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Shoots and leaves: the shotgun scientist who hunts moving trees

As forests evolve in the face of climate crisis, some surprising methods are being used to track how species migrate

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Angelica Patterson is on the lookout, shotgun in hand, as she hikes through New York state's Black Rock Forest. She focuses on her target high up in the canopy, then bang - a branch falls to the ground. "I can't climb trees, building scaffolding is expensive, and using a slingshot requires a lot of skill," she says. "A shotgun is an efficient, cheap and effective way to collect the high-up leaves that have full exposure to the sun."

Patterson puts the northern red oak branch into a bucket of water, cutting the submerged stem to ensure that its leaves continue to function, before walking back to her laboratory in the forest.

Here she studies how trees adapt and move in response to increasing average air temperatures. "When I first started learning about how plant communities change through time, I'd never associated trees with migration because they're sessile and don't move like four-legged creatures or fly like insects. So it's eye-opening to realise that tree communities shift their ranges to migrate to places where they can thrive," says Patterson, 39, a PhD student at Columbia University's department of earth and environmental science.

"It's as simple as seed dispersal. But just because a seed from a tree can move to a place doesn't mean it will successfully grow or reproduce. Other factors come into play in order to establish a thriving population."

Black Rock Forest is unusual because extensive data collected since the 1930s shows exactly how tree distribution has changed there. "Over the past 90 years, there's been a shift in forest composition. Three species have left the region or become locally extinct and 11 have migrated in naturally from the south or been introduced anthropogenically," Patterson says. "I wanted to find out what mechanism drives this shift and how that affects the ability of our forest to become a source rather than a sink of carbon dioxide, therefore perpetuating climate change."

The forests in the north-eastern US are one of the world's fastest growing carbon stores on land as timber harvesting, large-scale agriculture and fire disturbance have declined. But a shifting forest composition could have a drastic impact on this region's carbon storage capacity – if the forest's carbon balance is disrupted, more carbon could be released into the atmosphere.

"Northern red oaks are so important to this region, they influence soil health, water quality, nutrients. When you start to lose large populations of trees, that complex forest ecosystem can break down," says Patterson.

"If an invasive tree comes into play, you'll start to have a monoculture and lose that biodiversity; then the whole system just isn't healthy."

Patterson, who also works as an educator, admits she has never really been a city person. She grew up immersed in nature – and trees – in the rural town of Lackawaxen, Pennsylvania, and thrives in the multisensory experience of a forest. "I love the calm, the peace, the intrigue; I can go for a walk and find a plant I've never seen before or hear a new bird call, or discover a weird fungus. This forest is an amazing space to be," says Patterson, who lives just 20 minutes away. "This place allows me to calm my mind but also stimulate it at the same time. I've never found another environment that does that."

Angelica Patterson at Mineral Springs, New York state. She studies how trees adapt and move in response to increasing average air temperatures.

Over the past eight years she has studied how hundreds of leaves from 22 species function differently to investigate how environments that are extreme to certain species can influence the physiology of the tree. “I liken it to working out which tree has the engine of a Toyota and which has the engine of a Ferrari - the oaks are not Ferraris. However, they are extremely resilient and there’s a reason they’ve been dominant here for centuries,” says Patterson, who explains the survival strategy of the northern red oak, which makes up 70% of this forest. “These oaks can live up to 350 years so they’re long-lived, they produce dominant seeds [acorns] and tolerate high-stress conditions.”

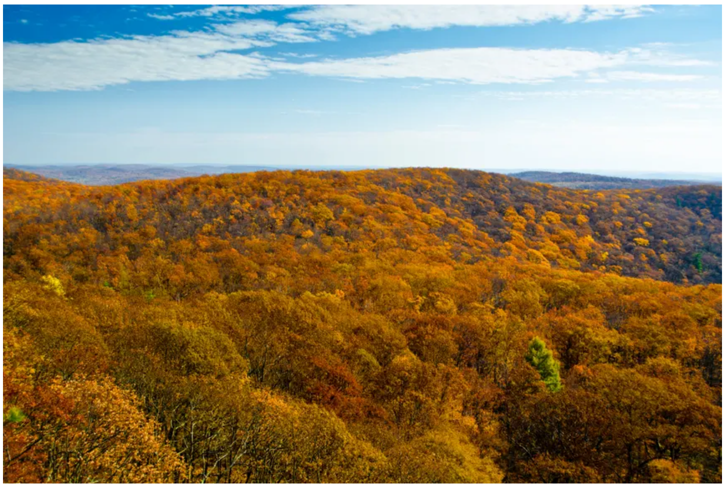
In the past, Black Rock Forest has been subject to fires but the oaks’ acorns can survive underground until conditions improve. However, now there are more settlements locally, fires are suppressed so these oaks must compete with fire-sensitive trees that would not have survived previously. More frequent tropical storms and heavy winds also threaten mature oak trees, a disease called oak blight is spreading into this region and deer browsing affects oak regeneration, potentially allowing other migrant trees to more easily fill this niche.

Kevin Griffin, professor in plant physiology at Columbia University, is Patterson’s PhD supervisor. He explains why Black Rock Forest is such a significant place to study tree migration. “There’s a huge mix of species here because tree species that typically have a southern or northern range all seem to crash together right in the Hudson valley,” he says. “At the end of the last ice age 14,000 years ago, glaciers receded from the Hudson valley and now after ecological succession we’re looking at this beautiful oak deciduous forest, but that’s just a snapshot in time.”

