

RESURRECTION SCIENCE



CONSERVATION, DE-EXTINCTION
AND THE PRECARIOUS
FUTURE OF WILD THINGS

M. R. O'CONNOR



St. Martin's Press
New York

Special appreciation to the Alfred P. Sloan Foundation's Program for the Public Understanding of Science, Technology, & Economics for their financial support of the writing of this manuscript.

Grateful acknowledgement is made to the editors of the periodicals in whose pages excerpts of this book first appeared:

Passages of Chapter 1 appeared in Guernica.

Excerpts of Chapter 6 appeared in The Atlantic.

RESURRECTION SCIENCE. Copyright © 2015 by M. R. O'Connor. All rights reserved. Printed in the United States of America. For information, address St. Martin's Press, 175 Fifth Avenue, New York, N.Y. 10010.

www.stmartins.com

Library of Congress Cataloging-in-Publication Data

O'Connor, M. R., 1982-

Resurrection science : conservation, de-extinction and the precarious future of wild things / M.R. O'Connor.

pages cm

Includes bibliographical references.

ISBN 978-1-137-27929-3

1. Animal diversity conservation—Anecdotes. 2. Animal diversity conservation—Moral and ethical aspects. 3. Endangered species—Anecdotes. 4. Wildlife conservationists—Anecdotes. I. Title.

QL82.O26 2015

591.68--dc23

2015004485

ISBN 978-1-137-27929-3 (hardcover)

ISBN 978-1-4668-7932-4 (e-book)

Our books may be purchased in bulk for educational, business, or promotional use. Please contact your local bookseller or the Macmillan Corporate and Premium Sales Department at 1-800-221-7945, extension 5442, or by email at MacmillanSpecialMarkets@macmillan.com.

Design by Letra Libre Inc.

First Edition: September 2015

10 9 8 7 6 5 4 3 2 1

CONTENTS

Introduction	1
1 An Ark of Toads	11
<i>Nectophrynoides asperginis</i>	
2 Tracking Chimeras in the Fakahatchee Strand	43
<i>Puma concolor coryi</i>	
3 Exuberant Evolution in a Desert Fish	69
<i>Cyprinodon tularosa</i>	
4 Mysteries of the Whale Called 1334	93
<i>Eubalaena glacialis</i>	
5 Freezing Crows	121
<i>Corvus hawaiiensis</i>	
6 Metaphysical Rhinos	147
<i>Ceratotherium simum cottoni</i>	
7 Regenesiis of the Passenger Pigeon	177
<i>Neo-Ectopistes migratorius</i>	
8 Nice to Meet You, Neanderthal	207
<i>Homo neanderthalensis</i>	
Coda	227
<i>Ultima Thule: Ends of the Earth</i>	
<i>Acknowledgements</i>	235
<i>Notes</i>	239
<i>Selected Bibliography</i>	248
<i>Index</i>	260

INTRODUCTION

When I was a kid in the 1990s, the world often felt like it was on the verge of catastrophe. At my California public school, to offset drought, teachers taught us to conserve water while brushing our teeth. I saw news stories about environmental crises such as burning rainforests and acid rain. None of these issues loomed as large in my imagination, though, as the idea that the world is in the midst of a “Sixth Extinction.” In the early 1990s, Richard Leakey, the famous Kenyan paleoanthropologist, used this term to describe the phenomenon of disappearing species; and it gained wide acceptance in the public domain, giving gravitas and urgency to media reports and conservation campaigns. When I was in middle school, I heard predictions like those made by the British environmentalist Norman Myers, who estimated that 50 percent of all species at that time would go extinct in the twenty-first century. Harvard biologist Edward O. Wilson estimated as many as 27,000 species were going extinct every year. Trying to understand these numbers is bewildering for anyone. As a kid, the idea that every hour three species disappeared was incomprehensible. I didn’t understand how there could be so many species on earth that we could lose so many. But I internalized these statistics, and developed a concern for the fate of species rooted in two beliefs: extinction is bad, and saving species from extinction is good.

Then a few years ago, I found myself in the back of the Bronx Zoo’s Reptile House peering through a little pane of glass into a room full of terrariums. Through the condensation on their walls, I barely made out dozens

of blurry, yellow frogs climbing over green moss. I wanted to get a closer look but the room was off-limits: the only people allowed inside were the herpetologists responsible for the frogs' care, and even they had to disinfect the bottom of their shoes with bleach. The frogs inside this bio-secure room were incredibly rare, one of two populations left in the world, both in captivity. The waterfall where they had come from in the Tanzanian rainforest was now the site of a hydroelectric dam, and the species was confined to these terrariums, painstakingly kept hydrated with an artificial misting system and fed specially bred insects. It was like peering into a hospital ward at a patient on life support.

The great lengths that had been taken to save the frogs from extinction intrigued me, and a year later I was in Tanzania interviewing some of the central characters of the Kihansi spray toad story. I expected to learn a lot about conservation biology. Instead I found myself on a crash course in national politics, development economics, racial privilege, bureaucratic subterfuge, and environmental ethics. I realized that my belief that conservation is self-evidently good was actually a social and cultural bias. By the time I made it into the country's remote forest where the frogs once thrived, I was having thoughts that would have previously struck me as unenlightened: maybe they should have just let those toads disappear. Staring at their former habitat, a mere two hectares of wetlands, the species struck me as a kind of evolutionary whimsy, extraordinary for its perfect adaptation to a waterfall and beautiful for its incredible rarity. But now they were confined to a little bathysphere suspended in a world aflood in disaster. Was that better than extinction? I couldn't say for sure. The millions of dollars that had been spent on their conservation seemed almost cruel in the context of the immense poverty of rural East Africa. Saving species, it turned out, was not a simple thing with bad guys and heroes and tidy endings.

In the years following my reporting in Tanzania, I began looking at other cases of threatened species and the efforts to protect them. Tragically, there are thousands of species to choose from, each conservation effort as scientifically fascinating and ethically complex as the next. My goal hasn't

been to write comprehensively about the field of conservation; instead I've focused on dramatic cases of animals that are on the precipice of dying out or have already vanished. The extreme nature of these stories crystalizes the questions at the heart of our evolving morals and relationship to the natural world. How can humans coexist with species in the modern world when our existence and their survival so often appear pitted against one another? What should we preserve of wilderness as we head toward a future of incredible technological control over biology? Is nature here to serve our interests, or is its independence worthy of protection? I discovered that contrary to a common perception that much of biology has been explained, scientists are making new and incredible discoveries today that give us a glimpse into the complex relationship between genes, ecology, and evolution. And at a time of rapid environmental change on earth—as industrialization, globalization, and human sprawl go unchecked—these discoveries are much more than intellectual marvels; they present clues as to how we might prevent snuffing out the existence of other species.

Until very recently, humans never really cared much about whether species disappeared. History is littered with our indifference—dodo birds, great auks, 24-rayed sunstars, dusky seaside sparrows, Bernard's wolves. For most of human civilization, no one really believed species *could* go extinct. The environmental ethic planted in me as a kid probably wouldn't have made sense even a hundred years ago to most people, who generally believed the earth's bounty was intended for the benefit of human survival. It wasn't until the early twentieth century—following the work of individuals such as John Muir, Henry David Thoreau, and Aldo Leopold—that an ethic in which species were valued was born in the modern mind. When the environmental movement gained traction in the 1960s, the linchpin in the argument to save species was the threat of their extinction. Extinction, it has been said, is the middle name of conservation biology, a discipline that coalesced in the late 1970s at a time when the impacts of humanity's disturbance of the earth's ecosystems were manifesting themselves and documented by scientists. This era has been described as a new geological epoch in which humans are a force of nature. Called the Anthropocene, its Noahs

are conservation biologists, people who dedicate their professional lives to saving species.

The field of conservation biology is a crisis discipline; Michael Soulé, one of its earliest visionaries, wrote that its relationship to the biological sciences is analogous to that of surgery to physiology and war to political science. Facing a Sixth Extinction, it's no surprise perhaps that conservation biologists can be a gloomy bunch. Conservationists themselves have said that the field breeds a culture of despair. And at times, their pessimism threatens to undermine the cause. "A society that is habituated to the urgency of environmental destruction by a constant stream of dire messages from scientists and the media will require bigger and bigger hits of catastrophe to be spurred to action," wrote biologists Ronald Swaisgood and James Sheppard in 2010.

The fact is, few of the dire predictions I heard as a kid about the Sixth Extinction have come to pass. It's generally thought that individual species last on average about a million years, and the idea that we are in the midst of a sixth mass extinction is based on an estimate that extinction rates have increased above this background rate. In 2000, the United Nations' Millennium Ecosystem Assessment estimated that extinction rates are now as much as 1,000 times this "normal" background rate and could increase to 10,000. But in the last 500 years, the number of species that have completely disappeared, what is known as a "true extinction," is less than 900. Some analyses show the rate of extinctions among birds and mammals has actually decreased since a peak in the eighteenth and nineteenth centuries; in 1900, they were going extinct at a rate of 1.6 per year, but that number has dropped to 0.2.

What's really going on? If we are in the midst of the Sixth Extinction, why aren't more species disappearing? Scientists know about this discrepancy between estimated extinction rates and actual extinctions and have chalked it up to something called the "extinction debt," the idea that species can be "committed" to extinction because of the loss of their habitat or shrinking population size, but can take a while to actually go extinct. But a few years ago, two researchers, Fangliang He and Stephen Hubbell, realized

the discrepancy was in part due to flawed math. The common formula used to estimate species loss as it relates to habitat destruction can inflate extinction rates by as much as 160 percent. When He and Hubbell published their findings in 2011 in *Nature*, it was tricky news to deliver and created much controversy.

A few of years later, the journal *Science* published a paper whose authors further challenged the perception that untold numbers of species are disappearing before they can be discovered or named, a concern partly based on an oft-cited statistic that there are as many as 30 million to 100 million species on earth. Instead, the authors argued that there are in all likelihood around 5 million species on earth. "A meeting of conservation biologists or ecologists is hardly complete without worries about extinction rates, that many millions of species are yet to be discovered, and that the taxonomic workforce is decreasing," wrote the authors. "We do not dispute that we are in a human-caused mass extinction phase with many species committed to extinction, but actual extinctions have been fewer than arguably expected. With a realistic surge effort, most species could be named within the present century."

Undoubtedly, it's good news that current extinction rates have largely been overestimated. But the fact that extinctions aren't occurring at the rate previously believed can misconstrue the problem of habitat loss. Wild, untrammled places are disappearing, and, with them, wild creatures independent from human influence. In 2009 the European Commission and World Bank published a study that showed a mere 10 percent of the earth's land today qualifies as "remote," meaning it takes more than forty-eight hours to travel to it from a city. As humans and their activities have spread across the globe to extract resources, plant crops, and build cities and roads, thousands of species inhabit slivers of their previous ranges, surviving in isolated populations with few places to expand and faced with a loss of genetic fitness and an increased vulnerability to climatic shifts, disease, and natural disasters. Tigers, for example, inhabit less than 7 percent of the space they inhabited a century ago. Caribou have lost half of their historic range in the last 100 years. The World Wildlife Fund (WWF) estimates that, on

average, vertebrate species populations have shrunk by half since 1990. Anthropogenic global warming has exacerbated the problem of disappearing habitat and shrinking abundance. Few landscapes around the world remain untouched by climate change today. And as they have for millennia, changes in climate are acting as selective pressures on species. For those animals that can't withstand changes to their environments, migrate or adapt fast enough, their survival often depends on human intervention. An estimated 4,000 to 6,000 vertebrate species will need captive breeding over the next 200 years in order to mitigate extinction threats. Faced with these emergencies, the urgency to *do something* to save these species seems like a good ethical argument for action. But what actions we take have enormous consequences for the evolution of species.

When Darwin published *On the Origin of Species* in 1859, he believed that evolution through natural selection was a gradual process that took place over millions of years. But species such as the White Sands pupfish of New Mexico, which I write about in this book, have shown in recent years that natural selection can occur at rapid speeds, over mere decades. What this means is that humans are in the midst of an unplanned experiment of influencing the evolution of the planet's biodiversity. The same forces driving extinctions—anthropogenic global warming, degraded habitats, overexploitation, disease, invasive species—are shaping the evolutionary trajectories of species. And which animals we prioritize, and how we choose to save them, tinkers with the biosphere as a whole.

The predominant thinking in conservation biology has been that preventing extinctions and hoping species will return to a fully conserved state—meaning free of direct human management—is enough. In an era of climate change, conservationists are realizing this is no longer a realistic expectation. Returning to a prelapsarian state of untouched wilderness, if one ever truly existed, is impossible. “It’s hard to future gaze to the next few hundred years, but unfortunately I think that’s what is going to happen: life on this planet will likely be managed,” Brad White, a conservation geneticist, told me. “It might not be as totally managed as a zoo or farm animals, but we are getting to that point.” The evolutionary ecologist Michael

Kinnison described it this way to me: "Early on, the goal was to save the organisms from the environment. Bring them into captivity, and if you treated them nicely and not too biased in how you bred them, it won't be an issue. Now there is much more of an understanding that organisms will adapt to those environments. In the process of trying to save them, we change them." The irony of this age is that often the more we intervene to save species, the less "wild" and autonomous they become.

The looming ethical question is now whether or not humans, recognizing their evolutionary impact on species, should begin to consciously direct or engineer evolution in the direction they want it to go. Sometimes called prescriptive evolution or directed evolution, it might take the form of imbuing a species with characteristics that can help it survive environmental impacts down the road; translocating animals; or creating new, more resilient hybrids. Engineering biological processes in this way represents a kind of devil's bargain for conservationists, who have traditionally separated people and nature. "When you are talking about messing with evolution, you are talking about the heart and core of what is special about this planet," said Scott Carroll, a biologist and founder of the Institute for Contemporary Evolution, in an interview. But Carroll, a leader in the nascent field of applied evolutionary biology, responds to skeptics of prescriptive evolution by pointing out that we are doing it anyway. "It's happening in this unplanned, unaware way in every living and breathing moment. We're proposing a more thoughtful way. I don't think we can come up with a sustainable relationship to the planet if we don't become cognizant evolutionary organisms."

The most explicit form of human bioengineering may be de-extinction, the ability to bring species that have already disappeared back to life with the goal of one day reintroducing them to their historical range. The technology of "resurrection science" is real and upon us. Scientists have not only successfully cloned endangered animals such as the European mouflon and the African wildcat, they are also working to bring back animals that are already extinct. In 2009, Spanish scientists successfully resurrected the Pyrenean ibex in the womb of a surrogate, though the animal lived just a few minutes after birth. International efforts are underway to bring

back mammoths. These attempts to repopulate the modern landscape with extinct fauna rest on an intriguing ethical argument: that humans have a moral responsibility to make amends for overexploitation by our ancient and recent ancestors.

Take the case of the passenger pigeon, whose potential de-extinction has become symbolic of both our incredible faith in science to solve our ecological problems as well as a metaphysical predicament. Is a bird born of human ingenuity in the laboratory the same as a bird born of natural selection in the wild? Or is it a case of what sociologists call bio-objectification, defined as the process by which life is made an object by humans? In 1982, Robert Elliot penned a paper called "Faking Nature" that rebuked the idea that an ecosystem disturbed or damaged by humans could be restored to its original state or has equal value to wilderness. Nature, wrote Elliot, is "not replaceable without depreciation in one aspect of its value which has to do with its genesis, its history." It seems that today we have to decide whether that genesis in the wild is something we value.

Some scientists see de-extinction as irrelevant to the real grunt work of fighting for the survival of species. "For people who are doing this work, the passenger pigeon stuff is just an offensive conversation," one biologist told me. "It's publicity for newspaper articles." There is real concern that the very idea that de-extinction is possible will weaken the will of the public and policy makers to protect endangered species or habitat.

I found the individuals working on de-extinction projects to be brilliant, and a few downright inspiring. But not many have shown how we will put resurrected animals back into the world at a time when humans can barely coexist with extant species. Florida panthers were once thought to be extinct in the mid-twentieth century. By the time a remnant population was discovered by a legendary predator hunter in southern Florida, the animals had characteristics of severe inbreeding. After a genetic rescue operation was carried out in the early 1990s, the number of Florida panthers increased, but the animals today are limited to a paltry fraction of their former habitat, bordered on all sides by Florida's booming population. "It's a success story because the panthers are sturdy, but they are raising them in

a cage.” Rocky McBride, someone who has tracked the panthers and other predator species for decades, told me.

After immersing myself in stories about extinction, the term *Sixth Extinction* has begun to feel unhelpful for grasping the scale and nature of the problem of diminishing biodiversity today. It is a monolithic idea; many of us are conscious that something terrible is happening to earth’s creatures even as the complexity of the problem eludes our full comprehension. Indeed, the idea of mass extinction can be so overwhelming, eliciting feelings of guilt and fear, that it eventually becomes an impotent fact in the same way that a million deaths is a statistic rather than a tragedy. In the stories that follow, I’ve tried to give flesh to a phenomenon that haunts the periphery of our awareness but is rarely seen or experienced directly. These stories are about just a handful of the animals that are on life support today, others that have already disappeared, and the people who discover, study, track, hunt, love, obsess, philosophize, save, and try to resurrect them.

6

METAPHYSICAL RHINOS

Ceratotherium simum cottoni

In early 2008, stem cell researcher Jeanne Loring decided to take her staff on a field trip to the San Diego Zoo. Loring had recently been recruited by the Scripps Research Institute in La Jolla, California, and the visit was an opportunity to thank her staff for moving their laboratory. It was an unusual field trip for this group of scientists. For decades, Scripps has been on the leading edge of medical research, developing and testing treatments for leukemia, HIV/AIDS, and multiple sclerosis. Loring's research is in the field of regenerative medicine—how to engineer human cells to treat and cure neurological disease. Regarded as a pioneer, she was one of the first people to master the production of human embryonic stem cells in a laboratory. She is a passionate evangelist for her field, involved in landmark legislation and patents. Loring describes herself as a scientist who likes big questions, and stem cells, she says, let you ask them. The subtext of the trip to San Diego was one of these big questions: Could they employ stem cell technology for the purpose of wildlife conservation?

Loring knew about the Frozen Zoo, the collection of tissue samples from more than 1,000 species run by conservation geneticist Oliver Ryder. There had even been some talk between Loring and Ryder before about how embryonic stem cells might be used in conservation biology. "The trouble was, the technology didn't exist," said Loring. "It was just talk." Harvesting stem cells from the embryos of endangered animals was both logistically and ethically challenging.

In 2006, however, Japanese scientist Shinya Yamanaka published his method for reprogramming any mature living cell into a stem cell, creating what is called induced pluripotent stem cells, or iPSCs. (The achievement would garner Yamanaka the Nobel Prize in Medicine in 2012.) In this immature state, these new cells are capable of developing into any type of cell in the body, including eggs or sperm. When Yamanaka's method was published, Loring immediately adopted it in her laboratory. It was no longer necessary to get stem cells from embryos; they could essentially grow as many as they wanted from a single skin biopsy. The method was so foolproof that she was soon assigning the job of reprogramming cells into iPSCs to her undergraduate interns. "This, in my field, was like getting a huge present," she said.

