Home, Home Outside the Range?

Conservationists and ecologists are at odds over the wisdom of moving species threatened by climate change to new homes

HUAPING, CHINA—The stem of the ground-hugging orchid is bowed at the top, weighted down by five violet-tipped buds on the verge of blossoming. The swan's-neck shape gives the flower a demure look. Or perhaps it's just resigned to its fate: This is one of the last *Geodorum eulophioides* left on the planet.

The species is confined to a single hill behind a farmer's home in southwest China's Guangxi Province. Villagers "didn't know they had something so precious here," says Hong Liu, a conservation biologist at Florida International University and Fairchild Tropical Botanic Garden in Miami. But Guangxi is one of the world's nine orchid hot spots, and this patch of land where *G. eulophioides* resides is now part of Yachang Orchid Nature Reserve, a 220-square-kilometer territory with more than 130 orchid species. Liu and colleagues persuaded reserve managers in Huaping to give *G. eulophioides* some breathing space by fencing off the hill.

That action may also give scientists time to learn more about the rare orchid's biology. But it's unclear how long the species can hold out in the wild. Across China, climate change is nudging temperatures higher, disrupting rainfall patterns, and reducing the frequency of foggy days. Like the rest of northwestern Guangxi, Yachang suffered a serious drought last winter that forced rangers for the first time to pipe water into the heart of the reserve. And for the *G. eulophioides* on the reserve's edge, the human threat hovers, like a sword of Damocles, just outside the hill's chain-link fence.

In light of shifting climates and relentless development, scientists here are contemplating a controversial intervention: assisted colonization (AC). "Orchids will be severely affected by warming," says Feng Changlin, an ecologist at the Experimental Center of Tropical Forestry in Pingxiang. The idea is to move *G. eulophioides* and other acutely vulnerable orchids to new habitats that, as the world warms, become more suitable than present habitats—and hopefully, for a time, put them beyond harm's reach. But some scientists argue that such forced migration could do more harm than good.

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Podcast interview with author Richard Stone.

One of the hottest debates in conservation biology these days is to what extent scientists should help embattled species cope with climate change. Not just orchids are at risk: All life forms, including our own, must adapt to climate change or dwindle and possibly perish. Scientists generally agree that first they should protect or shore up ecosystems, especially fragile ones such as cloud forests and coral reefs. Consensus breaks down, however, on what to do when a species can't keep pace with a changing world.

One camp insists that desperate times call for desperate measures. Habitat fragmentation caused by human activity has made it difficult or impossible for many species to migrate on their own to more suitable environments. Thus, a growing number of researchers argue that AC, also called managed relocation, is a vital conservation tool. "The future for many species and ecosystems is so bleak that assisted colonization might be their best chance," Ove Hoegh-Guldberg, director of the Global Change Institute at the University of Queensland in St. Lucia, Australia, and colleagues wrote in a clarion call for moving species in *Science* 2 years ago (18 July 2008, p. 345). "This is something that conservation organizations should and will start to do," says Chris Thomas, a conservation biologist at the University of York, U.K.

Other scientists worry that momentum for translocations is building too fast. "Advocates are not clear about what they are talking about. There are around 7 million species on Earth. Are they talking about moving them one at a time?" asks Daniel Simberloff, an éminence grise of conservation biology at the University of Tennessee, Knoxville. "There is no scientific basis to suggest that AC is the best alternative," adds Anthony Ricciardi, an invasive species biologist at McGill University in Montreal, Canada. AC, he warns, could interfere with habitat preservation and restoration and compete with such efforts

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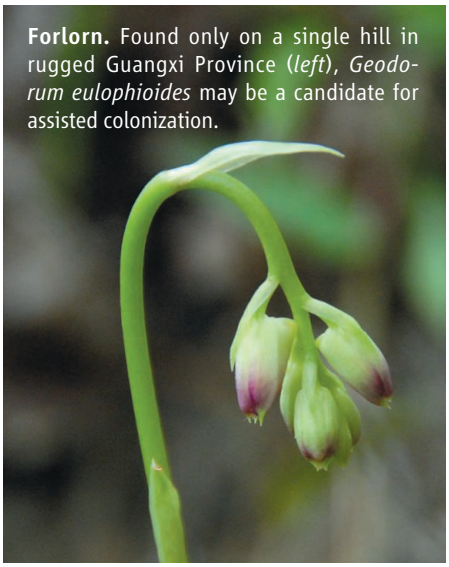


Forlorn. Found only on a single hill in rugged Guangxi Province (*left*), *Geodorum eulophioides* may be a candidate for assisted colonization.

for resources. "AC is nothing more than a techno-fix that may provide a temporary benefit in some cases but create new ecological problems in other cases. We cannot predict which outcome will occur," says Ricciardi, who, with Simberloff, laid out an indictment of AC in the September 2009 issue of *Trends in Ecology and Evolution*.

