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Letter from the Editor

The term "to bear witness" underlies the theme of this issue of *Site/Lines*: "Transforming the Planet: Landscape as Habitat." As FLS chairman Frederic Rich points out below, we are challenged as never before to testify to, and prevent or remediate wherever possible, the damage being inflicted on an unparalleled number of the habitats that form our planetary home.

Living as we do in the era that many scientists characterize as the Anthropocene, the geological age in which human activity has become the dominant influence on climate and environment, our species, Homo sapiens, is the primary agent in the wanton extinction of countless other inhabitants of the biosphere. The quadrupling of the earth's population from 2.5 billion in 1950 to 9.8 billion in 2050 will exacerbate to an almost unimaginable degree the losses already sustained in the animal and vegetable kingdoms. The forecast of ongoing harm by reckless emissions of greenhouse gases in the atmosphere, alterations of the oceans' chemistry, and unbridled exploitation of Earth's natural resources should be cause for deep concern, not greed and denial.

In his essay "Revive and Restore: Healing the Landscape through De-extinction," Fred Rich argues that science, with its ability to edit DNA to reintroduce the key traits of an extinct plant or animal, implies a moral duty to use that power, at least in the case of species whose extinctions were caused by man. Dan Flores takes up the theme of re-wilding in his article, "Silence and Emptiness," in which he discusses a fifteen-year-old, $100 million-plus, privately funded project to create a Great Plains wildlife park. It would feature animals that once roamed the region, which he documented in his acclaimed 2016 book *An American Serengeti*.

But what about rampant and unwanted growth of animal populations in habitats that have shrunk to fractions of their original extents? Julia Buckles, who takes us on a wilderness trek in "Wisconsin's Disappearing Forest," describes white-tailed deer as "plant-eating machines" (each of these herbivores consumes seven pounds of vegetation daily). Today they are multiplying due to milder winters, hunters who have a selfish interest in their unchecked procreation, and land-management officials who ignore their depredations. The environmental scientists the author interviews maintain that what is needed for habitat stabilization is a rigorous scientific assessment of the damage taking place so that adequate protections can be created and instituted.

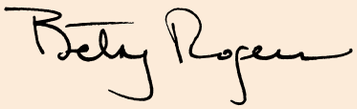
In "The Many Currents of the Mighty Hudson," biologist and environmental-research scientist John Waldman provides a case study of the radical transformation of the river's ecology in direct response to legislation – most notably the Clean Water Act of 1972 and subsequent strictures on dumping toxic industrial waste into waterways. This is a hopeful story that takes us from the mid-twentieth century annihilation of once-abundant species to the present-day, astonishing return of large sturgeon, striped bass, and bluefish; the successful seeding of oyster beds; and the post-pesticide-use presence of once-endangered Bald Eagles and Ospreys.

While this is cause for celebration, Roger Pasquier's "Interrupted Landscapes: The Future of Bird Migration" explains how, although all seems well on a beautiful spring day in the bird-teeming paradise known as Central Park's Ramble, the avian streams that ply the air currents of the Atlantic Flyway and other migratory corridors throughout the world are being compromised by shrinking forest acreage, sprawling suburbanization, destruction of breeding territories, and climate change.

In "Living the High Life: Green Rooftops as a Biodiverse Frontier," Annie Novak, herself a rooftop gardener in New York City, adds another dimension to the prescriptions of the writers mentioned above who seek to redress the balance of nature. She maintains that we are living in a world that is undergoing a second agricultural revolution at the same time that it is being transformed by information technology. As she shows, urbanites are finding that the tops of buildings are fertile fields for growing organic produce to feed local populations. But this is not all. There is a large biodiversity benefit as insect pollinators arrive, migratory birds refuel, and wildflower rarities without ground-level soil regenerate.

Thus in this issue of *Site/Lines* we are reminded that nature itself is a dynamic force. Despite the unintended – and, alas, often intended – consequences of human interventions, nature is our indispensable partner in reestablishing viable habitats for all life forms. Bearing witness can mean chronicling loss, observing transformation, or becoming the instruments of environmental recovery and ecological rehabilitation. The message here is that we must understand the dimensions of the current calamity in both scientific and spiritual terms and at the same serve as practical apostles in steering all life on our planet toward a more hopeful future.

With good green wishes,



Elizabeth Barlow Rogers
President

On the Cover:
More than 30 warbler species usually pass through Central Park during May and then, southbound, between August and October. The Canada Warbler (*Cardellina canadensis*) breeds in moist, mature northern woodlands and winters in Ecuador and Peru. Photograph by Will Pollard.

Chairman's Commentary

As this issue of *Site/Lines* goes to press, I cannot help but reflect on how the world has changed since last November, and the relevance of the Foundation for Landscape Studies to our current challenges.

We are reminded almost every day that we now live in a popular and political culture that is dominated by vanity, vulgarity, greed, deception, and intolerance. Many of us have been terrified to find that the ancient hatreds had not been expunged from the human heart but instead lurked all along under the cover of Pandora's Box, waiting to be unleashed again.

It is especially shocking that we now find ourselves having to defend the fundamentals: the ecology of our planet, which makes biological life possible; the arts and humanities, which make civilization possible; the very idea of objective truth, which makes science possible; and freedom of the press, which makes democracy possible.

Yet there is hope in this eternal truth: nature heals. Green places, noble places, empowering places – all can be an important part of the solution. Around the country, our parks are packed as never before with people from every class and region seeking the solace of nature and place. E. O. Wilson explains that the human brain evolved in a biocentric world, and science has demonstrated conclusively that nature is the indispensable predicate to both individual human happiness and a healthy society. A single tree can quicken recovery from disease. A patch of grass can unleash the imagination of a child. And a created landscape, whether a community garden or public park, can lift up the impoverished and marginalized and catapult a city to greatness.

The mission of the Foundation for Landscape Studies is "to foster an active understanding of the meaning of place in human life." When we understand the power of place, we act to make our natural and built places better and recoil at those who, indifferent to the future of the planet, would abandon the laws and norms that protect the precious habitats and landscapes that our authors explore in this issue.

With gratitude for your support of our commitment to this work,

Frederic C. Rich
Chairman

Transforming the Planet: Landscape as Habitat

Revive and Restore: Healing the Landscape through De-extinction

Extinction is no longer forever. This startling fact has the potential to up-end many of our conventional ideas about habitat, conservation, and the interaction between humans and the landscape.

