Scientists may be using a flawed strategy to predict how species will fare under climate change, suggests study

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A view overlooking a forest of ponderosa pine and Jeffrey pine from Verdi Mountain near Truckee in California. Credit: Daniel Perret

As the world heats up, and the climate shifts, life will migrate, adapt or go extinct. For decades, scientists have deployed a specific method to predict how a species will fare during this time of great change. But

according to new research, that method might be producing results that are misleading or wrong.

University of Arizona researchers and their team members at the U.S. Forest Service and Brown University found that the method—commonly referred to as space-for-time substitution—failed to accurately predict how a widespread tree of the Western U.S. called the ponderosa pine has actually responded to the last several decades of warming. This also implies that other research relying on space-for-time substitution may not accurately reflect how species will respond to climate change over the next several decades.

The team collected and measured ponderosa pine tree rings from across the Western U.S. going as far back as 1900 and compared the trees' actual growth to how the model predicted the trees should respond to warming.

"We found that space-for-time substitution generates predictions that are wrong in terms of whether the response to warming is a positive or negative one," said Margaret Evans, a co-author on the paper and an associate professor in the UArizona Laboratory of Tree-Ring Research. "This method says that ponderosa pines should benefit from warming, but they actually suffer with warming. This is dangerously misleading."

Their findings are published in the *Proceedings of the National Academy of Sciences*. U.S. Forest Service ORISE Fellow Daniel Perret is first author and received his tree ring analysis training at the UArizona laboratory through the university's summer field methods course. This research was part of his doctoral dissertation at Brown University with Dov Sax, a professor of biogeography and biodiversity and co-author on the paper.

This is how space-for-time substitution works: Every species occupies

their preferred range of climate conditions. Scientists have assumed that the individuals growing at the hotter end of that range can serve as an example of what might happen to populations at cooler locations in a warmer future.

The team found that ponderosa pine trees grow at a faster rate at warmer locations. Under the space-for-time substitution paradigm, then, this suggests that as the climate warms at the cool edge of distribution, things should be getting better.

"But in the tree ring data, that's not what it looks like," Evans said.

But when the team used tree rings to assess how individual trees responded to changes in temperature, they found that the ponderosa's were consistently negatively impacted by temperature variability.

"If it's a warmer-than-average year, they put on a smaller-than-average ring, so warming is actually bad for them, and that's true everywhere," she said.

The team suspects that this is happening because the trees can't adapt fast enough to keep up with the quickly changing climate.

An individual tree and all its rings are a record of the genetics of that specific tree being exposed to different climatic conditions in one year compared to the next, Evans said. But how a species responds as a whole is the result of the slow pace of evolutionary adaptation to the average conditions at a specific location, which are different from another location. Like evolution, migration of better-adapted trees with the changing temperatures could potentially rescue species, but climate change is happening too fast, Evans said.

Beyond temperature, the team also investigated how trees respond to

rainfall. They confirmed that more water is always better, whether you look across time or space.

"These spatially based predictions are really dangerous, because the spatial patterns reflect an end point after a long period of time when species have had a chance to evolve and disperse and, ultimately, sort themselves out on the landscape," Evans said.

"But that's just not how climate change works. Unfortunately, the trees find themselves in a situation where change is happening faster than the trees can adapt, which is really putting them at risk of going extinct. It's a word of caution for ecologists."

More information: Daniel L. Perret et al, A species' response to spatial climatic variation does not predict its response to climate change, *Proceedings of the National Academy of Sciences* (2023). DOI: 10.1073/pnas.2304404120. doi.org/10.1073/pnas.2304404120

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