The dueling articles have ignited a spirited debate in journal opinion pages, university classrooms, and conferences, and agencies responsible for conservation are trying to figure out where they stand. Thomas believes that AC should be a higher priority than breeding threatened species in captivity. Others see AC as a last resort. "It's much better to help species to shift naturally whenever possible," says Stephen Willis, a conservation biologist at Durham University in the United Kingdom. Even backers call for caution. "Other options need to be carefully considered first and not discarded as if AC was a panacea," says Hoegh-Guldberg.

Butterfly effect

The world is replete with species that have been moved far beyond their native habitats. Consequently, "it is senseless to consider species distributions as somehow fixed and 'natural' and that the establishment and occurrence of a species elsewhere is therefore 'unnatural,' " says Thomas. Still, scientists on both sides of the AC debate are skittish because even a seemingly benign or beneficial introduction of a species to a new habitat can have disastrous consequences.

One cautionary tale, Thomas notes, is the cane toad, brought from Hawaii to Australia in 1935 to consume beetles that were ravaging sugar-cane crops. The toad apparently had little effect on the cane beetles—and it spread widely, becoming a pest in its own right. It makes a toxin blamed for steep declines in predators such as freshwater crocodiles and the western quoll, a ferocious marsupial cat. Australia is littered with that sort of ecological train wreck. "You only have to look at our history with invasive cacti, poisonous toads, and exploding rabbit populations to know that there are some real risks attached to assisted colonization," says Hoegh-Guldberg.

Bearing that in mind, he and his *Science* co-authors devised a risk-assessment scheme in which AC would be considered only after other options are ruled out. To be a colonization candidate, they proposed, a species must be at high risk of decline or extinction because of climate change; it would have to be feasible to move and establish the species elsewhere; and the benefits of relocation would have to outweigh the biological and socioeconomic costs.

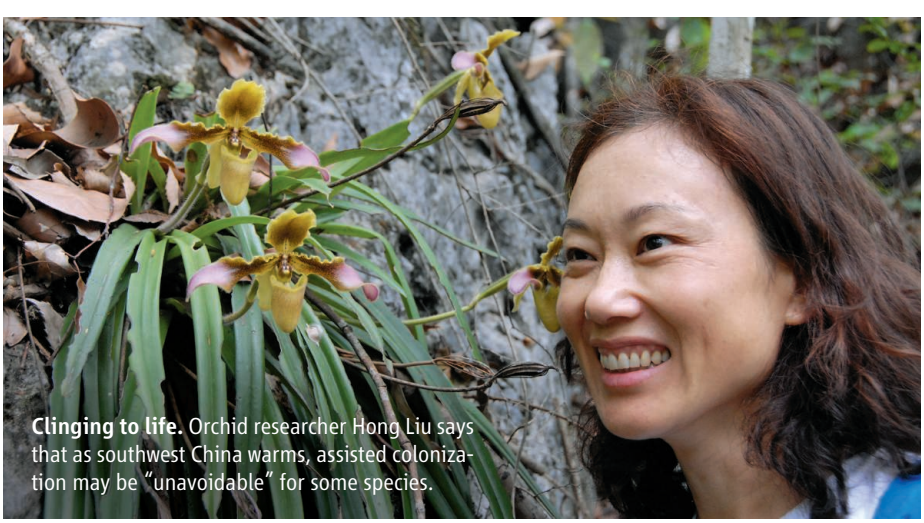
Scientists are beginning to contemplate which species might satisfy these requirements. In Australia, candidates include the greater glider and two other native possums that were victims of recent regional extirpations, says David Lindenmayer, an expert on climate-driven range changes based at Australian National University in Canberra. Another AC candidate is the Iberian desman, an amphibious insect-eating mammal whose present habitat in the Pyrenees is likely to vanish as the world warms. Since the last ice age, the Iberian desman has not expanded its range to the nearby Alps, another suitable habitat. Thus, it is unlikely to migrate on its own in the face of climate change, Naia Morueta-Holme and colleagues at Aarhus University in Rønde, Denmark, noted last April in *PLoS ONE*.

The challenge lies in assessing risk and guarding against unwelcome surprises. Transferred organisms can wipe out native species and disrupt food webs. Take, for example, the opossum shrimp. Thirty years ago, wildlife managers introduced the species into Flathead Lake in Montana to enrich the diet of kokanee salmon. It turned out that the nocturnal shrimp spent daytime at the lake bottom, while salmon fed in shallower water. So instead of becoming dinner, the shrimp competed with the salmon for food, and the kokanee crashed. A higher predator then suffered: Eagles that preyed on the salmon also crashed. "We can explain such complex effects after they have occurred," Ricciardi says, "but we can rarely predict them."

When assessing the likelihood of a species becoming an upstanding member of its new community or a vicious invader, looks can be deceptive. In the 19th century, two closely related Eurasian sparrows were introduced to North America. Since then, the tree sparrow, *Passer montanus*, has expanded its range slowly, while the house sparrow, *P. domesticus*, has spread widely and supplanted native birds. "Real knowledge of what determines the range limits of a particular species is extremely meager," says Simberloff. And ill effects of an introduced species may not be detected until years later.

