

Climate change may spur loss of mountain meadows, forest shifts

by [Sarah Gilman](#)
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GOthic -- This story of climate change begins with salamanders and ends with a creeping tide of sagebrush and lodgepole pine.

When University of California-Berkeley ecologist Dr. John Harte first began working at the Rocky Mountain Biological Lab near Crested Butte in the late 1970s and early 1980s, he climbed each summer to a notoriously beautiful place called Mexican Cut - a high-altitude preserve encompassing a string of glacial tarns -- to study the effects of acid rain on the lakes and the area's resident salamanders.

At the time, Harte recalled, acid rain -- the result of atmospheric sulfur and nitrogen compounds produced during fossil-fuel combustion -- was the en vogue environmental cause, a literal scourge of plants and animals, including Harte's amphibians. But the scientific community was only just beginning to buzz about the prospect of global warming, and its existence, causes and consequences were still a matter of hot debate for scientists around the world.

"There was not yet any discussion of what would happen to ecosystems under warming," Harte said. "I realized that global warming was very likely going to be a serious threat to the salamander population. If their ponds dry up, these guys are screwed."

Indeed, such changes would have sweeping implications for all sorts of species, plant and animal -- presenting another interesting question about what the future might hold.

The challenge, he said, was finding out through empirical data -- rather than just abstract computer models -- what climbing temperatures might mean for living things.

So was born Harte's warming meadow -- a curious network of electrical heaters suspended at regular intervals over the wildflowers and shrubs of a high-mountain field near the former silver mining town of Gothic, about 12 miles south of Aspen across the Maroon Bells-Snowmass Wilderness area, where the Rocky Mountain Biological Lab has operated for the last 80 years.

Every year since the experiment's inception in 1990, Harte has racked up a hefty electricity bill (\$6,000 annually at last count) heating parts of the meadow by an extra two degrees Celsius -- a conservative change that climate scientists once

predicted would happen around the year 2050. The meadow literally prickles with moisture and temperature sensors that feed information back to data loggers Harte calls "the brains," while Harte and a team of graduate students and research assistants periodically comb through the vegetation -- counting flowers, measuring plant growth rates, and getting biting flies up their nose.

It's elegant as experiments go: through winter and summer for 17 years, the meadow has baked, its soils dried out, and its snow melted out ever earlier, just as would happen in a warming world.

So what might our warmer mountains look like?

The heated portions of Harte's meadow, which is located well over 9,000 feet above sea level, are being taken over by a desert tangle of sagebrush and other shrubs.

"There's no longer any controversy among real scientists" about the coming onslaught of climate change and its link to humans, he said. And if we don't rein in our fossil fuel use, Harte sees a bleak future for high mountain meadows over the next century. Picture a campy spaghetti western in unholy union with the "Sound of Music" -- Maria traipsing and spinning across sere sagebrush mountaintops, the stomping grounds of sweaty Nevada cattle rustlers, instead of the verdant grass and wildflowers of the Alps.

"If this were the only experiment in the world, you'd say 'OK, it's true for a Gothic meadow, but so what?'" Harte said.

But other scientists share similar visions, and studies in other locations, from Stanford's Jasper Ridge grassland in California to sites in Abisko, Sweden, on the Tibetan Plateau, and a broad smattering of other places, point to significant changes in plant communities, even in the way plants move nutrients to and from the soil, as a result of experimental warming on the scale of one or two degrees Celsius.

THE CARBON CONUNDRUM

But there is a more interesting, alarming story at work behind the heartbreaking changes Harte predicts for Rocky Mountain meadows.

As sage takes over and wildflowers such as larkspur and showy fleabane daisy struggle to exist under Harte's heaters, producing as little as one-third the flowers of the same plants in unheated portions of the warming meadow and growing at much slower rates, the carbon content of the soil itself is changing.

Since the experiment began, the heated portions of the meadow have lost 20 percent of their soil carbon.

"That's a big deal, because a loss of soil carbon means a gain in atmospheric carbon," and an escalation of warming brought on by warming itself, Harte explained.

It turns out wildflowers "are responsible for pumping most of the carbon each year into the soil here," Harte said. Hyperactive photosynthesizers, they pull carbon dioxide, that most notorious of greenhouse gases, from the air and convert it into sugars for food, stems, leaves and blooms, then exude it into the soil via roots. Once dead, various critters eat and mulch these plants back into the soil, where their carbon lies banked for a time before it is eventually released back into the atmosphere by the microorganisms responsible for decay.