The Pyrenean ibex (*Capra pyrenaica pyrenaica*), a type of wild mountain goat commonly known as a bucardo, once was a common sight in the French Pyrenees and northern Spain. By the late-nineteenth century hunting had reduced the species to fewer than one hundred individuals. The last one, a female known as Celia, died in January 2000. And so the Pyrenean ibex joined the estimated five billion species to have become extinct since life arose on this planet.

But in this case, three years later, on July 30, 2003, a team of French and Spanish scientists gathered around a pregnant domestic goat and delivered by cesarean section a live kid genetically identical to the extinct bucardo. For the next seven minutes (after which the animal died from respiratory failure), the Pyrenean ibex was extinct no more. It was not only a turning point in science but also a pivot point in the long history of life on earth, with profound consequences for the future of the planet.

Pyrenean ibex from the book *Wild Oxen, Sheep & Goats of all Lands, Living and Extinct*, by Richard Lydekker, 1898.

The extinct bucardo was returned to life through the well-established technology of cloning through nuclear transfer – the same technique used to clone Dolly the sheep in 1996. The DNA from a frozen cell taken from the bucardo before its extinction was substituted for the DNA in the eggs of regular domestic goats. Four hundred and thirty-nine embryos were created, 57 were implanted into female goats, seven pregnancies resulted, and one of those pregnancies resulted in a live birth.

Subsequent advances in genetics have produced an alternative de-extinction technology that does not require a live or frozen cell from the extinct species. Instead, all scientists need are remnants – such as pieces of bone – that contain fragments of DNA sufficient to allow geneticists to reconstruct, or "sequence," the complete genome of the extinct animal. Scientists currently believe that DNA fragments cannot survive intact for more than about one million years, so this technique won't work for species such as dinosaurs, which have been extinct for much longer than that. But it does work on animals that disappeared more recently – including most of the species whose extinction was largely the consequence of human action.

When geneticists complete the sequencing of an extinct animal, they don't have actual DNA, but only the "recipe": a long list of protein-coding (and other) genes, typically consisting of billions of complementary pairs of nucleobases. Adenine pairs with thymine, and cytosine with guanine: these are the A-T and C-G base pairs most of us remember from biology. Discovering the recipe for, say, a woolly mammoth or a Neanderthal is enough to solve many mysteries about evolution and the traits and capabilities of extinct species. When the Swedish evolutionary biologist Svante Pääbo sequenced the complete genome of humanity's closest extinct relative, *Homo neanderthalensis*, for example, he found the FOXP2 "language gene," finally convincing most paleontologists that our Neanderthal cousins possessed the power of speech.

But it was a long leap from having the "recipe" for an extinct species to having the capability to create a living organism that approximates the extinct one. Now scientists are poised to make that leap, thanks to a revolutionary gene-editing technique, CRISPR-Cas9, that allows us to "edit" DNA with a high degree of accuracy. CRISPR-Cas9 identifies

and excises certain sequences of DNA – a process often described as being similar to the "find and replace" function on a word processor. Developed in nature to enable bacteria to hunt and disable viral invaders, the function has turned out to be "programmable," so that scientists can instruct the protein to find and alter, or "edit," any specific DNA sequence.

The implications of this discovery for de-extinction are profound. In the absence of intact nuclear DNA to use for cloning, scientists can now use the "recipe" for an extinct species (having sequenced its genome from fragments) to identify the living animal or plant with the most similar genome and then use CRISPR-Cas9 to edit that DNA to approximate the genetic code of the extinct species. Think of the living animal's DNA as version 2.0 of a piece of software; the goal is to get back to version 1.0. You compare all of the millions of lines of code to spot the differences and then painstakingly edit each of the lines with differences to restore them to their original state.

Once the DNA has been edited to reintroduce the key traits of the extinct plant or animal, the subsequent process is similar to the cloning technology used on the bucardo. The edited DNA is inserted into the nucleus of a reproducing cell. The resulting individual may not be genetically identical to the extinct species, but the key traits that made the extinct species unique are reintroduced, and the resulting animal or plant has the potential to be the functional equivalent of its extinct relative. So, for example, the scientists working on the de-extinction of the woolly mammoth (which became extinct about four thousand years ago) are starting with the DNA of an Asian elephant, and then reintroducing the traits that made the woolly mammoth unique, such as the metabolism, subcutaneous fat, and shaggy coat that allowed it to survive in the sub-Arctic tundra.

But why do it? Most proponents of de-extinction make an ecological case: that the disappearance of keystone species, such as the woolly mammoth, profoundly disrupted large-scale ecological systems. The consequences of these disruptions have been devastating to humans and other life-forms, and restoration of the extinct species may be the most effective way to heal the damaged biotic system. For example, large herbivores such as the woolly mammoth played a critical role – through trampling, grazing, and fertilization – in the maintenance of the grassy cap that insulated the permafrost of the great northern tundra. When these large grazing beasts disappeared, the grassy cap declined and the grasslands transitioned to mossy taiga, which in turn allowed the thawing of permafrost and consequential release of massive volumes of previously trapped greenhouse gases, significantly accelerating global warming. George Church, a Harvard geneticist, argues, "There's twice as much carbon at risk in the tundra than in all the forests of the world put together."

Another de-extinction currently being attempted for purposes of ecological restoration is the passenger pigeon, once North America's most abundant bird species. In only a few decades, mass slaughter devastated the population. A species with billions of individuals as late as the 1870s, the passenger pigeon had been hunted into extinction by 1914, when the last individual, Martha, died in a Cincinnati zoo. The consequences of the rapid extinction of a keystone species at this scale are not precisely understood, but we know enough to expect them to be widespread and profound. The loss of the passenger pigeon caused disruption of the forest regeneration cycle and significant declines in forest health. It may have precipitated the proliferation of Lyme disease as well.[1]

The strategy of reversing the ecological impacts of these extinctions, sometimes known as "rewilding," first came to widespread public attention in 2013 at a conference sponsored by the National Geographic Society, TED, and a new nonprofit, Revive & Restore. The mission of Revive & Restore, which is a project of the Long Now Foundation (a group started by Stewart Brand, author of *The Whole Earth Catalog*), "is to enhance biodiversity through the genetic rescue of endangered and extinct species." The conference also drew attention to an effort called "Pleistocene Park," a remote part of Eastern Siberia, north of the Arctic Circle, which Russian scientists envision as a restored Mammoth Steppe – a place where the Siberian permafrost is again insulated by treeless grasslands extending to the horizon in all directions, and on which vast herds of wild horses, bison, and de-extincted mammoths graze in symbiotic partnership with the restored cold-weather savanna.

