"In colorful prose that conjures up the rich spell of each landscape, Dinerstein takes us on an exhilarating expedition that crisscrosses the globe and travels deep into the heart of rare species . . ."

—Diane Ackerman, author of *The Zookeeper's Wife*

The Kingdom of Rarities

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To Roger and Vicki Sant, conservators of rarities

Look deep into nature, and then you will understand everything better.

—*Albert Einstein*

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Acknowledgments

My immersion in the Kingdom of Rarities began when I was a twenty-two-year-old American Peace Corps volunteer appointed as survey ecologist of a newly created tiger sanctuary in the jungles of Nepal. Rare species have been my passion ever since.

In the intervening decades, I have had the privilege of relying on many experts as my generous and knowledgeable guides, most recently the individuals portrayed in this book. Mike Parr, Tom Brooks, and John Lamoreux taught me about rarity in birds and invited me to be a founding member of the Alliance for Zero Extinction. Bruce Beehler kindly shared his vast knowledge of New Guinea and has been a great birding companion. George Powell, Sue Palminteri, Gregory Asner, Robin Foster, and many colleagues from the Organization for Tropical Studies shared their insights into the rarities that populate rain forests. Sarah Rockwell, Carol Bocetti, and Joe Wunderle kindly educated me about Kirtland's warblers, and conversations with Gordon Orians, Richard Cowling, David Wilcove, Bruce Beehler, Don Wilson, and Peter Raven helped clarify the links between rarity and habitat specialization. Nancy Kittle and Leslie Coolidge made it possible for me to go to Grayling, Michigan, and see the Kirtland's warbler.

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Chapter 1

The Uncommon Menagerie

Riding on an elephant's back offers a privileged, if distorted, perspective on the natural world. Wildlife species that seem large and scary at eye level, such as rhinos and tigers, appear as miniaturized versions from this elevated vantage. My well-trained mount, Kirti Kali, plowed boldly through the dense twenty-foot-tall grasslands of Chitwan National Park in lowland Nepal, scattering spotted deer and wild boars in our path. On elephant-back one feels invincible. As we emerged from the tall grass into an open area, my driver, Gyan Bahadur, calmly steered Kirti alongside a rare greater one-horned rhinoceros—a dangerous species that, locally, tramples and kills several villagers a year. The two-ton female and her young calf continued grazing peacefully on the floodplain. The rhinos seemed oblivious to our presence because we had spent months habituating these aggressive creatures to close contact. As long as we remained on the elephant, rather than approaching on

foot, the mother rhino would remain unfazed and we would stay in one piece.

My jungle wanderings also warped my perspective on how uncommon these animals had become. By 1988, at the end of my initial five years of research, I had recorded thousands of observations of Chitwan's 370 one-horned rhinos and had photographed, identified, and named nearly every one. Yet seeing them every day made me forget their global rarity. At the time, only about 1,500 survived in the wild worldwide; all but those in Chitwan roamed in Kaziranga National Park in northeastern India. Although the one-horned rhino's numbers have slowly increased since then—in 2012 there were over 2,900, distributed among twelve populations—this species remains among the most endangered large mammals on Earth. Its status during my initial study raised several questions: Had the ancestors of this rhino, a diverse ancient lineage, always been rare during their evolutionary history? Or is the rarity of the one-horned rhino a relatively recent phenomenon, triggered by habitat loss and poaching for the mythical qualities of the rhino's horn?

My ecological study took an unexpected turn when I asked Gyan to maneuver Kirti Kali into an ideal spot for a photograph. I raised my camera to capture an exquisite panorama: the rhino cow and calf in the foreground, perfectly framed by the Annapurna range and Mount Dhaulagiri to the north. Then I noticed some clumps of low trees that spoiled the picture's composition. Copses of a species called *bhellur* (*Trewia nudiflora*) stood out like archipelagoes in the midst of the grassland. I asked Gyan why the trees had assumed this pattern. He took a break from smoking a cigarette rolled in a jungle-leaf wrapper to answer my silly question. "Oh, it's the work of *gaida*," he said matter-of-factly, using the Nepali word for "rhino" and gesturing toward the tree islands. "Those are old rhino latrines."

