

Feature

After the fires: saving endangered plants from climate-driven extinction

As the bushfires swept through the Stirling Range, a mountainous national park in Western Australia, during the final days of 2019, Sarah Barrett was waiting anxiously. The flames were raging in a part of the park she had been visiting regularly since the mid-1990s to document and tend several plant species that appear nowhere else on Earth.

Previous fires, the last one just a year earlier, had already decimated many of these precious plants, including the Stirling Range dryandra, a hairy-stemmed evergreen shrub with leathery leaves and pale yellow flowers shaped like a bottle brush.

When Barrett, who works as a threatened-flora officer for Western Australia's Department of Biodiversity, Conservation, and Attractions, was finally able to hike back into the range a few weeks later, her worst fears were confirmed. The fire had swept across all four of the mountaintops where dryandras still grew. Every last mature plant had been burnt to a crisp.

"It was quite emotional at the time," Barrett says. "We knew them all, intimately," she says, referring to the plants.

Across Australia, a similar drama played out for hundreds of other species during the now historic 2019–2020 Black Summer

bushfire season, which burned some 24 million hectares of land across almost every state and territory.

The fires not only took a heavy toll on people and animals but wreaked havoc on many plants as well. During recent field surveys, scientists assessed some 150 species as either threatened for the first time or having an altered conservation status—changing mostly for the worse. Fifteen species, Barrett's dryandra among them, are now critically endangered. Another 100 assessments are still underway, so more could follow suit.

Scientists and volunteers are still trying to gauge the damage in parts of southeastern Australia, since the region has been hit by a series of devastating floods in the 2 years since the fires. The rains are potentially helping some plants recover but have also made on-the-ground surveys challenging.

"We've had field teams go out wherever they can get to," says Rachael Gallagher, an ecologist and associate professor at Western Sydney University, who sits on the committee that has been advising the Australian government on its response to the fires.

Gallagher says these field trips have shown that many species have indeed bounced back. Some thought to be at risk of



Scorched mountaintops in the Stirling Range, with burnt dryandras visible in the foreground. Wildfires have taken a heavy toll on some rare endemic plants in the park. Photograph: Department of Biodiversity, Conservation, and Attractions, Western Australia.

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A Stirling Range dryandra (*Banksia montana*) high above the clouds in Western Australia's Stirling Range National Park, prior to a series of fires that decimated the species' only remaining populations in 2018 and 2019. Photograph: Department of Biodiversity, Conservation, and Attractions, Western Australia.

extinction were actually thriving in freshly burnt areas. But more broadly, many ecologists warn that the Black Summer fire season could be a dark sign of things to come for much of Australia's rare flora—one of the most diverse in the world. The concern is intensified by other factors, too, with habitat loss, invasive species, and additional climate change impacts all taking a toll.

The Black Summer was "likely a harbinger of the types of fire seasons that will become more common due to climate change," Gallagher and more than a dozen other scientists write in a new book on the impact of the fires.

Although some Australian plants rely on smoke and fire to germinate in the first place, frequent burning can quickly become a problem. In parts of the Stirling Range, fire cycles were already twice as frequent as species recovery rates. Previous fires in 1990 and 2000 had decimated the population of dryandras, for instance, which take a decade to flower and at least twice as long to reproduce effectively. At the same time, a drying climate and dieback disease—a devastating infection caused by the water mold *Phytophthora cinnamomi*—have already made them more vulnerable.

Being on a mountaintop, "they have nowhere else to go," Barrett says. "If it's not one thing, it's another."

Insurance policies

Some 14,000 kilometers from Australia's Stirling Range, the low-slung complex of barrel-vaulted buildings housing the Millennium Seed Bank looks unassuming from the outside, tucked away inside a botanic garden an hour south of London, England.

But beneath its network of labs and spacious visitor's area lies perhaps the most biodiverse spot on Earth. A fire- and radiation-proof bunker in the building's basement houses more than 2.4 billion seeds from over 40,000 plant species. Lined up on metal shelves inside its storage vaults, all cooled to -20 degrees Celsius, the seed collections sit in individual mason jars, like the world's most eccentric pantry.

