How alpine plants respond to climate change

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Credit: ETH Zurich

Researchers from ETH Zurich are studying how alpine vegetation is responding to a warming climate—and how some plant communities are continuing to stand firm against newcomers from lower elevations.

A glance down the vertiginous slope is enough to create a dizzying sensation of being airborne. Far below is the city of Chur, with tiny cars beetling among toy houses. Keeping a firm grip on the wheel, Jake Alexander ascends the potholed road, which in many places is too narrow for two vehicles to pass.

His destination is Chrüzboden, an alpine meadow situated above the tree line on the Haldenstein peak of the Calanda massif, some 2,000 meters above sea level. It's a popular day trip from Chur, but Alexander is here in his role as Assistant Professor of Plant Ecology at ETH Zurich. For the past 15 years or so, he has been conducting experiments to better understand the effects of climate change on alpine flora.

Calanda is the perfect location for this kind of research. Over the space of 5 kilometers, it encompasses the full range of altitudinal vegetation zones in the Alps, from the colline zone on the valley floor to the alpine belt at its 2,800-meter peak. The entire massif is remarkably uniform in both aspect and geology—and the whole area lies within easy reach of Zurich. "We should really set up an alpine research station here; that would be fantastic!" Alexander says.

To cover the full span of altitudinal zones, he and his colleagues have set up multiple experimental sites at different elevations. The highest, Chrüzboden, is at 2,000 meters; the lowest is at 1,000 meters. The other sites are located at 200-meter intervals between the two.

After a climb of some 1,400 meters around countless hairpin bends, we finally reach Chrüzboden. It's June, and the cows are grazing among flowers of every shape and hue, meandering between patches of yellow, pink and purple.

Alexander parks the car and heads uphill to a patch of meadow that is protected from the cattle by an electric fence. Inside the fenced area are his research plots. Some of these are enclosed in open-topped Perspex chambers, which provide passive heating to simulate global warming.

The researchers are studying how plant communities at high elevations respond when confronted with species moving up from lower elevations. Previous research has shown that, on average, mountain regions are warming twice as fast as the rest of the world. This creates potential for certain species to extend their habitat, either to higher elevations or higher latitudes such as in the Arctic. Alexander's previous studies have shown that often alpine plants seem unfazed by global warming itself yet may struggle to cope with competition from new species migrating up the mountain.

Bigger and faster

Sooner or later, this could lead to changes in the species composition of today's alpine and subalpine plant communities. New species mean new interactions—and because plants from the lowlands are bigger and grow faster, they are literally leaving smaller alpine species in the shadows. "A warmer climate gives them a competitive edge, and they're threatening to displace alpine species," says Alexander.

Species that migrate to the summits generally face less competition for space, light, water and nutrients because vegetation tends to be sparser at such high elevations. But the situation is different at the tree line, where species ascending from lower elevations encounter meadows and pastures with almost no gaps in the vegetation. These communities of plants have evolved over centuries—time enough for countless interactions to have emerged between individuals and species, including with microorganisms such as soil bacteria and fungi.

Project leader Professor Jake Alexander is investigating whether meadow flowers from lower elevations can thrive at 2,000 metres. Credit: Peter Rueegg / ETH Zurich

At current levels of warming, new species might find it tough to gain a foothold, at least at first. But, as the climate gets hotter, they will gain a competitive edge—and, as plant species from the lowlands establish themselves, they will cause a shift in both the composition and myriad interactions of the original plant community. This is a phenomenon the researchers have already observed in experiments at their site at 1,400 meters.

"We want to discover how resistant today's plant communities are against newcomers. We also want to find out whether species from lower elevations can already establish themselves higher up the mountain and, if not, what's stopping them," says Alexander, as he surveys an experimental plot filled with a profusion of meadow flowers.

The researchers first removed all the original vegetation from the square-meter plot. They then planted the bare soil with ten different species that are predominantly native to low and medium elevations, including meadow sage, brown knapweed and bladder campion.

Alexander turns his attention to another densely vegetated plot, pushing the foliage apart with his hands. Buried in the middle is a brown knapweed plant, identified by a colored plastic toothpick. Unlike its peers in the bare plot, this plant is small and bears a solitary flower. "It's having a hard time competing against its new neighbors," he says. "But, in principle, it's certainly capable of growing at this elevation in today's climate."

Animal transport

However, the conquest of alpine or subalpine habitats by plants from lower altitudes is slower than expected, says the ecologist. He suggests that as well as resistance from existing vegetation, this may partly be due to the plants' poor dispersal abilities. Some have seeds that can be carried by the wind, but those that don't tend to rely on animals to disperse their seeds. For example, studies have shown that cows transport germinable seeds in their gut.

One of Alexander's Master's students will soon be embarking on a project to determine whether deer and chamois also disperse the seeds of certain plant species. Ultimately, these data should flow into mechanistic models that will help scientists predict changes in plant communities, including climate projections as well as dispersal mechanisms, interactions between plants, and the ways in which they evolve.

Alexander is already heading back down to Haldenstein and Chur, carefully navigating the car towards the houses far below. Reaching a hairpin bend, he takes a right turn to inspect their experimental site 1,400 meters above sea level. He parks the car at the end of the road and walks the last few hundred meters up a track. Soon he's standing on the edge of a large clearing known as Nesselboden. It's noticeably warmer here than 600 meters further up. The average temperature changes by approximately 0.5 degrees Celsius for every 100 meters of elevation, so a simple calculation suggests the air around us is now 3 degrees warmer. This, then, is the climate that alpine plants will be confronted with in the future.

Struggle for resources

The meadow flowers transplanted to this plot are even more exuberant, flourishing both in isolation and in the presence of existing vegetation. They clearly have no difficulty competing with other plants that are native to this elevation. But things look rather different in one of the other square-meter patches of soil. As part of an earlier experiment a few years ago, the researchers transplanted the soil and its community of plants from 2,000 meters to this site at 1,400 meters, effectively catapulting them into the climate of the future.

The patch is dominated by alchemilla, more commonly known as lady's mantle. "This species clearly has no problem with the new climate. But some of the other alpine plants that were transplanted at the same time have already lost the battle for resources against competitors who are better adapted to warm temperatures," says Alexander, raising a hand to shield his eyes from the setting sun. "So, assuming it continues to get warmer and drier at higher elevations, this is what the plants up there will be facing." Whatever the case, he says, they intend to study these research plots in the Nesselboden clearing for at least ten years to verify whether their predictions of how plant communities will change are accurate.

Alexander's research will eventually reveal exactly how the flora on Calanda will evolve. But it certainly seems that change is inevitable—and that plenty more patches of white, violet and yellow flowers will soon be dotted across today's alpine meadows.

Provided by ETH Zurich

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