The signature project of Revive & Restore, led by the charismatic young scientist Ben Novak, is the de-extinction and repopulation of the passenger pigeon. For all such projects, the birth of an individual with relevant traits of the extinct species is only a first step. Rewilding and its ecological benefits require a population large and genetically diverse enough to be sustainable in nature. Currently Novak estimates that captive breeding will begin in 2022 and re-establishment of wild populations in 2032. It's a long haul, but the dream of vast flocks of passenger pigeons once again filling the skies over North America provides a powerful motivation to those doing this work.

One of the other justifications for pursuing de-extinction is a moral one: possession of the power to bring back lost species implies a moral duty to use that power – at least in the case of species whose extinctions were caused by human beings. In other words, we have a duty to right our prior wrong. It is notoriously difficult to estimate the number of species whose disappearance can be blamed primarily on human interference. But all scientists agree that humanity's greed, recklessness, and negligence have greatly accelerated the natural pace of extinction, harming both the planet and ourselves.

The woolly mammoth, as depicted in this diorama in the Royal BC Museum in Victoria, Canada.

[1] David Blockstein et al., "Lyme Disease and the Passenger Pigeon?" *Science* 279, no. 5358 (March 20, 1998):1831.

The enthusiasm of de-extinction's supporters is nearly matched by the skepticism of its detractors. Many of the issues are practical, such as doubts that human beings can create populations with sufficient numbers and genetic diversity to be sustainable in the wild; concerns that replication of the genome alone fails to provide the epigenetic and environmental drivers that made the species what it was (e.g., without same-species parents, the learned behaviors essential to survival may not be recovered); and arguments that the biome to which the extinct species adapted by evolution has moved on and thus plants and animals created based on ancient genomes will not be able to adapt and flourish in contemporary conditions. For example, the passenger pigeon, if revived, would face a world in which the American chestnut, which provided a major part of its habitat and food, has disappeared.

Conservation biologists are split on the matter. Some argue that belief in the possibility of de-extinction creates a moral hazard, opening the door for those benefiting economically from the destruction of habitat to argue that even if a species is lost, it can always be "brought back." Others simply say that in the current era of human-caused mass extinction, society should prioritize saving those endangered species that can be saved rather than dreaming of returning lost ones to life. For example, the same genetic editing tools used for de-extinction can be used to increase the genetic diversity of a surviving endangered population, which in turn greatly increases the odds of its survival. This, these conservationists argue, is where our resources and efforts should be focused.

Philosophers and ethicists raise a different set of concerns. Some accuse scientists engaged in de-extinction of "playing God" and/or filling the planet with "Franken-species" and "eco-zombies" – accusations that ignore the long human experience with selective breeding and, more recently, the enormous benefits and well-established safety of direct genetic modification in agriculture. Others more thoughtfully point out that de-extinction is a sort of hack of evolution, a substitution of human desires for the process of natural selection. As such, it is likely to be marked by unintended consequences, some of which could be difficult to reverse once the relevant genes have been let loose in a naturally reproducing population. And ethicists argue that surely we have some sort of responsibility to the sentient creatures that we create – at least the duty to ensure that they have a viable prospect of lives that are more than an experiment or zoo exhibit: that they have, for example, mates, an appropriate ecological niche, and some chance to flourish.

Students of landscape and the garden will find it easier, I believe, to understand and embrace the potential of de-extinction. Gardeners and landscape architects have a high degree of comfort with human intervention in nature, and we know that not all such intervention is exploitative or reckless. We have a long tradition of making interventions designed to improve, restore, and steward the natural world. Moreover, gardeners have long shaped life to their desires: virtually no agricultural or horticultural species has been unaffected by hybridization, and most of those altered plants are now valued citizens of the natural world. Wheat, grapefruit, peppermint, and the London plane tree all resulted from interspecies breeding (as did, on other branches of the tree of life, cattle, bison, African bees, and honeybees). Genetic editing is without a doubt a new and different *tool*, but the *result*, species created by man (rather than by the operation of natural selection) is not.

All landscape is habitat. But habitat is not some stable, passive stage on which the dance of life plays out. Instead, the relationship between an environment and the life it hosts is highly interactive. Species adapt to their habitat and then change it. From the moment *Homo sapiens* emerged during the Middle Paleolithic, we inserted ourselves into this dance by transforming habitats and the life-forms they supported. Today, population growth and technology mean that the scale of our impact is now global, and scientific progress means that we are better equipped to understand the consequences of our decisions.

By the act of conceiving the current geological era as the Anthropocene, where human activity is the dominant influence on the planet, we have started to come to grips with the fact that we are now the creator; no longer merely the created. Now, human morality must catch up to our technology. We must prohibit the exercise of our power in selfish, shortsighted, or reckless ways, and instead encourage the use of the powerful technologies at our disposal to mitigate our past wrongs and reestablish healthy and sustainable biotic communities.

Of course, caution is always indicated. Too often, however, timidity and hostility to progress disguise themselves as the prudent mitigation of risk. If the tools of synthetic biology allow us to replace keystone species in order to keep greenhouse gases in the tundra or to restore healthy ecosystems in our rain forests and coral reefs, then this is what we must do. We must remember that we cannot escape choice through inaction. Now that we have the technology for de-extinction, the failure to use it is also a choice for which we will be held accountable by future generations. – Frederic C. Rich

Silence and Emptiness

If you have ever looked out the window of a speeding automobile and seen the vast sweep of fawn-hued grasslands that lie in America's center – or, especially, if you have ever pulled to the side of the road and, standing in the grass, taken in that vastness under its overarching bowl of blue – you will understand why this is a country that unnerves modern travelers. In the twenty-first century this region, which we have for two centuries called the Great Plains, has become America's Empty Quarter. Try driving a road like U.S. 160 eastward, from the Rocky Mountains across the plains to Springfield, Colorado, not far from the Kansas border. Unless you count Pritchett, just west of Springfield, which has a population of fewer than one hundred, there are no towns or gas stations. You will rarely pass another car on the road. Pull over at the sign for the Comanche National Grasslands, once the site of homesteads but reacquired by the federal government during the Dust Bowl, and a vast silence assaults the senses. Except for the occasional solitary house, now abandoned and collapsing, the Great Plains seems empty.

Of course, it is not. There are cattle ranches and absentee landowners. But there are few clues today that once this was a region of immense national significance. Today rural areas of Kansas, Nebraska, the Dakotas, and Montana are gradually emptying out; only the Indian reservations on the Great Plains have growing populations. But in the heyday of the Old West, the Great Plains was the part of western America that was brimming with opportunity. The members of the Lewis and Clark expedition, for example, could not wait to escape the Pacific Coast and the Rockies for the fat and easy living this region afforded. Why? Because the untold millions of wild animals there made the Great Plains one of the natural marvels of the world. Then, in the century between 1820 and 1920, railroads, homesteaders, and ranchers, with an appalling lack of appreciation for its ecological diversity, effected an almost complete destruction of the wildlife of the plains.

