Less forest, more species: Declining biodiversity in Tibet in response to climate change

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Normally, mountain forests are among the most diverse habitats in alpine regions. Yet, as a team from the Alfred Wegener Institute discovered in the Tibetan Plateau, the higher, treeless areas are home to far more species. Their findings, which were just published in the

journal *Nature Communications*, can help to predict how the biodiversity of alpine regions will decline in response to global warming—when the mountain forests spread to higher elevations.

As anyone who has ever hiked in the mountains knows, the landscape changes with the elevation. At first, for a long time, you trek uphill through forests, until they open up into the first meadows and pastures, where a wide range of plant species bloom in the spring. Farther up, the landscape becomes more barren. Only those plants that have adapted to the alpine climate can thrive there. In order to map the vegetation of the alpine world, biologists most often investigate plant diversity along so-called elevation levels. First they examine the plants in the sprawling forests, then in the alpine meadows, and then in the rocky upper reaches. No matter where researchers do so—in the Alps, the Caucasus or the Rocky Mountains—the results are always similar: the extensive forests are the most species-rich region. With increasing elevation, biodiversity steadily declines.

More species in treeless areas

A team led by biologist Prof Ulrike Herzschuh from the Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research (AWI) in Potsdam has now concluded that this thesis isn't necessarily correct: Forests by no means have to be the most diverse part of alpine regions. If the evolution of mountain ranges in the course of millennia is considered, it becomes clear that the landscape above the treeline contains many more species than the mountain forests. As Herzschuh and her colleagues report in the journal *Nature Communications*, they succeeded in reconstructing the evolution of plant diversity in the Tibetan Plateau over the past 17,000 years. When, in colder phases, the forests retreated to lower regions and the treeline followed suit, the alpine meadows and alpine landscape grew—and with them, the number of species. In warmer phases, the forests spread higher, and the number

of species declined. "If we assume the same size, there are more species in the treeless higher areas than in the forests," says Herzschuh. "This also came as a surprise to us, since conventional studies, which always reflect the elevation levels, have always indicated just the opposite."

Broader range of habitats

The study's authors don't yet have a definitive explanation for their discovery. "However, it's safe to assume that there are now more species in forest areas because they're more extensive than the more barren areas near mountain peaks," says Sisi Liu, first author of the study and member of the AWI's research section Polar Terrestrial Environmental Systems. As a result, today, there is much more forest available, which can contain various types of habitat, like glades and forest streams. The researchers surmise that if the alpine areas were larger instead, the result would be far more diverse habitats than those found in the forests—shady-moist and sunny-dry areas or sparsely vegetated, nutrient-poor areas and loamy soils—and therefore, a wide range of settings for diverse flora.

Ancient sediments from a Tibetan alpine lake

The southeast Tibetan Plateau is one of the most species-rich mountainous regions in the world, and a so-called biodiversity hotspot. Further, since the region is at such a high elevation, at the end of the last ice age, it was heavily glaciated; it was only with the gradual warming of the planet that the forests reclaimed parts of the Plateau. In order to determine how biodiversity changed with the disappearance and return of the forests, Herzschuh and her team assessed the sediments from an ancient lake in the Hengduan Mountains of eastern Tibet. Since the lake was formed after the last ice age, sand, dust and plant remains had gathered there for over 17,000 years. The researchers extracted ancient

fragments of DNA strands from the sediments, allowing them to identify which plants lived there at which times. They then combined these biological findings with analyses provided by a mathematical ice model, which can be used to reconstruct the glaciers' changing positions. Herzschuh says, "With the aid of an ice model developed by our colleagues at the German Research Center for Geosciences in Potsdam, we were able to precisely trace how the plant community changed with the elevation of the glacier and the shifting treeline."

More forest means less diversity

Interestingly, ca. 8,000 years ago there was a warm phase in which the forests spread further uphill than today—and the number of species to be found in the sediment record declined significantly. The findings gleaned by Herzschuh, her Ph.D. candidate Sisi Liu and other colleagues are important in terms of our ability to predict how the biodiversity of mountainous regions around the world could be impacted by climate change; what they learned about the situation in Tibet can also be applied to other alpine regions. "Our data could potentially help to develop new management strategies for combatting the loss of diversity," says Herzschuh. In any case, she claims, the stereotypical image of the mountain forest being the most species-rich type of region needs to be critically reconsidered.

More information: Sisi Liu, Stefan Kruse, Dirk Scherler, Richard H. Ree, Heike H. Zimmermann, Kathleen R. Stoof-Leichsenring, Laura S. Epp, Steffen Mischke and Ulrike Herzschuh: Sedimentary ancient DNA reveals a threat of warming-induced alpine habitat loss to Tibetan Plateau plant diversity. *Nature Communications* (2021), DOI: 10.1038/s41467-021-22986-4

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