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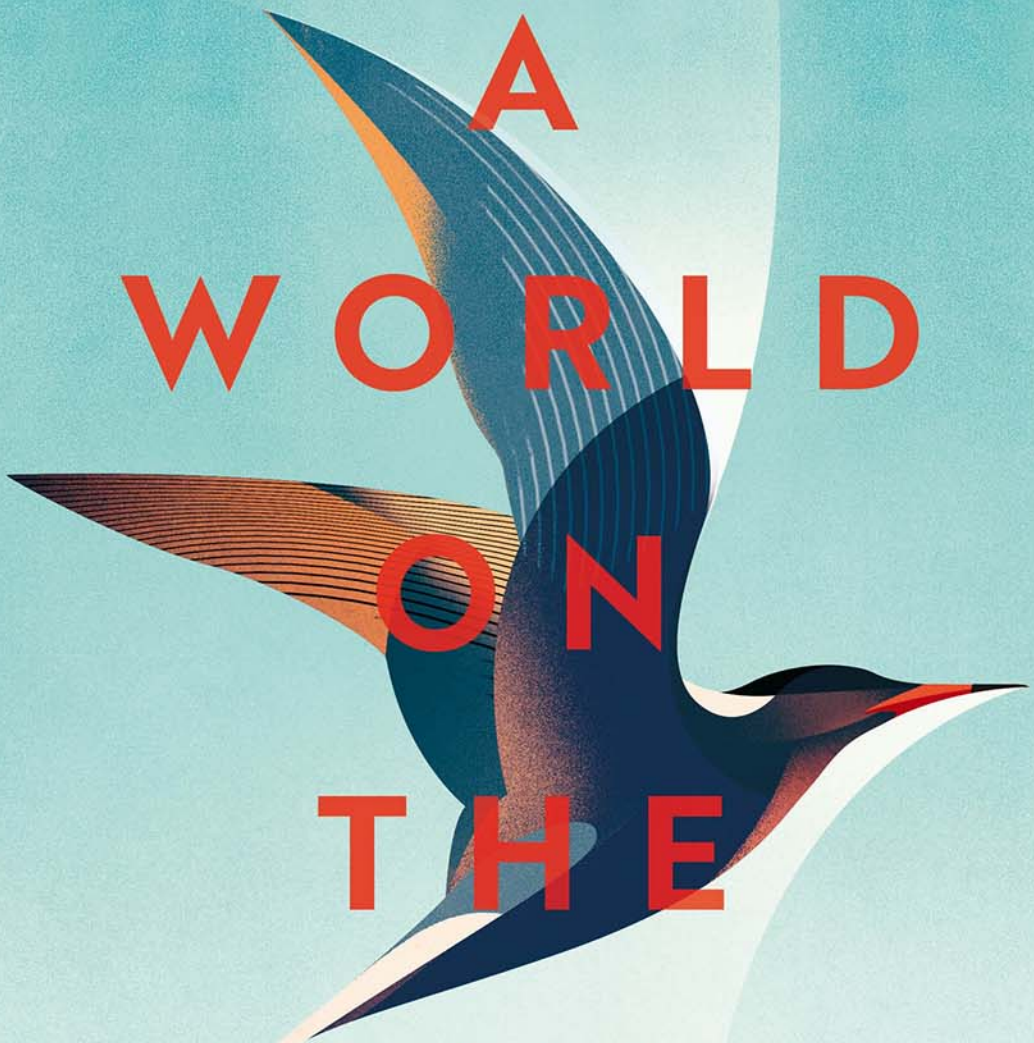

A WORLD ON THE WING

THE GLOBAL ODYSSEY OF MIGRATORY BIRDS

'A vaulting triumph of a book . . . compelling and often deeply moving, this is a summons for international co-operation and global conservation like no other'
Isabella Tree, author of *Wilding*

A WORLD *on the* WING

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The Global Odyssey of Migratory Birds

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For Amy, as always (but even more than usual)

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A WORLD *on the* WING

PROLOGUE

Tundra may be the most gloriously comfortable mattress in the world.

A little damp, it's true, which is why it's a good idea to wear rain pants and a jacket, even on a clear, chilly morning like this one—the sun just touching the peaks of the Alaska Range with pink-orange light, the glacier-wrapped bulk of Denali a vast, rosy monolith 70 miles to our west, uncharacteristically free of clouds.

My three companions and I flopped down with happy sighs, legs outstretched and hands laced behind our heads, onto the soft, spongy cushion of sphagnum moss, dwarf cranberries, reindeer lichen, and other Lilliputian tundra plants. The break felt good. We'd risen at two in the morning, in the bright twilight that passes for the middle of the subarctic night in the interior of Alaska. By three, keeping an eye out for moose or grizzlies, we were headed west along the 90-mile gravel road that bisects the six-million-acre wilderness of Denali National Park and Preserve. We never knew what we'd see. The day before, a large male wolf had trotted warily around our National Park Service truck before sniffing nervously at the rear fender, just a few feet from my open window.

There were no such interruptions today. By four o'clock, 30 miles inside the park, we'd shouldered our packs and bundles of aluminum net poles, then trudged down a long slope to a sinuous willow thicket that snaked through a mile-long draw. As luxurious as spongy tundra is to lie on, it is a tiring chore to hike across, with every footstep sink-

ing deep or rolling on some hidden tussock, while shin-high birches and willows claw at your feet and legs.

