De-extinction and Conservation

BY GREGORY E. KAEBNICK AND BRUCE JENNINGS

We are living in what is widely considered the sixth major extinction. Most ecologists believe that biodiversity is disappearing at an alarming rate, with up to 150 species going extinct per day according to scientists working with the United Nations Convention on Biological Diversity. The most alarming estimates, which are based on computer analyses and remain uncertain, hold that many species are vanishing before humans even know they were present, or at least before scientists had catalogued them. It is difficult to grasp the planetary magnitude of all this loss.

It's also hard not to mourn it. In the last few centuries, we have wiped out scores of species and subspecies; the lineages most commonly mentioned—the aurochs, the great auk, the Steller's sea cow, the sea mink, the Tasmanian tiger, the passenger pigeon, the dodo, the golden toad—are just a small selection of particularly well-known animals. And over a longer period—roughly the last ten or fifteen thousand years, as we humans have spread, developed, and multiplied across the Earth—we may have had a role in the disappearance of much of the Pleistocene megafauna. Just in North America, this category includes Columbian mammoths, wooly mammoths, mastodons, giant ground sloths, shasta ground sloths, dire wolves, lions, saber-toothed cats, cheetahs, giant short-faced bears, giant beavers, and glyptodonts the size and shape of Volkswagen Beetles. At one time, it was widely believed that complete extinction was scientifically and naturally impossible. Now we know better.

Gregory E. Kaebnick and Bruce Jennings, "De-extinction and Conservation," *Recreating the Wild: De-extinction, Technology, and the Ethics of Conservation,* special report, *Hastings Center Report* 47, no. 4 (2017): S2-S3. DOI: 10.1002/hast.744

Part of the reason the loss signified by biological extinction feels painful is that it seems irremediable. These creatures are gone, and there's nothing to be done about it. In recent years, however, the possibility has been broached that, just possibly, something can be done, in at least some cases. Human ingenuity, a contributing factor in the extinction crisis, might achieve their "de-extinction"—in at least some cases, and with sometimes significant qualifications about whether the original species had been "recreated" and whether it could resume its original place in the environment.

De-extinction would rely on genetic interventions, reproductive technologies, and clever strategies for rearing animals and helping them learn how to behave in the wild. By applying genetic sequencing to bits of preserved tissue, we can identify the genome of the extinct species. An assortment of methods for editing and synthesizing DNA could let us recreate the lost genome, probably by editing an existing genome. Somatic cell nuclear transfer (also known as cloning) could be used to get the newly created genome into an egg and turn the egg into an embryo. Assisted reproductive technologies might get the embryo into an adult female, where it can develop. And someday, maybe, an artificial womb could replace that adult female.

These techniques could be mixed and combined as needed. For example, if there is high-quality preserved tissue of the original animal, then genetic material from those cells can be used to create embryos directly, skipping the genetic tinkering. And for a few species, the whole process can be replaced with something that seems less high-tech: if there are surviving descendants of the lost species, then it may be possible to approximate the ancestral stock through a kind of breeding known as backbreeding, in which descendants that resemble their

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forebears (or can be shown to be genetically closer to their forebears) are iteratively crossed with each other.

Backbreeding has been under way for some years to try to get aurochs out of cows. Cloning is the key technique in efforts to recreate the bucardo, a subspecies of the Spanish ibex thought to have disappeared hundreds of years ago, rediscovered in the twentieth century in remote mountain valleys, and then lost again in 2000. A more elaborate program of genetic tinkering plus reproductive interventions is under way to "bring back" the passenger pigeon, a crow-sized bird that as recently as 1850 was the most populous bird on earth, congregating in the eastern United States in flocks that numbered in the billions and darkened the sky when they took to the air. Many elements of the demise of this species make it iconic, and the quest to restore it to its place in the contemporary world carries a high emotional intensity for some. De-extinction of the passenger pigeon presents special technical challenges, however.

But then again, every de-extinction effort presents special challenges. The effort that most rivets the public imagination faces enough obstacles that the chief claim of the book *How to Clone a Mammoth*, published in 2015 by Beth Shapiro, a scientist who has taken a central role in the sequencing of the mammoth genome, is that a mammoth will never be cloned—not, at least, unless we loosen our understanding of what counts as a "mammoth." And even if we were to succeed at the sequencing, editing, gestating, and baby mammoth raising, Shapiro adds, there might not be enough mammoth-like animals and enough genetic diversity to have a viable population, and there might not be a suitable habitat in which to put that population.

But the science should not be underestimated, either. *How to Clone a Mammoth* concludes that we are likely, at some point, to see something that resembles a mammoth. It concludes, too, that the effort might be worthwhile: it would be fascinating, terrific science, and it might even serve some conservation goals.

This issue—the extent to which de-extinction and related genetic technologies squares with the values of conservation—is what motivates this set of essays.

Until now, molecular biology (especially synthetic biology) and conservation biology have largely gone their separate ways. There has been little dialogue and probably some distrust between them. The values animating biotechnology have not necessarily been consonant with the values animating the conservation and environmental movements. The prospect of de-extinction, however, along with the possibility that genetic technologies might also be used to suppress invasive species or to help threatened species adapt to disease or climate change, has launched a conversation about how they may intersect.

