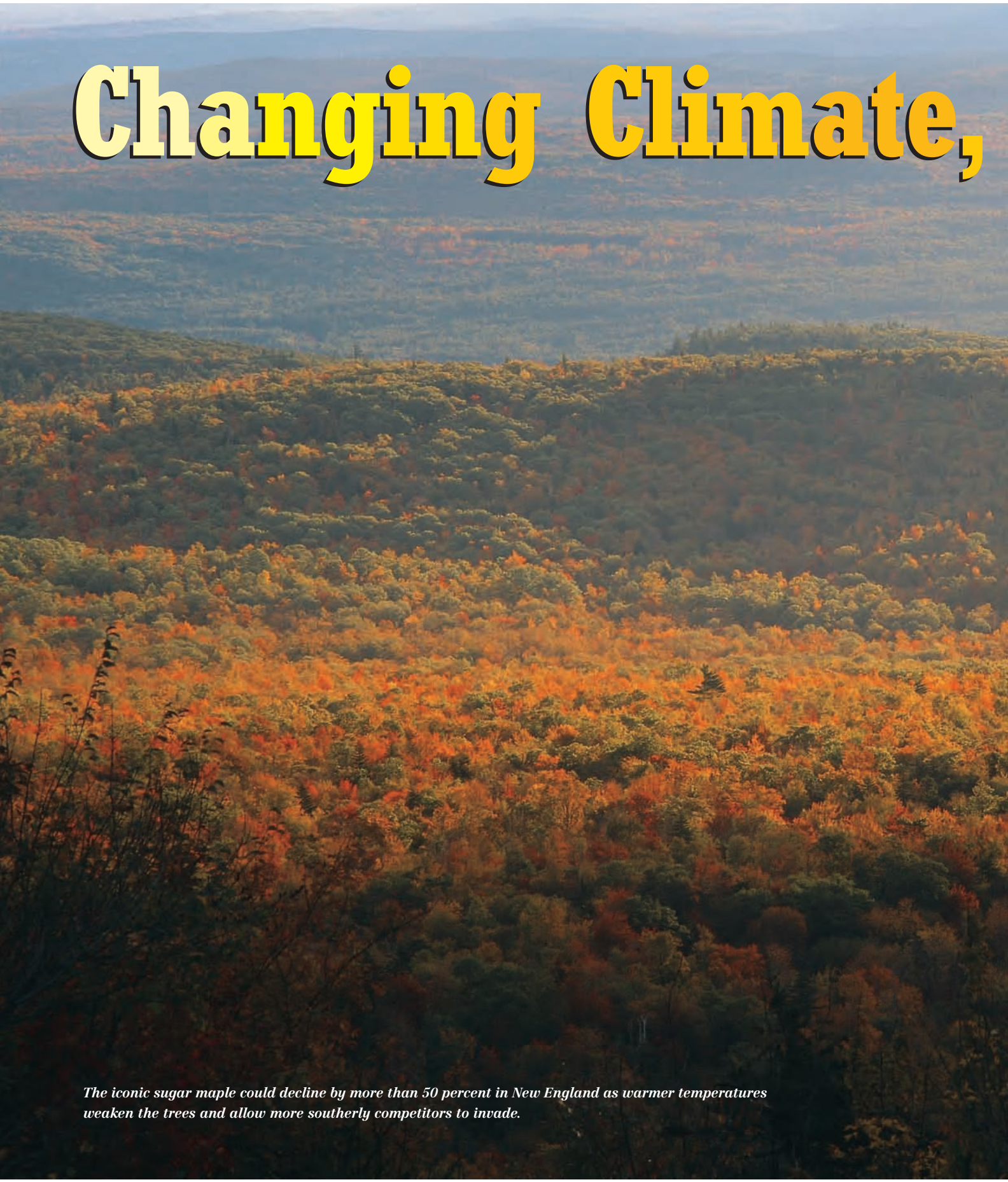
Changing Climate,



The iconic sugar maple could decline by more than 50 percent in New England as warmer temperatures weaken the trees and allow more southerly competitors to invade.

