Subscribe



New Zealand's War on Rats Could Change the World

The nation wants to eradicate all invasive mammal predators by 2050. Gene-editing technology could help—or it could trigger an ecological disaster of global proportions.



Story by Ed Yong

NOVEMBER 16, 2017

SCIENCE

Like The Atlantic? Subscribe to The Atlantic Daily, our free weekday email newsletter.

Enter your email		Sign up

THE FIRST THING that hit me about Zealandia was the noise.

I was a 15-minute drive from the center of Wellington, New Zealand's capital city, but instead of the honks of horns or the bustle of passersby, all I could hear was birdsong. It came in every flavor—resonant coos, high-pitched cheeps, and alien notes that seemed to come from otherworldly instruments.

Much of New Zealand, including national parks that supposedly epitomize the concept of wilderness, has been so denuded of birds that their melodies feel like a rare gift—a fleeting thing to make note of before it disappears. But Zealandia is a unique 225-hectare urban sanctuary into which many of the nation's most critically endangered species have been relocated. There, they are thriving—and singing. There, their tunes are not a scarce treasure, but part of the world's background hum. There, I realized how the nation must have sounded before it was invaded by mammals.

Until the 13th century, the only land mammals in New Zealand were bats. In this furless world, local birds evolved a docile temperament. Many of them, like the iconic kiwi and the giant kakapo parrot, lost their powers of flight. Gentle and grounded, they were easy prey for the rats, dogs, cats, stoats, weasels, and possums that were later introduced by humans. Between them, these predators devour more than 26 million chicks and eggs every year. They have already driven a quarter of the nation's unique birds to extinction.

Many species now persist only in offshore islands where rats and their ilk have been successfully eradicated, or in small mainland sites like Zealandia where they are encircled by predator-proof fences. The songs in those sanctuaries are echoes of the New Zealand that was.

But perhaps, they also represent the New Zealand that could be.

"It's crazy but it's ambitious, and I think it might be worth a shot. I think it's our great challenge."

In recent years, many of the country's conservationists and residents have rallied behind <u>Predator-Free 2050</u>, an extraordinarily ambitious plan to save the

country's birds by eradicating its invasive predators. Native birds of prey will be unharmed, but Predator-Free 2050's research strategy, which is released today, spells doom for rats, possums, and stoats (a large weasel). They are to die, every last one of them. No country, anywhere in the world, has managed such a task in an area that big. The largest island ever cleared of rats, Australia's Macquarie Island, is just 50 square miles in size. New Zealand is 2,000 times bigger. But, the country has committed to fulfilling its ecological moonshot within three decades.

Beginning as a grassroots movement, Predator-Free 2050 has picked up huge public support and official government backing. Former Minister for Conservation Maggie Barry once described the initiative as "the most important conservation project in the history of our country." If it works, Zealandia's fence would be irrelevant; the entire nation would be a song-filled sanctuary where kiwis trundle unthreatened and kakapos once again boom through the night.

By coincidence, the rise of the Predator-Free 2050 conceit took place alongside the birth of a tool that could help make it a reality—CRISPR, the revolutionary technique that allows scientists to edit genes with precision and ease. In its raw power, some conservationists see a way of achieving impossible-sounding feats like exterminating an island's rats by spreading genes through the wild population that make it difficult for the animals to reproduce. Think *Children of Men*, but for rats. Other scientists, including at least one gene-editing pioneer, see the potential for ecological catastrophe, beginning in an island nation with good intentions but eventually enveloping the globe.

N 2007, A retiree named Les Kelly returned to New Zealand after 25 years of working in Australia, and marked his homecoming with a four-month walking tour. And during that time, he realized that something had gone horribly wrong. The birds he remembered from his youth were gone. Learning that introduced pests were responsible, he conceived a bold plan to purge them and championed it through a self-created lobby group called Predator-Free New Zealand. Word got around, and in 2011, a regionally famous physicist named Paul Callaghan mentioned the idea in a rousing speech at Zealandia. "It can be done," he said. "It's crazy but it's ambitious, and I think it might be worth a shot. I think it's our great challenge."

Callaghan died a few months later, but those words, delivered by a well-liked celebrity, kept gathering momentum. They certainly lit a fire in James Russell, a young ecologist who was born and raised in New Zealand. "I grew up in suburban Auckland with kakariki—these really rare parakeets that my mother raised," he tells me. "Now, rats kill most of them, and it breaks my heart." In 2015, he and three colleagues wrote a paper in which they laid out the benefits of eradicating pests nationwide, and estimated that a 50-year scheme would cost 9 billion NZD (\$6 billion).