Our drive across Colorado on Highway 160 was part of a trip my wife Sara and I were making from Santa Fe to visit an old friend named Nicole Rosemarino, whom I had gotten to know when she worked on endangered species for an environmental organization in New Mexico. Although she hails from upstate New York, Nicole earned her Ph.D. at the University of Colorado. Her partner, Jay Tutchton, is an environmental lawyer out of UCLA, but grew up in Denver. Now the two of them are focusing their conservation efforts on the Colorado

Herd of bison, Heartland Ranch, Colorado.

plains, where land seems to get cheaper by the day. Their South Plains Land Trust (SPLT), for which Nicole is director and Jay field manager, has spent several years on a novel project in Bent County, north of Springfield. Like us, Nicole and Jay are passionately interested in the animals that once inhabited these open spaces.

In a 2016 book of mine, *American Serengeti: The Last Big Animals of the Great Plains*, I wrote of the Great Plains world we Americans first encountered two centuries ago. Our version of the Serengeti featured both poetry and spectacle: thronging bison playing the role of African wildebeests, pronghorns assuming the role of antelopes and gazelles, wild stallion bands functioning ecologically much like bands of zebras, gray and red wolves filling the niche of wild dogs, and coyotes doing an almost exact impression of jackals. While Africa had retained its lions, elephants, hyenas, and cheetahs (we'd lost our versions of all those to the Pleistocene Extinctions ten thousand years ago), the historic American Serengeti had its own king of beasts, the grizzly, which played a lionlike role on the prairies.

The problem for modern conservationists was that, aside from the coyotes and a scattered population of pronghorns, we Americans wiped these charismatic animals off the face of our topography more than a hundred years ago, leaving the Great Plains a setting erased of the bestiary that evolved here. While Africa still has grand game reserves like Kruger National Park in South Africa, Serengeti National Park in Tanzania, and the Masai Mara National Reserve in Kenya, on the Great Plains Americans have no equivalents.

Our best hope for a re-wilded American Serengeti in twenty-first-century America is the American Prairie Reserve in central Montana, with which I've been involved for the past couple of years. This fifteen-year-old, $100 million-plus project is a private endeavor to create a Great Plains wildlife park featuring all the creatures that once roamed here – predators included – by buying ranches along the Missouri River as they come up for sale. These ranches would be managed in concert with an existing national monument and wildlife refuge, creating a re-wilded park twice the size of Yellowstone National Park. To me, this is the most exciting conservation idea in the modern American West. In Montana, at least, the American Serengeti would live again.

After two days with Nicole and Jay, Sara and I learn that versions of an American Serengeti are emerging elsewhere on the Great Plains as well. Heading north out of Springfield, bound for their Heartland Ranch, we drive for miles over dirt roads shaded sporadically by the spinning turbines of a wind farm – one of the ways in which the land is being used as the region's population dwindles. The population of the Great Plains, excluding only its largest cities, reached its high point in the 1920s – unlike virtually every other region of the United States. Drive dirt roads like these and the most common sight other than wind turbines is the faded dream of American settlement, represented by abandoned homes and driveways, and once-cultivated fields overgrown with exotic, invading plants. Away from those aborted attempts to domesticate this country, however, buffalo grass and blue grama still stretch away to surrealistic distances. It's a country that gives the impression of silent waiting, as if for the next stage in its historical arc.

Heartland Ranch sits at the top of an escarpment overlooking a sweep of country that is almost more than the eye and mind can digest. When we arrive at the ranch headquarters on a May afternoon, it is still early enough to get a tour of what Nicole and SPLT have in mind for this part of Colorado. The plan, similar to that of the American Prairie Reserve, involves acquiring ranches and removing most of the interior fences to make the countryside compatible with wildlife rather than cattle. As we bounce down off the overlook in

Nicole and Jay's pickup, they explain their idea to us. "Heartland is 11,000 acres, but it's adjoined by a 7,000-acre ranch we're about to acquire," Nicole says as she points out the adjacent parcel. "Then, out on our northern boundary, there's a 27,000-acre ranch we're hoping to add. So we'd be at 45,000 acres if we can make all this happen."

And make it happen to what end? The deliciously fenceless, or almost so, plains country stretching away from us in green swells (we've had a wonderfully wet spring in 2017) serves up the answer to that question soon enough. Out on the horizon half a mile away, the iconic shapes of America's most famous animal are coming into focus. In 2015 the Summerlee Foundation, a Dallas, Texas-based group, had contacted Nicole about taking on the animals from their Medicine Mounds Ranch, a West Texas property just outside the Panhandle that they were about to sell. (This adventure was turning into a Moebius loop of sorts for me; in the early 1990s I had accompanied Summerlee Foundation people to Medicine Mounds when they were preparing to acquire the ranch and release bison and equines on it.) Nicole, it turned out, had inherited the eighty-five bison and fifteen burros from Medicine Mounds, along with a non-breeding herd of fifty-two longhorn cattle. She and Jay were obviously a little more ambivalent about the cattle, but they had been part of the deal with the Summerlee Foundation.

I've witnessed scenes like these before – bison appearing to roam wild on unfettered plains in places like Theodore Roosevelt Park in North Dakota, the Wichita Mountains Wildlife Refuge in Oklahoma, and a couple of other places – but I never fail to get a thrill from it. Seeing a herd of burros returning the equine presence to the continent where horses and asses evolved, and where they had again been an integral feature of plains ecology from 1680 to 1930, was something to be savored as well. Even the longhorns, trailed through this country on cattle drives northward from Texas throughout the 1860s and 1870s, look appealing enough when you see them from a great distance, strung out across plains that appeared to have never possessed a fence line. The latter was of course an illusion, but it was a pretty one.

I like seeing this happen in our lifetimes. The uneasy historical truth is that, in U.S. hands, a 10,000-year-old American Serengeti was, only a century ago, the scene of a slaughterhouse. From the 1820s to the 1920s, this single American region experienced the largest wholesale destruction of animal life discoverable in modern history. In years of good rainfall, like this one, the Great Plains was once capable of harboring thirty million bison. Who knows how many of them we humans killed in a hunt that went on for decades, but by the 1880s only about a thousand remained.