Rhinoceroses return to the same places time after time to deposit their dung—not out of tidiness but because these communal la-

trines allow solitary animals living in dense vegetation to exchange vital data, via scents within the dung, about their whereabouts and sexual activity. The sheer size of the dung piles, sometimes dozens of meters long, and the dense stands of *Trewia* trees that sprang from them were a revelation to me. All the more so because when I first arrived in Chitwan, I had wondered how this giant herbivore could have even a minor influence in cropping the lush vegetation—the wall of green grass surrounding me—which was recharged each year by the summer monsoon.

The answer lay buried in the dung. By voraciously consuming *Trewia* fruit and defecating intact seeds in latrines scattered throughout the floodplain, the rhinos could rapidly convert the world's tallest grasslands into *Trewia* forests. Countervailing the rhino-dispersal effect were the annual floods, which wash away and bury *Trewia* seedlings, and the annual natural fires, which incinerate much of the previous year's crop. But some of these seedlings obviously survived to become tree islands. What remained as an indelible imprint for me was the staggering potential of rhinos to reshape their surroundings, implying, in this case, that ecological impact does not always reflect numerical abundance.

It would be a stretch to say that sifting through rhino dung or musing while on elephant-back triggered my fascination with rarity. But my observations of these rhinos, and observations that I and others had recorded of another globally rare denizen of their neighborhood, the tiger, made me wonder: What if more biologists fanned out to study in depth not the common mongoose or the ubiquitous spotted deer but members of Chitwan's uncommon menagerie—great hornbills, Gangetic dolphins, gharial crocodiles, sloth bears, and Indian bison? How might one's perspective on the natural world change? What novelties, complexities, and even counterintuitive elements might emerge, and what adventures lay in store for the pursuer of these rarities?

As a scientist, I knew that the interplay of rarity and abundance is central to understanding patterns of nature as well as understand-

ing the idea of dynamic ecological balance. What do we mean by "rare," though? By what measure is a rhino or tiger considered rare? Most biologists would apply the term to a species that occupies a narrow geographic range, has a low abundance, or exhibits both traits. Often this label stems from a comparison of an uncommon creature with others that share its habitat or taxonomic group, but it can also be viewed in absolute terms. For example, sticking with rhinos, the greater one-horned rhinoceros is rare from a global perspective, with fewer than 3,000 individuals, but it's relatively common in comparison with the highly endangered Javan rhinoceros, of which fewer than 50 remain, and those restricted to one locale. In this book, I draw mainly on examples of rarity among mammals, birds, and plants—the creatures I know best. But the condition of rarity transcends appearance and taxonomy. Whether an organism has a backbone, a beak, pincers, or petals or is covered by scales, fur, feathers, or fins, the same rules apply—occupying a limited space geographically and exhibiting low population densities guarantees a place in what I call the Kingdom of Rarities.

The simple truth is that many, many species on Earth are rare, but few people other than biologists are even aware of this fact. A leading ecologist on the subject, Kevin Gaston, suggested an astonishing asymmetry of life on Earth: as few as 25 percent of the world's species, such as robins, rats, and roaches, may account for 90 to 95 percent of all individuals on Earth. But if Gaston's estimates are correct, as much as 75 percent of all species on Earth may be drawn from the ranks of the rare. It's a stunning idea to contemplate.

If relatively so few individual organisms on Earth make up the rare, why should biologists study rarity, the rhinos rather than the roaches? The obvious academic response is "Because we know so little about them." Rephrasing the question, though, brings into focus a profound and central riddle of nature: Why, wherever you land, do you always find a few superabundant species and a multitude of rare ones?