From there, the idea became a movement. "It stopped being aspirational," Russell says. The government got on board, setting up a limited company to administer an initial \$28 million NZD worth of funds. The public embraced the idea, too. People who had been individually trying to control invasive predators on their own land found common cause behind a unifying theme.

"It was profoundly wrong of me to even suggest it."

There are, of course, naysayers. Some accuse the initiative of ecological xenophobia, unfairly persecuting creatures that didn't hail from New Zealand but sure as hell are part of it now. But Russell notes that these displaced predators are still wreaking havoc. "Something is going to die," he says. "Either a bird is going to be killed by a rat that we brought here, or we're going to kill the rat. And I would rather humanely kill the rat than have the rat inhumanely kill a bird."

Other skeptics say that the task is simply too huge. So far, conservationists have successfully eradicated mammals from 100 small islands, but these represent just 10 percent of the offshore area, and just 0.2 percent of the far larger mainland. It's one thing to cull pests on small, waterlocked pimples of land whose forests are almost entirely owned by the government. It's quite another to repeat the feat in continuous stretches of land, dotted by cities and private homes.

But Russell, ever the optimist, notes that the daunting ascent ahead shouldn't distract people from the path already climbed. In 1963, after decades of unsuccessfully trying to save birds from invasive predators, the legendary conservationist Don Merton finally divested a tiny island of its rats, by poisoning

them by hand. In later decades, when the Department of Conservation started dropping poisoned bait by helicopter, larger islands became rat-free. Heavily visited islands just off the coast of Auckland were cleared. The mainland is a much bigger challenge but one that could be tackled gradually, by creating large sanctuaries like Zealandia and slowly expanding them. "This is a 2050 aspiration," says Russell. "It's not going to be solved in 3 to 5 years."

"It has become less about technical feasibility but about cost," he adds. "We could just use the tech today but it would be infinitely expensive. We need new control techniques that would be orders of magnitude cheaper. And that's when we get into questions about CRISPR."

In to this day. In it, he and his colleagues laid out several possible uses for gene drives—a nascent technology for spreading designer genes through groups of wild animals. Typically, a given gene has a 50-50 chance of being passed to the next generation. But gene drives turn that coin toss into a guarantee, allowing traits to zoom through populations in just a few generations. There are a few natural examples, but with CRISPR, scientists can deliberately engineer such drives.

Suppose you have a population of rats, roughly half of which are brown, and the other half white. Now, imagine there is a gene that affects each rat's color. It comes in two forms, one leading to brown fur, and the other leading to white fur. A male with two brown copies mates with a female with two white copies, and all their offspring inherit one of each. Those offspring breed themselves, and the brown and white genes continue cascading through the generations in a 50-50 split. This is the usual story of inheritance. But you can subvert it with CRISPR, by programming the brown gene to cut its counterpart and replace it with another copy of itself. Now, the rats' children are all brown-furred, as are their grandchildren, and soon the whole population is brown.

Forget fur. The same technique could spread an antimalarial gene through a mosquito population, or drought-resistance through crop plants. The applications are vast, but so are the risks. In theory, gene drives spread so quickly and relentlessly that they could rewrite an entire wild population, and once

released, they would be hard to contain. If the concept of modifying the genes of organisms is already distasteful to some, gene drives magnify that distaste across national, continental, and perhaps even global scales.

Esvelt understood that from the beginning. <u>In an early paper</u> discussing gene drives, he and his colleagues discussed the risks, and suggested several safeguards. But they also included <u>a pretty Venn diagram</u> that outlined several possible applications, including using gene drives to control invasive species—like rats. That was exactly the kind of innovation that New Zealand was after. You could spread a gene that messes with the rodent's fertility, or that biases them toward one sex or the other. Without need for poisons or traps, their population would eventually crash.

Please don't do it, says Esvelt. "It was profoundly wrong of me to even suggest it, because I badly misled many conservationists who are desperately in need of hope. It was an embarrassing mistake."

Through mathematical simulations conducted with colleagues at Harvard, he has now shown that gene drives are even more invasive than he expected. Even the weakest CRISPR-based gene drives would thoroughly invade wild populations, if just a few carriers were released. They're so powerful that Esvelt says they shouldn't be tested on a small scale. If conservationists tried to eliminate rats on a remote island using gene drives, it would only take a few strongly swimming rodents to spread the drive to the mainland—and beyond. "You cannot simply sequester them and wall them off from the wider world," Esvelt says. They'll eventually spread throughout the full range of the species they target. And if that species is the brown rat, you're talking about the entire planet.