Shifting Forests

TIM PALMER

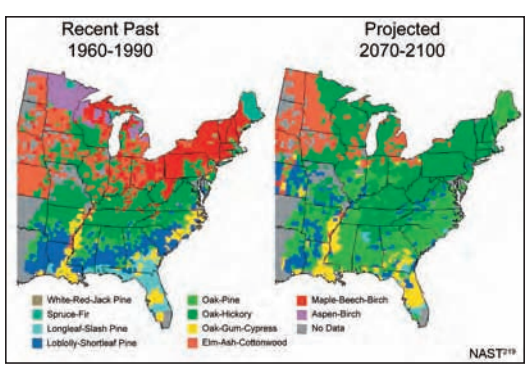
PREDICTING A FUTURE FOR AMERICA'S FORESTS.

By Cristina Santiestevan

Later this year when the U.S. Department of Agriculture releases its first official update of its 1990 map of plant-hardiness zones, expect to see drastic changes. Map makers will attribute many of the zone boundary changes to the massive increase in temperature data, and to major advances in computer mapping technology. But that is only part of the explanation. "The type of climate we have for plants now is what we had 20 years ago, but roughly 200 miles to the south," explains Katharine Hayhoe, a climate scientist at Texas Tech University who develops models to predict future climate impacts around the country. In other words, the hardiness zones on the old map are now off, in some cases by as much as 200 miles.

The USDA map was not at fault. Shifting plant-hardiness zones are also a reflection of actual on-the-ground changes in ecosystems across the country. Climate change — with its associated myriad impacts — is rewriting the American landscape.

Already, average temperatures in the United States have risen more than 2°F in the past 50 years, opening new habitats for some species, while driving others from regions that have suddenly grown too hot. In New England, for example, whole suites of species are climbing farther up slopes and closer to the Canadian border. One recent study found that the border between boreal and hardwood forests has already climbed approximately 100 meters (300 feet)

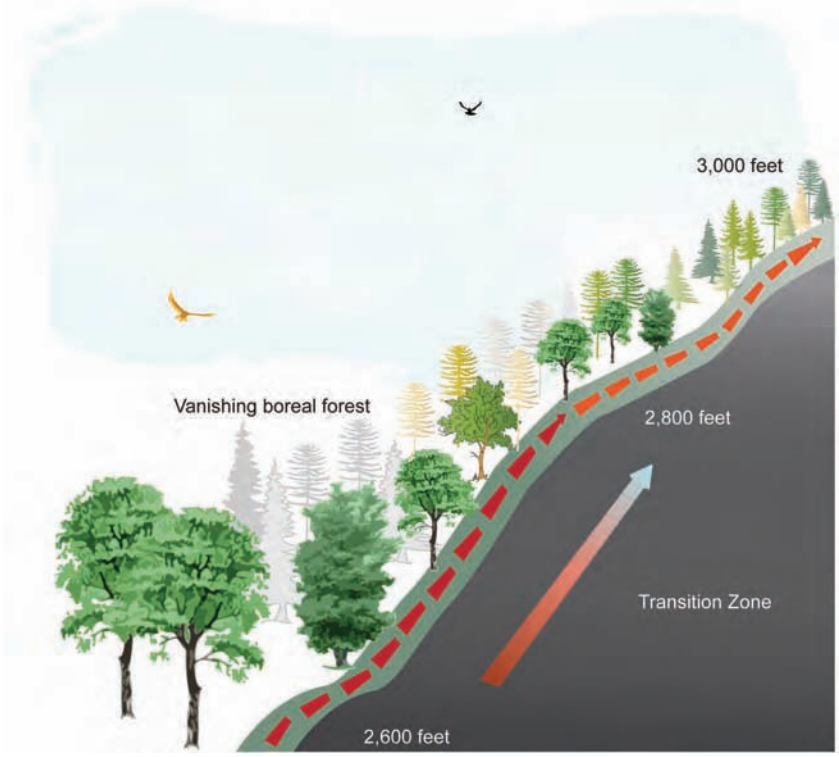


U.S. GLOBAL CHANGE RESEARCH PROGRAM

These maps show the current and projected changes in forest types in the U.S.

higher into New England's mountains over the past 40 years. This upward climb is expected to continue.

