# Isolated Torrey pine populations yield insights into genetic diversity

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Study co-first author Alayna Mead, postdoctoral scholar in the Department of Ecosystem Science and Management, stands among Torrey pine trees in southern California. Credit: Penn State. Creative Commons

Entire regions of trees are disappearing because of invasive pests, disease and a changing climate. The key to their ability to adapt to varied growing conditions and, ultimately, their survival, may reside in the complex genetic makeup of replacement trees, according to forest geneticists tasked with reintroducing tree species.

A study of one of the rarest pine trees in the world, Torrey pine, conducted by a team including Penn State scientists, has yielded what the researchers called valuable insight into the value of genetic diversity and the importance of ensuring locally adapted diversity is maintained for restoration. They published their findings in *Evolutionary Applications*.

"To conserve species with extremely low genetic diversity, introducing new genetic variation from one population to another can be beneficial, providing a 'rescue' to facilitate evolution and species adaptation," said team leader and senior author Jill Hamilton, Penn State associate professor in ecosystem science and management and director of the university's Schatz Center for Tree Molecular Genetics. "But we show that in some cases where populations have evolved in isolation, like Torrey pine, caution may be warranted when considering the introduction of new variation."

Critically endangered Torrey pine persists naturally across only one island and one coastal mainland population in southern California. Using a common garden experiment established in 2007 by the U.S. Forest Service Pacific Southwest Research Station that contains trees from both populations and hybrids from interbreeding, the researchers compared fitness between the island population of Torrey pines, the mainland population and hybrids of the two. They identified genetic variants within the two populations that may indicate reproductive barriers have evolved between the island and mainland populations.

To evaluate the genomic and fitness consequences of interpopulation gene flow or "rescue," the researchers extracted DNA from the pine needles of all three groups and sequenced it, identifying regions where the DNA sequence varied among individuals. They evaluated whether some of these genetic regions were responsible for differences in growth and cone production among the island and mainland populations and their hybrids.

Hamilton's research group in the College of Agricultural Sciences has studied the plight of Torrey pine over the last decade and how it may yield lessons that could guide efforts to save tree species in peril in the Eastern U.S. such as ash and American chestnut.

Study co-first author Alayna Mead, a postdoctoral scholar working in Hamilton's lab, noted that the unique history of the Torrey pine makes it an ideal system to study conservation genetics. Its two limited populations have been separated for a long time, and they're adapted to their local climates, she explained. So, if populations have evolved barriers to reproduction, interpopulation rescue via hybridization could negatively impact the fertility and health of hybrid offspring.

"Around 1.2 million years ago, on the coast of California, Torrey pine colonized an island, and since then, this pine species has persisted through multiple glacial periods and, eventually, the warming and drying of California's climate," Mead said. "Now, only two populations remain, one mainland and one island, both with very low genetic diversity, which could restrict their ability to adapt to a rapidly warming climate."

Hybrids between the island and mainland population grow faster than their parents, suggesting increased genetic rescue could be beneficial, Mead noted. However, the two populations may have adapted differently to the island and mainland climates, so hybrids planted in nature may carry genes that are adapted to the wrong climate.

"To test whether hybridization could impact the fitness of future generations, we looked for genes with low levels of mixing between island and mainland variants, which could indicate that island and mainland variants are incompatible and prevent pollination or cause young trees to die," she said. "For one of these genetic variants, having a mainland-type variant was associated with higher growth and cone production when trees were planted in a mainland garden."

Hamilton suggested that the findings of the Torrey pines study could inform efforts by Penn State's Schatz Center and others to rescue trees species in the East decimated by invasive disease and pests.

"For example, in Pennsylvania, forest geneticists are working to manage our forests under climate change," she said. "Unlike Torrey pine, populations are not separated by the ocean, but habitat fragmentation and 'sky islands'—where tree species have retreated to deal with warmer climatic conditions—on mountain peaks have caused more recent barriers. Genetics will be important to determining when and where introducing new genetic diversity could be beneficial to restoration efforts."

**More information:** Lionel N. Di Santo et al, Genetic Basis of Reproductive Isolation in Torrey Pine (Pinus torreyana Parry): Insights From Hybridization and Adaptation, *Evolutionary Applications* (2025).
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