During an historic drought, higher temperatures helped a beetle kill more California pine trees

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Dead ponderosa pine trees in California. Credit: Charles Koven, University of California, Berkeley.

A new study shows climate change can have cascading effects on forests. Using computer modeling, researchers from North Carolina State University, the Los Alamos National Laboratory and other institutions

found increased temperatures during an historic drought in California contributed to the death of large numbers of giant pine trees by speeding up the life cycle of a tree-killing beetle.

Published in the journal *Global Change Biology*, the study found a nearly 30 percent increase in ponderosa pine (Pinus ponderosa) tree death during California's 2012–2015 drought due to attacks from the western bark beetle. Researchers said the findings highlight how climate change can compound threats forests face, and raise questions about their ability to act as reservoirs for greenhouse gases.

"This has huge implications for how we manage forests—not just in California, but everywhere," said study co-author Robert Scheller, professor of forestry and environmental resources at North Carolina State University. "With climate change, it's not just wildfires and weather events, but also how changing climate conditions can impact insects, fungi and other biological agents of tree mortality."

During the drought, researchers documented widespread tree death throughout the central and southern Sierra Nevada mountain range of California. The ponderosa pine, a large tree that lives at higher elevations, suffered the most, as it's the only host for the western pine beetle in the region. In some areas, nearly 90 percent of large ponderosa pine trees died, U.S. Forest Service researchers found.

"There are dead trees snaking across the landscape—dead, giant trees," said Zachary Robbins, the study's lead author and a graduate student at NC State. "We estimated that this mortality event would have occurred during the drought, but it would have been less severe under historic temperatures."

To understand how temperature influenced the beetles' attacks on the trees, researchers created a computer simulation of the beetles' life

cycle, their attack behavior, the number and size of trees, tree defenses and likelihood of death during certain stages of the drought. Then they combined all of those variables to model the beetles' attack behavior and tree defenses under contemporary (2001–2018) compared with historical (1895–1945) temperatures. They compared and tested their model using data gathered in the field.

While the trees can defend themselves against attacks by the beetle, their defenses were down during drought, researchers said. To save water, the trees put the brakes on photosynthesis, which could affect their ability to expel the beetles as they try to chew through bark. The beetles kill the trees when they dig intricate tunnel systems to lay their eggs into the trees' circulatory system, preventing nutrients from flowing through the tree.

"These beetles primarily live in trees that are weakened or dying, but when weather events occur, they start spreading across the landscape, and multiplying rapidly," Robbins said. "The beetles can develop more quickly when it's warmer. Also, lower temperatures in winter keep the populations in check. They die when winters are cold, but as temperatures warm, that may occur less often."

They attributed a 29.9 percent increase in tree death to the beetles' attacks—primarily from increases in development rates of the pine beetle, and to a lesser degree, to reductions in the beetles' death over the winter.

They also reported that each degree increase in temperature may have increased the number of pine trees killed by more than 35 to 40 percent—if increased beetle populations and declines in host tree defenses act separately.

"Higher temperatures increased the number of beetles that existed on the

landscape by speeding up their life cycle by about a half generation," Robbins said. "It lowered the over-wintering mortality a little bit, but not in a very pronounced way. Overall, what this means is that the beetles were able to reproduce more efficiently because they had these quicker generation times, and killed trees more quickly during the drought period."

The researchers are also concerned that small changes in the beetle population could have big effects.

"Even a slight increase in generations can increase tree mortality considerably," Robbins said.

The researchers said the findings raise multiple questions about forests in the future. It creates a more nuanced picture of the role they could play in storing, or releasing, carbon. The ponderosa pineis thought of as a fire-resistant species that's less likely to burn in wildfire events.

"These old trees are large stores of carbon that could be released back into the atmosphere either slowly as they decompose, or rapidly through wildfire," Robbins said. "As you have new species replacing them that might be more fire prone, that can be a big deal in terms of how much carbon we're storing in these forests versus what we're releasing back into the atmosphere."

Scheller said the death of the trees is likely to leave a lasting mark. It also raises questions about forests as long-term tools for controlling climate change.

"We're talking about a mass mortality event of incredibly large and old conifers," he said. "There will be new species to replace those, but the forest won't recover right away. And those original tree species may not return for hundreds of years, if ever."

The study, "Warming Increased Bark Beetle-Induced Tree Mortality by 30 percent During an Extreme Drought in California," was published online in *Global Change Biology*.

More information: Zachary J. Robbins et al, Warming increased bark beetle-induced tree mortality by 30% during an extreme drought in California, *Global Change Biology* (2021). DOI: 10.1111/gcb.15927

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