The applications for research were seemingly limitless. iPSCs made it possible to generate living mice from mouse skin cells, an achievement that could pave the way for growing replacement organs from a patient's own cells. And because the iPSC lines could be specific to patients, their bodies wouldn't reject them. Loring's lab was soon initiating projects to reprogram the cells of people with Parkinson's into iPSCs, turn these into brain cells, and reintroduce them to the brain for treatment. The possibilities "were the kind of thing you dream about as a scientist," said Loring. "It's like magic."

After feeding giraffes and watching the animals on their trip to the San Diego Zoo, Loring's staff began to consider an unprecedented idea, that iPSCs could be created from the cells of endangered animals being held in the big liquid nitrogen containers within the Frozen Zoo. If this was successful, these new lines of iPSCs could be turned into any cells of the animals, including sperm and embryos that might be used to increase the genetic

diversity of existing populations or increase the number of individuals of an endangered species. "If you can make eggs and sperm, you should be able to use assisted reproduction methods. In vitro fertilization [to] create entirely new animals," said Loring. "So we would not just preserve ones that are left but create new combinations of genomes that would add diversity to populations. Diversity is what it's all about."

For Oliver Ryder, the obvious first candidate for such an experiment was the northern white rhinoceros, the rarest and second-largest land mammal on earth. There were only eight individuals alive in captivity and none left in the wild. The Frozen Zoo, however, had tissue samples from twelve different individuals in its collection. Ryder had long been interested in the fate of the subspecies and felt a personal stake in its survival, stemming from his work with Ian Player, the eminent South African conservationist whom he first met in the mid-1980s. Player had been instrumental in saving the southern white rhinoceros, the cousin of the northern subspecies, from extinction. In the early 1900s, there had been only a few dozen or so southern white rhinoceros alive in a remote game reserve called Umfolozi (today it is part of the Hluhluwe-Imfolozi Park). The South African government responded by banning rhino hunting. Player first went to Umfolozi in 1952 as a young gamekeeper and later described seeing his first white rhinos in mythic fashion: "Two bulls loomed out of the mist. I had a perfect view of their physical characteristics as they walked along a ridge. The mouth was square and the nuchal hump between the head and the withers bulged prominently. Flies clung to their flanks and steam rose from their backs. These were truly creatures from a bygone age. The two rhinos grazed as they moved, their heads swinging in a scythe-like motion as they fed on the grass. I watched them move through the gray nthombothi trees into a cluster of candelabra aloes, and disappear into the mist. I had a sudden feeling that my life would in some way be bound up with these prehistoric animals."

By the early 1960s, the animals' numbers had increased to more than 2,000, but the preserve had reached its maximum carrying capacity. There were two options, according to Player: either kill off a number of rhinos or capture them and send them to other places. The first option was

unthinkable to him, but the second seemed equally foolhardy. No one knew how to capture and translocate temperamental, 4,000-pound animals. Player pioneered the use of tranquilizer guns to do so and transformed what had been considered a nearly impossible and dangerous endeavor into a relatively easy task. Gamekeepers could now create backup populations in zoos and preserves around the world, ensuring the animals' survival into the future.

One of these institutions was the San Diego Zoo, which received a dozen southern white rhinos in the early 1970s. Soon thereafter, the luck of the northern and southern whites began to change and then reverse. South-erns were rebounding and numbered around 3,000 by 1980, but the north-ern population was shrinking fast. When they had been discovered in 1900, the northern animals were spread over sub-Saharan Africa, from parts of eastern Democratic Republic of Congo (DRC), to Central African Republic, northern Uganda, Sudan, and the southern edge of Chad, and the animals far outnumbered their cousins to the south. By 1981, these countries had been wracked by decades of civil wars and instability, and only a couple of remnant populations were left. When a comprehensive survey was under-taken in 1983, less than a hundred northern whites were believed to exist in the wild. Player's concern was that people were grouping the two subspecies together and, because the southernns were doing so well, wouldn't support protections for the dwindling northern population.

Player enlisted Ryder in the cause, asking him to analyze the two sub-species' DNA and report on their genetic relationship to each other. What Ryder found was that the two subspecies, separated by a million years of evolution, were about as different from each other genetically as they were from black rhinos. It didn't lead to a different categorization of the species, but it solidified the argument that the northern animals were genetically unique and worthy of protection. In the ensuing years, Ryder began stock-piling northern white tissue samples whenever he could. He traveled to a zoo in the Soviet Union to gather five skin biopsies. Later, the zoo in Khar-toum, Sudan, sent the San Diego Zoo a male northern white rhino, adding another specimen to the collection. In all, Ryder gathered samples from a

dozen northern whites for the Frozen Zoo. "This is a doomed population, it's widely recognized that they are going to decline further," said Ryder. "Yet there is a gene pool that could rescue the small population in our freezer. Mouse stem cells have been used to produce sperm and eggs. There are several pathways for creating stem cells that could bring back genetic variation that's been lost to the [rhino] population."

There was no funding for Loring's research. It fell outside the parameters of both stem cell research and conservation biology. So she decided to undertake it in parallel with experiments to reprogram human cells for the purpose of regenerative medicine, justifying the expense by arguing that the two things were related. In truth, there was no precedent indicating that what Loring and her staff were proposing was even possible. The method developed by Yamanaka to reprogram cells does so by introducing a set of four genes to a skin cell. These genes, what Loring describes as powerful "master" genes that act as modulators, trigger the cell to transform itself and return to a primitive state. For humans, those genes are taken from embryonic stem cells, but this would be impossible to do when it came to the rhinos. Loring thought reprogramming genes taken from horses might work, but on a whim she decided to introduce the human genes to the rhino cells just to see if they worked. A postdoctoral researcher, Inbar Friedrich Ben-Nun, who'd recently joined Loring's lab, volunteered to lead the experiments using a cell line taken from the youngest living northern white, named Fatu, who was born in 2000 at Dvur Kralove Zoo in the Czech Republic. Several thousand of Fatu's fibroblasts, the cells that make up her connective tissue, were put into petri dishes, and twenty-four hours later Ben-Nun introduced a virus to the dishes. This virus was designed to stick to the surface of the cells and act as a delivery mechanism for the genes, but the initial one failed and a second type had to be tried. Every day the cells in the dishes were provided with fresh nutrients. The genes were not very efficient at reprogramming the rhino cells: out of a million there might have only been ten that transformed. Nevertheless, a couple of weeks later, Ben-Nun started to see dramatic changes in the dishes: whole colonies of shiny, smooth cells were developing. The lab technicians began pulling those colonies out with

a pipette, cutting them into little pieces and placing them into new dishes. Within a few months, millions of stem cells belonging to Fatu had grown. Loring sent a few of these back to Ryder's laboratory, where the cells's chromosomes could be checked to ensure they hadn't developed abnormalities. Ryder's laboratory confirmed they appeared just as normal as though the sample had been plucked from Fatu herself.

Loring describes herself as the kind of scientist whose "fortunes are up and down all the time. Either I'm too far out or right in the mainstream." In this instance, she was out in the stratosphere. They had created the first iPSC lines for an endangered species, but there was no clear niche for the publication of research in a peer-reviewed journal. Finally in February 2011, they convinced the editors and reviewers of the journal *Nature Methods* to take a look. When it was published in August 2011, the results were heralded as representing a significant step toward creating regenerative treatments for endangered animals that might be afflicted with genetic diseases or metabolic disorders. And then there was the tantalizing possibility that the cells could actually be urged to develop into rhino sperm and eggs, capable of creating rare embryos. In theory, these embryos could be implanted into a related species, most likely a southern white rhino. The result wouldn't just be cloned rhinos, but all sorts of genetic variations of eggs and sperm from the twelve cell specimens at the San Diego Frozen Zoo. The first step in this process couldn't have come sooner for the northern white rhino population. During the time *Nature Methods* reviewed the paper, the worldwide population decreased by one when Nesari, a thirty-nine-year-old female at the Dvur Kralove Zoo, died of old age.

After the paper was published, however, the rhino iPSCs were frozen at the Scripps laboratory and that's where the experiments stopped. Human patients desperately hoping to have children fund the field of assisted reproduction. This marketplace gives doctors and researchers the incentive to create new methods, but there's no clear economic incentive to making northern white rhinos in the laboratory. Nonetheless Ryder assured me that within the next decade, these rhinos will come out of the freezer. "Reproduction in the current population isn't going to provide a sustainable

population,” said Ryder. “What we’re talking about is the only way to prevent the extinction of the northern white rhinoceros.” What no one knows is whether any of the rhinos alive today will survive to meet them. It is a species on the brink of extinction and resurrection at the same moment in time.



Would the rhinos from a freezer be an entirely new species? Is a rhino born of a laboratory from reprogrammed cells the same as one born of living rhinos? Trying to answer these questions I found myself going down a metaphysical rabbit hole, 2,000 years of debate over the nature of reality, impermanence, and identity that is summed up by a thought experiment called the “Ship of Theseus.”

The story goes something like this: Around 350 BCE, the Athenians established a memorial to the naval heroics of their founding king, Theseus. They placed his ship in port, where it stayed for centuries. Over the years, the planks of the ship began to decay, so the Athenians replaced the rotting planks with new wood until eventually all of the wood from the original ship was gone. According to the Greek historian Plutarch, the ship became the focus of a popular riddle among philosophers. Was it the same ship? Had the ship changed, and if so, how? Some philosophers believed the ship was still Theseus’s, and others contended that it wasn’t the same boat at all. Aristotelians believe the form of a thing is its essence, and according to this logic because the ship had the same exact form as the one that was sailed by Theseus, it was the same ship. Heraclitus, however, might have argued differently. According to him, everything moves on and nothing is at rest; comparing things to the flow of a river, he famously said that no one can step into the same river twice. This sage wisdom seems to prophesy the modern understanding of biology. We know today that all the component parts of our bodies—our cells—are in a state of constant flux, of dying and regenerating. Are we the same person nonetheless? Over generations of human history, natural selection has played upon the DNA in our cells, changing

the sequence of proteins in a never-ending rearrangement of molecules that adds up to human evolution. So am I the same species as my distant ancestors?

In 1949, paleontologist Benjamin Burma argued that because species change through time, they can't be the same species from one moment of history to the next, that the whole idea is a construct without reality in nature. This has since been proven to be nonsense, but trying to articulate *why* is difficult. When I tried to think about why a rhinoceros born of stem cells in a freezer would be different from one born in the wild, I intuitively felt the answer had something to do with authenticity. But evolution complicates and obfuscates the idea of any species as something that has an "authentic" identity. This is why scientists and philosophers have come up with over two dozen different species concepts. What persists through time? What *exactly* is a rhinoceros?

Metaphysicists can bring clarity to this question where biologists cannot, but only by grappling with concepts such as space-time dimensions and wormholes. To try to understand these ideas, I turned to French philosopher Julien Delord. In a 2014 essay called "Can We Really Re-create an Extinct Species by Cloning? A Metaphysical Analysis," Delord explained two popular metaphysical stances on species, "real essentialism" and "three-dimensional individualism." The first, real essentialism, is rooted in the ideas of Aristotle and his notion that a horse is a horse because all horses share the same properties and therefore the essence of horse-iness. Some modern philosophers have equated this essence to DNA, but essentialism is mostly considered indefensible after Charles Darwin because the properties of what makes a horse a horse are not static. A genetic trait or mechanism might disappear over generations of horses, but this doesn't mean that the offspring are necessarily a new species of horse. A genetic code might also be shared by different kinds of animals, dogs and wolves for instance, but this doesn't make them the same species.

The second idea Delord wrote about, three-dimensional individualism, is that species aren't really a class of organisms at all, but are better described as individuals. The American philosopher and biologist Michael Ghiselin

articulated this idea in the 1960s, and he believed it was not as radical a proposition as one might initially think. Individual organisms like you and me have proper names, and we are made up of parts that are restricted to a particular time and space: I can't be in New York while my feet are in San Francisco. Species also have proper names and are limited by time and space, yet they are considered taxonomic classes, groups of entities that are defined by their shared properties that are true at any time and place in the universe.

In his essay, Delord used these two concepts to try to solve what he calls the "resurrection paradox," the problem of knowing whether a resurrected animal is truly a member of the original species. The conundrum comes down to whether we can transform an evolutionary product (a resurrected rhino) into an evolutionary process (a species of rhino), explained Delord. If you are an essentialist, true resurrection of an animal might actually be possible, particularly if you believe "essence" is equated with an animal's genetic code. A resurrected rhinoceros would have the genome of its ancestors, and therefore be a member of the same species. But if you think of species as individuals, the whole idea of authentic resurrection is impossible. Delord wrote,

According to this metaphysical stance, when a species goes phyletically extinct (succumbing to terminal extinction), one can make a straightforward analogy with the death of an organism. It ceases to exist both functionally, as there are no more vital relations (reproductive, ecological and so on), and even materially, as no spatio-temporal entity that was part of the species exists anymore. . . . All attempts to resurrect it from a cell or from the genetic information taken from the dead organism is doomed to failure, as this would create a new organism, that is a new spatio-temporally delimited individual, although one very similar in many aspects to the dead organism.

Then Delord introduced wormholes to his analysis and the metaphysical debate over whether reality is best described as having three or four dimensions. In three-dimensional reality, things exist in space but not time. If we think about Theseus's boat from this "endurantism" perspective, wrote

Delord, it's clear that it's not the same boat once even one plank of wood has been replaced, because all its original parts are not present at the same instant in the form of the boat. It's difficult to make sense of species from the three-dimensional perspective because the animals change over generations but, biologists tell us, are still the same species.

Species start making more sense if you think in terms of four-dimensions, what's called the "perdurantist" view, which beautifully solves the paradox of species resurrection, according to Delord. In four-dimensional thinking, entities persist in many possible states by virtue of a kind of temporal wormhole extending in a continuum from past, present, and future. An entity's existence at different stages in time is an aspect of that entity. So even as Theseus's boat is changed plank by plank, it inhabits the same space-time continuum as the original boat—even if all its wood has been replaced over the centuries. A perdurantist might say that a rhino born of a freezer after all other rhinos have died inhabits the same space-time continuum of the species. Its resurrection is as natural as a bear's awakening from the slumber of winter.

All this hand wringing over the metaphysical status of resurrected animals might seem arcane and silly. We don't ask the same questions of human children born of in vitro fertilization or surrogate mothers. But to give humans a moral status is unambiguous. Delord rightfully pointed out that metaphysics of animal re-creation matters a lot when it comes to ethics and how we treat animals that are created by humans. If they aren't allowed full membership to the species they descend from, they might deserve less attention and preservation than "natural" beings. And so whether a re-created rhino is "authentic" or not may matter a great deal in the near future. My head full of these metaphysical debates, I took a plane to Kenya to meet four of the last living northern white rhinos on earth.



On a cool and sunny morning in Nairobi, I piled my things into a Land Cruiser and headed north toward Nanyuki, a busy market town at the base

of Mount Kenya. In the driver's seat was Kes Hillman Smith, a British-born, Kenyan zoologist, and the world's expert on wild northern white rhinos. We were headed to see Fatu, the rhino whose cells had been used to create the first iPSCs from an endangered animal. Now fourteen years old, Fatu was living on a 90,000-acre wildlife preserve called Ol Pejeta Conservancy near Nanyuki, after being translocated from Dvur Kralove Zoo in the Czech Republic along with three other northern whites including her mother, Najin. At the time, biologists had hoped that their introduction to the grassland of the East African bush would stimulate the animals to successfully mate. But five years later, there still hadn't been a successful conception. Fatu, it seemed, was the last of the subspecies to be born. Kes had been with the rhinos shortly after they arrived at the conservancy, sleeping on a bedroll next to their enclosures. In order to protect them in their crates during the journey from eastern Europe, caretakers had sawed the rhinos' long horns off, giving them a stunted, somewhat sad appearance. Over the next few weeks, Kes and the animals' keepers watched as the rhinos adapted to their new surroundings. Sudan, the only rhino to be born in Africa, was the eldest at thirty-six years old and the dominant male. He seemed to adjust immediately, freely leaving his scent on whatever bush he wanted, marking territory and lying down for a snooze. Suni, the younger male, was different, sniffing around but leaving few scent marks and acting more anxious. Fatu and Najin stayed close together, even though the daughter was well into adulthood. Clearly, the animals had an established dynamic that came from living in close quarters at the zoo. The quickest way to get the rhinos to mate, Kes believed, was to create conditions where social dynamics observed in the wild could develop. Both Sudan and Suni needed to establish separate but parallel territories. That way they could each stake a claim and feel confident mating with the females when they were in estrus; the proximity to another male would spur them on. In the wild, Smith had seen a single rhino population double in the span of eight years, an incredible fact given that females have a fifteen- to sixteen-month gestation period, so she knew what the animals were capable of under good conditions. Clearly something at Ol Pejeta wasn't working.

No one knows more about northern white rhinos in the wild than Kes. In the early 1980s she lived in the eastern corner of the Democratic Republic of Congo (then called Zaire) where the last population was located. She originally planned to stay for a year and ended up staying for twenty-four. It was the only long-standing monitoring project of the animals ever undertaken. Unlike Jane Goodall or Diane Fossey, who both worked in the same corner of Africa as Kes, she never gained notoriety for her work beyond a small, international circle of zoologists and conservationists. This isn't because her work was any less dramatic. During her time at Garamba, a remote and long-neglected preserve, she watched as the rhino population grew to thirty-two individuals, and she then launched a guerrilla war against poachers who hunted and killed one rhino after another. By the time she and her husband left in 2005 there were less than ten rhinos left, and there haven't been any sightings or evidence of them in years.

The pioneering wildlife filmmaker Alan Root described Kes as an unsung hero in one of Africa's fiercest conservation battles, a "pocket-sized Venus, usually dressed in old military gear and boots." She was, Root wrote, like a poster girl for the Israeli Army. I had first heard about Kes's work in Africa from Oliver Ryder, but later I realized that I had actually read about her when I was fourteen years old in *Last Chance to See*, Douglas Adams's funny and moving account of traveling around the world to see endangered species in the early 1990s. The northern white rhino was one of them, and he went to Garamba where he described scanning the horizon with binoculars from a termite hill next to Kes, hoping in vain for a glimpse of a rhino. At that time, there were around thirty rhinos in an area of roughly 650,000 acres.

Kes is a formidable woman, who looks as if she has just walked off the screen of a slightly naughty adventure movie: lean, fit, strikingly beautiful, and usually dressed in old combat gear that's had a number of its buttons shot off. She decided it wasn't time to be businesslike about the map, which was a fairly rough representation of a fairly rough landscape. She worked out once and for all where the Landrover had to be,

and worked it out with such ruthless determination that the Landrover would hardly dare not to be there, and eventually, of course, after miles of trekking, it was exactly there, hiding behind a bush with a thermos of tea wedged behind the seat.