One of the first lessons in community ecology—the science of how species interact in nature—is the prevalence of rarity at any locale in the tropics. Sweep a forest plot with a butterfly net, identify all the trees in that tract, scan those trees for singing birds, and you'll find the same result: many individuals of a few species and a lengthy list of singletons. This pattern holds from the forests of Madre de Dios, Peru, to Mondulkiri Province, Cambodia. Even though rare species occur everywhere, we still know too little about how they fit into the big picture of our wild menagerie. But some intriguing answers have emerged regarding, for example, the roles various rare species play in shaping the form and functioning of ecosystems and how ecosystems are affected as particular rare species are lost.

Attention to rarity can raise vital questions: Are all rare species, for example, by definition on the verge of extinction? Have all species that are currently rare been historically rare? Which species common now are likely to become rare? Greater clarity on these fundamental issues will help shape our response to saving wild nature. Will species that are common now become rare as a result of changing climate? For example, how will egg-laying sea turtles find nesting sites when sea levels rise, and how will moisture-dependent frogs lay eggs when rain forests face prolonged droughts, in some cases by the middle of this century? When the microclimate at the summit of Mount Udzungwa in southern Tanzania changes in a profound way, will the African violet—ancestor of the familiar houseplant—and the Udzungwa partridge disappear, or will they be able to adapt to the new conditions?

During the 1980s, leading biologists began to suggest that we were in the midst of the sixth great extinction event in the history of Earth. And in 1995, Stuart Pimm, one of the fathers of modern conservation biology, calculated that the current rate of species extinctions was as much as 1,000 times the normal background extinction rate. If so, newly rare species may face different, and more serious, problems from those encountered by species that have

historically been rare—another major reason for exploring rarity in the natural world.

Beyond the extinction crisis, some scientists refer to our current epoch, the Holocene, as the Anthropocene or the Homogenocene, terms that describe two aspects of a new ecological state that is still poorly understood. The first refers to our period, wherein the human footprint extends everywhere in nature. The second refers to another kind of affront in which certain species have spread or been introduced by humans far beyond these species' original range and, as a result, natural habitats around the world, full of invasive species, begin to resemble one another. Being rare in this brave new homogenized world, as we'll see in the case of Hawaii, could mean something much different from when these same species first appeared in relative isolation. Rarity is not just a condition of nature; it is a condition that can be—and has been—imposed on species by human activity, all too often sending them on the road toward endangerment and extinction. In short, viewing the natural world through the lens of rarity can bring certain facts and species traits to our attention that we might otherwise overlook. Understanding these facts and traits may in turn provide insights that can help us save species from the current state of environmental deterioration.

Many conservation biologists target "saving rare species" as the ultimate aim of their work. Yet rarity, as a phenomenon in nature, can take many forms, not only among species, although that is central, but also in the building blocks of the natural world: genes, populations of species, habitats, assemblages, and ecological and evolutionary phenomena. Species, with few exceptions, are made up of populations distributed across the landscape. Saving only one population of each rare species simply as a token gesture would be of little ecological value, especially where those species play a role in maintaining a given ecosystem's integrity. So an essential goal is to conserve multiple populations of species and the genetic, ecological, and behavioral features that these building blocks contain. Conserving dispersed populations and their genetic variability

gives species a better chance of adapting to and persisting amid changing conditions, such as a rapidly changing climate or invasion of their homeland by introduced species.

Buried within the species extinction crisis is another, less publicized calamity: the increasing rarity of species populations. These losses of populations, as well as in some cases entire species, have led biologists to sound warning after warning. The eminent biologist E. O. Wilson, for example, pronounced in a speech in early 2000 that "biodiversity cannot afford another century like the last one. We are about to lose thousands of species a year, especially in rainforests." Wilson could have extended the depth of the problem, if risking the simplicity of his message, by adding a phrase whose meaning has gone unnoticed by the general public: we have been losing *populations* of species faster than we have been losing species themselves.

These two concerns—rarity of species and paucity of particular populations—merge when it comes to those species whose entire earthly existence is represented by a single population, as a result of either natural forces or human encroachment. Who are these singleton species, and how many of them are now close to the abyss of extinction?

