



JOEL SARTORE

## The Butterfly Effect

Striking a blow against climate change, San Francisco scientists are working to return the iconic Xerces blue from extinction.

BY JOHN MARKOFF | APR 19, 2021

**T** heir colors are brilliant.

Set against a black background that conveys the frozen motion of an M.C. Escher print, 63 plants and creatures populate an improbable jungle of species that have become extinct since the height of colonization of the New World in the 1700s.

There are birds like the laughing owl, the akialoa, and the Carolina parakeet and such animals as Darwin's Galapagos mouse tucked into this fantastical portrait that includes Maui lovegrass, Hawaiian ferns, and single-flowered Mariposa lily, all now gone.

**California Academy of Sciences senior research fellow Durrell Kapan and *Alta Journal* contributor John Markoff sat down with *Alta Live*.**

#### WATCH

There are also insects, and one in particular catches my eye. Hidden and barely noticeable amid the clutter is an iridescent butterfly, the Xerces blue. Once found exclusively in the dwindling sand dunes of the Sunset district in San Francisco, it became extinct, probably in 1943. It has the dubious distinction of being the first butterfly to vanish because of the destruction of its habitat as a consequence of urban development.

*Gone* is a striking oil canvas painted by Sausalito artist Isabella Kirkland in 2004. Although Xerces is virtually lost in Kirkland's extinction collage, the butterfly has now become a symbol of a growing effort to, in effect, put Humpty Dumpty back together again.

While the effort hasn't received the attention or generated the controversy of the proposals to bring back the woolly mammoth or the passenger pigeon, it's quite possible that Xerces will become the first species to be returned from extinction. Two approaches to its de-extinction—one that gives evolution an assist and one involving genetic engineering—are underway, and if either works, Xerces blue butterflies might once again flutter among San Francisco's sand dunes, possibly in this decade.

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*“Gone” (2004), by Isabella Kirkland, depicts 63 species that have become extinct since the 1700s and the colonization of the New World. View the species key at [isabellakirkland.com/gone](http://isabellakirkland.com/gone).*

**WINGED REVIVAL**

If Xerces flies again, it will happen in part because of the efforts of a Bay Area–based conservation group named Revive & Restore. The organization began as a project of San Francisco’s Long Now Foundation in early 2012 after *Whole Earth Catalog* creator Stewart Brand (a member of *Alta Journal*’s editorial board) and his wife, social entrepreneur Ryan Phelan, attended a small symposium titled “Bringing Back the Passenger Pigeon,” hosted by geneticist George Church at Harvard Medical School.

While Brand and Phelan watched Church demonstrate new gene-editing techniques, it dawned on them that if it was possible to revive the passenger pigeon, then it would be possible to bring back other species or modify the genomes of species threatened by climate change or disease. The science offered a route to restoring biodiversity and boosting species’ resilience to help them adapt to temperature, rainfall, and wind-pattern changes in their ecosystems. The possibility of de-extinctions, of bringing back near-mythic beasts like the woolly mammoth—one of Church’s crusades—now promised dividends. Already, genetic changes to coral are being explored in order to one day help protect coral against bleaching caused by warming oceans.

Brand has long understood the importance of technologies in shaping and reshaping our world. The debut edition of his *Whole Earth Catalog* in 1968 established the publication as an idiosyncratic guide to an array of tools, books, and services, often for the betterment of all, that resonated with ’60s counterculture. He wrote in the preface: “We are as gods and might as well get good at it.” The 12 words formed a simple, if controversial, statement about humanity’s use of increasingly powerful technologies: solar energy, space travel, computing, and more. Some 50 years later, at a time when the threats posed by climate change are no longer theoretical, the use of new techniques by godlike mortals—scientists—has grown more acceptable, if not urgent.