But the market's insatiable appetite for wildlife wasn't just confined to bison – usually the only plains animal one hears discussed. Pronghorn antelope numbers had at one time rivaled those of bison; in 1820 they probably were fifteen million strong. We got their numbers down to a mere seven thousand before we decided we'd killed enough of them. Grizzly bears, with a continental population once in excess of a hundred thousand, had ranged across the plains from Texas and Kansas to the Dakotas. By the twentieth century they were down to a few hundred, scattered around the West, with none on the Plains. We had killed off bighorn sheep in the Great Plains badlands by 1906 and decimated the elk that had once ranged all across the Plains. The survivors of the bighorns and elk had been driven to the mountains like the grizzlies – although Nicole and Jay were excited that there are elk colonizing the Bent County plains around them now.

Then there are the wild horse and wolf stories. When the Pueblo Indians drove Spanish settlers out of the Southwest in 1680, some of the horse herds they liberated escaped into the same western landscape where the horses' ancestors had evolved. Within two centuries there were between two and three million of them running wild on the Great Plains. But by the 1920s, after herds had been rounded up, shot as competitors with cattle, or killed to use as predator baits, the last horses ended up sold to Europeans and sacrificed to their wars, or bound for the dog food plants that had sprung up in the Midwest.

As for gray wolves, for at least twenty thousand years – since they had followed big herds of grazers pushing across the Bering land bridge from Asia – somewhere between a quarter and a half million of them had been the dominant, keystone predators on the Great Plains. But bounties and wolf hunters with their strychnine baits took thousands, and by the 1920s salaried federal hunters trapped and poisoned the final few scattered Plains lobos. Wolves named Rags, Whitey, and Lefty were among the last gray wolves in Colorado. On the Montana Plains the last wolf was called Snowdrift; in the Dakotas it was the Custer Wolf, charged with livestock depredations a T-rex couldn't have pulled off. A final, pathetic story from the Colorado Plains, not far from where we are exploring SPLT's ranches, was of a famous female wolf named Three-Toes. With no male to create a pair-bond with, she was so desperate to find a mate on the now wolfless Great Plains that she mated with a collie ranch dog. Federal hunters killed her collie paramour, then all their hybrid pups, and finally Three-Toes herself in the early 1920s.

We had our reasons for doing all this, of course, along with our excuses and our bravado about how we were doing it for civilization. In much the same way that the Civil War seemed more palatable to subsequent generations if the South was said to have fought to preserve states' rights or a way of life rather than the ownership of slaves, we invented an explana-

Herd of longhorn cattle, Heartland Ranch, Colorado.

tion to salve the national conscience. Post-frontier Americans seemed to prefer a wildlife story that placed the blame for slaughter not on individual self-interest or capitalism, but on a secret conspiracy by the government to promote the destruction of wildlife as a way to control native peoples. It's a story that hasn't held up to historical scrutiny, but it did serve one purpose: it allowed Americans to avoid thinking too hard about what we'd allowed to happen to wildlife on the Great Plains.

Our last morning in Colorado broke in what I used to call, when I'd lived on the plains, a blanket-of-heaven kind of day. High pressure had built up overnight, clouds from the previous afternoon had entirely dispersed, and the air was so calm that, for hours, not a single rotor turned on the turbines of the nearby wind farm. I slipped out early to watch the sunrise sweep across the horizontal, yellow country. Pronghorns danced in the raking light, a golden eagle swung overhead, prairie dogs scurried and chirruped, and, more than a mile distant, I could see Heartland's bison grazing their way across a green swell. We were about to spend another day with Nicole and Jay, checking out a spring on the ranch and then driving deeper into the Colorado vastness to visit their properties – present and, perhaps, future. When Sara and I finally bid adieu and turned the car towards Santa Fe, we were shocked to discover that it was sixty miles via dirt roads to the nearest pavement!

Driving home by a different route that afternoon, across the agricultural Oklahoma Panhandle and then, once again, through intact High Plains grasslands in northeastern New Mexico, we passed within a few miles of one of early America's most important archeological sites. Just north of today's Capulin Volcano National Monument lies the first site ever discovered of the famous Folsom Culture, whose creators lived out their lives on these grasslands ten thousand years in the past. That's yet another irony of the Great Plains' peculiar burden of history. When humans first came to America, this was the place they sought out. In our time, we can't leave it fast enough. One hundred centuries ago, though, it was the Great Plains' marvelous wildlife riches that drew the Folsom people here. And that's the key insight that projects like the American Prairie Reserve and Southern Plains Land Trust seem to be taking to heart. – Dan Flores

Wisconsin's Disappearing Forest

One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well and does not want to be told otherwise. – Aldo Leopold, A Sand County Almanac

I'm standing in a northern Wisconsin forest with botanist Sarah Johnson, an associate professor of natural resources and biology at Northland College, where I work. She has been checking text messages from her student researchers, who are working on Outer Island – one of the twenty-two Apostle Islands on Lake Superior that are located roughly thirty miles from where we stand. The wind has picked up and the National Park Service boat may not be able to get to them tonight. "I tell them to pack extra clothes and food, just in case," she says.

Johnson is one of the hardest-working professors I know. She teaches September through May; then, in summer, she's out in the field. She and her students chiefly focus on the islands, conducting plant and field studies. Johnson is particularly interested in the effects of deer on the forest understory. The islands offer a unique view of a northern forest with little deer pressure.

Johnson is walking in the woods with me on a Friday afternoon in June for two reasons. First, because I asked her if she would show me the impacts of high-density "deer browse" on the landscape. Second, because further down this road is a thirty-acre, fenced "exclosure," built to keep deer out. County foresters want to see the difference between deer and no deer on a new forest. Johnson is interested in scouting the exclosure as a teaching tool for her students in the fall. Exclosures permit the scientific community to study the impacts of deer and to preserve plant species. They are also becoming a necessity among foresters and timber-industry professionals for tree regeneration.

White-tailed deer are plant-eating machines – and, in some places, there are more of them than ever due to milder winters, hunters that lobby for letting them multiply, and land-management policies that favor them. They consume seven pounds of vegetation daily – tree saplings, adult branches, shrubs, flowers, sedges, and anything else in their vicinity. Their impact is so severe that biologists use terms that could have been coined by Dr. Seuss to describe what they're seeing: "sandwich" trees (where deer have eaten out the tree's middle), "lollipop" trees (where deer leave only a rounded crown, pruning like bonsai masters), deer "candy" (the edibles deer prefer), and the "molar zone" – the region from Johnson's calf to just above her head that is in reach of munching deer.

Johnson has found that plant communities on sites with long-term deer pressure are becoming increasingly different from those on sites that have never had deer. Before European settlement, scientists estimate there were about eight deer per square mile in Wisconsin. Now there can be as many as seventy-two per square mile.