The migration is driven by two factors — the loss of once-suitable habitat that has grown too warm, and the gain of once-unsuitable habitat that is now warm enough to support a new suite of species. Each species responds differently, depending on its temperature tolerances and other ecological needs. The iconic sugar maple, for example, could decline by more than 50 percent in New England as warmer temperatures weaken the trees and allow more southerly competitors to invade. Eventually, much of New England's classic maple forest could be overrun by oaks and hickories: temperate trees that currently dominate the forests of Virginia, West Virginia, and similar latitudes. Likewise, the sugar maple and its cohorts are steadily encroaching on the territory that once belonged solely to the firs and spruces. In time, New England's blazing fall color — largely fueled by the sugar maple's bright orange-red foliage — could be confined to the tallest peaks. Or, possibly, Canada.



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Warming climates make New England's evergreens, which are adapted to cooler conditions, more susceptible to competition from hardwoods, effectively moving the species' ranges north or to higher elevations.

Across the country, rising temperatures are also beginning to affect a particularly remarkable group of trees. California's coast redwoods are the tallest trees in the world, sometimes reaching more than 320 feet toward the heavens. In fact, the world's tallest known tree is a coast redwood that measures just over 379 feet tall. The tree is called Hyperion, after the Titan god of Ancient Greece who was son of Gaia and Uranus — literally Earth and Sky.

Despite their mythological proportions, coast redwoods are held captive by the subtleties of fog. The California fog belt, which stretches from southern Oregon to California's Monterey County, encompasses the entirety of the coast redwood's range. During California's dry summer months, coast redwoods acquire more than half of their water from this fog.

The prevalence of fog in this region is an accident of geography, winds, and sea currents — fog forms along California's coast when warm, moist air interacts with the region's cool ocean waters. Anything that affects this balance between air moisture and water temperature can impact fog formation. Climate change could tip the scale from either side: warmer summers can both strip the air of its moisture and increase sea surface temperatures, either of which could hinder fog formation.

Recent research indicates that fog production has already declined by as much as 50 percent within the past century, suggesting that climate change has already begun to make an impact here. The implications for redwoods are dramatic, although the results will probably move too slowly for any one human to witness. Drier conditions affect the growth and survival of redwood seedlings more than mature trees. As a result, mature redwoods may stand for centuries past the point when their forests have grown inhospitable to seedlings. Only after these giants begin to perish without replacement will the impacts of climate change be fully realized.

Or change could come much faster, in the time required for lightning to spark a fire in bone-dry forest debris. Fire is a regular visitor to California's ecosystems. Even the moist redwood forests burn, on average, every six to eight years. Current predictions and past evidence suggest that such fires will become more frequent and more fierce in the coming years. For example, fires raged in the Sierra Nevada's giant sequoia groves every two to three years during an unusually warm period between the years 1000 and 1300, rather than the more typical three- to eight-year cycle. A similar change could be seen in today's coast redwood forests.

Mature redwoods are rarely killed by forest fires, but understory plants — including redwood seedlings — are more vulnerable. And even established redwoods may be felled by repeated fires, which can carve out cavities in the heart of some trees. These hollowed trees are weakened by repeated fires and eventually fall. Such events will open gaps in the redwood canopy, allowing light to reach the forest floor and perhaps speeding the establishment of new understory plants. These, in turn, would also affect the fire cycle.

Fire may also be the ultimate change agent in the Rocky Mountains, where the kindling and tinder are already provided. From Mexico to British Columbia, the diminutive mountain pine beetle — roughly the size of a grain of rice — has been decimating whole forests of lodgepole and ponderosa pine. The beetle has already killed 6.5 million acres of pine forest in

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Light plays through the fog that sustains these massive coast redwoods in the Del Norte Coast Redwoods State Park

the U.S., and an astonishing 14 million acres in British Columbia. Ultimately, the beetle is expected to destroy almost every individual ponderosa and lodgepole pine with a diameter greater than five inches. This amounts to 80 percent of British Columbia's pine forest.

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Wildfires like this one in Yellowstone National Park could become a greater threat as changing climates allow for conditions and pests that make the forests more susceptible to fire.

The beetle is no introduced pest — it has co-existed with these pines for ages. And while this is not the first time the bark beetle has killed trees, or even whole forests, this may be the first time the devastation has been so ferocious.

The difference is not the beetle, but the climate. Healthy pines are able to withstand beetle attacks by flooding their tunnels with sap. But these trees are not healthy. Drier and hotter conditions associated with climate change have left the trees weak and vulnerable to attack. The beetles, however, are thriving under the changing climate. Earlier springs and later falls grant the beetles a longer growing season, while less severe winters have freed the beetles from their greatest population control device—a hard freeze.