I noticed there was a thermos in the Land Cruiser with us now, which Kes encouraged me to drink from. In her sixties, she has retained both the petite elegance and simmering intensity of her younger years. Frequently dressed in worn horse-riding breeches and a stylish black leather belt slung low around her hips—the buckle a shiny brass rhinoceros—she drew upon angers and frustrations from decades ago as she told me the story of what went wrong in saving the world's last wild northern white rhinos. "If you think about subsistence living, poaching or hunting is fair enough. People are using traditional methods and hunting for the pot. They need it," said Kes. "The trouble is, it doesn't stop there." We barreled north on a two-lane highway through rich Kikuyu farmland. In the opposite direction was a stream of vehicles returning from an annual charity event farther north in Samburu County. Called the Rhino Charge, the difficult off-road rally race raises money for rhino conservation. The event had raised a record \$1.16 million this year, and Kes's son Doungu, named after a river in Garamba, had been a member of the winning car's team.

Rhino conservation in Kenya has entered a period of crisis in the last few years. Poachers killed double the number of rhinos in 2013 than the year before, encroaching on even highly secured preserves with seeming impunity. Kenyan newspapers had begun reporting on the fact that most of these poachers are armed and supported by international criminal networks operating with the help of corrupt politicians. The crime syndicates are feeding a seemingly insatiable hunger in countries like Vietnam and China, where the nouveau riche view rhino horn for medicine or hangover prevention as a status symbol. A kilogram of rhino horn reportedly fetches up to \$100,000 in these countries, much more than gold. The number of rhinos being poached is even worse in South Africa; in 2013, poachers were killing on average three rhinos every day.

Kes has seen this all before. It was during the poaching epidemic of rhinos in the 1970s that she had moved to Kenya and was soon hired by the New York Zoological Society and the International Union for Conservation of Nature to do aerial surveys over Africa and analyze elephant and rhino populations. Kes's father was in the British air force and had once given her flying lessons as a birthday present. It was the sort of work she had been preparing and hoping for her whole life. "I suppose I've always loved animals," she said. "I wanted to travel and work in Africa because I wanted to get out of England and be in a more interesting and challenging place." Her doctoral work had focused on electron microscopy in frog hearts, an academic exercise she felt was pointless. "It taught me how to ask questions and formulate investigations, but it didn't seem to have any meaning in the real world. As soon as possible, I got out and into what I considered to be much more meaningful conservation."

What she saw during the aerial surveys was grim. In the Luangwa Valley in Zambia, 2,500 black rhinos had been killed. Three thousand rhinos had disappeared in Tanzania's Selous Game Reserve. The Central African Republic's rhinos were just about gone with about fifty left, and populations in Chad had dwindled toward probable extinction. Southern white rhino populations had rebounded to around 17,000 but now their cousins, the northern whites, were difficult to find. Kes initially estimated that around a thousand were left, mainly in the south of Sudan in the Shambe Game Reserve and at Garamba. Kes became the head of the IUCN's Rhino Specialist Group and proposed that Shambe and Garamba be the focus of funding and efforts to conserve the remaining northern white rhinos. But in April 1981, as civil conflicts were broiling in the region, she flew another aerial survey and couldn't find a single live rhino in Shambe. She began ground surveys in other parts of Sudan, but there were so many poachers armed with military equipment that by 1983 it was hard to penetrate even the national parks. It was becoming clear that the previous population estimate of a thousand northern white rhinos had been optimistic. The total number of rhinos alive, Kes realized, was likely less than a hundred. In 1983, the Second Sudanese Civil War erupted between the Islamic government in the

north and the Sudan People's Liberation Army (SPLA). Kes had to give up the idea of working in Shambe and she turned her sight across the border to Garamba in the DRC.

Today, Kes and her husband, Fraser, live in the wealthy Nairobi suburb of Langata, just a stone's throw from where Karen Blixen toiled in the black cotton soil trying to grow coffee, a struggle that would become the basis for her book *Out of Africa*. Their large, well-worn home is concealed from the road by trees. Driving down the lane you pass a barn with horses, and inside the house is a central courtyard overrun by vines, four dogs, and handfuls of cats. In the evenings, their large veranda is often filled with buoyant guests who sit in the canvas safari chairs and watch the wild warthogs and bush babies as the sun sets in the direction of the Ngong Hills. Just beyond the backyard is a 150-acre giraffe conservancy where Fraser rambles with the dogs or Kes rides her horses.

It's an idyllic home but one that seems cast in the shadow of their previous life at Garamba. Entire rooms of the house are filled with papers, research, and funding campaigns for saving the last northern white rhinos. Pictures from their years at the park cover the walls. Kes and Fraser were married on the banks of the Doungu River at Garamba. A daughter came, Chyulu, and then their son. The children both grew up there. In one photograph, Kes grins at the camera as she stands in front of a river, holding a white parasol over her baby girl, who sits in a carrier on her mother's back. Kes looks beautiful in a way that seemed to me to indicate great fulfillment, like she was exactly where she was meant to be. In light of what would come in later years, the photo has a slightly tragic feeling. Fraser intimated this general feeling during an evening stroll through the giraffe conservancy, when he told me we often don't recognize the good times until later, when things are so much worse.



Garamba's ecosystem is shaped by rain and fire. During the long wet season from April to November, rain feeds the savanna and the perennial grass,

which grows thick and tall until it becomes an undulating, rich green sea. During the dry season, the eight-foot-long grass loses so much moisture in the sun and heat that it becomes combustible and ready to explode. When the wildfires begin, they are ferocious and fast moving, turning the soil gray with the ash left behind. A couple of weeks after the pyrotechnics end, tender green shoots begin to appear, ready for eating by buffalo, elephants, and rhinos, and the whole cycle begins again. Buffaloes were once the most numerous animals in the park. In the 1970s there were around 53,000, in addition to hundreds of Congolese giraffes, kob, warthogs, roan antelope, bushbuck, hartebeest, oribi, duikers, lions, spotted hyenas, and an abundance of hippos and crocodiles. Sometimes the crocodiles in the two rivers running through the park were twenty feet long. The landscape of Garamba wasn't as dramatic as the volcanic mountain regions of the DRC or as impressive as the country's impenetrable interior jungle, but it was unique in its ability to support an incredible density of wildlife. The filmmaker Alan Root wrote that filming the elephants at Garamba was like seeing a remnant of the old Africa, when the continent had "huge herds moving across endless space."

When Garamba had been created in 1938 in what was then the Belgian Congo, the idea was to maintain the natural processes of the ecosystem by completely isolating the land from human activities. The nation's parks, including Virunga, where the country's only population of mountain gorillas live, were to be places in which wild nature could evolve without any interference. When Kes arrived, the brutal irony of this founding vision became apparent. The country's politics, starting with independence from Belgium in 1960, followed by the Simba Rebellion and then an invasion of rebels from Angola, had created instability and a scarcity of funding. Local communities and paramilitary groups used the park's animals as a resource to feed themselves and to create an income. The population of rhinos was as high as 490 in the early 1970s but had since sunk to around twenty. The number of elephants had similarly decreased, from 22,000 in 1976 to 7,000 by 1983. Many of the animals had been pushed into the southern sector of the park by the poachers, who made their camps in the thicker bush toward the

north, where they could smoke their meat before taking it to sell in nearby villages or across the border into Sudan.

On the invitation of the government's wildlife agency, Institut Zairois pour la Conservation de la Nature, Kes moved to the park in March 1984 to live full time. Fraser came with her, hired to rehabilitate the park's ailing infrastructure. Fraser was a trained wildlife park manager who had grown up in South Africa and Botswana. He lived in safari shorts and sandals, even when he was darting rhinos or flying a Cessna on poaching reconnaissance missions, and was a natural tinkerer and problem solver, perfectly suited for the challenges of working in Zaire where problems were everywhere. In order to deter the poachers, the Smiths and the park staff began building roads, bridges, airfields, a radio communication system, and strategically located patrol posts. It was an overwhelming and relentless job. In her 2015 book *Garamba: Conservation in Peace and War*, Kes described the difficulty of maintaining a network of roads in the park:

Under ideal conditions the tractor would cut the grass down the centre of the tracks in June, just as the grass was reaching the height of a Land Rover bonnet and causing the radiators to clog and over heat. If the cut grass was burnt a few days later, the tracks would remain usable through September when another cut was necessary for the centre and sides, to prevent the long grass being bent over the tracks by storms. If all this grass was burnt, the roads would remain open until the dry season when the whole lot would often get burnt regardless of our efforts to control constant burning year after year. It sounds simple, but in practice was seldom possible to achieve. For a start, four cuts down every road added up to thousands of kilometres a year. The tractor was not designed to cope with such a task, nor was the driver, who had to sit day after day in the swirling dust of slashed grass with blood shot eyes peering through thick layers of yellow pollen. Worse still was the task of the aide-chauffeur walking ahead checking for rocks, holes, termite mounds and tree stumps through grass no-less coarse than sugar cane! They stopped only to repair punctures.

Fraser built a mud hut and then a mud-brick house with bookcases and open windows and doors to let in the breeze, and their initial efforts to rehabilitate the park had almost immediate and positive results. Kes was able to do some of the first and only long-term monitoring of northern white rhinos, observing their social dynamics and mating habits across multiple generations. Every month she flew the park's Super Cruiser to conduct a total survey of the population. What she found gave her hope: the population nearly doubled to thirty individuals over the first ten years. With veterinarians Peter Morkel and Billy Karesh, she developed an innovative way to follow their movements using telemetry by drilling into the rhinos' horns and placing radio transmitters inside and up through the center. She was concerned that the small population could result in inbreeding, and began doing biopsy darting and taking small ear notches to send to laboratories in Kenya and Cape Town. Students were coming to the park, including Emmanuel de Merode, who would go on to become the director of Virunga National Park. During this time the poaching was mostly limited to buffalo and the fires from bush camps were easy to detect from planes. Around 1991 the Smiths instituted a rigorous reporting system for the park rangers that gave them ongoing data on the type of illegal activities that they found in the park and the movements of the patrols themselves. "It was a way of being able to analyze and compare information over time and space which was collected in a systematic way," said Kes. "That was incredibly useful. We were getting so much information, which was being fed directly into guiding patrols and improving antipoaching. And we could use it to raise support."

By working with the guards and reinforcing the rules and logistics of antipoaching, explained Kes, virtually all of the hunting stopped. Then unrest came to the park. In 1991, the SPLA took the town of Maridi and 80,000 refugees fled across the border, many of them into the park. Eventually they were resettled nearby, but the ongoing war in South Sudan meant the poaching only increased. When the First Congo War started in 1996, it brought a wave of militias moving through the region; the guards were disarmed and a three-month free-for-all by poachers ensued. The Smiths didn't know it

then, but this period of instability would mark a turning point in the fight to protect Garamba, setting off a war between the park rangers and poachers that escalated as the violence around them surged. This was Garamba's curse: it was surrounded on all sides by countries awash in war. The poachers were armed with increasingly heavy ammunitions: automatic weapons, hand grenades, rocket launchers. Antipoaching units, previously eight men and now increased to twenty, were forced to respond by arming themselves more heavily. The fighting escalated. Confrontations with poachers could easily end in casualties on both sides. "They were supposed to give three warnings before they could legally shoot to kill," explained Kes. "But of course they didn't."

Despite the continued aerial surveillance and patrols, the assaults on animals by the poachers were relentless. "We knew it was getting dangerous," said Kes. And they also knew it was only matter of time before the poachers pushed farther south into the park and the long-grass savanna favored by the rhinos. In 1996, patrol units reported hearing gunfire near the Garamba River and discovered two rhino carcasses. The first one was Mai, a young female, freshly killed. Inside her was a male rhino fetus; she had been close to giving birth. The second carcass, a male called Bawesi, had already started to decompose. The rangers cut off Mai's head and brought it back to headquarters. Kes knew some people were poaching animals in the park to feed themselves. But this, she was sure, was the work of the SPLA, which was still fighting a civil war against the Sudanese government in Khartoum, just across the border from Garamba. These men were not poaching because they were starving. "There was a massive amount of food aid that was being flown into Sudan," said Kes. "They were just exploiting their neighbor, selling ivory and rhino horn to get weapons and continue their war." At times her frustration was overwhelming. "You're angry and you think, how are we going to fight this? This is so big," she recalled. "It's a fatalistic anger. So you have to try to create positive force from it, some way to combat it."

The first strategy was to go to the SPLA directly and negotiate to get the poachers to stop. She traveled to the main SPLA headquarters in Nairobi as well as Uganda, where the SPLA had training camps. The army's

higher-ups claimed the poaching was just a few stragglers here and there, deserters mostly trying to make an extra buck. They even agreed to do some antipoaching joint operations with Garamba's park rangers. But the Smiths knew things were much more complicated than what the SPLA leaders were telling them. The army had camps just across the boundary of the park, places from which they could cross back and forth with impunity. The park rangers were discovering too many poachers who were Sudanese to believe they were just deserters acting alone. Later that same year, Laurent-Désiré Kabila, the Congolese rebel, began leading his forces over the eastern border of the country from Rwanda. As they marched toward Kinshasa, their presence created a tsunami of military forces fleeing for their lives and pillaging along the way. For the first time, the security situation forced the Smiths and their children to evacuate their home; they hid photos and valuables where they could and flew to Kenya in one of the small planes. After they left, Mobutu's mercenaries took up residence in the park, staying for a few months before Kabila's Alliance des Forces Démocratiques pour la Libération du Congo-Zaïre finally disarmed them and drove them out. In May of 1997, Kabila became president of the newly named Democratic Republic of Congo, and in July the Smiths were able to get back into Garamba. Vehicles, computers, and fuel had all been pillaged. But worse than that, the months of disruption to the antipoaching patrols had led to 6,000 elephants and two-thirds of all the buffalo and hippos in the park being killed. Poaching camps littered the park. Somehow only two rhinos had died and five rhino calves had been born.

They were barely in the midst of rebuilding when the country's second civil war erupted in 1998. President Kabila had tried to force Rwandan Tutsi refugees to leave the DRC and return home. The park's officer in charge of elephants was killed by an army firing squad for his Tutsi ethnicity. It wasn't difficult to understand why the World Wildlife Fund decided to close its projects in the DRC. Luckily for the Smiths, the International Rhino Fund—a conservation organization based in Fort Worth, Texas—took over even as the violence escalated. As Kes explains in her book, three different parallel governments backed by foreign interests effectively controlled

the country, and Garamba fell into territory under warlords supported by Ugandan forces. The park was also close to the conflict in Sudan and very near a territory controlled by Rwandan-backed rebels. Dealing with these different factions made it difficult to transfer fuel and supplies and to keep staff paid on time, if at all.

When I asked Kes how many rangers died during this time on anti-poaching patrols, she avoided giving a number. But it was clearly not unusual for rangers to lose their lives or to have to be evacuated after being wounded. It was equally brutal for the poachers themselves. If they were caught alive, they were imprisoned, and the park rangers sometimes tortured them to get information. "We couldn't really stop them doing that, we weren't the authority in that sense," said Kes. "There is a cruel streak," she added, "which seems to have grown in response to the type of colonialism there." During one debriefing, the rangers told Fraser they had killed some poachers in an attack. When Fraser asked how they could be sure the poachers had died, the rangers started bringing in ears cut from the poachers' bodies. Fraser put an end to the practice, but it was a glimpse into how the park itself was susceptible to the unforgiving violence that surrounded it.

For the next few years, even as political instability in the region continued, the population of rhinos held steady against the poachers' incursions. In April 2003, Kes flew one of her regular aerial surveys and found thirty individuals in Garamba. Oddly, it was a cease-fire between the SPLA and the government of Sudan that was the beginning of the end. For years the SPLA had monitored the border between DRC and Sudan, but after the cease-fire they no longer controlled the area, creating a porous boundary that let an entirely new enemy into the park. Smith began seeing herds of elephants gunned down in her aerial surveys; even tuskless females and infants were shot. In early 2004, the rangers got their first sighting of who was responsible: not SPLA but Sudanese men on horses. This was the *janjaweed*, the Muslim horsemen who were creating havoc in Darfur. These skilled fighters could move fast through the park, much quicker than a vehicle or men on foot, and the small planes were useless in cutting off their retreats to the border. They needed a helicopter or two but appeals to the

United Nations—Garamba was in fact a UNESCO World Heritage Site—went nowhere. In May 2004, an early morning attack against the horsemen in which the park rangers were outmanned and outgunned resulted in two rangers being killed and others wounded. Three *janjaweed* were also killed. “It was a disaster,” said Kes. “As a result, there was a lot of fear. The guys were scared and coming up against horsemen who were really brilliant shooters and fighters.” By July there were only fourteen rhinos left in the park, and by December Smith could find only four in addition to four outside the park’s border.

As early as 1995, the government wildlife agency—now called the Institut Congolais pour la Conservation de la Nature (ICCN)—international donors, and Kes had discussed emergency measures to take some rhinos out of Garamba if the threat of poaching threatened to wipe them out. It was an idea Kes endorsed with great hesitation. The rhinos were the flagship species of the park, the reason international interest and donor dollars were being directed to conserving a small ecosystem in eastern DRC. If the rhinos were gone, the will to invest in the area might leave with them. She had long fought for the rhinos to stay where they were in the hopes it would rally support for the park. But by January 2005 it was clear that if the rhinos were going to survive they needed to be removed from Garamba. The idea was to move them to Kenya and bring them back once things were safer. President Kabila and four joint vice presidents in Kinshasa agreed to the plan, but the minister of environment refused to endorse it. He insinuated on live television that the government, ICCN, and the conservation effort were selling the rhinos to Kenya, where they would be used to increase tourism. The government, wary of its image in the public eye during an election year, decided to sack the plan.

After this, things became very sinister. A delegation from the government’s wildlife organization in Kinshasa was met by machete-wielding mobs near the park. The Smiths were briefly arrested and accused of sneaking into the park illegally. The park’s warden canceled a donor-strategy meeting at Garamba. By this stage, the Smiths had already bought their house in Langata, and the donors decided to gather there instead. For many of them, the

politicking by the DRC government and power plays within the ICCN ranks were the last straw. They had stuck with the rehabilitation project through civil wars and unrest, but the latest string of events had spoiled their goodwill. The NGOs decided to pull their aid to Garamba and told the ICCN the only way to get it back was for it to sort out its internal problems. By the end of the summer, with no evidence things had changed, the International Rhino Fund—the Smiths' employer—ended their funding permanently. After twenty-four years, the Garamba project the Smiths had given their lives to was over.

"We spent millions of dollars in the Congo trying to save it in situ," said Susie Ellis, the current executive director of the International Rhino Fund. "And for various reasons outside our manageable interests, it didn't work." In 2008, a team of biologists went into Garamba in search of rhinos. They found nothing. "The thing we all agree on is that the population is extinct. Definitely in the DRC and most likely in Sudan," said Ellis. Like Oliver Ryder at the Frozen Zoo in San Diego and others, Ellis considers the last rhinos in captivity doomed, and missed opportunities to bring more into captivity from the wild a tragedy. "The view most of us have is it's too late for the northern white rhino. We really messed up. The technologies to bring them back through cloning are long, long away. In the meantime, I think probably the most important thing we have learned is where the mistakes were made. This will never happen again with another species of rhino."