To the untrained eye – my eye – the forest Johnson and I are standing in seems fine. The trees are about thirty years old, and there is a mixture of birch, aspen, and conifers. The forest floor is carpeted in Pennsylvania sedge – an inviting grassy green perennial – and I can see for a distance through the trees. It feels neat and, well, parklike. Comfortable.

What's missing, Johnson tells me, is what the UW-Madison limnologist John Magnuson called the "invisible present." It refers to changes that happen so slowly that most of us don't notice what is changing and therefore don't recognize what's missing. In this case, a lot is missing: bush cherries, sumac, blackberries, saplings, bluebead lily, and Canada yew – basically, the preferred plant species that live within the "molar zone."

This is a forest of the invisible present – mostly trees and Pennsylvania sedge, a species that tolerates grazing by deer by regrowing from buried meristems, just as mowed grass in a lawn does. Forests are essentially a four-layer cake of ground flora, shrubs and saplings, subcanopy (younger trees), and canopy. And yet in this random but fairly typical northern forest, we're missing diversity in the ground flora, shrubs, saplings, and subcanopy – three of the four layers.

Johnson tells me that the changes in the landscape are not only due to plants gone missing but also to invasive species, like garlic mustard, filling in the gaps while plants that belong get smaller. Johnson provided testimony in 2009 at a Wisconsin state legislative hearing regarding placing a moratorium on the Wisconsin Department of Natural Resources' "earn-a-buck" program – one of the most immediate and

Exclosures allow the scientific community to study the impacts of deer and to preserve plants.

useful methods for controlling deer populations, according to Johnson. This program, which many state botanists and foresters supported, required that hunters shoot a doe before shooting a buck to keep the deer population in check.

In giving testimony, Johnson listed trillium – a popular and showy white-to-pink flower that appears in the Wisconsin woods in early summer – as one of the impacted understory species. She said a hunter testified after her, stating that he had lots of trillium in his woods. "I have trillium in my woods too," Johnson said. "The difference is in the size." Trillium has become smaller as deer prune out the biggest and most obvious plants.

The earn-a-buck program was unpopular with a vocal and politicized segment of Wisconsin hunters, who argued they did not want to shoot anterless deer and potentially pass up trophy kills. And in 2011, Governor Scott Walker signed a law repealing the earn-a-buck, thereby barring the Department of Natural Resources from using their most effective management tool.

Don Waller – a plant ecologist, professor at UW-Madison, and expert on high-density deer damage to forest ecosystems – says that the forests are at a crossroads, facing deer destruction and other threats, such as invasive species and overlogging. Now more than ever, the scientific community needs to monitor and manage forests with care. "We have the tools and the capability," he says. "Instead, politicians are cutting science while increasing logging and eliminating protection of wolves that act – at least, locally – to reduce browsing impact."

The twentieth-century conservationist Aldo Leopold – a wildlife biologist and professor at UW-Madison who wrote *A Sand County Almanac* – was the first to observe that we can change landscapes to favor certain species and that species can, in turn, affect the land. He noticed that deer and grouse, for instance, prefer open, younger forests to old growth. In the early twentieth century, when Leopold observed this, deer were nearly gone from Wisconsin.

By the 1940s Leopold had traveled to Europe and walked in German forests devoid of diversity. In Wisconsin, where deer had rebounded, Leopold began to warn of overabundance and the impact that high deer density could have on the landscape. In one of his most famous essays, "Thinking Like a Mountain," he describes shooting at a pack of wolves in the days when that's what young men did and then watching an old wolf fade, the "fierce green fire dying in her eyes." In his final paragraphs, Leopold warns of an ecosystem out of balance:

> *Since then I have lived to see state after state extirpate its wolves. I have watched the face of many a newly wolfless mountain, and seen the south-facing slopes wrinkle with a maze of new deer trails. I have seen every edible bush and seedling browsed, first to anaemic desuetude, and then to death. I have seen every edible tree defoliated to the height of a saddlehorn. Such a mountain looks as if someone had given God a new pruning shears, and forbidden Him all other exercise. In the end the starved bones of the hoped-for deer herd, dead of its own too-much, bleach with the bones of the dead sage, or molder under the high-lined junipers.*
>
> *I now suspect that just as a deer herd lives in mortal fear of its wolves, so does a mountain live in mortal fear of its deer. And perhaps with better cause, for while a buck pulled down by wolves can be replaced in two or three years, a range pulled down by too many deer may fail of replacement in as many decades.*

Leopold died in 1948. Although *Sand County Almanac* remains a classic, in the decades following his death, his home state of Wisconsin has largely forgotten the lessons he imparted. This seemed odd to Waller, who only became aware of deer impacts in the 1980s, when his colleague and student Bill Alverson alerted him to the fact that deer threatened several plant species, including some of the state's rarest plants. They were both startled to learn that no one was researching or monitoring these impacts. "I did not plan to pursue this so much," Waller admits. "But I kept expecting someone else to do more about deer impacts, and no one was."

Waller's group started to document the deer impacts in Wisconsin's forests and found them to be surprising in both their number and variety. By the 1990s deer densities started to match, then exceed, the high densities of the 1940s that had so alarmed Leopold – and they have not slowed. The group has published more than a dozen articles documenting in detail the impacts deer are having – on seedlings of eastern hemlock and northern white cedar; on the size, flowering, and fruiting of understory herbs; and on plant diversity over the past half century.

Their latest study drew on the careful baseline studies of the Wisconsin plant ecologist John Curtis, who surveyed the vegetation of Wisconsin with his students in the 1950s. It was telling that three state parks in northern Wisconsin had lost

the most diversity – more than half of their original species: all these parks had also prohibited deer hunting for decades.

Waller and his team identified species that have increased or decreased over the past fifty years, creating a winners-and-losers list. Winners included grasses, sedges, invasive exotics, and several tough or toxic species that resist or tolerate deer herbivory. The big losers included pretty wildflowers like trillium, bluebead lily, and rosy twisted stalk, all of which have declined by more than 50 percent. "These changes parallel many differences we see between in and outside the fences of exclosures," Waller notes.

Waller and Johnson continue to research how deer affect plant communities in the Apostle Islands and elsewhere, treating unrestricted areas as natural experiments that complement the exclosures they have built. They are also busy trying to design and test simple methods to measure deer impacts. "We want to find a method that is easy, cheap, and quick to apply," Waller says. "The method could then be shared with foresters, wildlife biologists, and citizen scientists to build a network for monitoring deer impacts over space and time."