Combine the exploding pest population with weakened hosts, and the current infestation becomes understandable.

It is almost impossible to predict what the future holds for the ponderosa and lodgepole pines, so recently the dominant trees along the full length of the Rocky Mountains. While the smallest trees are expected to survive the beetles, they could still fall victim to raging forest fires that many forest managers worry will begin to plague the region as more and more trees die. And sudden deforestation — with or without forest fire — is also likely to result in dramatic erosion, which will redistribute topsoil and essential nutrients.

Some evidence suggests that ponderosa pines currently found in the Cascade Mountains will shift more toward the Pacific Northwest, where they could increase by 5 to 10 percent over the next 100 years in Oregon, Idaho, and Washington. A similar shift toward cooler and wetter regions could also be seen within the Rocky Mountains. The ponderosa saplings that survive the beetle attack may be the last of their kind in some areas, as more drought- and heat-tolerant species expand into the region.

Confronted with warming temperatures, changing precipitation patterns, and rampaging pests, ponderosa pines are at least spared one known climate-change impact — rising sea level. Sea-level rise is one of the most predictable and dramatic consequences we can expect to see as a result of climate change. And while most trees and forests will be spared, mangroves are already suffering the effects of the rising sea level, a problem climate scientists agree will worsen in the coming decades.

"We're probably looking at three feet of sea-level rise over the next 80 to 90 years," says Hayhoe. "Most of the Keys and the Everglades will be pretty much completely flooded."

Three feet of sea-level rise is more than many mangroves could survive in their present location, and whole forests will need to migrate inland with the rising waters. In the Florida Everglades, for example, mangroves are expected to claim more than 600,000 acres of new habitat. This gain, however, does not consider mangrove habitat that will be lost. The same rising waters that will create more than 600,000 new acres of mangrove-suitable habitat inland will also swallow whole swaths of existing mangrove forest along the current coast. In many areas the water will simply be too deep to support mangrove trees.

The Everglades — the largest protected mangrove forest in this hemisphere — are a unique example. Many mangrove forests, however, are not protected. These trees are often bound by human development — caught between the water and an impassable barrier of concrete and asphalt — and will have few opportunities for inland migration as sea level rises. Some mangrove forests may be reduced to small patches of trees. Others could disappear altogether.

MIKADX/ISTOCK

Mangroves like these in Florida's Everglades National Park will face many obstacles with changing climate conditions.

No good models exist yet to predict the future range of mangroves along the U.S. Gulf Coast. The trouble with predicting the future — for mangroves, redwoods, or any species — is the vast number of variables that must be considered. Mangroves, for example, will be confronted with a long list of threats that include rising sea level, increasing temperatures, more frequent and violent storms, and human habitat alteration. In some areas, natural or human-influenced subsidence and erosion are also important factors, effectively accelerating sea-level rise.

The threats associated with climate change vary from species to species and habitat to habitat, but one thing remains constant: no tree or forest is affected by just one thing.

"It's not just one factor," explains Hayhoe. "It's all the confounding factors, each of which is negative. They just add up on each other." The cumulative effect is difficult to predict, and often devastating to the species it affects.

Amid these complexities, some things are certain. Temperatures will continue to rise. Sea levels will continue to encroach on the shore. Altered precipitation, migrating pests, and more frequent and violent storms will remain with us far into the future. "These trends will just continue," says Hayhoe. And as long as they continue, our forests will continue to respond.

We think of forests as timeless places where life holds still. But this is no more than a comforting fallacy, born of the contrast between our short attention spans and trees' great patience. Forests do change, albeit slowly. Trees shift their ranges via windblown seeds, buried acorns, and flocks of hungry birds. As our climate continues to change, these natural migrations will be pressed to keep pace with shifting temperature extremes and precipitation patterns. Some trees could expand their ranges mightily, while others could disappear almost entirely from the American landscape.

Ultimately, climate change will draw new lines between species and ecosystems. Some changes may be subtle and hard to notice, such as the gradual decline of coastal redwood forests over the coming centuries. Other changes will be hard to miss, such as the absence of blazing sugar maple trees in much of New England's autumn landscape.

"If you haven't seen changes yet, you probably will soon," says Hayhoe. "If you are a careful observer, you probably already have."

Cristina Santiestevan writes from the foothills of Virginia's Blue Ridge Mountains.

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