"Hey! Hey!" we yelled, to alert any moose or grizzly bear that might be hidden in the dense, 10-foot-high brush ahead. "Blah blah blah blah!" I shouted nonsensically; it doesn't matter what you bellow, just so you don't surprise a protective cow moose with a calf, or startle a grizzly whose first reaction might be to charge. Unlike many hikers, one thing we never did was yell, "Hey bear!" Those words, old Alaskan hands will tell you, should be reserved solely for the gut-twisting moment when a grizzly pops up at close range—a warning to the bear, but more importantly to everyone else in earshot.

As it was, all we alerted was a family of willow ptarmigan, half a dozen rotund, brown fledglings that boomed off in as many directions while the mother grouse barked her displeasure. We shucked our loads, and I followed Laura Phillips, the park's avian ecologist, as she wormed her way into the seemingly impenetrable tangle of willows. Somehow, the moose had no trouble maneuvering in there—the wet ground was pocked with their saucer-sized tracks and piles of oblong droppings. But in the middle we found a slender lozenge-shaped meadow just a few yards wide, blue with the stately flowers of monkshood and larkspur, its margins purple with spires of fireweed.

We weren't looking for ptarmigan or wildflowers, though, but for thrushes—and not to watch, but to catch. After more than three decades of visiting Denali, I was helping to launch a new research project there to better understand the lives of the park's birds, which every year fan out across three-quarters of the earth's surface on their migrations.

Soon, we had three 40-foot-long mist nets radiating out into the brush. David Tomeo, with Alaska Geographic, and seabird biologist Iain Stenhouse—a transplanted Scot now living in Maine, who was once Audubon's director of bird conservation in Alaska—secured the net poles with guy lines of bright red parachute cord. I jammed a long wooden dowel into the ground mid-net, and perched on its tip a painted, life-sized wooden thrush decoy. Then I thumbed the con-

trols of a battered old MP3 player, from which emerged the buzzy, ethereal song of a gray-cheeked thrush. Our work finished for the moment, the four of us walked 10 or 15 yards up the hill, out of the willows and into the open tundra, and sank down to relax for a few minutes. Our hope was that a male thrush—hearing what sounded like an intruder in his jealously defended territory—would come barreling down through the shrubs and collide harmlessly with our delicate nets. Then we could carefully attach a tiny device called a geolocator, weighing barely half a gram, to the small of his back. For the next year, it would record the bird's location as it flew to South America and back, giving us the first glimpse anyone's had into the specifics of this bird's epic migration.

For the better part of a century, the only means scientists had of figuring out where birds traveled was by putting lightweight numbered bands on their legs, and hoping to hear if the banded bird was ever encountered again. Banding is still a critical element of migration research—some 7 million mallard ducks have been banded in the past century, for example, and 1.2 million of them recovered (mostly by hunters), providing data that help underpin our very successful management of waterfowl populations. But it's a long, slow slog if you're studying a rarely banded bird in a remote area—a bird that, unlike mallards, isn't legally hunted. In the past century, roughly 82,000 gray-cheeked thrushes have been banded in North America as a whole, but only 4,312 of them were in Alaska—and of those banded Alaskan thrushes, only three have ever been encountered again. One was caught close to where it was banded, one on its spring migration north through Illinois, and one heading south in the fall in Georgia. That's not much to go on.

What banding data and observations we do have show that gray-cheeked thrushes are exceptionally long-distance migrants. Even though they weigh only about 30 grams—a shade more than an ounce—they travel from conifer forests and thickets in northern Alaska and the Canadian subarctic to South America and back each year. At least some of them cross the Gulf of Mexico in a 600-mile

nonstop leap, while others may follow the long finger of Florida and then overfly the Caribbean. In winter, they disappear into the rain forests of northern South America, but we have only the sketchiest notion of where they go within that vast continent.

But where banding struggles to fill in the blanks, newly miniaturized technology is opening exciting horizons in the study of bird migration. The geolocators we were using are just one example of tiny, relatively inexpensive tracking devices that are revolutionizing migration research. Instead of depending on satellite transmitters that cost $4,000–$5,000 each (and which are, in any case, far too heavy for small songbirds), our geolocators weigh a fraction of a gram and cost just a few hundred dollars each. Our team, headed by National Park Service ecologist Carol McIntyre, was starting a multiyear project to trace the migratory links between Denali and the far corners of the globe to which the park's birds fly. Our geolocators would give us the first opportunity anyone's ever had to track the actual route and destinations of the park's thrushes.

But first we had to catch some. We'd had easy success the previous week tagging Swainson's thrushes, which are abundant in the spruce forests of Denali. The closely related gray-cheeked thrushes, on the other hand, were proving to be a little more challenging, and we hoped that the use of a few extra nets might make a difference that morning.

The tundra was almost *too* comfortable, and after about 15 minutes of waiting and dozing, I levered myself off the ground and trotted down the hill to the willows to see what we had caught. In one net, a male blackpoll warbler hung head-down in the cushioning mesh—another bird that makes an extraordinary migration, from Alaska to the Atlantic coast of Canada and the northeastern United States, then south in a nonstop 90-hour flight over the western Atlantic to South America. The next net held a male Wilson's warbler, tinier even than the blackpoll, weighing just nine grams, less than a third of an ounce. Those Wilson's warblers that breed in central Alaska migrate (we think) to the Gulf Coast of Texas and eastern Mexico

and south into Central America. Many of them may commute to the Yucatán Peninsula across the Gulf of Mexico—but no one really knows. Only a single Wilson's banded in the Alaskan interior has ever been recovered away from the breeding grounds, and that one was found in Idaho on its way south.