The seed bank, part of the Royal Botanic Gardens, Kew, forms a living insurance policy for the world's plants—many of them

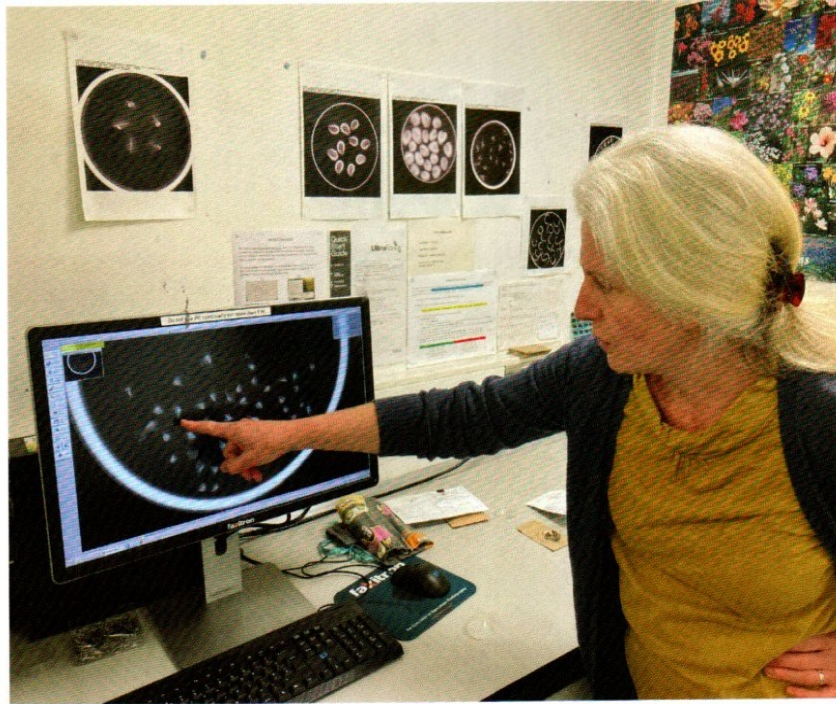
threatened and some already extinct in the wild. The vaults and their collections are meant to last 500 years. Each one is raised on cinder blocks to buy time in the case of a flood and, due to the facility's proximity to a major airport, the entire complex was built to withstand the impact of a plane crash. Similar smaller seed banks for wild plants exist around the world, but most send some of their seeds here as a backup to add an extra layer of security.

"You can come in here, and you can go on a little trip around the world," says Elinor Breman, who runs the bank's seed conservation team. Standing in the building's ground floor drying room, where new arrivals are paper-bagged and stacked in plastic crates, she points out labels from Armenia and Brazil, Pakistan and Zambia. After several months here, the seeds are cleaned and X-rayed to check for pests before eventually making their way into the vault.

Every 10 years, a few samples from each collection are tested to make sure the seeds still sprout. And although the Millennium Seed Bank has been running for just a little over two decades, it is filling up fast. New cold storage has already been added downstairs.

"They thought, originally, that this would hold 75% of the world's plant species that have orthodox seeds," Breman says, referring to seeds that can withstand drying and freezing. "But I think we've only got about 15% now, and we're already about halfway through capacity," she adds. Recalcitrant seeds that cannot survive freezing are preserved in vats of liquid nitrogen instead.

What's there has already come in handy. In South Australia's Lobethal Bushland Park, fires in December 2019 burned some 24,000 hectares and wiped out an entire population of clover glycine, a purple-flowering perennial. Luckily, a small seed collection had been made in 2007 and sent for storage at the Millennium Seed Bank. After the fires, South Australian conservationists asked for some of the seeds to be returned and used them to plant more than 230 seedlings in the park and at another bushland reserve. Later, they gathered hundreds of seeds from the new stock to create their own backup for the future.



Elinor Breman, who runs the seed conservation team at the Millennium Seed Bank, examining a newly arrived batch of seeds under a microscope. Photograph: Yannic Rack.



Plants grown from seed stored in the Millennium Seed Bank's vaults inside a nursery on site. Seeds are periodically germinated and planted to test their health or when new seedlings are needed for restoration projects. Photograph: Yannic Rack.

Breman says cases like this show the value of so-called *ex situ* conservation, where a species is kept outside its natural habitat. She also notes that this type of restoration requires substantial planning and forethought. In the aftermath of the fires, emergency funding brought a rare opportunity for large-scale surveys in many areas that scientists had not observed for years. But that also means conservationists are playing catch up instead of collecting seeds long before disaster strikes.

"That's when you have a more intact population and you're more likely to make a robust collection," Breman says. "You

needed to be doing this 20 years before there ever was such a large-scale bushfire."

Although much of the seed bank's work is focused on research, Breman says restoration has started to take on a much larger role for her team. That's in part because her collectors are increasingly bringing back bad news from the field.

"There have been cases where our collectors have gone out and that population is no longer there," she says. "Unfortunately, I think that will only increase in the future. But every species we can conserve now is one that will never go extinct."



Scientists at the Millennium Seed Bank examine seeds under microscopes in the facilities' labs at Wakehurst botanic garden. Photograph: Yannic Rack.

To seed or not to seed

Even once a species is backed up in the vault, the question of whether—and how—to reintroduce it in the wild has proven thorny.