## **JURASSIC NO MORE**

Since their invention, genetic-engineering techniques have conjured the rampaging dinosaurs of Steven Spielberg’s *Jurassic Park*, in which returning species from

extinction has unintended and harmful consequences. But for Brand and Phelan and a diverse group of biologists and conservationists, the geographic counterpoint to Spielberg's fictional island is a patch of sand dunes in the southwest corner of San Francisco's Presidio. The area has been painstakingly restored by Presidio Trust, a nonprofit that helps oversee the former military base turned national park. The dunes have become a model and a laboratory for restoring native habitats that have been eroded or destroyed by human development or climate change.

The Xerces de-extinction effort was jump-started two decades ago by lepidopterist Robert Michael Pyle, who had founded the Xerces Society in 1971 to help protect invertebrates of all kinds. He took the name Xerces because the letter X evoked both extinction and the X shape of a butterfly's wings. That was during the era when a popular environmentalist bumper sticker read "Extinction Is Forever." In his 2000 article "Resurrection Ecology: Bring Back the Xerces Blue!," published in the journal *Wild Earth*, Pyle wrote that "perhaps the Presidio restoration will succeed in bringing back a patch of habitat bearing some resemblance to the city's lost landscape." He speculated that if a butterfly species whose genome was close enough to the Xerces was relocated to a suitable habitat, it might re-evolve into something akin to the original Xerces. It was an approach similar to one that had brought back a popular British butterfly, the large blue, after it had gone extinct in England. In that case, biologists had successfully relocated populations of related butterflies from Europe, and the large blue, which went extinct in 1979, flourished in 2000.

What Pyle and like-minded conservation biologists have made clear, however, is that their goal is not merely to revive an individual species. Rather, they aim to restore remarkably complex ecological systems composed of large numbers of species of plants and animals that interact. For instance, some butterfly species have—as the Xerces blue did—a symbiotic relationship with the ant colonies that share their territories. Ants help look after butterfly larvae because they secrete a sweet substance that the ants can consume without harming the larvae.

In San Francisco, the Presidio habitat-restoration project has been aided by the unexpected appearance in 2019 of a colony of silver digger bees, a rare sand-loving

insect that had not been seen in San Francisco since 1928. In another half dozen cases, the Presidio biologists have reintroduced species ranging from mussels to butterflies. In 2017, the variable checkerspot butterfly (*Euphydryas chalcedona*) was restored to the park by bringing in larvae from nearby San Bruno Mountain, in San Mateo County. The Presidio conservationists have also planted deerweed, a low shrub that grows in sandy coastal areas and served as a host plant for Xerces blue larvae.

This spring, the Presidio biologists plan to test Pyle's vision by relocating a population of silvery blues, a species they believe is closely related to the Xerces blue. The silvery blues will most likely come from the Marina Dunes, near Monterey, a region with a climate similar to the Presidio's and whose ecology is a close match for a butterfly species that also uses deerweed for a host plant.

How quickly might a silvery blue reemerge as a Xerces? Researchers for the project say that changes could happen in just a few generations, perhaps even in a single generation. They caution that the conditions that originally shaped the Xerces blue may now be missing.

“Assisted migration is an important solution to climate change,” says Lewis Stringer, the associate director of natural resources at [Presidio Trust](#). “In order for an individual species to be able to adapt to climate change, humans will have to step in and bring them to the places that they wouldn't otherwise be able to bring themselves.”

## **BLUE AND SILVERY**

As promising as relocation may be, the Xerces restoration effort has another tool at its disposal: namely CRISPR, a gene-editing technique pioneered by Jennifer Doudna, a UC Berkeley biochemist, and Emmanuelle Charpentier, founder of the Max Planck Unit for the Science of Pathogens in Berlin, for which they earned the 2020 Nobel Prize in Chemistry.

At the end of 2019, David Lang, an entrepreneur and writer, was meeting with Brand and Phelan. He described how he had seen gene-editing tools alter the appearance of butterfly wings. “Couldn’t these tools be used to restore a butterfly like Xerces?” Lang asked.

