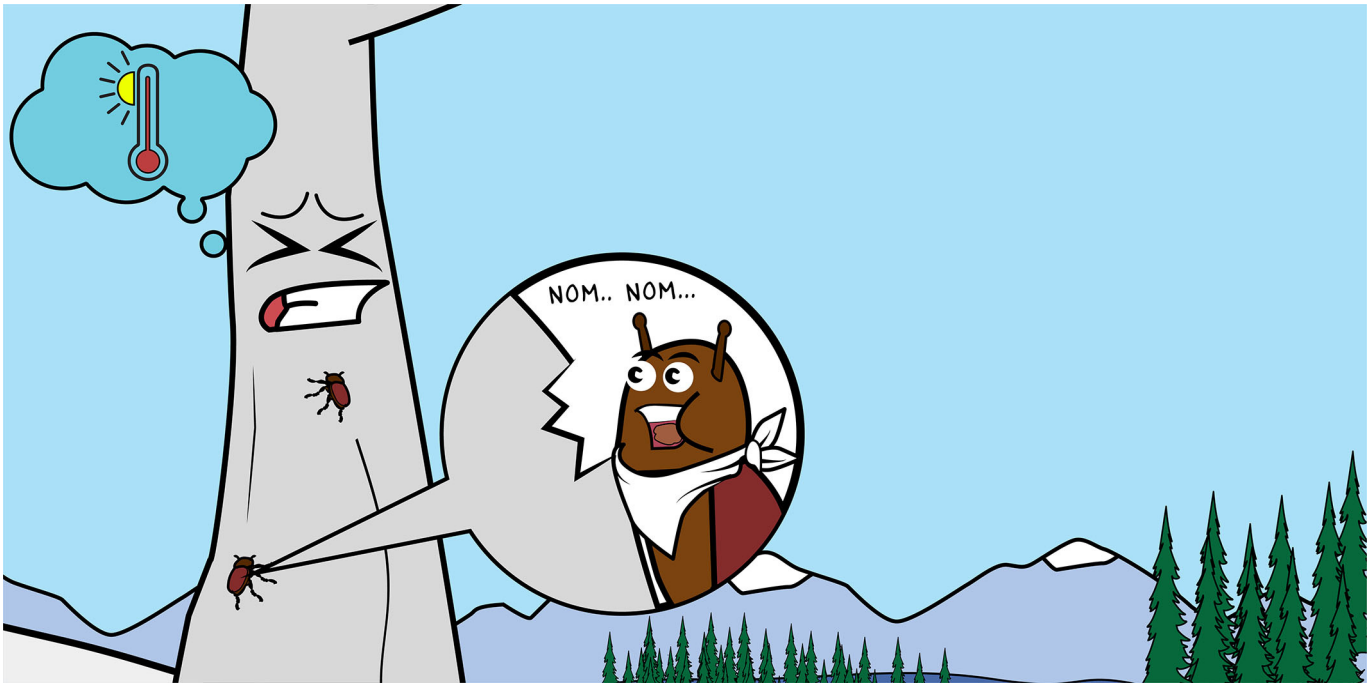

TROUBLE IN THE FOREST: WHITEBARK PINE TREES, MOUNTAIN PINE BEETLES, AND CLIMATE CHANGE

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Have you ever hiked up a mountain and felt a frosty wind blowing across your face? You might need to button up your jacket to visit this place, but here, whitebark pine trees are right at home. Whitebark pines thrive in the highest forests of western North America. In these environments, whitebark pines help other, less-hardy species to establish, grow, and survive. For this pine, chilly mountaintops provide a refuge from insects, disease, and competition with other trees. Yet as our climate changes, whitebark pines no longer have the cold on their side. They are dying at alarming rates, and one of the biggest killers is a tiny bark beetle. How is climate change helping this little insect munch through huge swaths of forest? National Park Service scientists use long-term monitoring studies to unravel this complicated relationship. This information guides resource managers entrusted with protecting whitebark pines.

HOW DOES CLIMATE CHANGE AFFECT COLD-ADAPTED SPECIES?

You may have heard that climate change will contribute to the extinction of many species over your lifetime. But have you thought about why? For some species, the environment is going to get too warm too fast for them to live: think of a goldfish in a bowl of hot water. For most other species, the interaction between climate change and survival is more complex. While some species will suffer in warmer temperatures, others may thrive. And this difference in survival can throw off the natural balance in an ecosystem.