Hugh Possingham, a professor at the University of Queensland and until recently the state's chief scientist, ruffled some feathers when, during a speech in mid-2022, he called out his fellow conservationists for being far too cautious when it comes to actively managing threatened species.

Possingham thinks that Australia could learn a thing or two from countries like the United States, where he says restoration has been far more progressive, involving relocating some species hundreds of miles. If it were up to him, Australia would greatly expand its decimated rainforests to restore threatened ecosystems and reduce fire risk in the future. In general, more plants and animals, squeezed out of their native ranges, should be relocated "where they're safe," he says, advocating for what ecologists call *assisted migration*.

"That is generally [seen as] a last resort. The psyche of Australian conservation is that you should manage the threats and let nature take its course," Possingham says.

Coming in the wake of the bushfires, his comments hit a nerve. Gallagher, although careful to note that she values Possingham's contribution to the broader debate around conservation, admits that she has not listened to the speech because she would find it too upsetting. "Ecology is rarely simple," she says.

Even when it comes to less controversial projects that merely seek to restore a plant to its native habitat, Gallagher and others point out legitimate concerns: Some seeds require precise germination sequences, meaning scientists risk getting things wrong and wasting their scarce collections if they are unsuccessful. They might end up planting a genetic variety unsuited to a specific location, for example. Meanwhile, a plant's own natural seed bank may be sitting in the soil for years, simply waiting for the right conditions.

"There is still a hesitancy around replanting and reseeded species in the field, which is potentially cultural; it's seen by some

as overly prescriptive," Gallagher says. "There's a sense that's sort of meddling in natural processes."

Lee Hannah, a senior scientist in climate change biology at Conservation International's Moore Center for Science, is also cautious when it comes to assisted migration, which he says raises ethical questions. At the very least, he believes in avoiding the situation of amateur naturalists rushing to transplant species unless scientists determine that it is the only option.

Still, as climate change supercharges natural disruptions like Australia's wildfires, he says that equation may have to change—not least because invasive weeds and other factors, such as encroaching agriculture and prescribed burns, are now more likely to hamper the recovery of damaged ecosystems.

"There's little question that, in the long run, it's going to require human intervention to keep some natural systems functioning," Hannah says. "It's not a level playing field, and you can't always rely on things that have worked in nature in the past."

Possingham believes that things are indeed starting to change, albeit slowly. He points to a seed production garden on Kangaroo Island, off Australia's southern coast, which was set up with government recovery funding after the 2019 fires. Led by botanists from the South Australia Seed Conservation Centre, workers there are planting some 60 species in raised beds, wetlands, and ponds as insurance populations to restore the island's threatened plants.

Although he says such projects are still few and far between, Possingham hopes the fires were a wake-up call for skeptics of his interventionist approach. "I think conservationists have realized that the old ways aren't working. We're not winning this battle."

Indigenous involvement

In Australia and plenty of other biodiversity hotspots, respecting the wishes of traditional landowners has also added another dimension to threatened species management.

Ecologists broadly acknowledge that introducing plants or animals into areas where they have not occurred—or removing them from their natural habitats—should happen in accordance with



Seeds selected for test germination from the Millennium Seed Bank's storage vaults. Photograph: Yannic Rack.



One of the cold storage vaults beneath the Millennium Seed Bank, where billions of seeds are kept at -20 degrees Celsius. Photograph: Yannic Rack.

the wishes of Indigenous Australians. Their involvement in conservation and restoration has indeed come a long way in recent years, according to Stephen van Leeuwen, a professor at Curtin University and Australia's first Indigenous chair of biodiversity and environmental science.

Himself part of the Noongar peoples native to Western Australia, van Leeuwen says this recent engagement is, in part, a consequence of the rise in native land ownership. More than half of the country's land is now officially recognized as Indigenous owned.

But there are more pragmatic reasons, too. Hiring locals with intimate knowledge of the land and its native species as rangers

or seed collectors is much more economical than paying the travel costs for sending out scientists from far away. For large companies doing mine-site restoration, one of van Leeuwen's specialties, engaging traditional landowners also ticks another box on environmental, social, and governance targets. And for local communities, the work means more income and an active say in how their land is managed.

"It's about free, prior, and informed consent," van Leeuwen says. "It's about asking communities what they actually want on their country."

In their book on the Australian fires, Gallagher and her colleagues flagged another issue: Despite millennia-old traditions

of shaping the landscape, including through burning, Indigenous knowledge has largely been ignored when it comes to both managing forest fires and restoring ecosystems.

For now, Indigenous involvement is still largely restricted to activities like industrial rehabilitation. Despite their own colonial legacy, seed banks also mostly operate within the confines of White Western academia. In an ideal world, van Leeuwen thinks Indigenous peoples should be more involved in the whole conservation and restoration process, from collecting and cleaning seeds to eventually restoring wild populations.