We arrived at Ol Pejeta Conservancy in the early evening, just as the sun was starting to cast its last light of the day on Mount Kenya, now looming to our east. The park rangers at the registration gate greeted Kes warmly; she was the lady that only came to see the rhinos. We drove down an empty dirt road through open bush passing herds of buffalo, plains zebras, and delicate gazelles munching on green grass. A brisk wind came down from the mountain but the air felt sweet after the congested streets of Nairobi. When we reached the research camp, there were only two other people there, a

woman collecting ticks and a young undergraduate student radio-tracking lions. We slept in beds made up with thick down comforters under Masai tartan prints.

By seven the next morning we were back on the dirt road and headed deeper into the 90,000-acre preserve to the area where the rhinos were kept in large enclosures protected by electric fencing and armed guards. Ol Pej, as the locals call it for short, has some of the highest security of any park in Kenya. There is a canine antipoaching unit consisting of German shepherd guard dogs that can detect and give chase to poachers. In 2013 the conservancy crowd-sourced \$45,000 to purchase several aerial drones to help patrol the perimeter. But poachers still get in. The previous month they came at night and killed a southern white rhino. "I hate poachers," said Mohammed Doyo, the head keeper of the rhinos at Ol Pej. Doyo has been working with rhinos since 1989, when he was just a teenager and nursed an orphaned animal at the park. He slept in the same room as the baby rhino, which would wake him up in the middle of the night to be fed with a bottle. Doyo has three young children but he said rhinos are his real babies. When the four northern whites arrived at Ol Pejeta, their survival and ability to reproduce became Doyo's personal cause. "When they have a baby, we are going to get Kes and open a bottle of champagne," he said.

As the guards let us into the first enclosure—about 140 acres of scattered brush and grass—Doyo gave Kes an update from the backseat of the Land Cruiser. Four months earlier, the keepers had brought in a young southern white male from a neighboring conservancy and introduced him to Fatu and her mother, Najin, hoping the animals might crossbreed. The male northern whites were proving to be very unreliable studs. Other than a promising instance when Suni, the younger male, mated with Najin, there hadn't been much copulation, and none resulting in conception. It was unclear whether the problem was physiological, environmental, or just bad luck. Had the females developed fertility pathologies? It was possible that years of living in a zoo and not producing high levels of hormones had affected their reproductive organs. At least one aspect of the problem was that Sudan, the oldest and dominant male at forty-one, had an arthritic leg as a result of growing

up in captivity. This made mounting the females extremely difficult for him. "Maybe we'll get him a stool," joked Doyo. Meanwhile, Suni, now thirty-six, still appeared to have the finicky and anxious personality of an adolescent.

The decision to try crossbreeding the animals was a drastic measure. It was made by a management committee, including representatives of the Dvur Kralove Zoo, wildlife veterinarian Peter Morkel, who worked with Kes at Garamba, and Martin Mulama, the chief conservation officer at Ol Pejeta. Crossbreeding could speed up the extinction of the species through hybridization, and no one even knew whether the offspring of such a union would themselves be capable of reproducing. But preserving *any* of the species' genes in a living animal was now seen as a better alternative to oblivion. If crossbreeding succeeded, the committee's reasoning went, the offspring might be mated back with the pure northern whites in an attempt to rescue an even larger part of the species gene pool. So in January 2014, the gamekeepers moved a male southern white rhino into an enclosure with Fatu and Najin. Soon after, they moved two southern white females into an enclosure with Suni.

We found Suni in the first enclosure, munching on the short grass and lazily shifting from one foot to another. About thirty yards away two female southern white rhinos did the same thing. We stepped out of the Land Cruiser, and Doyo grabbed some hay and waved it around to catch Suni's attention. Because Suni and the other northern whites at Ol Pej were brought up in a zoo, they are used to humans and can be approached under the right circumstances with great caution. Suni lumbered toward us, his head hung low, until he got so close, within a few yards and no signs of stopping that Doyo had to chastise him. "Suni, no!" he shouted. "No, no." The rhinoceros stopped and backed up a few steps to begin munching on his hay, but soon the females were coming over to investigate what all the excitement was about and Suni relinquished his treat to them. "They are very interested in him," explained Doyo. "But sometimes they are bullying him." Doyo tried to interest the girls in other fresh hay he spread nearby, but they seemed intent on keeping Suni away from the food, sending up puffs of dust with their stumpy legs as they chased him about. I hadn't expected that we would be so

close to the animals, and trying to dodge all three of them, with sometimes only a small bush in between their hulking bodies and me, was making my heart pound.

Wild rhinoceros have long had a reputation as ill-tempered, dangerous, and stupid creatures. In a periodical about colonial Kenyan history, I read a story about a rhinoceros charging a bus pulled over on the side of the road, thrusting her horn with so much force it went straight through the metal. Sport hunters considered them to have vicious tempers; they would destroy a campfire on a malicious whim. In fact, rhinoceros are fairly docile vegetarians that spend as much as 50 percent of their days snacking on grass and a good part of the rest of their days napping. When I asked Kes what it was like to watch rhinos in the wild, she chuckled and explained that initially it was pretty boring work. Monitoring the rhinos involved a lot of sitting in tall grass being cooked by the sun while the animals comfortably napped under the shade of the only tree. To me, the rhinos seemed to have both sweet and obstinate temperaments. They needed constant chiding. It was like being around overly affectionate dogs that don't know their own strength.

We made our way to the next enclosure, a 700-acre open plain where Fatu and Najin were located. Kes expressed her disappointment at the way things were being run. While all the females were staying in one place, Suni and Sudan were being moved around from one enclosure to the next, making it impossible in her opinion for them to establish themselves in a territory. "It's not reproducing the wild situation in a way that's conducive to mating," she said. The enclosures needed to be parallel but separate from each other, with the males stationary and the females being switched to stimulate their estrus cycles. "That could help stimulate them to mate." Doyo encouraged her to appeal to the management committee. The rhinos had been in Kenya for five years and nothing was working, so any new arrangement was worth pursuing. As we stopped the vehicle, Fatu and Najin stood close together about thirty yards away and stared at us before strolling over to see what we were all about. From far away, rhinos look as though they are chipped out of rock. Their shape is part bovine and part dinosaur, and the color of their skin is a monolithic gray. Up close, you can see the skin is textured with

ruts and cracks, like the surface of parched earth, and their horns are not perfectly cylindrical but rather like a piece of wood that has been unevenly chiseled to a point. Looking at Fatu, round like a Venus with sleepy eyelids, long black lashes and miniature elephant tail, I thought that rhinos were the most awkwardly beautiful animals I had ever seen. It seemed incredible that evolution had produced a living thing so strange.

The mother and daughter finally decided to meander away; it was almost noon and time for a nap. They both lay down with surprising grace, one arm and leg tucked under their body as though retired on a daybed. We stood a short distance away observing them in silence. Kes seemed like she would have contentedly watched them all day and into the next.

To my untrained eye there were no visible differences between northern and southern white rhinos. I asked Kes about this, and she explained that northern whites have developed distinct characteristics since they split from a common ancestor a million years ago. They hold their heads higher and have shorter head lengths and dorsal concavities, advantages in an ecosystem such as that in Garamba where the grass grows so tall. "These characteristics are worth preserving," said Smith, whether it's in iPSC lines or by crossbreeding. Hopefully, rhinos will one day be returned to Garamba, where the environment can once again select for their unique characteristics. Within a couple of generations, it might be impossible for even a biologist like Kes to tell the difference between a northern white born in the laboratory or one born in the wild.

Whether Garamba, the ecosystem itself, will be waiting for the rhinos to return is a big question mark. A few years after the Smiths left the park, the Lord's Resistance Army, a Ugandan rebel group infamous for using child soldiers and led by the brutal war criminal Joseph Kony, began setting up camps inside Garamba, now managed by an organization called African Parks, and poaching elephants for their ivory. Now, in addition to local and Sudanese poachers, the Ugandan rebels were reportedly using helicopters to wipe out fifty elephants at a time, many of them with a single shot to the head from above. The DRC's army began sending soldiers as reinforcements to the park rangers, but it appears that history is repeating itself. Violence

is spilling into the park from north, south, east, and west as paramilitary groups rush to exploit the value of the animals within Garamba's borders. The situation today is arguably as bad as it has ever been, and this is true for much of the wildlife throughout the African continent.

When Kes came to Africa in her twenties to fly airplane surveys, she was part of a wave of passionate conservationists who came to study wildlife, were changed by the experience, and never left. One evening at the Smiths' home, I sat around a dinner table with a few of their friends, including wildlife filmmaker Alan Root and conservationist Rosemarie Ruf. Ruf, a Swiss national, was traveling through Nairobi from the DRC, where she has lived since 1979, with almost all of that time in the Ituri rainforest trying to protect the elusive and chimeric creatures called okapis. These animals are at least 6 million years old and look like a hybrid of giraffes, horses, and zebras, with the behavior and temperament of shy, docile deer. Illegal gold mining, civil conflict, and poaching within the reserve threaten their existence. In 2002, Ruf's husband, Karl, who directed the okapi preservation project, was killed in an automobile accident in eastern DRC. Then in 2012, six of Ruf's staff and fourteen okapis kept in captivity were massacred by a Mai Mai rebel known as Morgan, a cannibalistic war criminal who liked to call himself Chuck Norris and was an enthusiastic elephant poacher. Ruf happened to be away at the time of the massacre, but she later found out that Morgan was disappointed she wasn't there because he had hoped to publicly rape her. In 2013, the IUCN listed the okapi as endangered. (The DRC government killed Morgan in April 2014.) In Alan Root's memoir, *Ivory, Apes & Peacocks*, he writes about how his life in Africa "has run in parallel with a heartbreaking holocaust as wildlife conservation has proved to be a disastrous failure. The reasons are many, ranging from greed, myopia, and failed policies to the exponential growth of the human population, which continues to sweep away wildlife and wild places." Sitting at dinner, it was impossible for me not to think about the individuals around the table as testaments to the personal sacrifice and tragedy that can befall those who commit themselves to fighting battles, ultimately losing them.

I revisited these thoughts again five months later when I heard that Suni, the young rhino on which so many hopes were placed, died one night in his enclosure at Ol Pejeta from natural causes. Soon after, a male rhino in San Diego, Angalifu, passed away, and the northern white rhinos were down to five. In an e-mail, Kes acknowledged the tragedy of Suni's death but didn't express fatalism over the species' future. She continues to believe that there may be some northern white rhinos left in the DRC, not in the park itself but in the outlying areas surrounding Garamba that are heavily wooded. She was heartened in 2012 by a report of a rhino in Uganda, though it couldn't be substantiated. As optimistic as this might sound, the discovery that some rhinos have survived against all odds wouldn't be unprecedented. There are in fact many instances of this sort of miracle in conservation, when extinct animals reappear long after biologists believed they were gone. In 2000, the Arakan forest turtle thought to be extinct since 1908 was rediscovered in Burma. In 2009, researchers discovered three small-eared shrews of southern Mexico, a creature not seen for 109 years. Recently, an insect called a tree lobster thought to be extinct for eighty years was rediscovered on a remote rock in the South Pacific Ocean. And in 2013 in eastern Borneo, a wild Sumatran rhino, thought to have gone extinct in the area decades ago, was captured on a grainy black-and-white video, a ghost in the forest oblivious to the wonder of its existence. Some 67 species of mammals have been rediscovered in recent decades. These stories belie the mysterious resilience of some species to persevere against all odds. If you believe in four-dimensional thinking, these miracles make a certain kind of sense. According to perdurantism, the philosophical theory that says things persist through their temporal parts, species could never really disappear and they never go extinct. The space-time wormhole between a species' existence in the past and the present just gets longer and longer. The dead are only ever further away from the moment in time they were alive.

NOTES

INTRODUCTION

"extinction, it has been said" Kent H. Redford et al., "What Does It Mean to Successfully Conserve a (Vertebrate) Species?," *BioScience* 61, no. 1 (January 2011): 39–48, doi:10.1525/bio.2011.61.1.9.

"A society that is habituated" Ronald R. Swaisgood and James K. Sheppard, "The Culture of Conservation Biologists: Show Me the Hope!," *BioScience* 60, no. 8 (September 2010): 626–30, doi:10.1525/bio.2010.60.8.8.

"extinction debt" Fangliang He and Stephen P. Hubbell, "Species-Area Relationships Always Overestimate Extinction Rates from Habitat Loss," *Nature* 473, no. 7347 (May 19, 2011): 368–71, doi:10.1038/nature09985.

"A meeting of conservation biologists" M. J. Costello, R. M. May, and N. E. Stork. "Can We Name Earth's Species Before They Go Extinct?" *Science* 339, no. 6118 (January 25, 2013): 413. doi:10.1126/science.1230318.

"10 percent of the earth's land" Buckley, Robert M., Patricia Clarke Annez, and Michael Spence, eds. *Urbanization and Growth*. The World Bank, 2008. <http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-7573-0>.

"Caribou have lost" Schaefer, James A. "Long-Term Range Recession and the Persistence of Caribou in the Taiga." *Conservation Biology* 17, no. 5 (2003): 1435.

"not replaceable without depreciation" Robert Elliot, "Faking Nature," *Inquiry* 25, no. 1 (January 1, 1982): 81–93, doi:10.1080/00201748208601955.

CHAPTER 1: AN ARK OF TOADS

"the area to be lost" Ekono Energy. *Kihansi Hydroelectric Project Environmental Assessment*. Environmental Assessment. Kihansi Hydroelectric Project. Nordic Development Fund, July 31, 1991.

"reliable power is so important" Paul Romer, "For Richer, for Poorer," *Prospect Magazine*, February 2010. <http://www.prospectmagazine.co.uk/features/for-richer-for-poorer>.

"esthetic, ecological, educational, recreational, and scientific value" "Endangered Species | Laws & Policies | Endangered Species Act." Signed into law, December 28, 1973. U.S. Fish and Wildlife Service, <http://www.fws.gov/endangered/laws-policies/>.

"made to serve" Bryan G. Norton, *Why Preserve Natural Variety?*. Princeton, N.J.: Princeton University Press, 1990, 195.

"last man" Richard Sylvan (Routley). "Is There a Need for a New, an Environmental, Ethic?" In *Environmental Ethics: An Anthology*, edited by Andrew Light and Holmes Rolston III, 1 edition., 49. Malden, MA: Wiley-Blackwell, 2002.

"Human interests and preferences" *Ibid.*, 52.

"intrinsic value" For discussion and background on the idea of intrinsic value in environmental ethics, see J. Baird Callicott. "Rolston on Intrinsic Value: A Deconstruction," *Environmental Ethics*, Vol. 14, No. 2 (1992): 129–43, doi:10.5840/enviroethics199214229.

"the world, we are told" John Muir and Peter Jenkins. *A Thousand-Mile Walk to the Gulf*. Boston: Mariner Books, 1998, 136.

"theoretical quest" J. Baird Callicott. "Rolston on Intrinsic Value: A Deconstruction." *Environmental Ethics* 14, no. 2 (1992): 129–43. doi:10.5840/enviroethics199214229., 129.

"Perhaps there can be no science" Holmes Rolston III. "Value in Nature and the Nature of Value." In *Philosophy and the Natural Environment*, edited by Robin Attfield and Andrew Belsey :13–30. Royal Institute of Philosophy Supplement. University of Wales, Cardiff: Cambridge University Press, 1994, 29.

"an adventure in what it means" Holmes Rolston III. "PL: 345 Environmental Ethics," Fall 2002. <http://lamar.colostate.edu/~rolston/345-SYL.htm>.

"Our efforts at conservation" Stephen Jay Gould, *An Urchin in the Storm: Essays About Books and Ideas* (New York: W. W. Norton, 1988), 21.

"we shall finally understand" *Ibid.*, 21.

"The species defends a particular form of life," "Value in Nature and the Nature of Value." In *Philosophy and the Natural Environment*, edited by Robin Attfield and Andrew Belsey: 13–30. Royal Institute of Philosophy Supplement. University of Wales, Cardiff: Cambridge University Press, 1994, 21.

"form of life is unique, warranting respect" "World Charter for Nature, 48th Plenary Meeting," United Nations A/RES/37/7, October 28, 1982, <http://www.un.org/documents/ga/res/37/a37r007.htm>.

"intrinsic value of biological diversity" "Preamble," Convention on Biological Diversity, June 5, 1992. <http://www.cbd.int/convention/articles/default.shtml?a=cbd-00>.

"he named academic philosophy" J. Baird Callicott, *Beyond the Land Ethic: More Essays in Environmental Philosophy* (Albany: State University of New York Press, 1999), 42.

"continue to dance with Cartesian ghosts" Bryan G. Norton, "Epistemology and Environmental Values," *Monist*, April, 1992, 224.

"From an environmental professional's perspective" John Lemons. "Nature Diminished or Nature Managed: Applying Rolston's Environmental Ethics in National Parks." In *Nature, Value, Duty: Life on Earth with Holmes Rolston, III*, edited by Christopher J. Preston and Wayne Ouderkirk, Springer Netherlands, 2010, 212.

"There is no evidence for" Michael Soulé, "The 'New Conservation,'" *Conservation Biology* 27, no. 5 (October 2013): 895–97, doi:10.1111/cobi.12147.

"Is it worth" Author's field notes, Tanzania, 2010.

CHAPTER 2: TRACKING CHIMERAS IN THE FAKAHATCHEE STRAND

"The exact range of the form" Boston Society of Natural History, *Proceedings of the Boston Society of Natural History*, vol. 28 (Ulan Press, 2011), 235.

"During his younger days" Donald G. Schueler, *Incident at Eagle Ranch: Predators as Prey in the American West* (Tucson: University of Arizona Press, 1991), 177.

"The wolf seldom used the same trail twice" Roy T. McBride, *The Mexican Wolf (Canis Lupus Bailey): A Historical Review and Observations on Its Status and Distribution: A Progress Report to the U.S. Fish and Wildlife Service*. U.S. Fish and Wildlife Service, 1980, 33.

"Almost a year had passed" *Ibid.*, 33.

"I set a trap" *Ibid.*, 33.

"Not many" Roy T. McBride, "Three Decades of Searching South Florida for Panthers," (presentation at the Proceedings of the Florida Panther Conference, Fort Myers, Florida, November 1, 1994). <http://www.panthersociety.org/decades.html>.

"I was amazed to find them" *Ibid.*

"I don't like those damn things" Craig Pittman, "Young Florida Panther Shot Dead on Big Cypress Preserve," *Tampa Bay Times*, December 9, 2013, <http://www.tampabay.com/news/environment/wildlife/panther-shot-dead-on-big-cypress-preserve/2156228>.

"The average sperm count" U.S. Fish and Wildlife Service. *Final Environmental Assessment: Genetic Restoration of the Florida Panther*. Gainesville, Florida, December 20, 1994, 3.

"classic example of what happens" David Maehr, *The Florida Panther: Life and Death of a Vanishing Carnivore* (Washington, DC: Island Press, 1997), xi.

"quick fix to a complex problem" *Ibid.*, xi.

"reinstate gene flow" U.S. Fish and Wildlife Service. *Final Environmental Assessment: Genetic Restoration of the Florida Panther*. Gainesville, Florida, December 20, 1994, 5.

"human-caused isolation" *Ibid.*, 5.

"genetic augmentation" David Maehr, *The Florida Panther: Life and Death of a Vanishing Carnivore* (Washington, DC: Island Press, 1997), 204.