In the absence of hard data, AC risk assessments boil down to guesswork. "It's really a Delphic process," says Simberloff. "Someone says the risk is high, another says it is low." Medium becomes the consensus. He is calling for "souped-up natural histories" that might be undertaken as doctoral theses about a given species. "This kind of research is not fashionable," Simberloff says, "but it's what you will need."

AC advocates acknowledge that data gaps must be filled before the approach is ready for prime time. One lacuna is how much climate variation species can tolerate beyond the conditions in their native habitats. "This has been



Clinging to life. Orchid researcher Hong Liu says that as southwest China warms, assisted colonization may be "unavoidable" for some species.

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Moving experience. In a landmark experiment, Stephen Willis and colleagues moved populations of two butterflies—the small skipper (*top right*) and the marbled white—north of their ranges. Ten years later, both species are thriving in their new homes.

worked out for a few species, but there are no general rules of thumb yet," says Dov Sax, a conservation biologist at Brown University. Another issue is the degree to which species may evolve in response to climate change. "The quick answer is that we expect species with lots of genetic variation and very short generation times to be able to adapt," Sax says. "The trouble is that we don't know where the cutoffs should be for expecting trouble."

Fundamental questions remain unanswered. As the climate changes, which creatures will migrate too slowly? And which will face insurmountable barriers? Answers may come too late for some species. But at least one study has shown that AC can work.

In what may be the first AC field trial, a decade ago Willis and colleagues moved populations of two butterfly species in England from their ranges at that time to new areas to the north. "We wanted to see whether those areas could support viable populations," says Willis. The idea was to test the feasibility of AC using a species that was not already on the ropes. There was a good shot the experiment would work. The butterflies—the marbled white and the small skipper—had pushed northward in England in recent years.

Based on species distribution models, Willis's team forecast areas of the British Isles in which temperatures and rainfall amounts in coming years should provide suitable habitat. In summer 1999, they captured 400 adult small skippers and the next day whisked them to an abandoned quarry in Northumberland 35 kilometers north of their then-range. Another 200 were moved the following July. Also, in 2000, the researchers moved 500 adult marbled whites to a reserve in Durham, 65 kilometers north of the butterfly's then-range.

The scientists have been tracking the butterflies ever since. After a rough couple of summers in 2008 and 2009, when England was unseasonably chilly, the butterflies have bounced back this year. "They are behaving very much like natural populations," says Willis. In the February 2009 issue of *Conservation Letters*, his team concluded that "assisted colonization has the potential to be a useful conservation tool" to soften the blow of climate change for species with poor mobility or whose habitat is fragmented. The study "makes a strong case that managed relocation is feasible," says Sax.

Turn on the AC? Warming threatens the Iberian desman (*left*) and the greater glider.

Dire straits

Deep in Yachang orchid reserve, a trail covered with skin-flaying bramble gives way to a sunlit meadow filled with young corn stalks. "It's almost like Iowa," mutters Liu, clearly disappointed that villagers are growing corn in the heart of orchid country. At the edge of the meadow, fresh cuts ringing the base of an oak tree are a disturbing sign. It's illegal to fell living trees in the reserve. To expand their cornfield, villagers inflict mortal wounds by girdling trees and later legally remove the dead wood. Prosecutions are rare because offenders can be fined or sent to labor camp, and that would sow enmity in a small town such as Huaping. Therefore, despite the blatant transgressions, "we have to be careful," says Yachang director Wu Tian-gui. He and his staff members don't want villagers to strike back at the reserve by poaching rare orchids that can fetch hundreds of dollars from collectors.

Meanwhile, for Yachang's orchids, the noose tightens. As the region warms, many orchids will migrate naturally, and tissue culture could augment existing populations, says Feng. But some species will be driven higher up mountainsides, and eventually "they will have no higher places to go," says Liu, who describes the threat to orchids in the June issue of *The Botanical Review*. Other orchids may be stymied as the habitat grows ever more fragmented. "Managed relocation of certain orchids may be unavoidable," she says.

It won't be easy. Orchids have a poorly understood symbiotic relationship with soil fungi. And pollinators are species-specific. New habitat for any orchid given a moving assist must have not only a tolerable temperature and precipitation regime but also the right species assemblage. AC for orchids, says Feng, "will be very tricky."

As questions swirl about how best to proceed, the plight of one species has driven people to take matters into their own hands. Blighted by disease, the Florida Torreya pine has lost more than 98% of its population since the 1950s. Over the past decade, the Torreya Guardians have been distributing seeds well beyond the tree's historic range. The private group cites climate change as one rationale for its "assisted migration."

Sax sees a moral justification for this ecoactivism. "They have every right to try and fix a problem that they don't see anyone else dealing with," he says. But there is a dark side, he notes. "It makes me nervous to think that any group could move any species they wanted. This would occasionally lead to some nasty ecological consequences."

Thus, it is imperative that scientists illuminate the benefits and risks of moving species before agencies, citizens' groups, or their own colleagues take action. "Before AC can become a safe tool, we would need to develop a much better understanding of how introduced species and recipient ecosystems respond to each other," says Ricciardi. "Until then, AC amounts to ecological gambling: The more frequently we do it, the more we spin a roulette wheel of unintended consequences." **–RICHARD STONE**