Shootingstars provide clues to likely response of plants to global warming

April 11 2011

A study of two rare species of shootingstar that grow in cliff habitats, the jeweled shootingstar (middle) and French's shootingstar (right) asked whether these are true species, glacial relicts now confined to refuge habitats, or variants of the widespread Mead's shootingstar (left) that adapted to the cliff microclimates. Credit: Brad Oberle

Many scientists are concerned that plant and animal species may face extinction due to global warming, but biologists at Washington University in St. Louis are trying to predict exactly what will happen to them. Which species will migrate? Which evolve? Which change their behavior? Which become extinct?

Rather than peer into the future, they are looking backward, exploring how species alive today survived global warming at the end of the Pleistocene and asking whether their responses provide any guidance for us today.

For his dissertation Brad Oberle, a doctoral candidate in biology in Arts & Sciences at Washington University in St. Louis, delved into the post-Pleistocene history of three species of shootingstars (Dodecatheon).

Dodecatheon is a genus of flowering plant in the Primrose family, the petals of whose nodding flowers flex upward, giving the flowers the appearance of a star falling to earth, trailing flames behind it.

Two of the species, the jeweled shootingstar (*D. amethystinum*), and French's shootingstar (*D. frenchii*), are rare and grow only in cliff habitats.

Are the rare species glacial relicts, species adapted to the cool wet conditions during the Pleistocene that gradually retreated to smaller and smaller refuges as the climate warmed? Or were they ecotypes, local variants of a widespread species, Mead's shootingstar (*D. meadia*), that had adapted to cliff microclimates but were genetically similar to Mead's shootingstar.

"As is typical of science," says Barbara A. Schaal, PhD, the Mary-Dell Chilton Distinguished Professor of biology in Arts & Sciences, Oberle's dissertation advisor, and his co-author, "the result was mixed. One species is probably a relict species, and the other is probably an ecotype. Some species responded to warming by migrating but other populations apparently adapted in place."

The article was published in the April 5th issue of the *Proceedings of the National Academy of Science* (*PNAS*).

"It's a lovely piece of work," Schaal says.

Why shootingstars?

"On hikes I took as a kid," says Oberle, who grew up in Missouri, "I noticed it felt very different if you were out in a glade, an open habitat with intense sunshine and high temperatures, than if you were down in a hollow, where it's more sheltered, cooler and tends to be a lot more moist. I also noticed that the plant communities in these two places also differed a lot."

"When I was just getting started on my Ph, I read a book called The Terrestrial Natural Communities of Missouri by Paul Nelson.

"One species I learned about, French's shootingstar, specializes in habitats that occur where ledges overhang the bottom of cliffs. These rock houses, as they're called, tend to form in sandstone cliffs because of the way sandstone weathers. The cliff habitats are typically damp and shelter other interesting plants, as well.

"And then, flipping through the book, I found the jeweled shootingstar, another rare species, but one that specializes on limestone cliffs. It usually grows on slopes at the top of the cliffs right before the rock face becomes vertical.

"It also tends to grow in little patches on the rock face itself," says Oberle, who admits both to learning technical climbing to prepare for his fieldwork and to twice falling off cliffs in the field.

"The widespread species, *D. meadia*, is a real mess," he says. "It's a beautiful plant and one that tends to catch a botanist's eye. And almost every botanist that looks at a population of this plant feels that population is special and unique. When botanists have that reaction, they tend to slap a name on the population and call it a new species. Fifty to 100 names have been thrown onto this one species of shootingstar because it's so beautiful, and comes up in the spring when everybody wants to go out and botanize," he says laughing.

The jeweled shootingstar, which prefers cool, moist limestone cliffs, turned out to be a glacial relict and is thus at great risk of extinction from global warming. Credit: Brad Oberle

"The number of species in the genus is still an open question," Oberle says, "but a revision of this genus published a few years ago named 18 species of Dodecatheon in the United States. The revision identified three species in the eastern U.S. and those are the species I worked with."

The relict hypothesis and the ecotype hypothesis

Botanists who believe the rare species of shootingstar are distinct species explain their distribution and ecology as a response to historical climate change.

These species really like cold and moist conditions. They throve

throughout the last glacial period.

"If you roll the clock back to 20,000 years ago, St. Louis was 50 to 100 miles from a glacier that was about a mile thick," Oberle says.

These species were widespread at the last glacial maximum when conditions were cooler, but when the climate started to warm up, they couldn't adapt, so their ranges shrank and they became stuck —i solated in these cliff habitats.

Other botanists, however, think that the shootingstars are just one big jumbled species. If you find an odd-looking shootingstar in a cliff habitat, it isn't because it had some special history, but instead because the cliff habitat has unusual characteristics and the process of natural selection produces local variants that are adapted to those characteristics. So the rare species are ecotypes, plants specialized for a particular habitat, not relicts.