"genetic restoration" *Ibid.*, 204.

"anthropogenic hybridization" Fred W. Allendorf, Paul A. Hohenlohe, and Gordon Luikart. "Genomics and the Future of Conservation Genetics." *Nature Reviews Genetics* 11, no. 10 (October 2010): 697-709. doi:10.1038/nrg2844.

"The possibility that a subspecies carries" Stephen J. O'Brien and Ernst Mayr, "Bureaucratic Mischief: Recognizing Endangered Species and Subspecies," *Science* 251, no. 4998 (March 8, 1991): 1187 (2).

"thing of immortal make, not human" Matt Kaplan, *The Science of Monsters: The Origins of the Creatures We Love to Fear* (New York: Scribner, 2013), 34.

"I don't think ranchers should" Murray T. Walton, "Rancher Use of Livestock Protection Collars in Texas," In Proceedings of the Fourteenth Vertebrate Pest Conference 1990, 80, 1990., 277.

"I've done it all" Rick Bass, *The Ninemile Wolves* (1992; repr., Boston: Mariner Books, 2003), 79.

CHAPTER 3: EXUBERANT EVOLUTION IN A DESERT FISH

"the domestic races of many animals and plants" Charles Darwin. *The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, 6th Edition. (New York: Cambridge University Press, 2009), 12.

"The most simple of these is the biological concept" Ernst Mayr. "What Is a Species, and What Is Not?" *Philosophy of Science* 63, no. 2 (June 1996): 262.

"the phylogenetic concept" Paul-Michael Agapow et al., "The Impact of Species Concept on Biodiversity Studies," *Quarterly Review of Biology* 79, no. 2 (June 2004): 161, doi:10.1086/383542.

"In 2004, researchers published" *Ibid.*, 161.

"lineages of ancestral descent" E. O. Wiley, "The Evolutionary Species Concept Reconsidered," *Systematic Biology* 27, no. 1 (March 1, 1978): 17-26, doi:10.2307/2412809.

"Assiduous collecting up cliff faces" Niles Eldredge, *Reinventing Darwin: Great Evolutionary Debate* (London: Weidenfeld & Nicolson, 1995), 95.

"most obvious and gravest objection" Charles Darwin. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. (London: W. Clowes and Sons, 1859), 280.

"rejecting that which is bad" *Ibid.*, 84.

"we see nothing of these slow changes" *Ibid.*, 84.

"thirty to sixty generations" David A. Reznick, Heather Bryga, and John A. Endler. "Experimentally Induced Life-History Evolution in a Natural Population." *Nature* 346, no. 6282 (1990): 357.

"a year of fire" Oscar Edward Meinzer and Raleigh Frederick Hare. *Geology and Water Resources of Tularosa Basin, New Mexico*. 343. (Washington, DC: United States Geological Survey, Department of the Interior, 1915), 23.

"valley was filled with flames" *Ibid.*, 23.

"Because Lost River and Mound Spring populations" Michael L. Collyer et al., "Morphological Divergence of Native and Recently Established Populations of White Sands Pupfish (*Cyprinodon tularosa*)," *Copeia* 2005, no. 1 (2005), 9.

"might be too costly a gamble" Michael L. Collyer, Jeffrey S. Heilveil, and Craig A. Stockwell, "Contemporary Evolutionary Divergence for a Protected Species Following Assisted Colonization," *PLoS ONE* no. 6(8): e22310. doi:10.1371/journal.pone.0022310. (August 2011), 6.

"might best be viewed as evolutionary experiments" *Ibid.*, 5.

"preserve species as dynamic entities" Richard Frankham, Jonathan D. Ballou, and David A. Briscoe, *Introduction to Conservation Genetics*, 2nd ed. (Cambridge, UK; New York: Cambridge University Press, 2010), 119.

"the greatest contribution that evolutionary rate" A. P. Hendry and M. T. Kinnison. "The Pace of Modern Life: Measuring Rates of Contemporary Evolution," *Evolution: International Journal of Organic Evolution* 53, no. 6 (1999): 1650.

"We challenge conservation biologists" Craig A. Stockwell, Andrew P. Hendry, and Michael T. Kinnison, "Contemporary Evolution Meets Conservation Biology," *Trends in Ecology & Evolution* 18, no. 2 (2003): 99.

CHAPTER 4: MYSTERIES OF THE WHALE CALLED 1334

"most whale calves will likely" Philip K. Hamilton, Amy R. Knowlton, and Marilyn K. Marx, "Right Whales Tell Their Own Stories: The Photo-Identification Catalog," In *The Urban Whale: North Atlantic Right Whales at the Crossroads*, ed. Scott D. Kraus and Rosalind M. Rolland, (Cambridge, MA: Harvard University Press, 2007), 96.

"And every day we saw whales" Frederick W. True. "The Whalebone Whales of the Western North Atlantic, Compared with Those Occuring in European Water; With Some Observations On the Species of the North Pacific." In *Smithsonian Contributions to Knowledge*, Vol. 33. (Washington, DC: The Smithsonian Institution, 1904), 22.

"Albattrosses appear to challenge" E. Milot, H. Weimerskirch, P. Duchesne and L. Bernatchez. "Surviving with Low Genetic Diversity: The Case of Albatrosses." *Proceedings of the Royal Society B: Biological Sciences* 274, no. 1611 (March 22, 2007): 785. doi:10.1098/rspb.2006.0221.

"morning mowers, who side by side" Herman Melville, *Moby Dick: Or the Whale* (London: Modern Library, 1992), 396.

"The climate-driven changes in ocean" Charles H. Greene et al., "Impact of Climate Variability on the Recovery of Endangered North Atlantic Right Whales," *Oceanography* 16, no. 4 (2003): 100. doi.org/10.5670/oceanog.2003.16

"Ultimately, our ability to assess" Ibid., 102.

CHAPTER 5: FREEZING CROWS

"The ability to examine" Fred W. Allendorf, Paul A. Hohenlohe, and Gordon Luikart. "Genomics and the Future of Conservation Genetics." *Nature Reviews Genetics* 11, no. 10 (October 2010), 697. doi:10.1038/nrg2844.

"acquired evolutionary responsibility" L. T. Evans, "Sir Otto Frankel: Biographical Memoirs," Australian Academy of Science, 1999.

"Neither our pre-agricultural ancestor" Otto H. Frankel, "Genetic Conservation: Our Evolutionary Responsibility," *Genetics* 78, no. 1 (1974): 54.

"There is a benefit in maintaining genetic diversity" Janet Chernela, "A Species Apart: Ideology, Science, and the End of Life," In *The Anthropology of Extinction: Essays on Culture and Species Death*, ed. Genese Marie Sodikoff (Bloomington and Indianapolis: Indiana University Press, 2012), 30.

"Cryopreservation of gametes and embryos" Professor George Amato, Professor Howard C. Rosenbaum, and Professor Rob DeSalle. *Conservation Genetics in the Age of Genomics*. (New York: Columbia University Press, 2009), 61.

"It took all one's scientific ardor" Lyle Rexer et al., Carl E. Akeley. In *Brightest Africa* (Garden City: Doubleday, 1923), 229.

"the life that the organismic individual has" Holmes Rolston III, *Genes, Genesis, and God: Values and Their Origins in Natural and Human History* (Cambridge, UK: Cambridge University Press, 1999), 42.

"Cells can be kept frozen" Andrea Johnson, "Preserving Hawaiian Bird Cell Lines," *Animals & Plants* (blog), San Diego Zoo, November 7, 2008, <http://blogs.sandiegozoo.org/2008/11/07/preserving-hawaiian-bird-cell-lines/>.

"One of the rewarding things" Ibid.

"to bawl, bleat, squeal, cry" US Fish and Wildlife Service, "Revised Recovery Plan for the 'Alala (*Corvus hawaiiensis*)," Portland, Oregon, January 27, 2009. http://www.fws.gov/pacific/eco_services/documents/Alala_Revised_Recovery_Plan.pdf

"It would be difficult to imagine" Mark Jerome Walters. *Seeking the Sacred Raven: Politics and Extinction on a Hawaiian Island*. 2nd ed. (Washington D.C.: Island Press, 2006) 52.

"The arrogance implied" Mark Jerome Walters, *Seeking the Sacred Raven: Politics and Extinction on a Hawaiian Island*, 2nd ed. (Washington, DC: Island Press, 2006), 145.

"They were kind of like the kings and queens of the forest" Thom van Dooren. "Authentic Crows: Identity, Captivity and Emergent Forms of Life." *Theory, Culture and Society*, forthcoming.

"Conserving species is" Ibid.

"delicately interwoven ways of life" Thom van Dooren. "Banking the Forest: Loss, Hope and Care in Hawaiian Conservation." In *Defrost: New Perspectives on Temperature, Time, and Survival*, edited by Joanna Radin and Emma Kowal, forthcoming.

"All cryo-technologies" Ibid.

"If the death of a single crow signals" Thom van Dooren, *Flight Ways: Life and Loss at the Edge of Extinction* (New York: Columbia University Press, 2014), 142.

a quote the Frozen Ark "The Future of the Frozen Ark." *The Frozen Ark: Saving the DNA of Endangered Species*. <http://www.frozenark.org/future-frozen-ark>. accessed December 6, 2014.

"With its biblical reference" Tracey Heatherington, "From Ecocide to Genetic Rescue: Can Technoscience Save the Wild?," In *The Anthropology of Extinction: Essays on Culture and Species Death*, ed. Genese Marie Sodikoff (Bloomington and Indianapolis: Indiana University Press, 2012), 40.

"Loss of genetic diversity" Bryan G. Norton, *Why Preserve Natural Variety?* (Princeton, NJ: Princeton University Press, 1990), 260.

"keep the endangered forest" George Amato. "Moving Toward a More Integrated Approach." In *Conservation Genetics in the Age of Genomics*, edited by George Amato, Howard C. Rosenbaum, Rob DeSalle, and Oliver A. Ryder. (New York: Columbia University Press, 2009), 36.

"I could not limit myself" Walters, *Seeking the Sacred Raven*, 110.

CHAPTER 6: METAPHYSICAL RHINOS

"two bulls loomed out" Ian Player. *The White Rhino Saga*. 1st edition. (New York: Stein and Day, 1973), 17.

"real essentialism' and 'three-dimensional individualism'" Julien Delord. "Can We Really Re-create an Extinct Species by Cloning?" In *The Ethics of Animal Re-Creation and Modification: Reviving, Rewilding, Restoring*, edited by Markku Oksanen and Helena Siipi. (New York, Palgrave Macmillan, 2014), 28.

"pocket-sized Venus" Alan Root. *Ivory, Apes & Peacocks: Animals, Adventure and Discovery in the Wild Places of Africa*. (London: Chatto & Windus, 2012), 259.

"Kes is a formidable woman" Douglas Adams and Mark Carwardine, "Last Chance to See," (repr., New York: Ballantine Books, 1992), 84.

"huge herds moving across" Kes Smith, ed., *Garamba: Conservation in Peace and War*, forthcoming.

"has run in parallel with" Alan Root, *Ivory, Apes & Peacocks: Animals, Adventure and Discovery in the Wild Places of Africa* (London: Chatto & Windus, 2012), 299.

CHAPTER 7: REGENESIS OF THE PASSENGER PIGEON

"feathered tribes" Clark Hunter, ed., *The Life and Letters of Alexander Wilson*, Vol. 154 (Philadelphia: Memoirs of the American Philosophical Society, 1983), 100.

"While others are immersed" *Ibid.*, p. 106.

"great Author of the Universe" *Ibid.*, p. 269.

"There are such prodigious numbers" A. W. Schorger, *The Passenger Pigeon: Its History and Extinction* (Caldwell, NJ: Blackburn Press, 2004), 11.

"unearthly" A. W. Schorger, "The Great Wisconsin Passenger Pigeon Nesting of 1871," *Passenger Pigeon: Monthly Bulletin of the Wisconsin Society of Ornithology* 1, no. 1 (February 1939): 31.

"When such myriads" Schorger, *Passenger Pigeon*, 54.

"arose a roar, compared with" *Ibid.*, 189.

"The slaughter was terrible" *Ibid.*

"The passenger pigeon needs no protection" *Ibid.*, 225.

"If the world will endure" *Ibid.*, 208.

"In due course, the day will come" Mark V. Barrow Jr., *Nature's Ghosts: Confronting Extinction from the Age of Jefferson to the Age of Ecology* (Chicago: University of Chicago Press, 2009), 127.

"This species became extinct" Schorger, *Passenger Pigeon*, 230.

"culminating effort of Nature" William Beebe, *The Bird: Its Form and Function* (1906; repr., Ulan Press, 2012), 17.

"Let us beware of needlessly" *Ibid.*, 18.

"Since my childhood days" George Landry, "The Final Tale of a Passenger Pigeon Named 'George,'" Exotic Dove website, accessed September 2013 www.exoticdove.com/P_pigeon/George_3.html.

"Like a dodo bird" Ben Novak, "Flights of Fancy: A Tiny Tube of Clear Liquid," Project Passenger Pigeon, n.d., <http://passengerpigeon.org/flights.html>.

"deep ecological enrichment" Ryan Phelan, "About TEDxDeExtinction and TED," Revive & Restore, Long Now Foundation, accessed December 6, 2014, <http://longnow.org/revive/events/tedxdeextinction/about/>.

"genetic rescue" "What 'Genetic Rescue' Means," Revive & Restore, Long Now Foundation, accessed December 6, 2014, <http://longnow.org/revive/what-we-do/genetic-rescue/>.

"A bit of cloning can" Stewart Brand, "Transcript of 'The Dawn of de-Extinction. Are You Ready?'" TED, March 2013, accessed December 6, 2014 https://www.ted.com/talks/stewart_brand_the_dawn_of_de_extinction_are_you_ready/transcript.

"It was a wonderful movie" "Frequently Asked Questions," Revive & Restore, Long Now Foundation, accessed December 6, 2014, <http://longnow.org/revive/faq/>.

"the de-extinction of animals" Antonio Regalado, "De-Extinction Startup, Ark Corporation, Could Engineer Animals, Humans." *MIT Technology Review*, March 19, 2013. <http://www.technologyreview.com/view/512671/a-stealthy-de-extinction-startup/>.

"solve death" Antonio Regalado, "Google's New Company Calico to Try to Cheat Death," *MIT Technology Review*, September 18, 2013, <http://www.technologyreview.com/view/519456/google-to-try-to-solve-death-lol/>.

"The finality of extinction" Peter Matthiessen, *The Peter Matthiessen Reader*, ed. Mckay Jenkins (New York: Vintage, 2000), 7.

"attenuate, even partially" George M. Church and Ed Regis, *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves* (New York: Basic Books, 2014), 140.

"boutique" *Ibid.*, 143.

"We had this meeting" Author interview with Joel Greenberg, July 15, 2013.

"If the definition of 'endangered'" Jamie Rappaport Clark, "Politics of De-Extinction" (conference presentation, "De-Extinction: Ethics, Law & Politics," Stanford Law School, California, May 31, 2013), <https://www.law.stanford.edu/event/2013/05/31/de-extinction-ethics-law-politics>.

"Revived species are cool" *Ibid.*

"playing God" Jay Odenbaugh, "Hubris and Naturalness" (conference presentation at "De-Extinction: Ethics, Law & Politics," Stanford University, California, May 31, 2013), <https://www.law.stanford.edu/event/2013/05/31/de-extinction-ethics-law-politics>.

"Define moral hazard" "Justice, Hubris, and Moral Issues." Conference presentation, "De-Extinction: Ethics, Law & Politics, Stanford University, California, May 31, 2013. <https://www.law.stanford.edu/event/2013/05/31/de-extinction-ethics-law-politics>.

"non-tragic relationship to nature" Jay Odenbaugh. "Justice, Hubris, and Moral Issues." Conference presentation, "De-Extinction: Ethics, Law & Politics, Stanford University, California, May 31, 2013. <https://www.law.stanford.edu/event/2013/05/31/de-extinction-ethics-law-politics>.

"Shipment of 100 barrels" Schorger, "Great Wisconsin Passenger Pigeon Nesting of 1871," 23.

"until the road was dotted" Schorger, *Passenger Pigeon*, vii.

"Deep, youthful impressions" *Ibid.*

"The conclusion is inescapable" *Ibid.*, 229.

"This species was in danger" *Ibid.*, 223.

"social facilitation at low densities" Enrique H. Bucher, "The Causes of Extinction of the Passenger Pigeon," *Current Ornithology*, volume 9 (New York: Plenum Press, 1992), 2.

"sucking up the laden fruits" Aldo Leopold, *A Sand County Almanac* (New York: Ballantine Books, 1986), 118.

"As moral agents" Eric Katz, *Nature as Subject* (Lanham, Maryland: Rowman & Littlefield, 1996), xxv.

"interspecific chimeras" Marie-Cecile Van de Lavoie et al., "Interspecific Germline Transmission of Cultured Primordial Germ Cells," *PLoS ONE* 7, no. 5 (May 21, 2012): e35664, doi:10.1371/journal.pone.0035664.

"After two or three years" Ben Novak, "How to Bring Passenger Pigeons All the Way Back," March 15, 2013. Revive & Restore, Long Now Foundation, accessed December 6, 2014, <http://longnow.org/revive/events/tedxdeextinction/>.

"outbreak population" Charles C. Mann, "Unnatural Abundance," Opinion sec., *New York Times*, November 25, 2004.

CHAPTER 8: NICE TO MEET YOU, NEANDERTHAL

"what did happen to you" L. Sprague de Camp, "The Gnarly Man," *Modern Classics of Fantasy*, edited by Gardner Dozois. (New York: St. Martin's Press, 1997), 26.

"They could maybe even create" "George Church Explains How DNA Will Be Construction Material of the Future," *Spiegel Online*, January 18, 2013, <http://www.spiegel.de/international/zeitgeist/george-church-explains-how-dna-will-be-construction-material-of-the-future-a-877634.html>.

"the question arises whether" George M. Church and Ed Regis, *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves* (New York: Basic Books, 2014), 137.

"Wanted: 'Adventurous woman'" Allan Hall and Fiona Macrae, "Wanted: 'Adventurous Woman' to Give Birth to Neanderthal Man—Harvard Professor Seeks Mother for Cloned Cave Baby," *Daily Mail*, January 20, 2013. <http://www.dailymail.co.uk/news/article-2265402/Adventurous-human-woman-wanted-birth-Neanderthal-man-Harvard-professor.html>.

"Neanderthals were sentient human beings" Svante Pääbo, "Neanderthals Are People, Too," *New York Times*, April 24, 2014, <http://www.nytimes.com/2014/04/25/opinion/neanderthals-are-people-too.html>.

"constantly expanding upward range" Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W. W. Norton, 1990), 233.

"In direct competition with Cro-Magnons" Thomas Wynn and Frederick L. Coolidge, *How To Think Like a Neandertal* (New York: Oxford University Press, 2011), 187.

"Neanderthal people were" Gould, *Wonderful Life*, 233.

"Why did one type" Pääbo, "Neanderthals Are People, Too."

"lacked reflective awareness" Max Oelschlaeger, *The Idea of Wilderness: From Prehistory to the Age of Ecology*. (New Haven: Yale University Press, 1993), 11.

