



## ECOLOGY

## Western U.S. Forests Suffer Death by Degrees

An insidious problem has taken hold in the forests of the American West, quietly thinning their ranks. Mortality rates in seemingly healthy conifer stands have doubled in the past several decades. Often, new trees aren't replacing dying ones, setting the stage for a potentially dramatic change in forest structure, says Phillip J. van Mantgem, a forest ecologist at the U.S. Geological Survey (USGS) in Arcata, California. Warmer temperatures and subsequent water shortfalls are the likely cause of the trees' increased death rate, he and his colleagues report on page 521.

"This is a stunningly important paper," says David Breshears, an ecologist at the University of Arizona, Tucson. For years, he and others have lamented massive diebacks that occur when fungal and insect pests ravage stands of trees. "What's harder to detect," he explains, is any subtle but significant shift in the trees' background death rate. "They have done a very thorough job" of documenting it.

In 2005, mortality rates weren't even on van Mantgem's radar. But while he was evaluating long-term data about forests in California's Sierra Nevada mountains for changes in species composition and other forest characteristics, he noticed an upward trend in tree deaths. At first he thought it was an artifact. Once he and his colleagues became convinced that the trend was real, they looked to see how widespread it might be.

Forest ecologist Nathan Stephenson of USGS in Three Rivers, California, combed the literature and canvassed his colleagues for long-term sites in the western United States where forest experts had tracked mortality and other parameters at regular intervals. They considered only old-growth



**Slow demise.** A comprehensive study shows that forests are losing trees faster now than they were 40 years ago.

forests, as these well-established communities would be less likely to undergo changes that could confound the analysis. "They were extremely rigorous in site selection," says Nate McDowell, an ecologist at Los Alamos National Laboratory in New Mexico.

All told, they wound up with 76 sites in the Pacific Northwest, California, Idaho, Colorado, and Arizona. They found that in the Pacific Northwest, mortality rates jumped to 1.3% today from 0.3% in the 1970s; in California, that percentage went to 1.7% from 1% in 1983; mortality in the interior forests climbed to 0.6% from 0.2% in roughly the same period. "It's not just one local spot," says van Mantgem. In contrast, they detected no trends in recruitment, the number of seedlings that survive to become mature trees. New growth is often failing to replace dying trees, he notes. Oliver Phillips, a tropical ecologist at the University of Leeds in the United Kingdom, says mortality rates have similarly increased in the tropics, but forest growth rates have increased there, more than compensating for the loss.

At first glance, a shift of a percent or less may seem insignificant. "The change in forests is subtle so far," says Stephenson. But just as a small percent difference in interest rates can compound the cost of a loan, a small difference in mortality rates can have a big effect over time. As the forest thins, ever smaller trees become dominant, affecting the land's carbon storage capacity and ability to support wildlife.

Next, the researchers evaluated the possible causes of the increased mortality rate. No matter how they sliced and analyzed the tree data—by size, type, elevation, and location—they still detected the increase in mortality. Air pollution couldn't be blamed because the increase occurred in pristine as well as polluted areas.

Ultimately, "the finger seems to be pointed to warming," says Breshears. Temperatures in the United States have risen about 0.4°C per decade in the past 40 years. Snowpack of the regions examined diminished over the time period they studied and is melting earlier, effectively lengthening the summer drought. Warmer air also leads to more evaporative loss, exacerbating the effect.

Michael Goulden, an ecosystem ecologist at the University of California, Irvine, thinks the data fall short of pinning the problem on global warming, as regional warming related to natural climatic variation could be to blame. But Julio Betancourt of USGS in Tucson, Arizona, disagrees. "Models suggest that most of this change was due to the buildup of greenhouse gases," he says. Moreover, local Pacific Northwest and Southwest climates tend to fluctuate in opposite directions.

However, Betancourt, who is not a co-author of the paper, stresses that forest researchers need to focus on seedlings, not mortality, in these threatened ecosystems. "If there is an affordable point of intervention, a way to adaptively manage for climate change," he points out, "it may be in how we manage seedlings, not mature forests and adult trees."

—ELIZABETH PENNISI

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