

Islands in the sky: How isolated are mountain top plant populations?

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This is *Penstemon pachyphyllus* and a bumblebee. Credit: Courtesy of Andrea Kramer, Chicago Botanic Garden.

Do mountain tops act as sky islands for species that live at high elevations? Are plant populations on these mountain tops isolated from one another because the valleys between them act as barriers, or can pollinators act as bridges allowing genes to flow among distant populations?

Dr. Andrea Kramer and colleagues from the Chicago Botanic Garden and the University of Illinois at Chicago were interested in pursuing these questions, particularly for a genus of plants, *Penstemon* (Plantaginaceae), endemic to the Great Basin region of the Western United States. They published their findings in the January issue of the

[American Journal of Botany.](#)

The flow of genetic material between populations maintains a species. In plants, if populations are separated by a landscape barrier such that pollen or seeds are unable to traverse either over or through, then the populations will begin to differ, either via mutations or genetic drift over time. However, [habitat fragmentation](#) and distance may not always be barriers, depending on the species and their modes of dispersal. And sometimes studies surprise us with their findings.

"These questions become increasingly important in places like the Great Basin as we consider the effects of climate change on native plant communities and the wildlife that depend upon them," Kramer commented. "The majority of the Great Basin region's [species diversity](#) is located on mountain tops, and as a generally warming climate drives species to higher elevations, the distance between mountaintop [plant populations](#) increases and more is required of the pollinators in order to traverse the arid valleys between them."

Kramer and her colleagues chose *Penstemon* because these plants provide critical resources for pollinators and other wildlife. But, as Kramer notes, "Until recently they haven't been used in large-scale restoration projects because key research needed to guide restoration of these species hasn't been available. Without an understanding of the population genetic structure of natural populations it is very difficult to determine what seed sources should be used where to ensure maximum success of a restoration."

The authors selected three *Penstemon* species with similar dispersal modes, a key element to the study design. For all three, seeds are dispersed by gravity and are not likely to be moved very far—thus, any long-distance movement of genes (or gene flow) should primarily be due to movement of pollen. This critical aspect is where the species differ:

Penstemon deustus and *P. pachyphyllus* are both pollinated primarily by bees, while *P. rostriflorus* is pollinated primarily by hummingbirds.

For each species the authors were able to sample individuals from 6 to 8 populations on 4 to 6 mountain ranges. By extracting genomic DNA from leaf tissues and using molecular analytical tools they identified up to 8 polymorphic microsatellite loci and used these data to determine patterns of gene diversity both within each population on a mountain top and between more distant populations found on other mountain tops. They then pieced this information together to assess the degree of genetic relatedness among the different populations.

The authors found interesting differences between the bee- and bird-pollinated *Penstemon*. Although all three species had significant genetic differentiation among the populations, the two bee-pollinated species were found to have genetic clusters that were distinct for each mountain range, with little or no mixing between mountain ranges; the bird-pollinated species had far less genetic structure across all the ranges sampled. Thus, hummingbirds seem to be more effective at crossing large distances and pollinating flowers from distinct mountains than bees. Bees either do not cross the arid valley floors to visit populations on neighboring mountains or, if they do, they may be ineffective at transferring pollen across these long distances. In contrast, hummingbirds may be transferring pollen across very large distances—additional analysis indicated that hummingbirds may be visiting populations 19 km apart within a mountain range and over 100 km apart on different mountain ranges.

One of the take-home messages from this is that the interaction between pollinators and their landscape differs for different species, and yet this very interaction can have a significant impact on the genetic structure of a plant species' populations. In addition, their results suggest that pollination syndromes do not just capture the morphology and likely

pollinators of flowers, but may also impact the population structure and genetic isolation of populations.

There are evolutionary implications as well. Hummingbird pollination has arisen independently in *Penstemon* at least 10 times, and possibly as many as 20 times, yet a shift back to bee pollination has never been reported. The results from this study may shed light on why that might be. Because populations of a bird-pollinated plant experience greater gene flow among distant populations, there is greater connectivity among these populations. Any changes that might arise due to the local presence of bees would be negated by the gene flow facilitated by birds, which would constrain any adaptations at the local level and prevent plants from shifting back to a more confined bee-pollination syndrome.

Furthermore, the results from Kramer's work can be used directly in restoration efforts. "The Bureau of Land Management is working to increase the species diversity and success of large-scale restoration work on public land in the western United States," Kramer notes. "The BLM supported this work and will be able to put the results of this research on *Penstemon* to use in developing seed transfer zones for these and similar animal-pollinated [species](#)."

Kramer's next step is to determine whether the patterns of neutral genetic diversity they identified translate to similar patterns in adaptive genetic diversity. "The [Great Basin](#) is an amazing place full of incredible climatic and geological extremes, and we are very interested in understanding how these extremes drive population divergence due to, or in spite of, the differences in gene flow we observed," she said.

More information: Andrea T. Kramer, Jeremie B. Fant, and Mary V. Ashley (2011). Influences of landscape and pollinators on population genetic structure: Examples from three *Penstemon* (Plantaginaceae) species in the Great Basin. *American Journal of Botany* 98(1): 109-121.

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