In 2003, several colleagues and I put together a paper for the *Proceedings of the National Academy of Sciences* to address this question, name those species, and suggest how their imminent extinction might be prevented. Our work on the paper, which was published in 2005, sparked the scientific basis for this book, an interpretation of the evolutionary and contemporary aspects of rarity. We focused our effort on a subgroup of relatively well known but threatened vertebrates, our fellow creatures with backbones—birds, mammals, reptiles, amphibians (fishes are yet to be analyzed). We postulated that certain of these species were already so uncommon that they would be extinction's next dodo birds unless action were taken to prevent their disappearance.

To begin, we turned to the gold standard for evaluating rarity of wild species, the International Union for Conservation of Nature

and Natural Resources (IUCN) and its famed Red List of Threatened Species, which ranks species on the basis of sizes of remaining populations. The IUCN assigns the category "endangered" or "critically endangered" to species whose numbers have plummeted toward extinction. We then went a step further. "Let's name the rarest of the rare, those species whose entire global range is limited to one population at a single site," my colleague John Lamoreux suggested. He was proposing that we limit our survey to such species as the Bloody Bay poison frog, which hails from the last patches of rain forest on the island of Trinidad, the only place on Earth where it can be found.

Once a species such as the Bloody Bay poison frog is restricted to a single dot on the map, if one or another of several catastrophes strikes—if the spot is plowed, burned, flooded, drained, paved, polluted, or overrun with pigs, rats, or other invasive species—the threatened species that lived in that dot is gone: vanished forever. Rarity then becomes the precursor to extinction or, at least, its preexisting condition. Alternatively, if you save the place, you save the rare species—conservation in black-and-white.

Our results provided some new insights and a number of surprises. First, despite there being 20,000 species on the IUCN Red List, only 800 species found at 600 sites (some species shared the same site) met our criteria. Second, half of the species limited to a single site turned out to be amphibians. Third, many single-population species were restricted to isolated mountaintops. A botanist on our team, George Schatz, cautioned the vertebrate specialists against any euphoric notion that saving the world's rarities might be as easy as saving some isolated mountaintops where few people live. "Remember," he warned, "the 250,000 or so vascular plant species have yet to be evaluated for levels of threat. At least 10 percent of these are known only from the single site where they were first collected." There is a joke among field biologists that rarity is partly a natural phenomenon and partly the result of some less energetic biologists failing to wander far enough from the road or the field

station in surveying their specialty. There may be an ounce of truth to that, but the idea that the populations of many plant species, and the insect species they host, could be so few only reaffirms the important role of rarity, especially in the tropics.

The next question for our group of biologists was which rare species or place we should try to save first. This exercise drew us to a global map and triggered much debate. "Here." Mike Parr leaned over northern South America to point out the location of a mother lode of rarities. His pen tip lingered on a massif that stood by itself in northern Colombia, the Sierra Nevada de Santa Marta. The solitary giant sat about 42 kilometers from the Caribbean coast and about 115 kilometers from where the sawtooth eruptions of the northern Andean chain began. Santa Marta in Colombia, like Mounts Kilimanjaro and Udzungwa in Tanzania, Mount Cameroon on the border of Nigeria and Cameroon, and Mount Kinabalu in Sabah, Malaysia, are but a few of the dozens of solitary mountains in the tropical belt that are hotbeds of natural rarities. Why this might be so was one of the questions I wanted to investigate.

"Here is where I want to go next," I said, pointing to the Zapata Swamp on the island of Cuba. Considered the Cuban version of the Everglades, this freshwater swamp is home to the Cuban crocodile, the Zapata wren, the Zapata rail, and two species of hutia (a guinea pig–like rodent) found nowhere else in Cuba, the Caribbean, or anywhere else. In the same swamp are the only robust populations of several Cuban birds—the Cuban sparrow, Fernandina's flicker, Gundlach's hawk, and the blue-headed quail-dove—proving that rarity is not confined to tropical mountains or even rain forests.