"Sagebrush is a much slower, sluggish player in terms of turnover in the carbon cycle," explained Harte. And without that speedy influx of carbon into the soil, "it's like you have a bank account that's shrinking over time, not because you are withdrawing more money, but because you're putting less in each year."

If carbon dioxide levels in the atmosphere double, as some scientists predict will happen this century, based on current emissions and growth -- we could see average temperature increases between three and eight degrees Fahrenheit around the world (a range confirmed in the recent Intergovernmental Panel on Climate Change report), Harte said. Soils hold five times as much carbon as the atmosphere, he explained; and if predicted warming leads to the loss of one fifth of soil carbon -- as happened the warming meadow -- it could ultimately mean a tripling of atmospheric carbon, and even higher temperatures.

Indeed, Harte is beginning to see nature mimic the results of his experiment. Areas of the warming meadow that have not been artificially heated -- known in science speak as control plots -- have also begun to lose a significant amount of soil carbon. Harte's analyses show this is likely due to drought-like conditions in the area over the last five years, resulting in a warming and drying of the soil and the beginning of a shift into sagebrush.

TIDE OF FORESTS

Fortunately, though sagebrush is slow to photosynthesize, Harte predicts that the long-lived plant may ultimately be able to recover some or all the carbon content of the soil from the atmosphere if given enough time, in part because its shed leaves and twigs take longer for microorganisms to break down.

But there's a different dynamic at work in some conifer forests, which wrap high mountain ranges and wreath a large part of the Northern Hemisphere in an ecological zone called the Taiga.

Studies of pollen records from the soil of Yellowstone and elsewhere indicate that lodgepole pine forests, which favor warmer, drier places, have tended to creep uphill during past warming cycles, gradually replacing the fragrant spruce and fir forests one usually finds at higher altitudes in the Rockies, where it is cooler and wetter.

On a purely aesthetic level, some might not like the prospect of claustrophobically close-growing, scrappy lodgepole pines expanding their range. But such a shift also has much more major implications for the delicate balance between soil and atmospheric carbon than what Harte has observed with sagebrush.

A few years ago, Harte and then graduate student Dr. Lara Kueppers -- now a professor in her own right at University of California-Merced -- analyzed soil carbon and other factors along a climate and elevational gradient from lower-altitude lodgepole pine forest, through higher spruce and fir, all the way to treeline in the Fossil Ridge Wilderness near Gunnison. What they found, Harte said, is that the pine does not bank nearly as much carbon in the soil as spruce and fir, and it also breaks down more quickly -- meaning a faster turnover back into the atmosphere.

A shift from spruce and fir to pine brought on by climate change would lead to a loss of 50 tons of soil carbon per hectare (about 2.5 acres), according to Kueppers' and Harte's findings. Lodgepole pine forest could plausibly overtake perhaps a third of Gunnison County's 120,000 hectares of spruce and fir forest given current warming projections, Harte said -- meaning a loss of 2 million tons of carbon from the area's soil into the air over time as warming increases.

"For comparison, that is the annual carbon emissions from 280,000 people in the U.S.," he said.

SOBERING

After years of research, the questions that started with a few salamanders and a curving swath of verdant mountain meadow have turned out answers with global implications.

"Climate models are physics-based models. They're really good at the thermodynamics and physics of climate, but they don't have biology in them," explained Harte, who is also a physicist by training. But when you insert the messy business of life into the equation, you begin to see feedback loops -- cascades of warming-triggered effects that can themselves bring on more warming -- that suggest "global warming is going to be a lot worse than we project it to be," he said. "Instead of that upper limit of seven or eight degrees average increase (in temperature), we could be looking at 12 or 13."

As far as our mountains go, Harte said, "people can grasp the idea that over evolutionary time and paleo-climate time, these changes can occur. But we're talking 50 to 100 years now. And maybe even faster."

But even faced with the dire prospect of Maria (from "The Sound of Music") prancing through sage instead of wildflowers, Harte has some hope.

"I know we have the knowledge and the technologies today to solve this problem," he said, adding that the combination of conserving energy, pushing renewable

energy, and stopping deforestation could do the trick, if we have the will.

"My worries about the future are really worries that corporate interests will impede solutions," he said.

Editor's note: This is the third installment of a series of articles on climate change. The first two stories may be found at www.aspendailynews.com. Click on the archives search link, then enter "Inouye" into the text search box.

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