Together with Neil Gemmell from the University of Otago, who is advising Predator-Free 2050, Esvelt has written an opinion piece explicitly asking conservationists to steer clear of standard gene drives. "We want to really drive home—ha ha—that this is a technology that isn't suitable for the vast majority of potential applications that people imagine for it," he says. (The only possible exceptions, he says, are eliminating certain diseases like malaria and schistosomiasis, which affect hundreds of millions of lives and have proven hard to control.)

It's not ready yet, either. Even if gene drives were given a green light today, Gemmell says it would take at least 2 to 3 years to develop carrier animals, another 2 years to test those individuals in a lab, and several years more to set up a small field trial. And these technical hurdles pale in comparison to the political ones. Rats are vermin to many cultures, but they're also holy to some, and they're likely to be crucial parts of many ecosystems around the world. Eradicating them is not something that any single nation could do unilaterally. It would have to be a global decision—and that's unlikely. Consider how much effort it has taken to reach international agreements about climate change—another crisis in which the actions of certain nations have disproportionately reshaped the ecosystems of the entire world. Genetic tools have now become so powerful that they could trigger similar changes, but faster and perhaps more irreversibly.

"In a global society, we can't act in isolation," says Gemmell. "Some of these tools we're thinking about developing will cross international borders. New Zealand is an island nation relatively isolated from everyone else, but what if this was a conversation happening in the United States about eradicating rodents? What if Canadians and Mexicans had a different view? This is something that should be addressed."

"Māori tend to have a precautionary approach because we've already had many cases of wrongdoing for the right reasons."

Russell agrees with a precautionary approach but he isn't ready to dismiss gene drives yet. For a start, he feels that Esvelt's simulations overestimate the risk that such drives would establish themselves in the wild. Yes, rats are very good at traveling and colonizing new lands, but they're surprisingly bad at invading places where other rats already exist. "Rats have a strong incumbent advantage," he says. "You really have to introduce a lot of individuals" for them to successfully invade an already-established population.

Esvelt thinks that people would do exactly that. Gene-drive rats may not be able to swim or stow away in sufficient numbers to occupy new lands, but people could carry them. There is precedent for this: In 1997, farmers illegally smuggled

a hemorrhagic virus into New Zealand to control rabbit pests. They could just as easily smuggle gene-drive rats in the other direction, to control the rodents in their own particular corners of the world. "New Zealand has very good biosecurity but it's mostly focused on stopping things from getting in," says Gemmell. "I'm not sure we're that good at stopping things from getting out."

If gene drives are deployed, it's not unreasonable to imagine a black market in genetic rodenticide, which is exactly the kind of deliberate malfeasance that Esvelt says scientists rarely anticipate. "We don't consider everything that will happen when technology gets in touch with reality," he says.

All of this assumes that genes drives would be used to spread genes that kill or suppress pests outright. Instead, conservationists could use them to spread genes that are tied to particular ecosystems. "Imagine giving all rats in New Zealand a peanut butter allergy, and then we feed them all peanut butter," Russell says. "Well sure," Esvelt counters, "but then you've just converted all the rats in the world into GMOs without asking other countries." The same problem remains: How do you keep the modification from spreading beyond New Zealand?

Esvelt is working on a couple of tricks for corralling the awesome power of gene drives. In a basic gene drive, a chosen gene has all the components it needs to spread itself. But you could split those components between several genes that are connected in a daisy chain, so that gene C is driven by gene B, B is driven by A, and A is driven by nothing. If rats with these genes were released into the wild, the A-carriers would initially spread the B and C genes, but would eventually disappear themselves. After they go, B would follow. Ultimately, so would C. These "daisy drives," as Esvelt calls them, are self-exhausting. They're designed to run out of steam. If they work, they are tools that countries could justifiably use without involving the entire world.

O BE CLEAR, despite the buzz around gene drives in New Zealand's conservation circles, there are <u>no concrete plans</u> to actually use them. "There is currently no research being conducted in New Zealand to develop gene drives for Predator-Free targets, nor are there any plans for such research in the near future," says Andrea Byrom, director of New Zealand's Biological-Heritage National Science Challenge. Indeed, Predator-Free 2050's

research strategy mentions only the most exploratory of steps, such as sequencing the genomes of local rats, talking to international experts like Esvelt, and running mathematical simulations. Genuine research into the drives themselves wouldn't begin any earlier than 2020, and would depend on "technological hurdles being surmounted, supportive policy, and New Zealand/international appetite to proceed."

The group has also funded social research looking into how New Zealanders feel about using genetic technologies to control pests. That's the right order, Byrom says: Work out what people want, and act accordingly. The first results, published this week, showed that 32 percent of the 8,000 people surveyed were comfortable with technologies like gene drives, 18 percent felt that they should never be used, and 50 percent were undecided or wanted strong controls.

"Conservation must be something that happens not just in national parks and the backcountry, but in people's backyards."