Some countries are further ahead on the curve. In Brazil, Indigenous communities have banded together in projects like the Xingu Seeds Network, which employs hundreds of Indigenous seed collectors in the Amazon to harvest seeds from more than 100 plant species and sells them to private companies for reforestation projects. Oreme Ikpeng, who helps coordinate groups within the network, says it has allowed the communities to preserve their natural environment and keep resources within their territory—some seeds, which the locals regard as essential to their heritage, are never sold. For the collectors, most of whom are women, the work goes beyond economic opportunity.

“They are more empowered,” Ikpeng says. “They are examples for girls in their villages.”

Van Leeuwen thinks projects on a similar scale would make sense in Australia. One Indigenous-led group, Noongar Land Enterprises, plans to start centrally collecting seeds harvested by Indigenous peoples and lend out equipment in order to lower costs for individual collectors. But for now, most Indigenous involvement still happens at a hyperlocal level and is usually tied to individual mine-site restoration projects.

“There is no single network, but that would be really desirable,” van Leeuwen says.

Running out of time

As is so often the case, there is a large caveat hanging over any discussion of whether and how to restore threatened ecosystems: money.

Although Australia made billions of dollars in recovery funding available after the Black Summer fires, only a fraction went to plants—which, as many ecologists ruefully point out, rarely elicit

the same emotional response as koalas and kangaroos. Perhaps the bigger issue is that this kind of financing tends to be temporary; much of the postdisaster spending has already dried up. So, although the fires sparked much on-the-ground surveying and recovery work, the sheer number of threatened species in a country like Australia means that will not be nearly enough.

“Potentially, there are more extinctions sitting out there, and we live in blissful ignorance,” says Kingsley Dixon, a professor at Curtin University and founding director of science at Kings Park and Botanic Gardens in Perth. The rarest plants, he notes, are often particularly remote and difficult to reach, with limited expertise available to carry out survey work.

In a paper published in 2019 (<https://conbio.onlinelibrary.wiley.com/doi/pdf/10.1111/conl.12682>), Possingham and several of his colleagues tried to calculate the scale of the issue. They found that Australia spent less than \$100 million per year on targeted threatened species recovery, a fraction of the roughly \$1.3 billion his team say is needed. The United States, by comparison, spends more than \$1.45 billion annually on similar measures, with the results to match: Dozens of species there have been delisted due to recovery.

“That’s why we are losing species so quickly, because we’re spending about a tenth of the money we need to,” Possingham says. He adds that although scientists have developed comprehensive protocols for how to effectively prioritize species, governments often fail to use them.

In the meantime, professional ecologists and enthusiastic volunteers are doing as much as they can to prepare for the next disaster, keenly aware that time is running out for many species. Globally, two of every five plant species are threatened with extinction, according to a 2020 estimate by researchers at Kew. Australian firefighters fear that, after 3 wet years caused by a protracted La Niña event, 2023 will once again see widespread wildfires that could add up to another devastating season.

Back in the Stirling Range, a few hundred seedlings of dryandras are still left in the mountains, although Barrett expects the species could soon disappear from two of the four sites. To keep it from vanishing altogether, she and her team have set up a project that Possingham would likely approve of: At two in-situ seed production areas outside the range, new dryandras have been grown since 2021. After the fires, some were flown in by helicopter and



Seed collectors with the Yarang Women’s Movement, part of the Xingu Seeds Network, harvest tree seeds in Brazil that will be sold to companies for forest restoration. Photograph: Scene from the movie *Yarang Mamin: Yarang Women’s Movement* (2019), Manoela Meyer/ISA.

planted back onto burned areas. So far, about three dozen plants have survived the procedure.

More than simply replacing burned specimens, Barrett says the nurseries could provide an opportunity to breed individuals that are more resistant to dieback. A fungicide is regularly sprayed from planes or by hand to further fight the disease. When planting back onto the mountains, Barrett has sought out south-facing sites, where, because of their southern hemisphere location, the air and soil are cooler and less conducive to the infection.

"We're trying to identify microhabitats that are better for its persistence. But it's a little bit experimental," she says.

Other measures have included burning off brush in the lowlands to stop future fires from spreading up the mountain. Fences

keep out quokka, small native marsupials, as well as invasive rabbits, both of which like to munch on the endangered plants. On her most recent visit, Barrett says she even watered the remaining plants—although she admits it may have done little more than make her feel better.

Despite all these efforts, Barrett knows that the clock is ticking for dryandras in their natural habitat.

"If there was another fire in 10 years," she says, "that would be it. It would be over."

Yannic Rack

Yannic Rack is a journalist based in Scotland who writes mainly about climate change and the environment.