We would be tagging blackpolls and Wilson's warblers another time, but for the moment, that mystery would have to wait, and I released them quickly. Our focus this morning was thrushes, and to my disappointment, there were none in our nets. I turned to trudge back up the hill—and in that moment, the quiet of the morning became a terrifying chaos.

"Hey bear! *HEY BEAR!*" Laura and David's voices had the rough edge of panic, their arms raised and waving wildly against the pale dawn sky. I couldn't see Iain, hidden from me by the willows.

I heard a huffing, staccato roar, and an explosive wooden sound like someone pounding two-by-fours together, which I realized were the clashing jaws of an angry grizzly "popping" its teeth in rage. Time, as often happens in moments of extremity, seemed to slow. I couldn't see the charging bear, but assumed it was coming out of the willows where I was standing. I froze.

"*HEY BEAR!*" The roaring and popping sounds were much closer now, and the thicket was filled with the crashing of a large animal, very close and moving very fast. David bellowed, "Scott, get the *hell* out of there!"

I bolted from the willows as the bear passed a few yards away, so close that I could hear its ragged, woofing breaths and smell its pungent odor, but invisible behind the screen of brush. In seconds I scrambled back up the hill to my friends. Turning, we saw the bear—a big female with a dark yearling cub in tow—burst out the far side of the willows and race away from us with the horse-like speed for which grizzlies are famous. The sow's straw-blonde fur rippled as she pounded up the far tundra slope, vanishing over the crest.

The story emerged in shaky, disjointed pieces. Everyone was still lying down when the bear emerged from a hidden draw, just 50 or 60

feet away and a little behind them. "I looked over to say something to Iain," Laura said, "and I saw this grizzly head beyond him. I said, 'Oh shit.' We started to stand up, and she just charged."

Iain was closest. "I heard you and David yell, but I couldn't move," he said in his Glasgow accent, shaking his head. "I was just—I couldn't move." The grizzly crossed the distance in seconds. Only a few feet from Iain, the bear changed its mind; Laura and Iain both said they could see the fraction of a moment when the sow decided not to maul them—and turned instead to race down the hill, directly toward me.

"It's ironic," David said, "that the one person who didn't see the bear coming is the one who was probably in the greatest danger of getting mauled." It took me a second to realize he meant me. Even for an angry grizzly, three people together is a lot to tackle. But alone and hemmed in by the willows, I would have been helpless if she'd spotted me just a few yards from her in the thicket, and had decided to vent her frustration and fear.

Laura drew a long, uneven breath and looked around. "You guys think we have any nets left?"

The bears' path had been right through the middle of our array, but somehow the 400-pound sow and her cub had missed them. And whether because of all the commotion, or because they'd fallen to the lure of the recorded song in spite of it, there were three gray-cheeked thrushes hanging in the mesh. Knowing the bears were safely gone—and with a sense of relief that we had something else to think about—we set to work.

Placing the birds in lightweight cloth holding bags, we spread a small tarp on the damp ground and laid out our tools—banding pliers, clipboard, a spring scale, a small camera, and the first geolocator. The device was maybe a third of an inch long, with a short plastic stalk poking out its rear that carried a light sensor. Small elastic loops stuck out to either side like rabbit ears. Laura removed the first thrush, gently caging it in her hand with its neck between her first two fingers. Gray-cheekeds are two-thirds the size of robins,

lovely in their subtlety. Their upperparts are a cool olive-gray, their off-white chests covered in brownish spots that look like watercolor gently seeping into thick paper. Attaching the geolocator took less than a minute. Iain worked an elastic loop high up one leg, to the top of the bird's thigh. With her thumb, Laura steadied the geolocator in the small of the thrush's back while Iain slid the other loop up the opposite leg; thus secured, the tracker rode snugly just above the bird's rump, all but the light stalk hidden beneath its back feathers.

With practiced moves, Laura banded the thrush—a standard metal band on the right leg, and two colored plastic bands, yellow above orange, on the left. When Denali's migrants returned the next spring, the color bands would make it easier to relocate this and the other tagged thrushes so we could recapture them, remove the geolocators, and download their data. One by one, we processed and released the thrushes, each of which flew back into the sheltering willows with nasal, scolding *jee-eer* notes. We packed up the gear, but as we rose to go, I realized Iain was staring out over the hills, in the direction where the bears had gone.

"You know what?" he said, his bright smile conveying a sense of cheerful discovery. "I didn't think my sphincter muscle was that strong!"

For almost six years in the 1990s, I followed birds up and down the Western Hemisphere, exploring the phenomenon of migration for a book called *Living on the Wind*. I'd come to the subject largely as a deeply interested observer—a lifelong birder who had, a decade or so earlier, become obsessed with banding raptors. Initially, I must admit, the attraction to banding was largely the adrenaline-surging thrill of luring a goshawk or golden eagle out of the sky and into my nets—fly-fishing in the air, on an epic scale, for prey with talons and a regal mastery of the wind. But with each hawk or falcon on whose leg I placed a band—and with each time one of those marked birds was recaptured or found dead in some distant place, adding a little

more to our understanding of their migrations—I became more fascinated with the natural forces that push not just powerful birds of prey but even the tiniest and seemingly most fragile warbler to cross immensities of space with a speed and physical tenacity that beggars human imagination.