Whitebark pine trees are found in cold, high-elevation forests across western North America (Figure 1). They are adapted to live on mountain slopes and ridges at the upper limits of where trees can survive. Warmer temperatures are not always harmful to whitebark pine trees. Like many plant species, whitebark pines can grow faster if conditions are warmer. But frequent periods of warmer temperatures favor mountain pine beetles, which can be a serious threat to whitebark pine health. By studying the relationship between whitebark pines and mountain pine beetles, scientists can determine how climate change influences certain aspects of whitebark pine survival. This information can also help us learn about the potential effects of climate change on other plant species.

WHITEBARK PINES ARE AN IMPORTANT SPECIES

KEYSTONE SPECIES

A species that greatly influences the wellbeing of many other species in its ecosystem. Like the keystone in a rock archway, if this species is removed, the system collapses.

The whitebark pine is a **keystone species**. This means that these trees are very important to other species within the ecosystems where they grow. Whitebark pines produce nutritious seeds that provide fat and calories for grizzly and black bears, squirrels, and birds (Figure 2). When trees produce a lot of cones, well-fed grizzly bears can give birth to more cubs [1]. With higher body fat, bears also have an increased chance of survival through the winter. Grizzly bears are top predators and will eat just about anything, but whitebark pine seeds are one of their favorite foods!

MUTUALISM

A type of relationship between different species in which both organisms benefit. Some examples include bees and the flowers they pollinate, and helpful bacteria inside the human digestive system.

Whitebark pines also have a special relationship with Clark's nutcrackers. This loud, gray bird collects whitebark pine seeds throughout the summer and fall, burying them in little holes in the ground. Stored seeds, or caches, supply food for the birds during the long winter months. Fortunately for whitebark pines, the birds cache more seeds than they need to eat. Many of these forgotten seeds sprout into new trees. Clark's nutcrackers like to hide their seeds in forest openings, particularly in areas that have been burned by wildfires. Because of this behavior, whitebark pines are often the first trees to grow back after a wildfire. This type of relationship, in which two species benefit from one another, is known as **mutualism**.

Figure 1

Locations of whitebark pine trees in western North America. The black lines show the boundaries of Yellowstone, Grand Teton, Sequoia, Kings Canyon, and Yosemite National Parks, and the yellow line outlines the Greater Yellowstone Ecosystem.