There are some signs, for example, that the conservation movement is moving toward embracing or at least accepting de-extinction under some circumstances. Last summer, a committee formed by the International Union for Conservation of Nature (IUCN), which keeps the authoritative lists of threatened and extinct species, finalized a set of guidelines for de-extinction. The document neither calls for nor argues against de-extinction, but it sets out "guiding principles" for deciding when and how de-extinction could be considered and how the release of the new organisms should be carried out, detailing the kinds of conservation benefits that could be significant and the potential negative outcomes that should be weighed against them.

More broadly, some conservationists are expressing a growing openness to biotechnology. They are not concerned about human alteration of genomes, per se. It is the overall human impact on the natural world that they care about, not specifically the alteration of DNA. They believe that, in principle, altering genomes can be a good thing for the environment and that, in practice, it sometimes is. In 2013, The Wildlife Conservation Society and The Nature Conservancy supported the drafting of a "framing paper" on the intersection of conservationism and technologies to edit and synthesize genomes. A group of environmentalists who have dubbed themselves "eco-modernists" argue that some kinds of genetically modified crops can be beneficial, for example, if the crops allow farmers to produce more food on less land with less pesticide use. The nonprofit group Island Conservation is exploring the use of genetic techniques to eradicate human-introduced rodents on ocean islands where they threaten the rookeries of endangered seabirds. In Hawaii, the U.S. Fish and Wildlife Service is investigating whether a similar intervention could wipe out a nonnative mosquito that transmits nonnative avian malaria to endangered native birds. And research funded by the American Chestnut Foundation has developed a strain of chestnut that uses a wheat gene to survive chestnut blight, a disease that was accidentally

brought to the United States in the early twentieth century and drove the tree effectively into extinction.

De-extinction is therefore just one among many possible genetic interventions into nature, and if it proves hard to achieve, then it might be important mostly as a colorful, arresting entry point into a larger set of questions about how biotechnological tools can support, coexist with, or undermine the goals of conservation. If the prospect of de-extinction affects the public's thinking about other forms of biotechnology, then de-extinction could have an impact even if it never actually works.

The breadth of these biotechnological interventions means that asking whether to try our hand at de-extinction is linked to the debate over whether Earth has entered a new geologic epoch, the so-called Anthropocene, in which human impact on Earth is so pervasive and profound that it will be written into the rock, discoverable by geologists working millions of years in the future. The idea of the Anthropocene is rooted in the growing recognition of how Earth's biophysical systems have been altered through land and water use, climate change, ocean acidification, extractive industries, and environmental exposure to synthetic chemical compounds and materials. Genomic editing adds to these biophysical influences the possibility of an orchestrated impact on biological evolution. We can, perhaps, eradicate species, replace them, steer them through their ecosystems, and bring them back from the dead.

The debate about the Anthropocene is altering the understanding of the values and goals of conservation and of the role and promise of biotechnology. For a long time, a fundamental commitment among many conservationists has been that nature is worth preserving, not just because it is useful to us humans, but because of values we attach to nature itself. Some environmentalists now hold, however, that the ideal of preservation no longer works. Nature no longer exists, and maybe the concept of nature never made sense. Humans and their technology are not an alien intrusion on the world but rather an integral part of it. Life and Earth are dynamic phenomena; species and places undergo constant change and have always popped into and out of existence. And the world is now so deeply altered by human forces that we have no alternative but to craft an ideal that tolerates and maybe celebrates human activity in it. A number of environmentalists, including some who would call themselves conservationists, have suggested that humans should strive to be gardeners in nature rather than preservers of it.

The question about how de-extinction squares with conservation is therefore connected to broader questions about the overall relationship between biotechnology and conservation and about the very meaning of conservation. Are we beings in control of the world or beings who prosper by accommodating ourselves to webs of symbiotic interdependencies? Are we creators or creatures, or both—and if both, then how can we achieve the balance between them that might be called humility? The interplay of perfecting and accommodating is not unique to human beings—perhaps it characterizes all forms of life on Earth—but with humans, these modes of being are distinctive, and our technology greatly expands their scale and effects.

It is such questions that are explored in this report. The first set of essays lays out some of the basic issues, leading off with a piece from the chair of the IUCN committee that generated guidelines for attempting de-extinction. That essay holds that de-extinction aligns with and extends the traditional values of environmental conservation. Other essays in the first set offer contrasting historical, scientific, and sociological perspectives on that question. The second set considers whether de-extinction calls for a new ethic. The lead-off essay in this set, also by a member of the IUCN committee, argues that it does not, that the significant issues with de-extinction are the same as those of many other gene-editing technologies; animal welfare, for example, must be considered. The other essays, by environmentalists, environmental philosophers, and bioethicists, argue that de-extinction and related genetic technologies significantly expand human powers to alter the world and that the decision whether and how to use them requires a rethinking of the values of conservation.