In the past two decades, science's understanding of migration—of the mechanics that allow a bird, alone and on its first journey, to find its way across the globe in the face of crosswinds, storms, and exhaustion—has exploded. To take just one especially mind-bending example, we've known since the 1950s that birds use the earth's magnetic field to orient themselves. Ornithologists long assumed this ability was a sort of biological compass, and the presence of magnetic iron crystals in the heads of many birds seemed to bear this out—except that those magnetite deposits actually appear to play little role in orientation. Vision, quite unexpectedly, does. Expose a bird to red wavelengths instead of natural white light, and it loses its ability to orient magnetically, regardless of what minute lumps of iron might be in its head. But just why this should be has baffled ornithologists since at least the 1970s.

It now appears that birds may visualize the earth's magnetic field through a form of quantum entanglement, which is just as bizarre as it sounds. Quantum mechanics dictates that two particles, created at the same instant, are linked at the most profound level—that they are, in essence, one *thing*, and remain "entangled" with each other so that regardless of distance, what affects one instantly affects the other. No wonder the technical term in physics for this effect is "spooky action." Even Einstein was unsettled by the implications.

Theoretically, entanglement occurs even across millions of light-years of space, but what happens within the much smaller scale of a bird's eye may produce that mysterious ability to use the planetary magnetic field. Scientists now believe that wavelengths of blue light strike a migratory bird's eye, exciting the entangled electrons in a chemical called cryptochrome. The energy from an incoming photon splits an entangled pair of electrons, knocking one into an adjacent

cryptochrome molecule—yet the two particles remain entangled. However minute, the distance between them means the electrons react to the planet's magnetic field in subtly different ways, creating slightly different chemical reactions in the molecules. Microsecond by microsecond, this palette of varying chemical signals, spread across countless entangled pairs of electrons, apparently builds a map in the bird's eye of the geomagnetic fields through which it is traveling.

That's by no means the only gee-whiz discovery. Researchers have found that in advance of their flights, migrant birds can bulk up with new muscle mass without really exercising, something humans would love to copy. Because a bird's muscle tissue is all but identical to a human's, the trigger must be biochemical, but remains a tantalizing mystery. They also put on so much fat (in many cases more than doubling their weight in a few weeks) that they are, by any measure, grossly obese, and their blood chemistry at such times resembles that of diabetics and coronary patients—except that they suffer no harm. Nor do birds flying nonstop for days suffer from the effects of sleep deprivation; they can shut down one hemisphere of the brain (along with that side's eye) for a second or two at a time, switching back and forth as they fly through the night; during the day, they take thousands of little micronaps lasting just a few seconds. Researchers have found dozens of similarly extraordinary ways in which a bird's body copes with and overcomes the stress of long-distance travel.

And as science's grasp of the mechanics of migration has improved, so too has our understanding of the gritty, life-and-death challenges that increasingly face these travelers, and the almost inconceivable feats they accomplish twice each year to reach their destinations. In the past two decades we've realized how badly we have underestimated the simple physical abilities of birds.

Until recently, the acknowledged long-distance migration champion was the Arctic tern, a ghostly gray seabird the size of a dove, which breeds in the highest latitudes of the Northern Hemisphere and winters in the southern oceans between Africa, South America, and Antarctica. Draw lines on a map between those waypoints,

scratch a few calculations on a table napkin, and you reach the conclusion that generations of ornithologists had—that Arctic terns migrate some 22,000 to 25,000 miles each year. It was a guess, because tracking technology wasn't nearly small enough for a delicate creature like the tern to carry. But as transmitters and data-loggers began to grow smaller, they could be deployed on other, somewhat bigger seabirds—which soon left the Arctic tern's assumed record in the dust.

In 2006, scientists using geolocators announced they had successfully tracked 19 sooty shearwaters from their breeding colonies in New Zealand. Even a "local" feeding run during the breeding season, when the parents forage for squid and fish to bring back to their nest burrows for their chicks, carried these plump, dark gray birds from New Zealand down into the frigid sub-Antarctic waters thousands of miles away, and back. Once the chicks fledged, however, they and the adults all headed north, crossing the equator to reach "winter" feeding grounds in the boreal summer off Japan, Alaska, or California. By following wind and ocean currents in looping curlicues across the Pacific, the birds (in the words of the researchers) enjoyed "an endless summer." It's a helluva road trip, since the routes taken by some shearwaters exceed 46,000 miles a year.

Finally, by 2007, geolocators had grown small enough that my Scottish friend Iain and several of his colleagues were able to attach them to the legs of Arctic terns in Greenland and Iceland. A year later, the returning birds were recaptured, and the story that unspooled from their stored data was astonishing.

The first surprise was that the terns took one of two dramatically different tracks south, regardless of their colony of origin. Some veered east to the northwestern bulge of Africa, then angled back across the narrowest part of the Atlantic to the coast of Brazil before continuing south to the Weddell Sea along the Antarctic Peninsula. In spring they migrated to the waters off southern Africa, then across the Atlantic again to northern South America, and finally on to the North Atlantic—a figure eight, inscribed on the planet by endlessly

beating wings. For some reason, other terns from the same colonies instead shadowed the coast of Africa almost to the Cape of Good Hope, then either crossed the Southern Ocean to the Antarctic coast, or followed the screaming gales of those high, storm-raked latitudes for thousands of miles farther east, south of the Indian Ocean.