What the hypotheses predict

As Oberle realized, these hypotheses make specific predictions that could be falsified by research.

The relict hypothesis predicts that the relict species will be genetically distinct from any other species in the area. It's doing its own thing and it has its own history and it should be possible to detect that history by looking at patterns of genetic variation.

The relict hypothesis also predicts that far flung populations of the relict species will occur in the same kind of habitat and be genetically more similar to one another than to plants that occur in different habitats, even if those plants are nearby.

The ecotype hypothesis makes a contrasting set of predictions. If the rare species are ecotypes, just local variants of the widespread species, their genomes should not vary markedly from that of another random population of the widespread species.

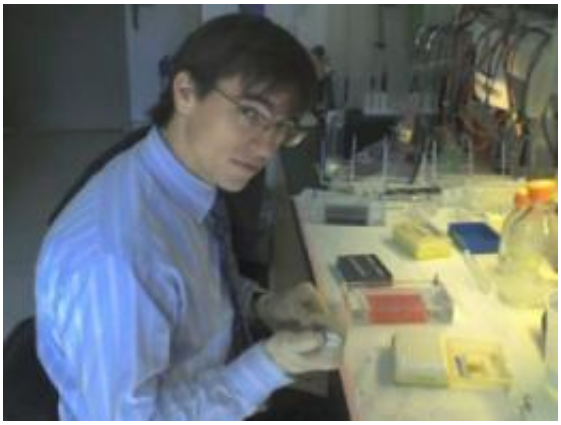
Further, if the rare populations are ecotypes, they should be more similar genetically to nearby ecotypes than they are to distant ones.

The fieldwork

To distinguish between these hypothesesm Oberle collected shootingstars across the eadtern United States, from Pennsylvania to Texas, and from Georgia up to Minnesota.

"One of the ironies of this project," he says ruefully, "was that I was doing this research about global warming and I was driving all over the country to do it. But it was a fantastic trip, and I got to see amazing places and meet very generous people.

"At every location, I'd take GPS coordinates, try to get a sense for how big the population of plants was, and then sample the plants in a consistent way.



This images shows Brad Oberle doing the sequencing work that would reveal the post-glacial history of the jeweled shootingstar and French's shootingstar. Credit: Brad Allen

"I measured a trait called specific leaf area, or the fresh leaf area per unit mass, because it gave me insight into how well the plants were adapted to the habitats where I found them.

"I also grabbed leaves for genetic analysis. I sequenced some DNA from all of the plants, but because DNA sequences don't vary much between plants, I turned to a technique called amplified fragment-length polymorphism (AFLP). That technique tends to be very sensitive; closely related individuals often have very different AFLP banding patterns.

"And finally, I collected a voucher specimen from every population for the herbarium at the Missouri Botanical Garden," Oberle says.

Some relicts, some ecotypes

The results, which ultimately emerged from the genetic work, depended on the species.

"Populations of jeweled shootingstar from Wisconsin and from Pennsylvania are genetically distinct from all other shootingstars in North America and very similar to one another even though they are so far apart," Oberle says.

This suggests the jeweled shootingstar is a relict, a plant that was widespread in the past but whose range has become fragmented and that that now survives only in refuge habitats.

French's shootingstar, on the other hand, is not genetically distinct from *D. meadia* at all, even though these plants look different and grow in different habitats. Although earlier work has showed they were genetically adapted to different circumstances, overall their genomes are very much alike. So French's shootingstar is probably just a simple ecotype of *D. meadia*.

Conservation recommendations

The results suggest that the two rare "species" of shootingstar in the eastern United States should be managed quite differently. Because the jeweled shootingstar is a relict, it's probably hanging on by a thread. If climate continues to warm, it is likely to go extinct.

"Because we know this species is genetically distinctive, the jeweled shootingstar should be a priority for conservation as climate continues to warm," Oberle says.

On the other hand, since French's shootingstar is an ecotype, that suggests that it's capable of adapting to changing climate.

And, because it isn't genetically distinctive, a population of French's shootingstar has the same conservation value as any other random population of *D. meadia*.

But, Oberle cautions, shootingstars may not respond to human-caused global warming as they did to the warming at the end of the last ice age, both because the warming is more rapid and because the habitat is now fragmented.

The sad part

"I was sad to come to the conclusion that *D. frenchii* wasn't really a distinct species, because it is a beautiful plant and it grows in a beautiful habitat, so part of me wanted to recognize the beautiful distinction of it, too.

"My family has owned a farm since the 1860s that is near one of these sandstone cliff habitats. My grandparents and my great-grandparents used to go there in the summertime to rest under the waterfall after working in the fields. And this cliff has a population of *D. frenchii*, one of the few populations in Missouri. So I have a family connection to this beautiful rare plant, and my research showed it is not as special as we thought it was.

"I felt almost as though I had caused an extinction, although the extinction was just an extinction on paper."

Provided by Washington University in St. Louis