"The tree-in-itself" Andrew Iliadis, "Interview with Graham Harman (2)," *Figure/Ground: An Open-Source, Para-Academic, Inter-Disciplinary Collaboration*, October 2, 2013, <http://figureground.org/interview-with-graham-harman-2/>.

"Given that almost every problem" Richard Grusin, ed., *The Nonhuman Turn* (Minneapolis: University of Minnesota Press, 2015), vii.

"An idea, a relationship" Bill McKibben, *The End of Nature* (New York: Random House Trade, 2006), 41.

CODA: ULTIMA THULE: ENDS OF THE EARTH

"consciousness of space" Christiane Ritter, *A Woman in the Polar Night* (1938; repr., Fairbanks: University of Alaska Press, 2010), 202.

"told of journeys" *Ibid.*, 12.

"It won't be too lonely" *Ibid.*

"thick books in the remote quiet" *Ibid.*

- "arid picture of death" Ibid., 30.
- "One day melts into" Ibid., 41.
- "when the reality of" Ibid., 110.
- "After a while my" Ibid., 94.
- "The power of this" Ibid., 98.
- "as in biblical times" Ibid., 102.
- "stronger than all reason" Ibid., 211.
- "tiny piece of coal" Ibid., 109.
- "unfathomable gulf between" Ibid., 136.
- "regional climate models" C. Lang, X. Fettweis, and M. Ericum. "Stable Climate and Surface Mass Balance in Svalbard over 1979–2013 despite the Arctic Warming." *The Cryosphere* 9, no. 1 (January 8, 2015): 83. doi:10.5194/tc-9-83-2015.
- "We see that there" Nilsen Thomas, "No Ice—No Cubs," *Barentsobserver*, June 27, 2012, <http://barentsobserver.com/en/nature/no-ice-no-cubs-27-06>.
- "Every head of wild life" Aldo Leopold. *Game Management*. (Madison, Univ of Wisconsin Press, 1987) xviii.

SELECTED BIBLIOGRAPHY

- Adams, Douglas, and Mark Carwardine. *Last Chance to See*. Reprint edition. New York: Ballantine Books, 1992.
- Agapow, Paul-Michael, Olaf R. P. Bininda-Emonds, Keith A. Crandall, John L. Gittleman, Georgina M. Mace, Jonathon C. Marshall, and Andy Purvis. "The Impact of Species Concept on Biodiversity Studies." *The Quarterly Review of Biology*, Vol. 79, No. 2, June 2004. doi:10.1086/383542.
- Aguilar, A. "A Review of Old Basque Whaling and Its Effect on the Right Whales (*Eubalaena Glacialis*) of the North Atlantic." *Report of the International Whaling Commission* (Special Issue), Vol. 10, 1986.
- Alexander, Helen K., Guillaume Martin, Oliver Y. Martin, and Sebastian Bonhoeffer. "Evolutionary Rescue: Linking Theory for Conservation and Medicine." *Evolutionary Applications*, Vol. 7, Issue 10, December 2014. doi:10.1111/eva.12221.
- Allendorf, Fred W., Paul A. Hohenlohe, and Gordon Luikart. "Genomics and the Future of Conservation Genetics." *Nature Reviews Genetics*, Vol. 11, No. 10, October 2010. doi:10.1038/nrg2844.
- Allendorf, Fred W., Robb F. Leary, Paul Spruell, and John K. Wenburg. "The Problems with Hybrids: Setting Conservation Guidelines." *Trends in Ecology & Evolution*, Vol. 16, No. 11 (2001).
- Alvarez, Ken. *Twilight of the Panther: Biology, Bureaucracy and Failure in an Endangered Species Program*. Sarasota: Myakka River Publishing, 1993.
- Amato, George D. "Species Hybridization and Protection of Endangered Animals." *Science*, Vol. 253, No. 5017, 1991.
- Amato, George, Howard C. Rosenbaum, and Rob DeSalle. *Conservation Genetics in the Age of Genomics*. New York: Columbia University Press, 2009.
- Anthes, Emily. *Frankenstein's Cat: Cuddling Up to Biotech's Brave New Beasts*. New York: Scientific American/Farrar, Straus and Giroux, 2014.
- Arch, Victoria S., Corinne L. Richards-Zawacki, and Albert S. Feng. "Acoustic Communication in the Kihansi Spray Toad (*Nectophrynoides Asperginis*): Insights from a Captive Population." *Journal of Herpetology*, Vol. 45, No. 1, March 1, 2011. doi:10.1670/10-084.1.
- Askins, Robert A. *Restoring North America's Birds: Lessons from Landscape Ecology*. New Haven: Yale University Press, 2000.
- Avant, Deborah D. *The Market for Force: The Consequences of Privatizing Security*. Cambridge, UK, and New York: Cambridge University Press, 2005.
- Barkham, Selma Huxley. "The Basque Whaling Establishments in Labrador 1536–1632: A Summary." *Arctic*, Vol. 37, No. 4, December 1984.

- Barrow, Mark V. Jr., *Nature's Ghosts: Confronting Extinction from the Age of Jefferson to the Age of Ecology*. First edition. Chicago and London: University of Chicago Press, 2009.
- Bass, Rick. *The Ninemile Wolves*. Boston: Mariner Books, 2003.
- Bell, Michael A., and Windsor E. Aguirre. "Contemporary Evolution, Allelic Recycling, and Adaptive Radiation of the Threespine Stickleback." *Evolutionary Ecology Research*, Vol. 15, 2013.
- Biermann, Christine, and Becky Mansfield. "Biodiversity, Purity, and Death: Conservation Biology as Biopolitics." *Environment and Planning D: Society and Space*, Vol. 32, No. 2, 2014. doi:10.1068/d13047p.
- Blockstein, D. E. "Lyme Disease and the Passenger Pigeon?" *Science*, Vol. 279, No. 5358, March 20, 1998. doi:10.1126/science.279.5358.1831c.
- Bogost, Ian. *Alien Phenomenology, or What It's Like to Be a Thing*. Minneapolis: University of Minnesota Press, 2012.
- Brand, Stewart. *Whole Earth Discipline: Why Dense Cities, Nuclear Power, Transgenic Crops, Restored Wildlands, and Geoengineering Are Necessary*. New York: Penguin Books, 2010.
- Brown, David E., ed. *The Wolf in the Southwest: The Making of an Endangered Species*. Silver City, NM: High Lonesome Books, 2002.
- Bruce, Donald, and Ann Bruce. *Engineering Genesis: Ethics of Genetic Engineering in Non-Human Species*. New York: Routledge, 2014.
- Bryant, Levi R. *The Democracy of Objects*. Ann Arbor: Open Humanities Press/Michigan Publishing, University of Michigan Library, 2011.
- Bucher, Enrique H. "The Causes of Extinction of the Passenger Pigeon." *Current Ornithology*, Vol. 9. Dennis M. Power, ed. New York: Plenum Press, 1992.
- Burgess, N. D., T. M. Butynski, N. J. Cordeiro, N. H. Doggart, J. Fjelds , K. M. Howell, F. B. Kilahama, et al. "The Biological Importance of the Eastern Arc Mountains of Tanzania and Kenya." *Biological Conservation*, Vol. 134, No. 2, January 2007. doi:10.1016/j.biocon.2006.08.015.
- Burgess, N. D., J. Fjelds , and R. Botterweg. "Faunal Importance of the Eastern Arc Mountains of Kenya and Tanzania." *Journal of East African Natural History*, Vol. 87, No. 1, January 1, 1998. doi:10.2982/0012-8317(1998)87[37:FIOTE]2.0.CO;2.
- Callicott, J. Baird. *Beyond the Land Ethic: More Essays in Environmental Philosophy*. Albany: State University of New York Press, 1999.
- . "Rolston on Intrinsic Value: A Deconstruction." *Environmental Ethics*, Vol. 14, No. 2, 1992. doi:10.5840/enviroethics199214229.
- Carroll, Scott P., and Charles W. Fox, eds. *Conservation Biology: Evolution in Action*. Oxford, UK, and New York: Oxford University Press, 2008.
- Carroll, S. P., P. S. Jorgensen, M. T. Kinnison, C. T. Bergstrom, R. F. Denison, P. Gluckman, T. B. Smith, S. Y. Strauss, and B. E. Tabashnik. "Applying Evolutionary Biology to Address Global Challenges." *Science*, Vol. 346, No. 6207, October 17, 2014. doi:10.1126/science.1245993.
- Chernela, Janet. "A Species Apart: Ideology, Science, and the End of Life." In *The Anthropology of Extinction: Essays on Culture and Species Death*, edited by Genese Marie Sodikoff. Bloomington: Indiana University Press, 2012.
- Church, George M., and Ed Regis. *Regenesis: How Synthetic Biology Will Reinvent Nature and Ourselves*. New York: Basic Books, 2014.
- Cole, Timothy V. N., Philip Hamilton, Allison Glass Henry, Peter Duley, Richard M. Pace, Bradley N. White, and Tim Frasier. "Evidence of a North Atlantic Right Whale *Eubalaena glacialis* Mating Ground." *Endangered Species Research*, Vol. 21, No. 1, July 3, 2013. doi:10.3354/esr00507.
- Collins, James P., and Andrew Storfer. "Global Amphibian Declines: Sorting the Hypotheses." *Diversity and Distributions*, Vol. 9, No. 2, March 1, 2003. doi:10.1046/j.1472-4642.2003.00012.x.
- Collyer, Michael L., Jeffrey S. Heilveil, and Craig A. Stockwell. "Contemporary Evolutionary Divergence for a Protected Species Following Assisted Colonization." *PLoS ONE*, Vol. 6, No. 8, e22310, August 31, 2011. doi:10.1371/journal.pone.0022310.
- Collyer, Michael L., James M. Novak, Craig A. Stockwell, and M. E. Douglas. "Morphological Divergence of Native and Recently Established Populations of White Sands Pupfish (*Cyprinodon tularosa*)." *Copeia*, No. 1, 2005.

- Corthals, Angélique, and Rob Desalle. "An Application of Tissue and DNA Banking for Genomics and Conservation: The Ambrose Monell Cryo-Collection (AMCC)." *Systematic Biology*, Vol. 54, No. 5, October 1, 2005. doi:10.1080/10635150590950353.
- Costello, M. J., R. M. May, and N. E. Stork. "Can We Name Earth's Species Before They Go Extinct?" *Science*, Vol. 339, No. 6118, January 25, 2013. doi:10.1126/science.1230318.
- Craig Pittman. "Saga of Florida Panther Is 'Sordid Story.'" *Tampa Bay Times*, April 16, 2010. <http://www.tampabay.com/news/environment/wildlife/saga-of-florida-panther-is-sordid-story/1087965>.
- Darwin, Charles. *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. London: W. Clowes and Sons, 1859.
- Day, J. J., J. L. Bamber, P. J. Valdes, and J. Kohler. "The Impact of a Seasonally Ice Free Arctic Ocean on the Temperature, Precipitation and Surface Mass Balance of Svalbard." *The Cryosphere*, Vol. 6, No. 1, January 10, 2012. doi:10.5194/tc-6-35-2012.
- Delord, Julien. "Can We Really Re-Create an Extinct Species by Cloning?" In *The Ethics of Animal Re-Creation and Modification: Reviving, Rewilding, Restoring*, edited by Markku Oksanen and Helena Siipi. New York: Palgrave Macmillan, 2014.
- DeSalle, Rob, and George Amato. "The Expansion of Conservation Genetics." *Nature Reviews Genetics*, Vol. 5, No. 9, September 2004. doi:10.1038/nrg1425.
- Dolin, Eric Jay. *Leviathan: The History of Whaling in America*. New York: W. W. Norton & Company, 2008.
- Eldredge, Niles. *Reinventing Darwin: Great Evolutionary Debate*. London: Weidenfeld & Nicolson, 1995.
- Elliot, Robert. "Faking Nature." *Inquiry*, Vol. 25, No. 1, January 1, 1982. doi:10.1080/00201748208601955.
- Fiege, Mark. *The Republic of Nature: An Environmental History of the United States*. Reprint edition. Seattle: University of Washington Press, 2013.
- Fisher, Diana O., and Simon P. Blomberg. "Correlates of Rediscovery and the Detectability of Extinction in Mammals." *Proceedings of the Royal Society of London B: Biological Sciences*, Vol. 278, No. 1708 (April 7, 2011). doi:10.1098/rspb.2010.1579.
- Fisher, Matthew C., and Trenton W. J. Garner. "The Relationship between the Emergence of Batrachochytrium Dendrobatidis, the International Trade in Amphibians and Introduced Amphibian Species." *Fungal Biology Reviews*, Vol. 21, No. 1, February 2007. doi:10.1016/j.fbr.2007.02.002.
- Fitch, W. M., and F. J. Ayala. "Tempo and Mode in Evolution." *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 91, No. 15, July 19, 1994.
- Fletcher, Amy L. "Mendel's Ark: Conservation Genetics and the Future of Extinction." *Review of Policy Research*, Vol. 25, No. 6, 2008. doi:10.1111/j.1541-1338.2008.00367_1.x.
- Folch, J., M. J. Cocero, P. Chesné, J. L. Alabart, V. Dominguez, Y. Coggié, A. Roche, et al. "First Birth of an Animal from an Extinct Subspecies (*Capra Pyrenaica Pyrenaica*) by Cloning." *Theriogenology*, Vol. 71, No. 6, April 1, 2009. doi:10.1016/j.theriogenology.2008.11.005.
- Frankel, Otto H. "Genetic Conservation: Our Evolutionary Responsibility." *Genetics*, Vol. 78, No. 1, 1974.
- Frankham, Richard, Jonathan D. Ballou, and David A. Briscoe. *Introduction to Conservation Genetics*. 2nd edition. Cambridge: Cambridge University Press, 2010.
- Frankham, Richard, Jonathan D. Ballou, Michele R. Dudash, Mark D. B. Eldridge, Charles B. Fenster, Robert C. Lacy, Joseph R. Mendelson, Ingrid J. Porton, Katherine Ralls, and Oliver A. Ryder. "Implications of Different Species Concepts for Conserving Biodiversity." *Biological Conservation*, Vol. 153, September 2012. doi:10.1016/j.biocon.2012.04.034.
- Franklin, I. R., and R. Frankham. "How Large Must Populations Be to Retain Evolutionary Potential?" *Animal Conservation*, Vol. 1, No. 1, February 1998. doi:10.1017/S1367943098211103.
- Frasier, T. R., P. K. Hamilton, M. W. Brown, L. A. Conger, A. R. Knowlton, M. K. Marx, C. K. Slay, S. D. Kraus, and B. N. White. "Patterns of Male Reproductive Success in a Highly Promiscuous Whale Species: The Endangered North Atlantic Right Whale." *Molecular Ecology*, Vol. 16, No. 24, December 2007. doi:10.1111/j.1365-294X.2007.03570.x.

- Friedrich Ben-Nun, Inbar, Susanne C. Montague, Marlys L. Houck, Ha T. Tran, Ibon Gari-tonandia, Trevor R. Leonardo, Yu-Chieh Wang, et al. "Induced Pluripotent Stem Cells from Highly Endangered Species." *Nature Methods*, Vol. 8, No. 10. September 4, 2011. doi:10.1038/nmeth.1706.
- Fujiwara, Masami, and Hal Caswell. "Demography of the Endangered North Atlantic Right Whale." *Nature*, Vol. 414, No. 6863, November 29, 2001. doi:10.1038/35107054.
- Genome 10K Community of Scientists. "Genome 10K: A Proposal to Obtain Whole-Genome Sequence for 10,000 Vertebrate Species." *Journal of Heredity*, Vol. 100, No. 6, November 1, 2009. doi:10.1093/jhered/esp086.
- Ghiselin, Michael T. "A Radical Solution to the Species Problem." *Systematic Biology*, Vol. 23, No. 4, December 1, 1974. doi:10.1093/sysbio/23.4.536.
- Gingerich, P. D. "Quantification and Comparison of Evolutionary Rates." *American Journal of Science*, Vol. 293-A, January 1, 1993. doi:10.2475/ajs.293.A.453.
- Gonzalez, Andrew, Ophélie Ronce, Regis Ferriere, and Michael E. Hochberg. "Evolutionary Rescue: An Emerging Focus at the Intersection between Ecology and Evolution." *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol. 368, No. 1610, January 19, 2013. doi:10.1098/rstb.2012.0404.
- Gould, Stephen Jay. *An Urchin in the Storm: Essays about Books and Ideas*. New York: W. W. Norton & Company, 1988.
- . *Wonderful Life: The Burgess Shale and the Nature of History*. New York: W. W. Norton & Company, 1990.
- . "Tempo and Mode in the Macroevolutionary Reconstruction of Darwinism." *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 91, No. 15, July 19, 1994.
- Greenberg, Joel. *A Feathered River Across the Sky: The Passenger Pigeon's Flight to Extinction*. New York: Bloomsbury, 2014.
- Greene, Charles H., Andrew J. Pershing, Robert D. Kenney, and Jack W. Jossi. "Impact of Climate Variability on the Recovery of Endangered North Atlantic Right Whales." *Oceanography*, Vol 16, No. 4, 2003.
- Grenier, Robert. "The Basque Whaling Ship from Red Bay, Labrador: A Treasure Trove of Data on Iberian Atlantic Shipbuilding Design and Techniques in the Mid-16th Century." In *Trabalhos de Arqueologia 18—Proceedings. International Symposium on Archaeology of Medieval and Modern Ships of Iberian-Atlantic Tradition. Hull Remains, Manuscripts and Ethnographic Sources: A Comparative Approach*, ed. Francisco Alves. Lisbon: Centro Nacional de Arqueologia Náutica e Subaquática/Academia de Marinha, 1998.
- Grusin, Richard, ed. *The Nonhuman Turn*. Minneapolis: University of Minnesota Press, 2015.
- Halliday, T. R. "The Extinction of the Passenger Pigeon *Ectopistes Migratorius* and Its Relevance to Contemporary Conservation." *Biological Conservation*, Vol. 17, 1980.
- Hambler, Clive, Peter A. Henderson, and Martin R. Speight. "Extinction Rates, Extinction-Prone Habitats, and Indicator Groups in Britain and at Larger Scales." *Biological Conservation*, Vol. 144, No. 2 (February 2011). doi:10.1016/j.biocon.2010.09.004.
- Harman, Graham. *Guerrilla Metaphysics: Phenomenology and the Carpentry of Things*. Chicago: Open Court, 2005.
- Harrison, K. David. *When Languages Die: The Extinction of the World's Languages and the Erosion of Human Knowledge*. Oxford: Oxford University Press, 2008.
- Heatherington, Tracey. "From Ecocide to Genetic Rescue: Can Technoscience Save the Wild?" In *The Anthropology of Extinction: Essays on Culture and Species Death*, edited by Genese Marie Sodikoff. Bloomington and Indianapolis: Indiana University Press, 2012.
- Hedrick, Philip W. "Gene Flow and Genetic Restoration: The Florida Panther as a Case Study." *Conservation Biology*, Vol. 9, No. 5, October 1, 1995. doi:10.1046/j.1523-1739.1995.9050988.x-ii.
- Hedrick, Philip W., and Richard Fredrickson. "Genetic Rescue Guidelines with Examples from Mexican Wolves and Florida Panthers." *Conservation Genetics*, Vol. 11, No. 2, April 2010. doi:10.1007/s10592-009-9999-5.