Once such a standardized method is applied widely, it provides forestland owners and the Department of Natural Resources with a tool they can use to manage deer. Waller points out that the practice of relying on imprecise estimates of deer density has been contentious with hunters while also failing to identify thresholds where deer impacts become unsustainable. He adds: "I predict continuing conflicts and forest degradation until we can figure out how to use our science and concern to reform forest and wildlife management. This was Leopold's vision."

Jim Meeker, a former botany professor at Northland College, studied with Waller and taught Johnson when she was an undergraduate; he subsequently worked in collaboration with her when she returned as a professor. Meeker, now deceased, moved from Madison to northern Wisconsin in 1990 and built a house there with his wife, the biologist Joan Elias.

When Meeker moved north, Canada yew, a low-growing evergreen shrub with bowl-shaped red arils, was in decline. According to early reports, the shrub was historically a dominant understory plant in many northern forests across the Great Lakes region. Meeker got to work almost immediately installing a dozen fenced squares in patches of Canada yew.

A week after my trek with Johnson, Elias and I go for a hike to look at the exclosures and get a visual read on the ecosystems in and outside them. She and Meeker built trails through their mixed-age northern forest of birch, hemlock, cedar, oak, and maple. As Elias and I walk past the exclosures protecting Canada yew and other deer favorites like bluebead lily, we talk about the botanists who have built upon the work of their predecessors – Aldo Leopold, John Curtis, Don Waller, Jim Meeker, Sarah Johnson, and others. "They have a sense of the long term and see the value in each other's work," she says.

We walk off the trail to the first fenced-in area. A Canada yew, which looks like Christmas wreath material, grows in an eight-foot-by-eight-foot square inside the fencing – the smallness of the fenced square is so that deer are not tempted to jump inside, Elias tells me. Outside of the exclosure, there is no longer any sign of Canada yew. Anywhere. It is night and day. Even this untrained eye gets it. Very little Canada yew persists at all in northern forests, except as a small, scattered shrub primarily present along ravine faces or around rock outcrops.

Johnson and her students have been documenting the presence of Canada yew in the Apostle Islands, comparing it to baseline data collected in the 1990s. Her surveys show a dramatic decline on islands that have recently had deer. "In short, deer and Canada yew are not compatible," she says. Not only is there a fast rate of decline but the plant does not return even when deer are out of the picture. For example, Rocky Island had deer in the 1940s, but even though the herd declined, the Canada yew that once flourished there had not returned by the 1990s and still hasn't today. In contrast, she has seen Canada yew as tall as she is on North Twin Island, where there is no deer activity. "There's a lot of factors that go into the differences – but we know Canada yew does best where you have old-growth features of a moist, shady forest with small light gaps and few deer."

A favorite delight of deer, Canada yew has nearly disappeared from the forests.

As Elias points to features in her forest (new discoveries, trees fallen, vanishing groundcover), she tells me about the one-two punching going on in the woods – deer being the first punch and nonnative earthworms the second. The worms eat the leafy duff layer, which means seedlings have a harder time taking hold. She also shows me the damage from flooding last year. I tell her about how I learned that the timber industry is starting to adapt by erecting large-scale exclosures to grow high-end timber. Elias explains that birds are also big losers in this story. Without the forest structure – the ground flora and the shrubs – they have no nesting habitat.

It occurs to me later that I am walking through a museum, filled with relics of the past, and I wonder about the future of the northern forest. I later ask Johnson her thoughts on this. She says she suspects that future generations will wonder why we didn't do more to stop the spread of deer impacts – chronic wasting disease, tick-borne illnesses, and decimation of understory plants. But she's hopeful they'll look back and be thankful for the land that has been protected and the plants that remain.

"When I take my students into the woods," she says, "we focus on what's here now, we look for evidence of legacies of past land use, and I push students to look for clues to consider the trajectory of change and the future of the forest." To the trained eye, she explains, the decisions of those who have come before are still legible, and our actions – or inactions – will be interpreted and judged as well: "Future generations of conservationists will be building narratives around our influence on these forests."

– Julie Buckles

The Many Currents of the Mighty Hudson

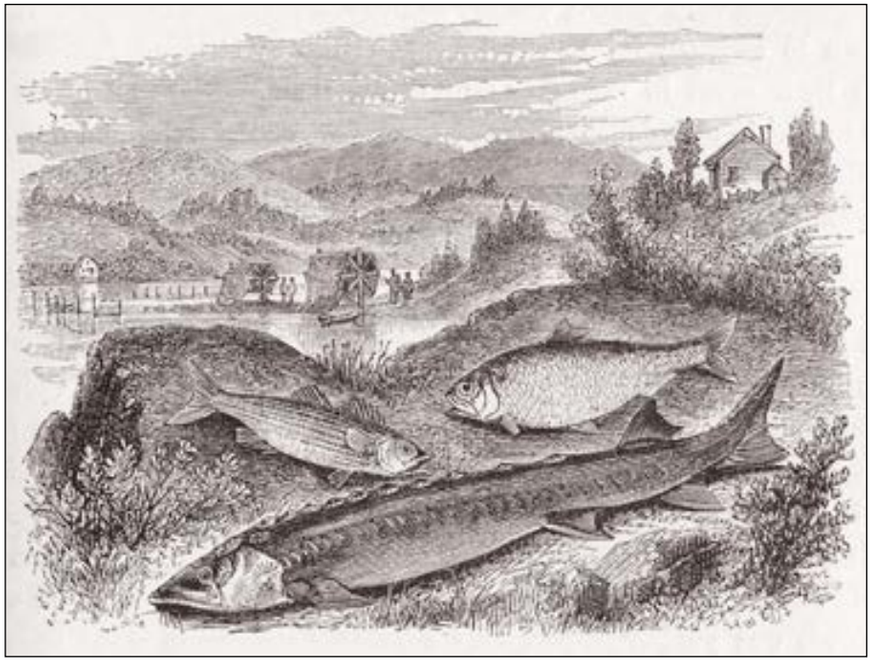
Roughly a million commuters travel to Manhattan every day through a tunnel from New Jersey, Brooklyn, or Queens. But very few of them – as they read the newspapers, check their cell phones, or chat with a friend – consider that they are passing under the Hudson or East rivers and that not far above their heads flounder, striped bass, bluefish, crabs, and a host of other creatures are swimming, walking, or crawling through the harbor's murky waters. Stranger still to contemplate, there might even be a ferry boat at the top of these strata, carrying people reading newspapers, checking their cell phones, or chatting with friends.

Unfortunately, even when we are *under* New York Harbor, we often forget about it. The harbor and the great river that feeds it are so integral to city life, so marvelous in their panoply of life forms, so rich in social and environmental history that it is hard to believe how overlooked, forgotten, and disregarded they are.