As we populated the map in front of us and delved into the causes of rarity for the 800 species that met our conditions, we saw another insight into rarity confirmed. Some of these species had likely always been rare, such as the 13 frog species sharing the same genus and the same mountaintop in Haiti, the Massif de la Hotte; others on the list had been made rare by human activities. Some species had been much more common during an era when

the climate was different from what it was during our mapping project—colder, hotter, drier, wetter. They were now climate refugees. Some species had been doing fine at a single site until rats arrived on their island. We realized that we had to consider all the different causes of rarity to better understand which species would be likely to persist without much conservation effort. We needed to know which species had always been rare but were now facing even lower numbers, a more limited range, or a new invader.

Some of the more promising places to look for the causes of rarity and of patterns of rarity and abundance are where there are no people. A remote mountainous region of New Guinea with no history of human visitation, the locale of chapter 2, offers a good venue to investigate the extent of rarity under natural conditions. By comparing what we discover there with what is found in other ranges where local tribes have access, we can begin to answer several fundamental questions about how rarity is created and what pattern exists where humans have had no perceivable influence. New Guinea also offers a rewarding glimpse of how extreme isolation and active geology can lead to rarity and a narrow range of resident species. In contrast, another area with low human activity, the Peruvian region of Madre de Dios, the locale of chapter 3, illustrates a condition that exists for many tropical rarities, from jaguars to canopy trees—a wide range of species living at extremely low densities.

The string of insults to nature brought about by human activities covers a staggering range including habitat loss, poaching and the consumption of body parts of rare creatures, introduction of diseases and invasive predators, expansion of agriculture to feed a growing human population, and the horrors of war. In this book I examine these human-induced causes of rarity, along with many natural influences, in a journey that spans most continents. In the natural world, the causes of rarity are often difficult to pin down or isolate to a single source. To untangle these strands, in each chapter that follows I sample different manifestations of rarity and con-

sider probable causes and consequences for species and the ecosystems they inhabit. Much can be done in the short term to preserve species populations. Ultimately, though, the future of many species depends on our ability to live in greater harmony with the rare creatures among us. In Bhutan, the setting of chapter 9, where Tibetan Buddhism is the dominant religion and cultural conservation is part of the fabric of society, we see how rare species can persist and recover when humans coexist peacefully with wildlife and treat rare species with respect and compassion.

What is in store for rare species? Looking backward and examining evolution's fingerprints may provide some clues. The renowned ecologist Gordon Orians has noted that natural selection, as an evolutionary process, lacks foresight. It can't look ahead to help a species best adapt to a threat to its future survival, be it next year or several centuries or millennia hence. Thus, all the current traits and behavioral responses we see in such species as the maned wolf, the giant anteater, the rhinoceroses, and the Kirtland's warbler—all protagonists in this story—were shaped in their predecessors' environments. Yet some of those traits, even if selected for other reasons, may enhance persistence when a species becomes rare or, if it has always been rare, faces even more dramatic threats to its survival. Phrased another way, at least some species that have always been rare may possess traits that will allow them to hang on in the face of changing circumstances. In each chapter I examine such traits to assess whether such a repertoire, however unintended, enhances adaptation to life in the Anthropocene.

If the search for rarity and an understanding of its origins holds evolutionary interest and conservation importance, it also has a strong allure of its own. The truth is as simple as it is universal: we are seduced by rarity and novelty. Scientists live with this affliction, shared with art collectors, car buffs, and wine connoisseurs, many of whom are willing to pay exorbitant prices to add the rarest of items to their collections. The allure of the rare is what motivates many of us to raise a pair of binoculars—from the birder who scans

the backyard feeder in hope of seeing an off-course migrant to the ornithologist who finds the now rare green peafowl in a Vietnamese jungle. Perhaps our search for rarity among wild things is a holdover from distant ancestors who sought to expand their monotonous diets, find new healing herbs, or discover a more potent aphrodisiac. A rare object might even have served as a status symbol and increased mating success. Whether stimulated by curiosity or by our most intense cravings, we humans, it seems, long to seek out what is scarce and, therefore, precious.