Much of this work has been done in consultation with Māori scientists and tribal leaders. But "the conversation happens in pockets, around networks that scientists have," says Maui Hudson from the University of Waikato, who studies Māori research ethics. That's good for working out the Māori perspective on gene drives, but not for actually engaging those communities in the debate about the risks. Aroha Te Pareake Mead, a political scientist who has studied indigenous perspectives on biotechnology, agrees that there hasn't yet been a robust and far-ranging discussion with Māori groups (iwi). "The idea of a predator-free New Zealand is widely endorsed throughout Māoridom," she says. It fits with the concept of kaitiaki or guardianship—the imperative to protect one's biological heritage. But the means of achieving that goal are more contentious.

"We've had many initiatives over the years that have sought to address environmental concerns, with unintended detrimental consequences," Mead says. "Māori tend to have a precautionary approach because we've already had many

cases of wrongdoing for the right reasons. Generally speaking, we are suspicious of any kind of genetic modification."

Despite those reservations, she enjoyed meeting Esvelt two months ago, when he spoke about daisy drives at a community meeting. "I found him to be refreshing as a scientist," she says. "He wasn't defensive and he thought that questioning the risks was essential. That gave the Māori who were present a lot of comfort because we're used to a very different type of geneticist who comes in, says this is the best thing since sliced bread, and if you question it, you're ignorant and you don't know the science. We want to be given a range of tools and to make an informed decision about the best one for the purpose."

Free 2050 are also working on ways of <u>upgrading tried-and-tested</u> technology. The most commonly used traps, for example, are simple one-use devices that must be manually checked and reset. But some companies have made self-resetting traps that can repeatedly kill dozens of rats with a gas-powered piston to the head, or <u>traps</u> that can spray 100 stoats with toxins before needing to be reset. Others are developing sensors that will tell trappers when their snares have snagged an animal, so they don't have to laboriously check every one.

These traps are typically baited with food, but food goes off in the field and must be frequently restocked. Ironically, it also becomes less effective in well-protected areas where actual prey are common. But stoats, it turns out, are <u>far more attracted</u> to the scent of ferrets—a fellow species of weasel—than they are to food smells. Scientists are now trying to isolate the chemicals that make Eau de Ferret so enticing, to turn them into a super-lure.

Aerial drops of 1080 poison, which have freed so many islands from predators, will almost certainly be part of any mainland campaign. Its use is controversial: It can harm the playful kea parrot, and the occasional unwary pet dog. But conservationists could deploy poisons more effectively if they had better ways of detecting pests, like footpad sensors that could track a rodent's footfalls, or cameras whose images are automatically analyzed by artificial intelligence. One

team is also trying to develop more specific toxins, by <u>analyzing the genome of possums</u> to find chemicals that will affect them alone.

And Russell believes that for Predator-Free 2050 to succeed, it has to marshal the most effective tool around: human enthusiasm. Thousands of volunteer groups already exist around the country, monitoring for invasive species and setting traps. That kind of fervor has to spread, especially if mammals are to be exiled from cities. Any pockets of resistance or apathy would create strongholds where pests could thrive. "Conservation must be something that happens not just in national parks and the backcountry, but in people's backyards," Russell says. "They not only allow it but participate in it."

Regardless of the technology that Predator-Free 2050 eventually settles on, there's no question that such measures are needed. Consider the kakapo—New Zealand's endearing, bumbling, giant, flightless parrot. In the 1960s, people thought it was extinct. Now, after the discovery of a surviving population and three decades of intense work, the population stands at 153.

The adults have been relocated to predator-free islands, but "in terms of large sites that would hold a decent population, we've saturated the market," says Deidre Vercoe, a manager at the Kakapo Recovery program. Her team will have to start releasing the birds into places where stoats and rats are still a threat. If Predator-Free 2050 achieved its goal, they could do so with relaxed smiles rather than gritted teeth. Even if Stewart Island, New Zealand's third-largest island, could be stripped of predators, "it would be an answer for kakapo for many, many years," she says.

New Zealand is far from the only country grappling with these issues. Over the last seven centuries, 60 percent of the vertebrates that have disappeared from the planet have disappeared from islands—and in half of those cases, invasive species are the culprits. If Predator-Free 2050 makes the right choices, it can indeed change the world—but not with an unstoppable wave of gene-drive rodents. Instead, it'll show other nations that islands can be protected, that invasive pests can be eradicated, that vanishing wildlife can be saved—even at scales once thought impossible.

"Even if we don't get to the finish line, the fact that we ran most of the marathon will be pretty damn impressive," says Russell.

Related Video

LOOKS LIKE YOU ARE OFFLINE

You'll need to check back here once you have restored your connection.