- Hedrick, P. W., and R. J. Fredrickson. "Captive Breeding and the Reintroduction of Mexican and Red Wolves." *Molecular Ecology*, Vol. 17, No. 1, January 2008. doi:10.1111/j.1365-294X.2007.03400.x.
- He, Fangliang, and Stephen P. Hubbell. "Species-Area Relationships Always Overestimate Extinction Rates from Habitat Loss." *Nature*, Vol. 473, No. 7347, May 19, 2011. doi:10.1038/nature09985.
- Hendry, A. P., and M. T. Kinnison. "An Introduction to Microevolution: Rate, Pattern, Process." *Genetica*, Vol. 112–113, November 1, 2001. doi:10.1023/A:1013368628607.
- . "The Pace of Modern Life: Measuring Rates of Contemporary Microevolution." *Evolution*, Vol. 53, No. 6, December 1999.
- . "The Pace of Modern Life II: From Rates of Contemporary Microevolution to Pattern and Process." *Genetica*, Vol. 112–113, 2001. doi:10.1023/A:1013375419520
- Hey, Jody. *Genes, Categories, and Species: The Evolutionary and Cognitive Cause of the Species Problem*. Oxford: Oxford University Press, 2001.
- Hickey, Joseph J. "In Memoriam: Arlie William Schorger." *The Auk*, Vol. 90, July 1973.
- Hillman Smith, Kes, and Fraser Smith. "Conservation Crises and Potential Solutions: Example of Garamba National Park Democratic Republic of Congo." Presented at the Second World Congress of the International Ranger Federation. Costa Rica, September 25, 1997.
- Holmberg, Tora, Nete Schwennessen, and Andrew Webster. "Bio-Objects and the Bio-Objectification Process." *Croatian Medical Journal*, Vol. 52, No. 6 (December 2011): 740–42. doi:10.3325/cmj.2011.52.740.
- Hostetler, Jeffrey A., David P. Onorato, Deborah Jansen, and Madan K. Oli. "A Cat's Tale: The Impact of Genetic Restoration on Florida Panther Population Dynamics and Persistence." *Journal of Animal Ecology*, Vol. 82, No. 3, May 2013. doi:10.1111/1365-2656.12033.
- Hunter Clark, ed. *The Life and Letters of Alexander Wilson*. Vol. 154. Philadelphia: Memoirs of the American Philosophical Society 1983.
- Iliadis, Andrew. "Interview with Graham Harman (2)." *Figure/Ground: An Open-Source, Para-Academic, Inter-Disciplinary Collaboration*, October 2, 2013. <http://figureground.org/interview-with-graham-harman-2/>.
- Johnson, Phillip. "The Extinction of Darwinism: Review of 'Extinction: Bad Gene or Bad Luck' by David M. Raup." *The Atlantic*, February 1992. <http://www.arn.org/docs/johnson/raup.htm>.
- Johnson, W. E., D. P. Onorato, M. E. Roelke, E. D. Land, M. Cunningham, R. C. Belden, R. McBride, et al. "Genetic Restoration of the Florida Panther." *Science*, Vol. 329, No. 5999, September 24, 2010. doi:10.1126/science.1192891.
- Kaliszewska, Zofia A., Jon Seger, Victoria J. Rowntree, Susan G. Barco, Rafael Benegas, Peter B. Best, Moira W. Brown, et al. "Population Histories of Right Whales (Cetacea: Eubalaena) Inferred from Mitochondrial Sequence Diversities and Divergences of Their Whale Lice (Amphipoda: Cyamus)." *Molecular Ecology*, Vol. 14, No. 11, October 2005. doi:10.1111/j.1365-294X.2005.02664.x.
- Kaplan, Matt. *The Science of Monsters: The Origins of the Creatures We Love to Fear*. New York: Simon and Schuster, 2013.
- Katz, Eric. *Nature as Subject*. Lanham: Rowman & Littlefield Publishers, 1996.
- Katz, Eric, and Andrew Light, eds. *Environmental Pragmatism*. London: Routledge, 1996.
- Kautz, Randy, Robert Kawula, Thomas Hoctor, Jane Comiskey, Deborah Jansen, Dawn Jennings, John Kasbohm, et al. "How Much Is Enough? Landscape-Scale Conservation for the Florida Panther." *Biological Conservation*, Vol. 130, No. 1, June 2006. doi:10.1016/j.biocon.2005.12.007.
- Kosek, Jake. *Understories: The Political Life of Forests in Northern New Mexico*. Durham: Duke University Press Books, 2006.
- Kouba, Andrew J., Rhiannon E. Lloyd, Marlys L. Houck, Aimee J. Silla, Natalie Calatayud, Vance L. Trudeau, John Clulow, et al. "Emerging Trends for Biobanking Amphibian Genetic Resources: The Hope, Reality and Challenges for the Next Decade." *Biological Conservation*, Vol. 164, August 2013. doi:10.1016/j.biocon.2013.03.010.
- Kraus, Scott D., and Rosalind M. Rolland. *The Urban Whale: North Atlantic Right Whales at the Crossroads*. Cambridge, MA: Harvard University Press, 2010.

- Krisch, Joshua A. "New Study Offers Clues to Swift Arctic Extinction." *The New York Times*, August 28, 2014.
- Lang, C., X. Fettweis, and M. Erpicum. "Stable Climate and Surface Mass Balance in Svalbard over 1979–2013 despite the Arctic Warming." *The Cryosphere*, Vol. 9, No. 1 (January 8, 2015): 83–101. doi:10.5194/tc-9-83-2015.
- Lee, S., K. Zippel, L. Ramos, and J. Searle. "Captive-Breeding Programme for the Kihansi Spray Toad *Nectophrynoides Asperginis* at the Wildlife Conservation Society, Bronx, New York." *International Zoo Yearbook*, Vol. 40, No. 1, July 1, 2006. doi:10.1111/j.1748-1090.2006.00241.x.
- Leopold, Aldo. *A Sand County Almanac*. New York: Ballantine Books, 1986.
- . *Game Management*. Madison: University of Wisconsin Press, 1987.
- Lestel, Dominique. "The Withering of Shared Life through the Loss of Biodiversity." *Social Science Information*, Vol. 52, No. 2, June 1, 2013. doi:10.1177/0539018413478325.
- Lévi-Strauss, Claude. *The Savage Mind*. Chicago: University of Chicago Press, 1966.
- Levy, Sharon. *Once and Future Giants: What Ice Age Extinctions Tell Us About the Fate of Earth's Largest Animals*. Oxford: Oxford University Press, 2011.
- Lieberman, Alan. "Alala Egg That Changed the Future." Hawaiian Birds, San Diego Zoo, January 8, 2013. <http://blogs.sandiegozoo.org/2013/01/08/alala-egg-changed-future/>.
- Light, Andrew, and Holmes Rolston III, eds. *Environmental Ethics: An Anthology*. Malden: Wiley-Blackwell, 2002.
- Lippsett, Lonny. "Diving into the Right Whale Gene Pool." *Oceanus Magazine*, Vol. 44, No. 3, December 3, 2005.
- Lopez, Barry. *Arctic Dreams*. New York: Vintage, 2001.
- MacPhee, R. D. E. *Extinctions in Near Time*. New York: Springer Science & Business Media, 1999.
- Maehr, David. *The Florida Panther: Life and Death of a Vanishing Carnivore*. Washington, DC: Island Press, 1997.
- Maehr, D. S., P. Crowley, J. J. Cox, M. J. Lacki, J. L. Larkin, T. S. Hoctor, L. D. Harris, and P. M. Hall. "Of Cats and Haruspices: Genetic Intervention in the Florida Panther. Response to Pimm et al. (2006)." *Animal Conservation*, Vol. 9, No. 2, May 2006. doi:10.1111/j.1469-1795.2005.00019.x.
- Mann, Charles C. "Unnatural Abundance." *The New York Times*, November 25, 2004, opinion section.
- Marchant, Jo. "Evolution Machine: Genetic Engineering on Fast Forward." *New Scientist*, Issue 2818, June 27, 2011.
- Martinelli, Lucia, Markku Oksanen, and Helena Siipi. "De-Extinction: A Novel and Remarkable Case of Bio-Objectification." *Croatian Medical Journal*, Vol. 55, No. 4, August 2014. doi:10.3325/cmj.2014.55.423.
- Martinez-Moreno, Jorge, Rafael Mora, and Ignacio de la Torre. "The Middle-to-Upper Palaeolithic Transition in Cova Gran (Catalunya, Spain) and the Extinction of Neanderthals in the Iberian Peninsula." *Journal of Human Evolution*, Vol. 58, No. 3, March 2010. doi:10.1016/j.jhev.2009.09.002.
- Marzluff, John M., Tony Angell, and Paul R. Ehrlich. *In the Company of Crows and Ravens*. New Haven: Yale University Press, 2007.
- Matthiessen, Peter. *Wildlife in America*. New York: Penguin Books, 1978.
- . *The Peter Matthiessen Reader*. Edited by McKay Jenkins. New York: Vintage, 2000.
- . *The Snow Leopard*. New York: Penguin Classics, 2008.
- . *African Silences*. New York: Vintage, 2012.
- Matthiessen, Peter, and Maurice Hornocker. *Tigers in the Snow*. New York: North Point Press, 2001.
- Mayr, Ernst. "What Is a Species, and What Is Not?" *Philosophy of Science*. Vol. 63, No. 2, June 1996.
- McBride, Roy T. *The Mexican Wolf (Canis Lupus Baileyi): A Historical Review and Observations on Its Status and Distribution: A Progress Report to the U.S. Fish and Wildlife Service*. U.S. Fish and Wildlife Service, 1980.
- . "Three Decades of Searching South Florida for Panthers." Presented at the Proceedings of The Florida Panther Conference, Fort Myers, Florida, November 1, 1994.

- McCabe, Robert A. "A. W. Schorger: Naturalist and Writer." *The Passenger Pigeon*, Vol. 55, No. 4, Winter 1993.
- McCarthy, Cormac. *The Crossing*. New York: Alfred A. Knopf, 1994.
- McCarthy, Michael A., Colin J. Thompson, and Stephen T. Garnett. "Optimal Investment in Conservation of Species." *Journal of Applied Ecology*. Vol. 45, No. 5, October 1, 2008. doi:10.1111/j.1365-2664.2008.01521.x.
- McKibben, Bill. *The End of Nature*. New York: Random House Trade Paperbacks, 2006.
- McLeod, B. A., Moira W. Brown, Michael J. Moore, W. Stevens, Selma H. Barkham, Michael Barkham, and B. N. White. "Bowhead Whales, and Not Right Whales, Were the Primary Target of 16th-to 17th-Century Basque Whalers in the Western North Atlantic." *Arctic*, Vol. 61, No. 1, 2008.
- McLeod, Brenna A., Moira W. Brown, Timothy R. Frasier, and Bradley N. White. "DNA Profile of a Sixteenth Century Western North Atlantic Right Whale (*Eubalaena glacialis*)." *Conservation Genetics*, Vol. 11, No. 1, February 2010. doi:10.1007/s10592-009-9811-6.
- Meinzer, Oscar Edward, and Raleigh Frederick Hare. *Geology and Water Resources of Tularosa Basin, New Mexico*. Vol. 343. Washington, DC: United States Geological Survey, Department of the Interior, 1915.
- Melville, Herman. *Moby Dick: Or the Whale*. London: Modern Library, 1992.
- Milledge, Simon A. H. "Illegal Killing of African Rhinos and Horn Trade, 2000–2005: The Era of Resurgent Markets and Emerging Organized Crime." *Pachyderm*, No. 43, 2007.
- Miller, Claire. "Great Barrier Reef 'on Ice.'" *Frontiers in Ecology and the Environment*, Vol. 10, No. 2, March 2012.
- Miller, Robert Rush, and Anthony A. Echelle. "Cyprinodon Tularosa, a New Cyprinodontid Fish from the Tularosa Basin, New Mexico." *The Southwestern Naturalist*. Vol. 19, No. 4, January 20, 1975. doi:10.2307/3670395.
- Miller, Webb, Vanessa M. Hayes, Aakrosh Ratan, Desiree C. Petersen, Nicola E. Wittekindt, Jason Miller, Brian Walenz, et al. "Genetic Diversity and Population Structure of the Endangered Marsupial *Sarcophilus harrisi* (Tasmanian Devil)." *Proceedings of the National Academy of Sciences*, Vol. 108, No. 30, July 26, 2011. doi:10.1073/pnas.1102838108.
- Milot, E., H. Weimerskirch, P. Duchesne, and L. Bernatchez. "Surviving with Low Genetic Diversity: The Case of Albatrosses." *Proceedings of the Royal Society B: Biological Sciences*, Vol. 274, No. 1611, March 22, 2007. doi:10.1098/rspb.2006.0221.
- Minard, Anne. "West Nile Devastated Bird Species." *National Geographic News*, May 16, 2007.
- . "'Reverse Evolution' Discovered in Seattle Fish." *National Geographic News*, May 20, 2008.
- Moore, Michael J. "Rosita Voyage Log." "Rosita"—*Voyage of Discovery*, 2004. www.whale.wheelock.edu/Rosita/.
- Morton, Timothy. *Ecology without Nature: Rethinking Environmental Aesthetics*. Cambridge: Harvard University Press, 2009.
- . "Here Comes Everything: The Promise of Object-Oriented Ontology." *Qui Parle: Critical Humanities and Social Sciences*, Vol. 19, No. 2, 2011.
- . "Sublime Objects." *Speculations*, Vol. 2, 2011.
- . *Hyperobjects: Philosophy and Ecology after the End of the World*. Minneapolis: University of Minnesota Press, 2013.
- Muir, John, and Peter Jenkins. *A Thousand-Mile Walk to the Gulf*. Boston: Mariner Books, 1998.
- "Multiplex Automated Genomic Engineering (MAGE): A Machine That Speeds up Evolution Is Revolutionizing Genome Design." *Wyss Institute*. www.wyss.harvard.edu/viewpage/330/.
- Myers, Norman. *The Sinking Ark: A New Look at the Problem of Disappearing Species*. Oxford: Pergamon Press, 1979.
- Nagel, Thomas. "What Is It Like to Be a Bat?" *The Philosophical Review*, Vol. 83, No. 4, October 1, 1974. doi:10.2307/2183914.
- National Resource Council. *The Scientific Bases for the Preservation of the Hawaiian Crow*, 1992. <http://www.nap.edu/catalog/2023/the-scientific-bases-for-the-preservation-of-the-hawaiian-crow>.

- Nelson, Barney, ed. *God's Country or Devil's Playground: The Best Nature Writing from the Big Bend of Texas*. Austin: University of Texas Press, 2002.
- Neumann, Thomas W. "Human-Wildlife Competition and the Passenger Pigeon: Population Growth from System Destabilization." *Human Ecology*, Vol. 13, No. 4, December 1985. doi:10.1007/BF01531152.
- Newmark, W. D. "Forest Area, Fragmentation, and Loss in the Eastern Arc Mountains: Implications for the Conservation of Biological Diversity." *Journal of East African Natural History*, Vol. 87, No. 1, January 1, 1998. doi:10.2982/0012-8317(1998)87[29:FAFALI]2.0.CO;2.
- . *Conserving Biodiversity in East African Forests: A Study of the Eastern Arc Mountains*. New York: Springer Science & Business Media, 2002.
- Norton, Bryan G. "Environmental Ethics and Weak Anthropocentrism." *Environmental Ethics*, Vol. 6, No. 2, 1984. doi:10.5840/enviroethics19846233.
- . *Why Preserve Natural Variety?*. Princeton: Princeton University Press, 1990.
- . "Epistemology and Environmental Values." *Monist*, Vol. 75, No. 2, April 1992.
- . "Why I am Not a Nonanthropocentrist: Callicott and the Failure of Monistic Inherentism." *Environmental Ethics*, Vol. 17, No. 4, 1995. doi:10.5840/enviroethics19951743.
- Norton, Bryan G., Michael Hutchins, Elizabeth F. Stevens, and Terry L. Maple, eds. *Ethics on the Ark*. Washington, DC: Smithsonian Books, 1996.
- Novak, Ben. "Flights of Fancy: A Tiny Tube of Clear Liquid." Project Passenger Pigeon—Memoirs, Stories, Paintings, Poems. <http://passengerpigeon.org/flights.html>.
- . "How to Bring Passenger Pigeons All the Way Back." Presentation at the TedX DeExtinction, Washington, DC, March 15, 2013.
- O'Brien, Stephen J. *Tears of the Cheetah: The Genetic Secrets of Our Animal Ancestors*. New York: St. Martin's Griffin, 2005.
- O'Brien, Stephen J., and Ernst Mayr. "Bureaucratic Mischief: Recognizing Endangered Species and Subspecies." *Science*, Vol. 51, No. 4998, March 8, 1991.
- Oelschlaeger, Max. *The Idea of Wilderness: From Prehistory to the Age of Ecology*. New Haven: Yale University Press, 1993.
- Oksanen, Markku, and Helena Siipi, eds. *The Ethics of Animal Re-Creation and Modification: Reviving, Rewilding, Restoring*. New York: Palgrave Macmillan, 2014.
- Ozgo, Małgorzata. "Rapid Evolution and the Potential for Evolutionary Rescue in Land Snails." *Journal of Molluscan Studies*, May 5, 2014. doi:10.1093/mollusc/eyu029.
- Palkovacs, Eric P., Michael T. Kinnison, Cristian Correa, Christopher M. Dalton, and Andrew P. Hendry. "Fates beyond Traits: Ecological Consequences of Human-Induced Trait Change." *Evolutionary Applications*, Vol. 5, Mo. 2, February 2012. doi:10.1111/j.1752-4571.2011.00212.x.
- Palumbi, Stephen R. *The Evolution Explosion: How Humans Cause Rapid Evolutionary Change*. New York: W. W. Norton & Company, 2002.
- Parry, Bronwyn. "The Fate of the Collections: Social Justice and the Annexation of Plant Genetic Resources." In *People, Plants, and Justice: The Politics of Nature Conservation*, ed. Charles Zerner. New York: Columbia University Press, 2000.
- Patenaude, N. J., V. A. Portway, C. M. Schaeff, J. L. Bannister, P. B. Best, R. S. Payne, V. J. Rowntree, M. Rivarola, and C. S. Baker. "Mitochondrial DNA Diversity and Population Structure among Southern Right Whales (*Eubalaena Australis*)." *Journal of Heredity*, Vol. 98, No. 2, January 6, 2007. doi:10.1093/jhered/esm005.
- Pershing, Andrew J. and Charles H. Greene. "Climate and the Conservation Biology of North Atlantic Right Whales: Being a Right Whale at the Wrong Time?" Accessed December 4, 2014. http://oceandata.gmri.org/environmentalprediction/docs/FrontiersinEcologyandtheEnvironment_2_29-34.pdf.
- Pigliucci, Massimo. "Wittgenstein Solves (Posthumously) the Species Problem." *Philosophy Now*, No. 51, March/April, 2005.
- Pimm, S. L., L. Dollar, and O. L. Bass. "The Genetic Rescue of the Florida Panther." *Animal Conservation*, Vol. 9, No. 2, May 2006. doi:10.1111/j.1469-1795.2005.00010.x.
- Pittenger, John S., and Craig L. Springer. "Native Range and Conservation of the White Sands Pupfish (*Cyprinodon Tularosa*)." *The Southwestern Naturalist*, Vol. 44, No. 2, June 1999.