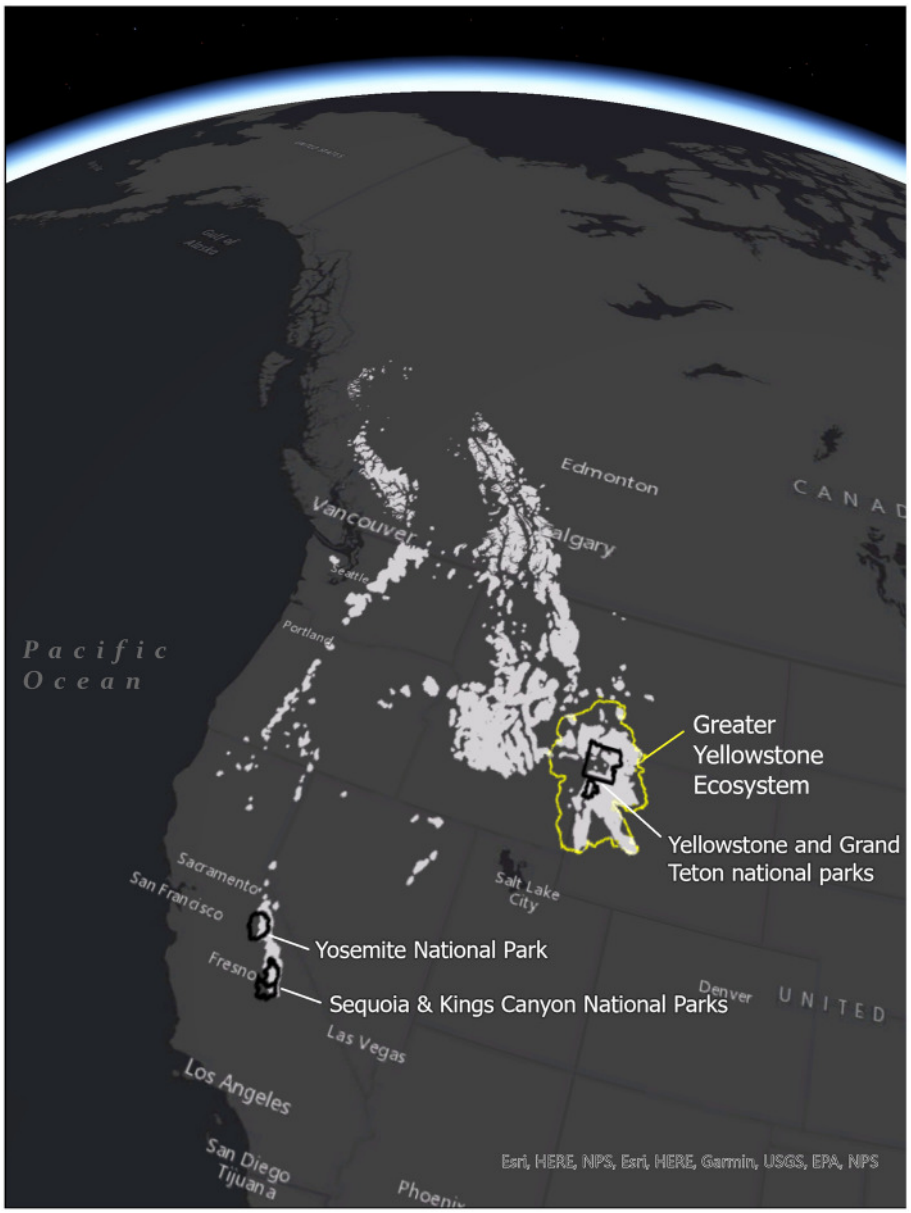

Figure 1

As a whitebark pine seed sprouts and develops into a mature tree, its roots stabilize and enrich the soil. After several years, the tree creates a welcoming environment where other less hardy plants can establish and grow. Shade from its wide-spread branches allows the snow underneath to melt more slowly over the spring and summer, which provides a steadier source of water for plants, animals, and people downstream.

It is common to find whitebark pine trees that are over 400 years old. The oldest one we know of is about 1275 years old! In their lifetime, these ancient trees may have withstood insect outbreaks, wildfire, and drought. They have witnessed generations of people come and go.

Figure 2

Figure 2

(A) This whitebark pine tree could be several 100 years old. **(B)** The Clark's nutcracker is the primary disperser of whitebark seeds. **(C)** Grizzly bears depend on fat and calories from whitebark pine seeds to survive the winter. **(D)** Squirrels use their sharp teeth to cut cones down from the high branches. Bears often raid their piles of cones for a meal! **(E)** Whitebark pine pinecones are dark purple and sticky with sap. **(F)** Areas where many trees have died are known as "ghost forests." Image credits: **(A,E,F)** Authors' own. **(B)** Walter Siegmund. Creative Commons License. https://commons.wikimedia.org/wiki/File:Pinus_albicaulis_7025.JPG. **(C)** Jim Peaco, NPS. Creative Commons License. https://www.flickr.com/photos/yellowstonenps/35472673145. **(D)** BlueCanoe. Creative Commons License. https://commons.wikimedia.org/wiki/File:Eastern_Gray_Squirrel_Sciurus_carolinensis_Lake_Juanita_WA.jpg.

But now, they are dying at an alarming rate. Where these majestic guardians of the mountains once thrived, "ghost forests" now stand. How did these mighty trees die after surviving for so long? One reason is that there is a wee beetle living in the forest, and it has a teeny, tiny mouth but a terrible bite.

MOUNTAIN PINE BEETLE—TINY AND HUNGRY

Mountain pine beetles may be small, but they have a huge effect on forests! The **life cycle** of mountain pine beetles includes egg, larva, pupa, and adult stages. Most of that life cycle is completed underneath the bark of host trees, which are trees that mountain pine beetles like to reproduce in and eat—including whitebark pines. Adult beetles swarm a tree and chew a network of paths inside the bark. Next, female beetles lay their eggs in the paths. After about 2 weeks, the eggs hatch into larvae. The hungry larvae dig horizontal channels in the living tissue under the bark, where they feed and develop. This stops the flow of water and nutrients, killing the tree. Once the larvae change into pupae and finally into adult beetles, they emerge from under the bark and fly to new trees to start the cycle again.