In all, Iain and his colleagues found that even the least ambitious of their terns migrated at least 37,000 miles a year, though some traveled almost 51,000 miles a year—a new long-distance record, and more than twice what scientists had once assumed was possible for this species. And just to cap that, three years later researchers who had tagged Arctic terns in the Netherlands found that those birds were traveling up to *57,000* miles a year, reaching the waters off Australia and using staging areas in the Indian Ocean (where, it turns out, tagged terns from the coast of Maine also gather). Any seabird biologist will admit, especially after a beer or two, that no one really has a clue what the true limits of tern migration might be.

Many other assumptions about migration have been turned on their heads in recent years. It's the nature of the beast; ecology is an almost perversely complicated subject, and every layer of the onion that we peel back just reveals further complexities.

Twenty years ago, North American ornithologists who had assumed the biggest challenge for migratory songbirds lay in the loss of wintering habitat from tropical deforestation were coming to grips with a problem much closer to home. A growing body of research showed that forest fragmentation—the endless slicing of large, intact tracts of woodland into smaller and smaller scrubby shards, bisected by roads, utility corridors, developments, and fields—posed a serious danger to many of the most prized and lovely migrant songbirds, like tanagers and thrushes, which evolved to nest in unbroken woodland. Fragmentation, it turns out, brings a host of evils. They include so-called edge predators that thrive in disturbed habitats, creatures like raccoons, skunks, opossums, grackles, crows, jays, and rat snakes—all adept nest predators that are rare or absent from deep woods. Fragments also invite brown-headed cowbirds, grassland birds that

parasitize the nests of other songbirds (and which were originally restricted to the Great Plains). What's more, fragmentation dries out the very forest itself, reducing insect abundance and creating other environmental challenges for the nesting birds.

Scientists have tracked the nesting success of so-called forest-interior songbirds like wood thrushes, monitoring their nests to see which ones produce the most eggs, and how many eggs successfully grow into fledglings that fly off on their own to form the next generation. Decades of such study confirm that when big expanses of woodland are chopped into smaller fragments, nesting success drops in lockstep with the splintering of the forest.

So, to save the bird, save the forest. While preventing fragmentation is challenging in practice, it's a simple target to articulate and to aim for, and one that has guided important elements of bird conservation since the 1980s. But—and in ecology, there is usually a *but* lurking in the underbrush—more recent research has uncovered a real surprise. This one came when scientists took the next step. Instead of just monitoring breeding success in those safe, intact forests, they began the much more arduous task of tracking fledgling thrushes after they left the nest and scattered to the four winds. When they put tiny radio transmitters on those adolescent thrushes and followed them until they were ready to migrate, the researchers found that many of the juveniles abandon the mature, expansive woods where their parents nested—the intact forests we've come to assume were of singular importance to their survival, and whose preservation has been a major focus of migrant conservation.

For a month or more leading up to migration, when the young songbirds must rapidly gain weight so they can make the exhausting flights to Latin America or the Caribbean that lie ahead, the fledglings congregate instead in scrubby, brushy, early successional thickets—the kind of habitat created, say, after a clear-cut has begun to regenerate, a clear-cut that might otherwise be seen as destroying habitat for forest-interior birds.

It's not that these birds don't need contiguous forests—they do.

But that's not *all* they need. Time and again, science has underestimated the complexity of migratory ecology.

This isn't willful ignorance; studying small, active creatures whose annual migrations cover tens of thousands of miles is inherently, extraordinarily difficult. But in a lot of ways that are not uncommon in science, ornithology has always been a victim of blinkered vision and the path of least resistance. For the better part of two centuries, ornithologists were almost exclusively North American or European—and because it's easiest to study something close to where you live and work, for a long while we therefore knew mostly about the lives of migratory birds during the few months when they were on their temperate breeding grounds. In the 1970s and '80s that began to change, and the emerging research from the tropical wintering grounds upended many comfortable assumptions about migrant ecology. Once thought to be adaptable, go-along-to-get-along types that could fit into any vacant slot in the tropics, many migrants proved to be every bit as specialized as the resident birds with which they shared the landscape, tightly bound to specific, often narrow ecological niches. Even within the same species, scientists found, different age and sex classes often had dramatically different needs, and used very different regions or habitats—adult males preferring dense rain forest, for example, and juvenile females drier, scrubbier habitat.

This new understanding came as alarm bells were sounding over rampant tropical deforestation, which quickly came to be seen as the greatest threat to neotropical songbirds. Conversely, neotropical migrants like warblers and tanagers simultaneously became poster children for the campaigns of the 1980s and '90s to save the rain forest, the most direct (and emotionally resonant) link between a distant and threatened ecosystem and American backyards.

The loss of tropical habitat was and is very real, but it was hardly the only threat. There's the degradation of habitat on the temperate breeding grounds, and the loss of stopover sites that make long-distance travel possible. You can't divvy up the lives of wild creatures, especially those with the wind at their command, into seasonal slices

or geographically discrete segments. We may finally be looking at migratory birds the way they should be viewed—not as residents of any one place, but of the whole. These are creatures whose entire life cycles must be understood if we're to have a prayer of preserving them against the onslaught they face at every moment, and at every step, of their migratory journey.