That conversation led to a meeting with scientists from the California Academy of Sciences at the start of 2020 to discuss both relocation and revival strategies. Ben J. Novak, the lead scientist at Revive & Restore, asked the CAS scientists whether there was a way to bring back a blue butterfly that would fill both the ecological and the evolutionary roles of the Xerces blue. The academy has a collection of 400 Xerces blue specimens. In December of last year, Revive & Restore gave an \$18,000 grant to the CAS scientists to support the sequencing of the genomes of both the Xerces blue and the silvery blue to determine whether and precisely how the species are related.

If the CAS researchers are able to extract the genome of the Xerces—something that is not yet certain, though early experiments have been promising—it will be the first

step toward figuring out what Xerces actually was. Whether it was a subspecies or a separate species from butterflies such as the silvery blue remains unknown. “The first and foremost thing would be to find that it was mostly similar to something that is local and nearby,” says Durrell Kapan, a senior research fellow at the academy.

Even if the CAS team determines that the Xerces was closely related to the silvery blue, the genetic engineering necessary to revive Xerces has not yet proved successful, acknowledges Novak. While much progress has been made in understanding the function of the so-called paintbrush genes that govern the patterns and colors of butterfly wings, more fundamental “germline editing” to make alterations heritable will be required to bring back an extinct Xerces blue, he says.

Such an advance will be necessary to complete the arc defined by the “We are as gods...” proclamation that opened the *Whole Earth Catalog*. In his 2009 book, *Whole Earth Discipline: An Ecopragmatist Manifesto*, Brand revised his declaration to read “We are as gods and HAVE to get good at it.”

CAYCE CLIFFORD

*Durrell Kapan, a senior research fellow at the California Academy of Sciences, is working to sequence the Xerces blue's genome.*



## DO NO HARM

The proposed revival of Xerces illustrates Brand and Phelan's pragmatic approach, a literal evocation of the butterfly effect, which suggests the possibility that the smallest change in the environment can have an immense and nondeterministic effect. The phrase comes from the work of meteorologist Edward Norton Lorenz. While running a computer program that simulated weather patterns, he made a tiny alteration in an initial value and found that it generated a completely different output. That led to the notion that a tornado might trace its origin to the flapping of a distant butterfly's wings weeks earlier—perhaps those of a Xerces.

To combat concern about unintended outcomes, last year Revive & Restore organized a symposium focused on the “intended consequences” of conservation. Research done by Novak, Phelan, and Michele Weber, the director of conservation innovation at Revive & Restore, found no “harmful unintended consequences” resulting from 1,013 conservation relocations. The proceedings of the conference will be published in a special issue of the journal *Conservation Science and Practice* this spring.

Brand's sense of urgency is broadly shared, even by those who have been skeptical of de-extinction. When he was a biology student at Stanford in 1960, his mentor was Paul R. Ehrlich, the well-known population biologist. Ehrlich has argued that de-extinction consumes resources that could be used on more urgent conservation tasks. Yet, he acknowledges that as a symbol, a revived Xerces blue would have value. “I think trying to restore some butterfly populations, while of utter insignificance in today's big picture, is more useful than many activities,” Ehrlich says. “It could add a small dollop of useful knowledge.”

Indeed, individual conservationists have put forward multiple answers to the question of why we might want to revive the Xerces blue, ranging from science to philosophy to aesthetics. For Liam O'Brien, a San Francisco-based lepidopterist who launched a project to create a corridor connecting different areas in the city that are habitats for the coast green hairstreak butterfly, the importance lies in creating the human experience of seeing butterflies that were once extinct come back to life, a notion that he learned from Robert Michael Pyle.

“A lot of species are hanging on by their fingertips,” O’Brien says, “but we have this material sitting in drawers that might be able to help us bring a butterfly back. I think that’s something we ought to try.” •

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**BY JOHN MARKOFF**

John Markoff wrote about technology and science for the New York Times beginning in March 1988 as the paper’s national computer writer.

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