- Player, Ian, and Alan Paton. *The White Rhino Saga*. New York: Stein and Day, 1973.
- Pond, David W., and Geraint A. Tarling. "Phase Transitions of Wax Esters Adjust Buoyancy in Diapausing Calanoides Acutus." *Limnology and Oceanography*, Vol. 56, No. 4, 2011. doi:10.4319/lo.2011.56.4.1310.
- Pounds, J. Alan. "Climate and Amphibian Declines." *Nature*, Vol. 410, No. 6829, April 5, 2001. doi:10.1038/35070683.
- Pounds, J. Alan, Martin R. Bustamante, Luis A. Coloma, Jamie A. Consuegra, Michael P. L. Fogden, Pru N. Foster, Enrique La Marca, et al. "Widespread Amphibian Extinctions from Epidemic Disease Driven by Global Warming." *Nature*, Vol. 439, No. 7073, January 12, 2006. doi:10.1038/nature04246.
- Powell, Alvin. *The Race to Save the World's Rarest Bird: The Discovery and Death of the Po'ouli*. Mechanicsburg, PA: Stackpole Books, 2008.
- Poynton, John C., Kim M. Howell, Barry T. Clarke, and Jon C. Lovett. "A Critically Endangered New Species of Nectophrynoides (Anura: Bufonidae) from the Kihansi Gorge, Udzungwa Mountains, Tanzania." *African Journal of Herpetology*, Vol. 47, No. 2, January 1, 1998. doi: 10.1080/21564574.1998.9650003.
- Pratt, Thane K., Carter T. Atkinson, Paul Christian Banko, James D. Jacobi, and Bethany Lee Woodworth, eds. *Conservation Biology of Hawaiian Forest Birds: Implications for Island Avifauna*. New Haven: Yale University Press, 2009.
- Preston, Christopher J., and Wayne Ouderkirk, eds. *Nature, Value, Duty: Life on Earth with Holmes Rolston, III*. The International Library of Environmental, Agricultural and Food Ethics. Houten: Springer Netherlands, 2010.
- Preston, Douglas J. *Dinosaurs in the Attic: An Excursion into the American Museum of Natural History*. New York: St. Martin's Griffin, 1993.
- Proença, Vânia, and Henrique Miguel Pereira. "Comparing Extinction Rates: Past, Present, and Future." In *Encyclopedia of Biodiversity*. Elsevier, 2013.
- Quammen, David. *The Song of the Dodo: Island Biogeography in an Age of Extinction*. New York: Scribner, 1997.
- Radin, J. "Latent Life: Concepts and Practices of Human Tissue Preservation in the International Biological Program." *Social Studies of Science*, Vol. 43, No. 4, August 1, 2013. doi:10.1177/0306312713476131.
- Rastogi, Toolika, Moira W. Brown, Brenna A. McLeod, Timothy R. Frasier, Robert Grenier, Stephen L. Cumbaa, Jeya Nadarajah, and Bradley N. White. "Genetic Analysis of 16th-Century Whale Bones Prompts a Revision of the Impact of Basque Whaling on Right and Bowhead Whales in the Western North Atlantic." *Canadian Journal of Zoology*, Vol. 82, No. 10, October 2004. doi:10.1139/z04-146.
- Redford, Kent H., George Amato, Jonathan Baillie, Pablo Beldomenico, Elizabeth L. Bennett, Nancy Clum, Robert Cook, et al. "What Does It Mean to Successfully Conserve a (Vertebrate) Species?" *BioScience*, Vol. 61, No. 1, January 2011. doi:10.1525/bio.2011.61.1.9.
- Reed, D. H. "Albatrosses, Eagles and Newts, Oh My!: Exceptions to the Prevailing Paradigm Concerning Genetic Diversity and Population Viability?: Genetic Diversity and Extinction." *Animal Conservation*, Vol. 13, No. 5, June 1, 2010. doi:10.1111/j.1469-1795.2010.00353.x.
- Regalado, Antonio. "De-Extinction Startup, Ark Corporation, Could Engineer Animals, Humans." *MIT Technology Review*, March 19, 2013. <http://www.technologyreview.com/view/512671/a-stealthy-de-extinction-startup/>.
- . "Google's New Company Calico to Try to Cheat Death." *MIT Technology Review*, September 18, 2013. <http://www.technologyreview.com/view/519456/google-to-try-to-solve-death-lol/>.
- Revised Recovery Plan for the 'Alala (Corvus Hawaiiensis)*. Portland, Oregon: U.S. Fish and Wildlife Service, January 27, 2009.
- Rexer, Lyle, Rachel Klein, Edward O. Wilson, and American Museum of Natural History. *American Museum of Natural History: 125 Years of Expedition and Discovery*. New York: Harry N. Abrams, 1995.

- Reygondeau, Gabriel, and Grégory Beaugrand. "Future Climate-Driven Shifts in Distribution of Calanus Finmarchicus." *Global Change Biology*, Vol. 17, No. 2, February 2011. doi:10.1111/j.1365-2486.2010.02310.x.
- Reznick, David A., Heather Bryga, and John A. Endler. "Experimentally Induced Life-History Evolution in a Natural Population." *Nature*, Vol. 346, No. 6282, 1990.
- Rice, Kevin J., and Nancy C. Emery. "Managing Microevolution: Restoration in the Face of Global Change." *Frontiers in Ecology and the Environment*, Vol. 1, No. 9, November 2003. doi:10.2307/3868114.
- Ridley, Matt. "Counting Species Out." www.rationaloptimist.com, August 27, 2011.
- Ritter, Christiane. *A Woman in the Polar Night*. Fairbanks: University of Alaska Press, 2010.
- Robert, Jason Scott, and Françoise Baylis. "Crossing Species Boundaries." *American Journal of Bioethics*, Vol. 3, No. 3, 2003.
- Rödger, D., J. Kielgast, and S. Lötters. "Future Potential Distribution of the Emerging Amphibian Chytrid Fungus under Anthropogenic Climate Change." *Diseases of Aquatic Organisms*, Vol. 92, No. 3, April 7, 2010. doi:10.3354/dao02197.
- Rolston III, Holmes. *Environmental Ethics: Duties to and Values in the Natural World*. Philadelphia: Temple University Press, 1989.
- . "Value in Nature and the Nature of Value." In *Philosophy and the Natural Environment*, edited by Robin Attfield and Andrew Belsey. Royal Institute of Philosophy Supplement, Vol. 36. Cambridge: Cambridge University Press, 1994.
- . *Genes, Genesis, and God: Values and Their Origins in Natural and Human History*. Cambridge: Cambridge University Press, 1999.
- . "What Is a Gene? From Molecules to Metaphysics." *Theoretical Medicine and Bioethics*. Vol. 27, No. 6, December 2006. doi:10.1007/s11017-006-9022-9.
- Romer, Paul. "For Richer, for Poorer." *Prospect Magazine: The Leading Magazine of Ideas*, February 2010. <http://www.prospectmagazine.co.uk/features/for-richer-for-poorer>.
- Root, Alan. *Ivory, Apes & Peacocks: Animals, Adventure and Discovery in the Wild Places of Africa*. London: Chatto & Windus, 2012.
- Rosen, Rebecca J. "The Climate Is Set to Change 'Orders of Magnitude' Faster Than at Any Other Time in the Past 65 Million Years." *The Atlantic*, August 2, 2013.
- Ryder, O. A. "DNA Banks for Endangered Animal Species." *Science*, Vol. 288, No. 5464, April 14, 2000. doi:10.1126/science.288.5464.275.
- Sagoff, Mark. "On Preserving the Natural Environment." *Yale Law Journal*, Vol. 84, No. 2, December 1974.
- Schaeff, Catherine M., Scott D. Kraus, Moira W. Brown, and Bradley N. White. "Assessment of the Population Structure of Western North Atlantic Right Whales (*Eubalaena glacialis*) Based on Sighting and mtDNA Data." *Canadian Journal of Zoology*, Vol. 71, No. 2, February 1, 1993. doi:10.1139/z93-047.
- Schorger, A. W. *The Chemistry of Cellulose and Wood*. New York: McGraw-Hill, 1926.
- . "The Great Wisconsin Passenger Pigeon Nesting of 1871." *The Passenger Pigeon: Monthly Bulletin of the Wisconsin Society of Ornithology*, Vol. 1, No. 1, February 1939.
- . *The Passenger Pigeon: Its Natural History and Extinction*. Madison: University of Wisconsin Press, 1955.
- Schueler, Donald G. *Incident at Eagle Ranch: Predators as Prey in the American West*. Tucson: University of Arizona Press, 1991.
- Seddon, Philip J., Axel Moehrensclager, and John Ewen. "Reintroducing Resurrected Species: Selecting DeExtinction Candidates." *Trends in Ecology & Evolution*, Vol. 29, No. 3, March 2014. doi:10.1016/j.tree.2014.01.007.
- Seto, Sonia J. "North Atlantic Right Whale DNA." *Right Whale News*, Vol. 17, No. 4, November 2009.
- Shaffer, Mark L. "Minimum Population Sizes for Species Conservation." *BioScience*, Vol. 31, No. 2, February 1, 1981. doi:10.2307/1308256.
- Simpson, George Gaylord. *Tempo and Mode in Evolution*. New York: Columbia University Press, 1944.

- Smith, Thomas B., Michael T. Kinnison, Sharon Y. Strauss, Trevon L. Fuller, and Scott P. Carroll. "Prescriptive Evolution to Conserve and Manage Biodiversity." *Annual Review of Ecology, Evolution, and Systematics*, Vol. 45, No. 1, November 23, 2014. doi:10.1146/annurev-ecolsys-120213-091747.
- Sodikoff, Genevieve Marie, ed. *The Anthropology of Extinction: Essays on Culture and Species Death*. Bloomington: Indiana University Press, 2011.
- Soulé, Michael E. "Thresholds for Survival: Maintaining Fitness and Evolutionary Potential." *Conservation Biology: An Evolutionary-Ecological Perspective*, Vol. 111, 1980.
- . "What Is Conservation Biology?" *BioScience*, Vol. 35, No. 11, December 1985. doi:10.2307/1310054.
- . "The 'New Conservation.'" *Conservation Biology*, Vol. 27, No. 5, October 2013. doi:10.1111/cobi.12147.
- Soulé, Michael E., and Bruce A. Wilcox, eds. "Conservation Biology. An Evolutionary-Ecological Perspective." Sunderland: Sinauer Associates, 1980.
- Steiner, Cynthia. "Looking at Alala Genome." San Diego Zoo. *Wildlife Field Notes: Firsthand Experiences With Saving Endangered Species*, December 6, 2013. <http://blog.sandiegozoo.org/2013/12/06/looking-at-alala-genomes/>.
- Stelkens, Rike B., Michael A. Brockhurst, Gregory D. D. Hurst, and Duncan Greig. "Hybridization Facilitates Evolutionary Rescue." *Evolutionary Applications*, Vol. 7, Issue. 10, September 1, 2014. doi:10.1111/eva.12214.
- Stewart, G., K. Mengersen, G. M. Mace, J. A. McNeely, J. Pitchforth, and B. Collen. "To Fund or Not to Fund: Using Bayesian Networks to Make Decisions about Conserving Our World's Endangered Species." *Chance: Magazine of the American Statistical Association*, 2013.
- Stockwell, Craig A., Jeffrey S. Heilveil, and Kevin Purcell. "Estimating Divergence Time for Two Evolutionarily Significant Units of a Protected Fish Species." *Conservation Genetics*, Vol. 14, No. 1, February 2013. doi:10.1007/s10592-013-0447-1.
- Stockwell, Craig A., Andrew P. Hendry, and Michael T. Kinnison. "Contemporary Evolution Meets Conservation Biology." *Trends in Ecology & Evolution*, Vol. 18, No. 2, 2003.
- Stockwell, Craig A., and Paul L. Leberg. "Ecological Genetics and the Translocation of Native Fishes: Emerging Experimental Approaches." *Western North American Naturalist*, Vol. 62, No. 1, 2002.
- Stockwell, Craig A., Margaret Mulvey, and Adam G. Jones. "Genetic Evidence for Two Evolutionarily Significant Units of White Sands Pupfish." *Animal Conservation*, Vol. 1, No. 3, August 1, 1998. doi:10.1111/j.1469-1795.1998.tb00031.x.
- Stockwell, Craig A., and Stephen C. Weeks. "Translocations and Rapid Evolutionary Responses in Recently Established Populations of Western Mosquitofish (*Gambusia affinis*)." *Animal Conservation*, Vol. 2, No. 02 (1999): 103–10.
- "Surviving Climate Change May Be Genetic According to Trent University Research." *Trent University*, April 25, 2012. <http://www.trentu.ca/newsevents/newsDetail.php?newsID=2485>.
- Swaisgood, Ronald R., and James K. Sheppard. "The Culture of Conservation Biologists: Show Me the Hope!" *BioScience*, Vol. 60, No. 8, September 1, 2010. doi:10.1525/bio.2010.60.8.8.
- Sylvan (formerly Routley), Richard. "Is There a Need for a New, an Environmental, Ethic?" In *XVth World Congress of Philosophy*, No. 1. Varna, Bulgaria: Sofia Press, 1973.
- Thatcher, Cindy A., Frank T. van Manen, and J. D. Clark. "An Assessment of Habitat North of the Caloosahatchee River for Florida Panthers." University of Tennessee and US Geological Survey, Knoxville, TN. Final Report to US Fish and Wildlife Service, Vero Beach, FL, 2006.
- Thomas, Nilsen. "No Ice—No Cubs." *Barents Observer*, June 27, 2012. <http://barentsobserver.com/en/nature/no-ice-no-cubs-27-06>.
- Tonnesen, Gail. "Mitochondrial DNA Haplogroup U5: Description of mtDNA Haplogroup U5." *Family Tree DNA*, July 18, 2014. <https://www.familytreedna.com/public/u5b/default.aspx?section=results>.
- "TRAFFIC—Wildlife Trade News—Pioneering Research Reveals New Insights into the Consumers behind Rhino Poaching." *Traffic: The Wildlife Trade Monitoring Network*, September

- 17, 2013. <http://www.traffic.org/home/2013/9/17/pioneering-research-reveals-new-insights-into-the-consumers.html>.
- Tuck, Robert A., and Robert Grenier. "A 16th-Century Basque Whaling Station in Labrador." *Scientific American*, Vol. 245, No. 5, 1981.
- Umbreit, Andreas Dr. *Svalbard: Spitzbergen, Jan Mayen, Frank Josef Land*. Fifth edition. Buckinghamshire, UK: Bradt Travel Guides, 2013.
- U.S. Fish and Wildlife Service. *Final Environmental Assessment: Genetic Restoration of the Florida Panther*. Gainesville, Florida, December 20, 1994.
- U.S. Seal and the Workshop Participants. *Genetic Management Strategy and Population Viability of the Florida Panther (Felis Concolor Coryi)*. National Zoological Park, Washington, DC and White Oak Plantation Conservation Center, Yulee, Florida: Captive Breeding Specialist Group SSC/IUCN, May 30, 1991.
- Van de Lavoie, Marie-Cecile, Ellen J. Collarini, Philip A. Leighton, Jeffrey Fesler, Daniel R. Lu, William D. Harriman, T. S. Thiyagasundaram, and Robert J. Etches. "Interspecific Germ-line Transmission of Cultured Primordial Germ Cells." Edited by Osman El-Maarri. *PLoS ONE*, Vol. 7, No. 5, e35664, May 21, 2012. doi:10.1371/journal.pone.0035664.
- Vander Wal, E., D. Garant, M. Festa-Bianchet, and F. Pelletier. "Evolutionary Rescue in Vertebrates: Evidence, Applications and Uncertainty." *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol. 368, No. 1610, December 3, 2012. doi:10.1098/rstb.2012.0090.
- Van Dooren, T. *Flight Ways: Life and Loss at the Edge of Extinction*. New York: Columbia University Press, 2014.
- . "Authentic Crows: Identity, Captivity and Emergent Forms of Life." *Theory, Culture and Society*, forthcoming.
- . "Banking the Forest: Loss, Hope and Care in Hawaiian Conservation." In *Defrost: New Perspectives on Temperature, Time, and Survival*, edited by Joanna Radin and Emma Kowal, forthcoming.
- Walters, Mark Jerome. *Seeking the Sacred Raven: Politics and Extinction on a Hawaiian Island*. Washington, DC: Island Press, 2006.
- Walton, Murray T. "Rancher Use of Livestock Protection Collars in Texas." In *Proceedings of the Fourteenth Vertebrate Pest Conference 1990*, 80, 1990.
- Weidensaul, Scott. *The Ghost with Trembling Wings: Science, Wishful Thinking and the Search for Lost Species*. New York: North Point Press, 2003.
- Weldon, Ché. "Chytridiomycosis, an Emerging Infectious Disease of Amphibians in South Africa." Thesis, North-West University, 2005. <http://dspace.nwu.ac.za/handle/10394/860>.
- Weldon, Ché, Louis H. du Preez, Alex D. Hyatt, Reinhold Muller, and Rick Speare. "Origin of the Amphibian Chytrid Fungus." *Emerging Infectious Diseases*, Vol. 10, No. 12, December 2004. doi:10.3201/eid1012.030804.
- West, Paige. *Conservation Is Our Government Now: The Politics of Ecology in Papua New Guinea*. Durham: Duke University Press Books, 2006.
- White, Lynn Jr. "The Historical Roots of Our Ecological Crisis." *Environmental Ethics: Readings in Theory and Application*, Belmont: Wadsworth Company, 1998.
- Wiley, E. O. "The Evolutionary Species Concept Reconsidered." *Systematic Biology*, Vol. 27, No. 1, March 1, 1978. doi:10.2307/2412809.
- Williams, Nigel. "Fears Grow for Amphibians." *Current Biology*, Vol. 14, No. 23, December 14, 2004. doi:10.1016/j.cub.2004.11.016.
- Wynn, Thomas, and Frederick L. Coolidge. *How To Think Like a Neandertal*. New York: Oxford University Press, 2011.
- Young, S. P., and E. A. Goldman. "Puma, Mysterious American Cat: Part I: History, Life Habits, Economic Status, and Control." American Wilderness Institution, Washington DC, 1946.
- Zippel, Kevin, Kevin Johnson, Ron Gagliardo, Richard Gibson, Michael McFadden, Robert Browne, Carlos Martinez, and Elizabeth Townsend. "The Amphibian Ark: A Global Community for Ex Situ Conservation of Amphibians." *Herpetological Conservation and Biology*, Vol. 6, No. 3, December 2011.