We still have much to learn. For example, we still know almost nothing about the precise routes that most migratory birds take, and we have only the sketchiest notion of which sites along the way are critical for rest and refueling. We've belatedly realized—though it should have come as no shock—that regional breeding populations within the same species, even those within fairly close proximity to each other, often have dramatically different migratory paths and wintering areas. Most of the wood thrushes from New York and New England, for example, head to a narrow swath of eastern Honduras and northern Nicaragua for the winter, while those from the mid-Atlantic crowd into the jungles of the Yucatán Peninsula. Geolocators and banding records show that ovenbirds from the Philadelphia suburbs mostly migrate to the Caribbean, especially the island of Hispaniola, while those from just across the Alleghenies near Pittsburgh fly straight across the Gulf of Mexico to northern Central America.

That's of more than academic interest. Lose one part of the wintering range, or one critical way station in between, and you may lose an entire regional population. If you want to keep wood thrushes or ovenbirds—or any of hundreds of other species of migrants—healthy and abundant across their entire range, you may need to take a far more expansive, muscular approach to land protection than has been the case until now.

The first step is knowledge, and a new generation of researchers is doing the grueling, difficult field work that's necessary to tease out all the strands of a bird's full life cycle, stretching across 12 months of the year and often thousands of miles between distant corners of the world. It's a field known as migratory connectivity—in a sense, the maturation of a process that began more than 200 or more years

ago, when John James Audubon tied silver wire to the legs of phoebes on his Pennsylvania estate to learn if the same birds came back each year to nest. Fortunately, we have more sophisticated tools than Audubon's silver wire. Mapping migratory connectivity was why we risk grizzly bears in the Alaskan interior, to better understand *exactly* where the park's birds spend the winter. It's no longer enough to say that gray-cheeked thrushes go to "northern South America." As the world changes and warms, the hurdles migrants face grow rapidly steeper—and conservationists need this information if we're to shepherd the birds through what is already a rapidly narrowing bottleneck.

This has become a very personal crusade for me, as it has for many of the men and women who study and protect migratory birds; the idea of a world without epic migrations is simply too poor and melancholy to contemplate. As with many of them, migration has captivated me all my life—an obsession that began in childhood and crystallized on a windy ridgetop in Pennsylvania, and which has led me from being an eager observer to an increasingly passionate participant; from a recreational birder to someone in the trenches of migration science.

I did not grow up among birders, but my parents loved the outdoors and offered encouragement (though at times bemusedly so) to their slightly strange son. My mother in particular paid attention to the rhythms of the seasons, and bird migration was central to this. She jotted down in her garden journal when the first juncos and white-throated sparrows of the fall appeared at the feeders, and when the first spring migrants returned to our yard in the mountains of eastern Pennsylvania. We paid special heed to the autumn and spring passages of Canada geese, which in the 1960s and early '70s (before nonmigratory flocks overspread every suburban office campus, city lake, and farm pond in the East) were still an electrifying benchmark of the changing seasons.

Most years there would be a single morning—exactly when depended on the severity of the winter, but it usually fell in early March—when we would wake to the sound of geese. We'd bundle

into coats and unlaced boots, racing outside to the first truly mild morning of the year, craning our necks up at a sky layered with chevrons of geese plowing north against the bleached-denim sky. It was, and remains, one of the most thrilling moments of the natural year for me, and each winter as the days lengthened and the snow melted, we looked forward to "Big Goose Day" as the singular pivot in the seasonal round. And we still do; the phone will ring early, as the sun is just rising and my wife is having her first cup of coffee, and my mother will say, "Have you heard them? Have you been outside? It's Big Goose Day!" And out we go, bootlaces trailing, to soak up the show all over again. (Many years ago I wrote about our odd little family observance in a state wildlife magazine, and someone who read it asked one of my sisters—who is definitely not a birder—whether it could possibly be true. C'mon, he said, you guys didn't really celebrate this goose-day thing, did you? "Yes," Jill replied with an exasperated sigh, "but it's not like we baked a *cake* or anything.")

So in some ways I was primed to spend a life chasing migration, but the pivotal moment came when I was 12. On an October day of blustery wind and ragged clouds, we climbed to the top of the Kittatinny Ridge, the southern lip of the Appalachian ridge-and-valley system, an hour or so from our home—a highway for migrating raptors, which ride its updrafts as they coast down the long, sinuous mountain range on their journey south.

It was, by luck, exactly the right conditions for a big flight—a powerful cold front the night before had dragged strong, northwest winds across the state—and the skies over Hawk Mountain Sanctuary's North Lookout were peppered with sleek, predatory shapes. My family forgotten, I tucked myself in among the gray boulders, sheltering from the wind as best I could, eyes wide and excited. The silhouettes in the air looked nothing at all like the tiny drawings I had studied in my field guide. But it did not matter. Hundreds of raptors glided down the ridge that day, surfing the invisible waves of air, and I stared hungrily through my cheap binoculars, as each passing hawk dragged my eyes along with it.

Adults around me called out identifications and landmarks: "Sharpie on the slope of Five!" "Two redtails over left Hunter's Field." One hawk, plunging down at a plastic owl decoy (placed, for just such a purpose, on a limbless sapling jammed in the rocks near where I sat) looked for long, heart-pounding seconds as though it was going to fly right through my binoculars. The spectacle was easily the most intoxicating thing I had ever witnessed, and the memory remains almost painfully intense today.