Whitebark pines and mountain pine beetles have lived in mountain environments for thousands of years. For most of that time, temperatures have kept them in balance. While whitebark pines are found at higher regions that are usually colder, beetles are normally more abundant at lower elevations, where temperatures are warmer. Where whitebark pines grow, beetle populations commonly

LIFE CYCLE

The developmental changes an organism goes through during its life. For mountain pine beetles, the life cycle consists of egg, larva, pupa, and finally adult stages.

stay at **endemic** levels, which means the typical, low numbers of beetles. Fewer beetles mean fewer trees are killed. However, when temperatures rise, beetle populations can explode to **epidemic** levels, meaning unusually high numbers of beetles. It is natural to see occasional beetle outbreaks in the forest, but recent outbreaks have been larger, lasting longer, and occurring at higher elevations.

ENDEMIC

A constantly maintained level of an organism in a particular geographic area. Mountain pine beetles are usually constantly present in western forests but at low numbers.

EPIDEMIC

A large increase in the number of organisms in an area. In the case of mountain pine beetles, the number of beetles increased substantially in western forests over several years.

A BEETLE OUTBREAK IN THE GREATER YELLOWSTONE ECOSYSTEM

The Greater Yellowstone Ecosystem is a vast, wild area in the northern Rocky Mountains. It includes Yellowstone and Grand Teton National Parks. In the early 2000s, National Park Service scientists and land managers noticed a dramatic increase in mountain pine beetle populations in this region. By the mid-2000s, beetle numbers had reached epidemic levels. This outbreak continued for several years. When it was over, about 75% of the large, older whitebark pine trees were dead [2].

The National Park Service uses long-term monitoring programs to study whitebark pine health. Park scientists collect data from the same trees, year after year. At each visit, they record whether trees are alive and healthy, diseased, infested with beetles, or dead. Park scientists also look at climate conditions such as air temperature and other factors that affect tree health.

Using the data collected during the mountain pine beetle outbreak, park scientists discovered what triggered the epidemic. Above-average temperatures were recorded in high mountain areas for several years in a row, which allowed beetle populations to expand into whitebark pine habitat and increase to epidemic levels. Higher temperatures speed up the mountain pine beetle's life cycle. Under colder conditions, the beetle life cycle might take two or even 3 years to complete. However, in warmer conditions, the beetle's life cycle happens faster, in as little as 1 year. Mild temperatures also mean that more beetles survive the winter. More beetles born in the summer plus more surviving through the winter adds up to a massive population explosion (Figure 3)!

Historically, the cold climate in whitebark pine habitats has safeguarded the trees from widespread beetle attacks. But as temperatures continue to warm, mountaintops may no longer offer the same protection they once did for whitebark pines.

STILL MORE TO LEARN

In Yosemite, Sequoia, and Kings Canyon National Parks, park scientists have also been monitoring the health of whitebark pines. Interestingly,