In the nearly forty years I have been studying rarity, a recurring fringe benefit has been the chance to visit exotic places and meet fascinating people in the search for spectacular species. I first heard the term "quest species" from Bruce Beehler, a scientist featured in chapter 2 who explored the most remote mountain range of New Guinea in search of rare birds of paradise. "A quest species," he imparted, "is a rare species, for sure. But it is also a near-mystical creature, one that shadows your existence, one that you must see before you die." Although avian specialists are famous for their single-minded pursuit of one bird or more for their life lists, they are far from unique. Primatologists scan the thickets for their quest mouse lemur. Herpetologists work the bushes for their prized chameleon. Botanists slog through swamps to find an orchid previously unknown to science. Even parasitologists seek their quest tick, embedded perhaps in the nether folds of a wombat or Tasmanian devil.

The study of rarity is of vital importance today, but it also allows us to glory in the extraordinary activity and variety of the natural world. Staring at a habituated rhinoceros in Nepal or contributing to a desk study on rarity, for example, can never replace the thrill of a first sighting: a rare species you have waited your entire life to see on its own terms, in its own place. A quest species, if you will.

I was on my way to the Amazon lowlands of southeastern Peru when I had the chance to see a rarity up close that I had always dreamt about. Before dawn, flashlights in hand, my guides led me to a bird blind at the edge of Manú National Park, where we waited

*Three male Andean cocks-of-the-rock (*Rupicola peruvianus*) singing, with a female in the background*

for the show to begin. Few rare species seek more attention than the flamboyant Andean cock-of-the-rock we had come to see. The male's molten-orange plumage virtually glows in the dark. His vocalizations—a series of hoots, growls, and chimp-like whimpers—accompany a ritualized shake of an unusual cowlick and rump. The bird's name, dare one ask, is a reference to its habit of nesting in rock walls rather than some biological double entendre.

The male's extravagant appearance flares when several of them gather in the dank, kaleidoscopic undergrowth. As the dawn light filters through the tropical highland forest of Peru, colorful bachelors scramble to their singing perches on nearby tree branches. Biologists describe the location of the courtship that ensues as a lek, a place where males congregate to advertise their individual greatness. One bird triggers an explosion of song and dance that

lasts for minutes. Just as suddenly, they all go mute. Perhaps the shadow of an eagle has passed overhead? Then the cacophony resumes in earnest. Soon a drab maroon bird slips into the center of the gathering, sparking a more intense bout of singing and feather shaking. The female has arrived.

By 6:45 a.m., the males had quieted down and dropped into the dense foliage. I left the bird blind with my guides and strolled down the dirt highway to the nearby lodge. It's hard to avoid descending into cliché after witnessing a lek display of any bird or mammal. For me, it was a lifelong yearning now sated, replaced by a sense of awe in how evolution and the essential mission to procreate can go to such lengths.

My group enjoyed a celebratory breakfast in the café of the Cock-of-the-Rock Lodge. Accessible cock-of-the-rock leks in nature, such as the one we visited, are rare and usually reached only after a long hike. Over a second cup of coffee, the conversation spun in a widening gyre of questions: What if the glorious Andean cock-of-the-rock, one of the most colorful birds on the planet, were as ubiquitous as the house sparrow? Would anyone bother to look at it? Or would its fate be like that of the blue jay, a stunner for visitors to the United States but a backyard fixture evoking yawns from the locals?

Back on the trail, we heard the males start up another chorus. Left to their own devices, most rare species, like this charismatic Andean bird, would persist for several million years. A logical conclusion, one that will be explored and challenged in this book, is that rare species have adapted to cope with life at low densities, in small areas, or in restricted habitats. Unfortunately, wild nature is no longer being left to its own devices, and many species face a tenuous future. Our own species, now shooting past 7 billion and far from rare, faces a different challenge: how to live sustainably without destroying the last strongholds of rarity. For rare species, the struggle is to hang on for dear life until, one day, humans gain the wisdom and humility to share nature's kingdom.