I didn't have the words, at the time, to articulate why I was so moved, why I found the sight so spellbinding. The hawks and falcons were beautiful, of course, their passage majestic; it was enthralling to watch the way they would, with subtle corrections of their wings and tails, counterbalance the gusting wind and yoke its energy. But it wasn't until I got home that evening, and dragged out my bird books and an old *National Geographic* map, that another, even more powerful reaction manifested itself. Tracing my finger down the curving spine of the Appalachians, I thought for the first time about where those hawks had been coming from, and where they were going. I'd been fuzzy on the details before, but now I read that some of these birds—the very ones I'd seen—may have come from far-off places like Greenland and Labrador, and were heading to destinations like Mexico or Colombia or Patagonia that seemed impossibly exotic to a kid growing up on the edge of Pennsylvania coal country.

I slept very little that night, and my dreams were full of wings. Half a century on, I am still captivated by migration.

What has changed is my involvement. That electrifying day on Hawk Mountain cemented my passion for birding, and especially hawk-watching, but while I became a serious bird geek as a teenager, it was all in fun. Birding was a hobby. Then a college course in ornithology that I hadn't planned to take, snagging the last remaining opening in the class of a wise and generous professor teaching his final semester before retirement, fully opened my eyes for the first time to the fascinating *science* of birds.

Life turns on such flukes and happy accidents. As a young newspa-

per reporter, I pitched an assignment to my editor—Hawk Mountain had hired its first director of research, a newly minted PhD named Jim Bednarz, who was putting tiny radio transmitters on migrating hawks. The editor nibbled, and I wrangled an invitation to spend a day with Jim in the trapping blind, notebook poised. The first time a red-tailed hawk dropped from the sky on folded wings, talons flexed, hurtling down into our nets like the messenger of some pagan god, I knew with the same lightning-bolt clarity as when I was 12 that the ground had shifted under me again. Apprenticing with Jim, within a few years I had a federal banding permit; when he left the organization, I ran Hawk Mountain's banding program for a time before taking over one of the sites myself. Soon I was also banding songbirds, then owls, then hummingbirds, always driven by a curiosity that verged on mania about migration.

Without really meaning to, I slid further and further from observer to participant. While my day job was (and remains) writing about the natural world, field research has occupied an ever larger and increasingly satisfying part of my life, even though I lack an academic degree in science. Fortunately, ornithology has a long tradition of welcoming experienced amateurs like me into the fold.

When I wrote *Living on the Wind*, I was very much still an outsider looking in on the world of migration science and conservation, but in the years since then, I've become ever more deeply enmeshed in the research itself—not just interpreting the work of others, but adding my own small contributions. Perhaps if research were my workaday job, some of the shine would have worn off, but it's more fulfilling than ever. For example, for more than 20 years I've overseen what has grown into one of the largest studies anywhere into the movements of the northern saw-whet owl—a fetching little raptor about the size of a robin, round-headed and enchantingly wide-eyed. Over the years, with a crew of about 100 volunteers, we've banded more than 12,000 of these elfin birds in the mountains of Pennsylvania, and used a variety of technologies—geolocators, radio transmitters, forward-looking infrared, and marine radar, among others—to

track their wanderings. I also help coordinate a continental network of more than 125 owl-banding stations, all cooperating in the same kind of research.

Intrigued by evidence that western hummingbirds were evolving a new migration route to the East instead of Mexico, I spent several years learning to catch and safely band them, until I qualified as one of fewer than 200 licensed hummingbird banders in the world. Every autumn, now, I chase hardy vagrant hummingbirds, coming from Alaska or the Pacific Northwest, which show up in the mid-Atlantic and New England during the chill winds of autumn and which often linger through the snowstorms and subzero temperatures of January, confounding all of our expectations about how fragile we assume these tiny birds must be.

Those same winter winds bring snowy owls down from the Arctic, and a few years ago—when the East experienced the largest such invasion in close to a century—several colleagues and I started something we dubbed Project SNOWstorm. Working in biting cold and snow, we lay nets for the great raptors, then fit them with transmitters that log incredibly precise GPS locations every few minutes, sending us the data through the cell-phone network—a marriage of two cutting-edge technologies that allow us to track the owls' movements in stupefying, three-dimensional detail. With a few keystrokes, we can follow our tagged owls as they hunt waterfowl at night over the open Atlantic, cruise the farmland of Michigan or Ontario for rodents, or ride summer icebergs pushed by wind and tide on Hudson Bay. Some of those same colleagues and I have also installed more than 100 automated receiver stations across the Northeast that detect the signals from radio transmitters tiny enough to let us track the smallest bird—and even migratory insects like dragonflies and monarch butterflies.

The project that brought me to Denali—and our hair-raising encounter with the grizzly—was another such collaborative venture, one that had been hatched out of a chance meeting years earlier. Carol McIntyre has been studying the birdlife of Alaska's national

parks for 30 years, and she is widely known for her groundbreaking studies of golden eagles in Denali—a place near to my heart, and to which I've been returning almost annually for more than three decades. The plan we concocted, at a raptor conference in Minnesota a few years ago, was a little breathtaking (and maybe a little crazy) in its audacity. We decided to launch an open-ended research program to map the migratory connectivity of an ever-changing suite of Denali's birds, shifting with time among songbirds, raptors, shorebirds, inland-nesting seabirds, and other groups. As we're proving its success in Denali, we and our colleagues are beginning to expand the study to other parks, with an ultimate goal of encompassing much of the 54 million acres of Alaska's national park lands. When you're studying a global phenomenon like migration, it pays to think big.