A plant or animal’s range - the geographical area in which a species can be found - is in constant flux. Ranges naturally shift, expand and contract over time, but it is the current speed of change that concerns scientists like Patterson and Griffin. “If the rate of change [in ranges] is greatly accelerated from human activities, then how does the ecology keep up with that?” asks Griffin.

For trees that grow and reproduce incredibly slowly, migration is a huge challenge. As Griffin puts it, “trees don’t have legs, seeds travel short distances and lots of things eat those seeds, plus trees need pollinators and the right soil for germination, so the ecology is fascinating but not obvious”. Crucially, there’s a mismatch between the speed at which ranges shift and the speed at which trees can respond and migrate.

Griffin and Patterson are investigating how shifting ranges affect the physiology or inner workings of these trees: “We’re trying to build a clearer picture of how the trees are currently surviving, how competitive they are and at what rate they may or may not be able to keep up with this shift in climatic conditions,” says Griffin, who says that temperature is one of the key drivers for shifting ranges.


Autumn foliage In Black Rock Forest. Photograph: Solon Chan/Getty Images

According to the US Forest Service Northern Research Station, more than 70% of saplings from northern tree species in the eastern US are showing a northwards migration. But temperature certainly isn't the only variable. In 2017, forest ecologist Songlin Fei at Indiana's Purdue University found more species moving west than north in eastern areas, possibly due to changes in precipitation or rainfall rather than changes in temperature. Total annual rainfall in central US had increased by more than 150mm and declined significantly in the south-east.

In order to compare metabolic activity inside every leaf she collects, Patterson clamps each one into the chamber of a photosynthesis machine. "I set the relative humidity, light, carbon dioxide levels and temperature to mimic the local conditions in the forest, or to recreate the southern range limit conditions, then allow each leaf to acclimatise and become happy. This encourages the stomas [pores] to open so that gas exchange can flow freely," she says. Patterson measures the rates of respiration and photosynthesis in mature trees.

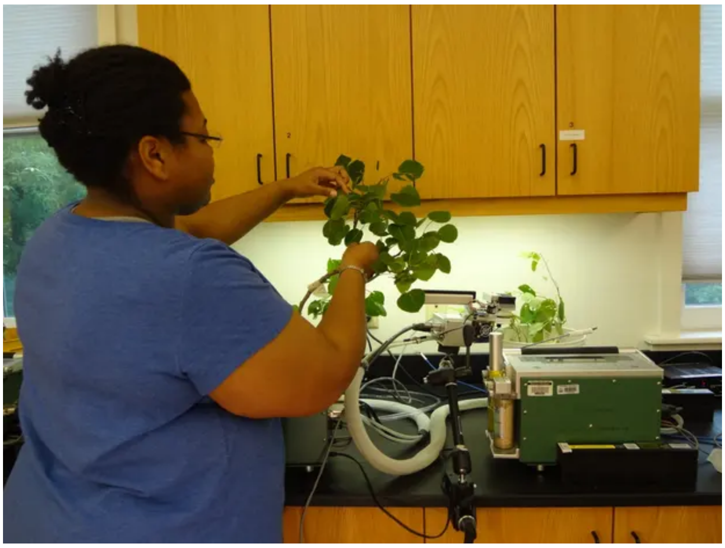
Griffin likens this to a bank account: "You have what you make and what you spend; tree growth is what's left over. So we study both photosynthesis - how carbon gets into the tree - and respiration - how carbon leaves the tree - to see if we can understand why some plants appear more or less successful."

In Black Rock Forest, the northern red oak is central to its range. But other broad-leaved and conifer trees found here might be living at the southern limit of their region (these northern-ranged trees include paper birch and red pine), or at the northern limit of their region (southern-ranged trees such as American sycamore and Atlantic white cedar). Patterson's initial results show that there are significant differences in the physiological capacities between northern-, central- and southern-ranged trees in Black Rock Forest.

"The patterns we find suggest that resident or centrally ranged trees, such as northern red oak, are physiologically disadvantaged when compared [with] the northern- and southern-ranged trees," she says.

But the trees may have been able to adapt to current climate conditions. "Within the next 50-100 years, high carbon emission scenarios predict that temperatures could feel as warm as Georgia's. So the oak's ability to continue to physiologically acclimate to a warming climate and persist among disturbance regimes such as deer browsing or ice storms will [influence] the health and survival of the oak population and the carbon storage potential of this region's forests," Patterson says.

There's also scope for this data to be incorporated into climate models so it might help predict future atmospheric carbon dioxide levels and evaluate which of the north-east US tree species may be better able to tolerate warmer climates over coming decades.



Angelica Patterson uses a photosynthesis machine to measure the rates of respiration and photosynthesis in mature trees. Photograph: Handout

The best approach to surviving a warming climate, according to researchers, could be to maintain "connective corridors" to allow trees to naturally migrate to new areas in a changing future and not be stopped by artificial boundaries such as cities, lakes or farmland.

Further research by the University of Tennessee indicates that underground "soil highways" could also be important, with certain combinations of fungi and bacteria microbiomes encouraging heat-sensitive trees to migrate to higher elevations where they can thrive.

Ultimately, tree migration is incredibly complex. But Patterson's work represents a valuable benchmark. Having recorded GPS coordinates for every leaf studied, researchers could take further measurements to assess how tree function changes over time.

"This is just a small snapshot of what's happening with certain trees," she says. "But it gives insight into which species will tolerate particular environments and that could help forest management now and in the future."

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