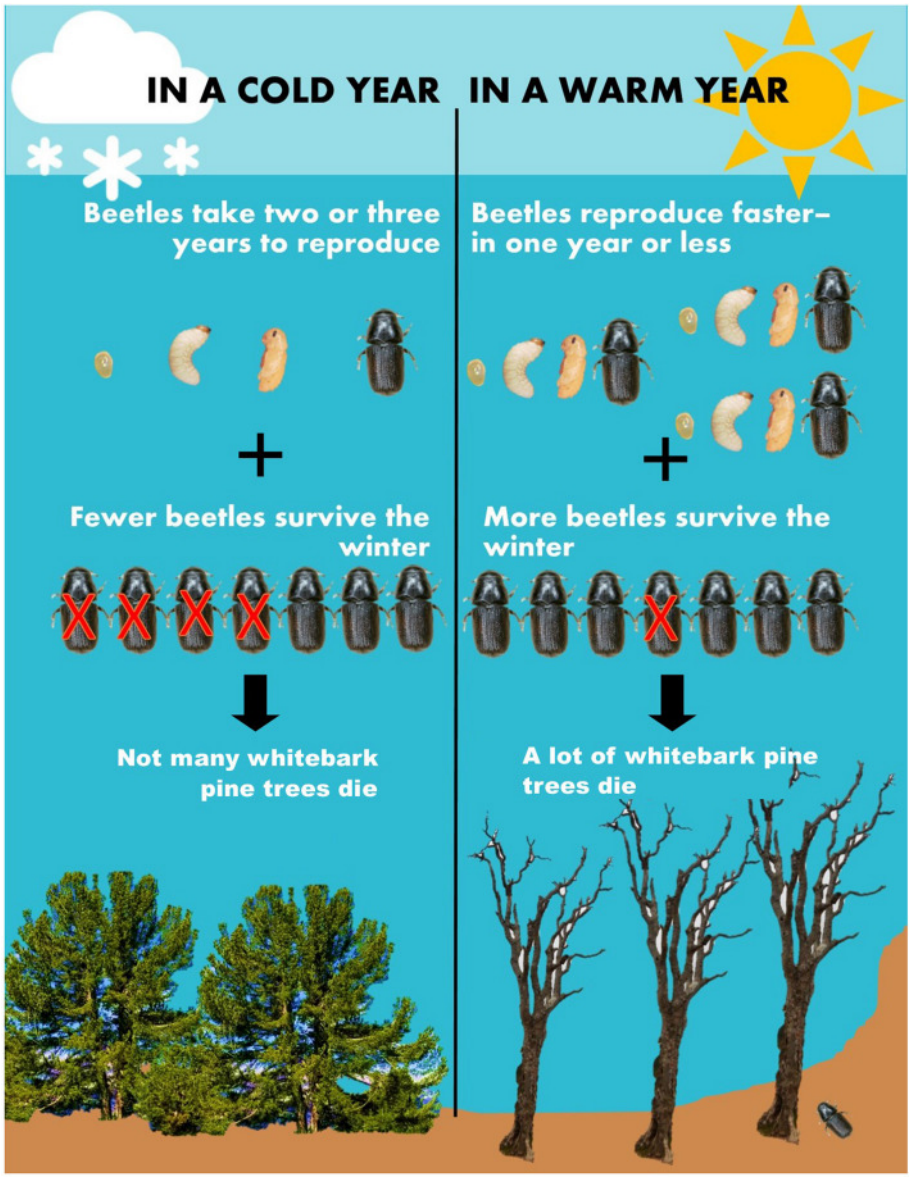

Figure 3

Figure 3

When temperatures remain cold over many years, it typically takes beetles 2–3 years to change from an egg to an adult beetle. Colder winters tend to kill more beetles. As a result, fewer beetles are present in the forest and lower numbers of whitebark pines die from beetle attacks. When temperatures are warmer than usual year after year, the beetles' life cycle speeds up, and more beetles can live through warmer winter months. With loads of hungry beetles flying around the forest, a lot of whitebark pines die. Image credits: Beetle and larvae: USDA Forest Service—Region 2—Rocky Mountain Region, USDA Forest Service, Creative commons license. Bugwood.org. Live tree: Erin Shanahan, NPS. Dead Tree: A-wiki-guest-user. Creative Commons License. https://commons.wikimedia.org/wiki/File:Dead_tree_in_Horton_Plains.jpg.

these parks did not have big beetle outbreaks like the ones in Yellowstone and Grand Teton National Parks. California parks differ from the parks in the Greater Yellowstone Ecosystem in several ways, including climate. Currently, we do not know why the trees there are healthier. Do you have a hypothesis for why the whitebark pine populations in these areas are different? If so, it would be a good topic for a research project! Studying other whitebark pine populations can help park scientists understand how climate change is affecting our high-elevation forests across the West.

HOW CAN WE SECURE A FUTURE FOR WHITEBARK PINES?

By now you may be wondering whether it is even possible for whitebark pines to survive. Forest managers hope so. If whitebark pine populations disappear from the mountaintops, it will have a huge impact on the community of plants and animals that live there. Squirrels, bears, and Clark's nutcrackers will have to look elsewhere for food. Snow will melt sooner without the shade of the pines' branches. And the plants and soil that whitebark pines shelter will have to face the harsh conditions on their own.

Fortunately, there are many people working to preserve this important species. Scientists from the National Park Service and land managers from other U.S. government agencies are working hard to protect and restore whitebark pines. While they may not be able to stop climate change and keep mountaintops cold, they are taking important actions. Using what we have learned about the complicated relationship of whitebark pines, mountain pine beetles, and climate change, managers are focusing their efforts on tasks like collecting and planting seeds in places that might stay colder in the future, defending trees from wildfires, and protecting trees from beetle attacks. Most importantly, they are also educating the public about the ecosystem value of whitebark pines and the impacts of global warming. By working together, park scientists, and land managers will continue to fight for this amazing tree species.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Aya wants to study marine biology. She wants to specialize in sharks and rays. Her favorite subjects in school are reading, writing, math, and music. In her free time she likes to read books, try out challenging puzzles, train for track and cross country, and play the violin.

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Hi! I am Nicole and my favorite hobbies are reading, running, playing the violin, and spending time outdoors. I am interested in Anthropology and hope to do something close to nature.

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