For that same reason, this book takes the wide view as it explores the fascinating state of migration research and conservation today. Like the birds, it required a lot of miles, and more than a little stamina. With seabird experts, I sailed through the storm-wracked waters of the Bering Sea, and to the edge of the continental shelf off the Outer Banks, the better to understand one of the least-known frontiers of migration. I talked to white-coated scientists in high-tech labs—people working at the subatomic level to understand the mechanics of navigation—and with ornithologists who work on the dusty, dangerous southern fringe of the Sahara, keeping one eye on the birds they study, and another peeled for Islamic insurgents who would gladly kill or kidnap them. I dodged gunners and trappers in the Mediterranean, where a guerilla war to stop the illegal slaughter of millions of songbirds goes on largely out of sight, and I visited China, where rampant coastal development and a hunger for wild birds in the pot are causing a conservation catastrophe, but where unlooked-for hope still glimmers. And I traveled to one of the most remote parts of Asia, to a forgotten corner of India where former headhunters turned one of the grimmest stories of migratory crisis into an unprecedented conservation success.

Nor are the scientists and conservationists who people these pages

strangers; many of them have become my friends and colleagues over the years, part of the tight-knit global community working to know and save migration. Some have been mentors of mine, others collaborators, a few of them former protégés who have gone on to do remarkable work in their own right. It is a privilege to work with them, and to share the stories of their discoveries and insights.

And so, as I set out once again to follow the myriad threads of bird migration for this book, I found myself coming to the subject from a very different and, in many ways, much more intimate perspective than I had 20 years ago—not as an enthusiastic outsider, but as someone directly involved in the hard, exciting work of puzzling out how and why birds crisscross the planet, and how to make sure they always do.

Yet however much I may like to think otherwise, in truth I remain very much an outsider—as is every human who tries to penetrate the inner workings of this phenomenon. The best we can do is scratch at the margins of this majestic global pageant, to try to comprehend the sheer physicality of the migratory feats going on all around us, and to understand the natural systems on which they depend. The world is changing around us, in ways that we barely understand and show little ability to control, and birds—especially migratory birds—are our best and most compelling window into those changes. The news is often grim; by one measure, North America has lost fully a third of its birds, some three billion individuals, since the day I had that childhood epiphany on Hawk Mountain. That tells us, with frightening clarity, how very badly we've mangled our shared world. Birds are sentinels and bellwethers, the victims of our follies—but also, if we are heedful of their needs, guides to a more sustainable future for ourselves as well.

And they are everywhere, whether we know it or not. Last night, before I went to bed, I pulled up a Doppler radar image of the Northeast—not to look for rain, but for birds. On the computer screen, the whole region was occluded by immense blobs of pale blue and green, the radar signature of millions of songbirds aloft in the

clear night sky on their way south. Night after night, from the muggy depths of August to the frosty weeks before Thanksgiving, they stream south in numbers that would leave those of us over whose homes they fly mute with awe, if only we could see them.

On such nights (as I knew from work we had done a few years ago in Pennsylvania, using specialized radar) migrants may pass at a rate of a couple *million* an hour. It is arguably the world's greatest natural spectacle, and a nearly universal one, playing out twice a year over every landmass except Antarctica (where the migrant penguins shamble on foot), but one hidden from our sight by the anonymity of darkness. We sleep, unaware of the marvel above our heads.

This morning I slipped outside just after daybreak, careful not to wake Amy. The air was bracing; overnight, autumn had clearly taken command, and I pushed my hands deep into the warm pockets of my fleece. The trees and thickets were trembling with movement and the flickering of wings. Tired from a night of flight, the birds were snatching a few quick bites, then moving on, looking for a safe place to nap for a few hours. Catbirds, slender and sooty gray, gobbled the blue-black berries of a dogwood. A common yellowthroat—small, plump, its short tail cocked like a wren's—eyed me from a stalk of goldenrod that matched the color of its chin. Several red-eyed vireos moved methodically through the leafy branches of a crab apple, plucking cold-numbed insects from their hiding places.

In the dim shade of the pines, where night seemed to linger, I saw a cautious movement near the ground, and raised my binoculars. The wet-on-wet watercolor breast and umber plumage of a gray-cheeked thrush came into view. The bird eyed me suspiciously a few yards away and gave a quiet alarm call, but necessity drove it. Apparently deciding I was the lesser of evils, it turned its back to scuff in the needles, looking for its first meal after 12 hours of exhausting flight. Pale tips on the covert feathers of its wings told me this thrush was a juvenile, on its first migration. It was probably born in the spruce woods of Newfoundland or northern Labrador, a continent away from those we'd tagged in Alaska. But I was gripped by the same urgent desire

to know it as we would come to know those Denali thrushes—not as a here-and-gone distraction, one among a multitude of migrants on a busy morning, but as an individual, a singular creature with a singular and extraordinary life.

It was an utterly ordinary, *extra*ordinary bird—as is every migrant that makes the leap into the void, guided by instinct, shaped by millions of generations of toil and savage selection, crossing the vaults of space through dangers we cannot comprehend, by lucky chance and near-calamity and great endurance, on the strength of its own muscle and wings. For eons uncounted, that has always been enough. But no longer. Now their future, for good or ill, lies in our hands.