Every body of water has not only a unique natural ecology but also an unnatural human history. In the case of the waters that bathe American metropolises, that history often follows some sort of arc. At one end of the curve is the primordial baseline: the barely disturbed, precontact watershed. Low numbers of Native Americans inhabited the Hudson Valley for millennia, but it was Henry Hudson's visit in 1609 that inaugurated rapid and profound changes. By this point, the Old World – although quite similar to the Northeast in climate and biota – had been overfished, overhunted, and overlogged for centuries, and so European arrivals had never experienced such organismic abundance. They took note.

There are a number of accounts describing what early colonists found upon their arrival; I am partial to the detailed journal kept in 1679 and 1680 by the Dutchman Jasper Danckaerts. Of New York Harbor, Danckaerts wrote, "It is not possible to describe how this bay swarms with fish, both large and small, whale, tunnies, and porpoises, whole schools of innumerable other fish, which the eagles and other birds of prey swiftly seize in their talons when the fish come to the surface."

Such riches of the estuary helped feed the early settlers – and feed them well. An estimated 350 square miles of oyster beds were ready for the plucking. Even as late as the mid-nineteenth century, oysters were made into soups, patties, and puddings, and eaten for breakfast, lunch, and dinner. In 1851, a traveler remarked, "Everyone here eats oysters all day long." Fish also abounded. Each year untold numbers of migratory fish were birthed in the Hudson and reared in the estuary's fertile waters, before they headed out to sea. Then



Hudson River fishing station at Hyde Park, New York, and the three main migratory fish species sought there. Lithograph by Benson J. Lossing, 1866.

predictably, reliably – even wonderfully – they returned as fat striped bass, sturgeon, and shad to waiting nets each spring. Indeed, for decades, community "shad bakes" celebrated the promise of the equinox. And in summer multitudinous blue-claw crabs swam and clambered from the ocean to fill fishermen's traps, and would later be sold at docks up and down the river.

Generous provisioning from the Hudson could have been sustained indefinitely, but waste from a growing human population and the toxic by-products of the Industrial Revolution crippled its ecology. The historical arc bent sharply – few rivers anywhere have been so badly mistreated.

With migrants pouring in from Italy, Ireland, Germany, and elsewhere, Manhattan alone went from about one hundred thousand residents in 1800 to two million in 1900. And at the turn of the century, none of the voluminous human waste from those masses and from the inhabitants of the other boroughs and New Jersey was treated. Instead fecal material entered the waters in raw form, where it accumulated in layers as thick as ten feet. As the wastes decomposed, they sucked oxygen from the waters, described by Joseph Mitchell in *The Bottom of the Harbor* as a process "in which the rising and breaking of sludge bubbles makes the water seethe and spit." During the warmer months, when oxygen levels were at their lowest, fish made themselves scarce. Oysters didn't have a chance.

At the same time, industry dumped a litany of chemicals into the estuary, legally or not, under the prevailing view that the answer to "pollution was dilution." Petroleum was handled so carelessly that portions of the harbor's surface caught fire – a full century before a similar conflagration, in Ohio's Cuyahoga River in 1969, helped precipitate the Clean Water Act.

Dead-end creeks that flushed poorly became especially fetid – most famously, Brooklyn's Gowanus Canal. Indeed, the canal's filth became legendary, engendering both a morbid curiosity and lasting mythology in which the line between fact and hyperbole is difficult to draw. Dye works brightened its waters with the colors of each day's production – hence one of its nicknames: Lavender Lake. Sea captains were said to dock their ships there so that the poisonous waters would kill barnacles growing on their ship's hulls. The Mafia was claimed to routinely sink bodies and murder weapons in the canal – because who would be willing to look for them? The canal's offensive odor was infamous; hence another nickname, this one sardonic: Perfume Creek. Yet there was confusion then, as now, about the state of the city's waters – mothers were said to carry their asthmatic children to the canal's bridges to have them inhale its health-giving vapors.

The federal Clean Water Act of 1972 delivered both more stringent standards and funding to help meet them; this led to miracles in the nation's urbanized waterways, the Hudson included. Although regular, quantitative water-quality measurements revealed rapid improvements, it was the more easily-interpreted response by nature that enthused natural-resource managers and the public. Fish rebounded in the once-oxygen-poor waterways in the vicinity of the harbor, such as the Hackensack River and the Arthur Kill. But more evident to observers was the return of long-legged wading birds after an absence of nearly a century. These "harbor herons," a catch-all phrase for nearly ten species of herons,

egrets, and glossy ibis, almost magically recolonized New York City's archipelago of human-abandoned wild islands. On Shooters, Prall's, Hoffman, Swinburne, and North Brother, these iconic figures could once again be seen stalking fish in the shallows.

Meanwhile, other threats to the Hudson remained. A proposal to build a pumped-storage hydroelectric facility next to the river would have involved blasting a reservoir out of the bedrock dome of Storm King, a locally revered mountain in the Hudson Highlands. Residents of communities along the Hudson were also concerned about the ecological effects of water withdrawals from the river by nuclear and fossil-fuel electric generating stations that used the liquid as a coolant. These battles led to a citizen's revolt against a heavy-handed government-corporate partnership. Lengthy and heated legal and public-relations battles ensued. In the end the new facility project was canceled, the power plants were managed in ways that lessened their ecological harm, and – perhaps most importantly – the public learned that it had both the power and the right to resist egregious environmental insults. Moreover, the green community had become well organized and battle tested: now the Hudson Valley boasted some of the fiercest and most effective nongovernmental organizations in the world. From that passionate beginning, many education programs have sprung – most famously, the realization of Pete Seeger's vision of a sloop for learning about the river, appropriately named the Clearwater.

The increasing health of the Hudson and the growth of the environmental movement as a whole have changed the very direction from which we view and regulate the use of its waters. In the era when industrial contaminants and untreated sewage were being dumped with impunity, we set a ceiling on the river's ecological functioning by using it as a convenient depository for harmful wastes. Today, the hard-earned lessons of history have led us to set a floor: we have minimum standards for oxygen levels and contaminants; we monitor the waters; and we are ready to repel any backsliding.

However, a major setback occurred with the discovery in 1974 of polychlorinated biphenyls or PCBs in Hudson River fish. Though PCBs have become ubiquitous worldwide – being found even in polar bears – the Hudson was one place where PCBs were used in manufacturing, with General Electric dumping an estimated 1.3 million pounds of PCBs into its waters between 1947 and 1977. Fisheries that had existed for centuries had to shut down because of PCB contamination. Just when the river seemed to be recovering in so many ways, suddenly the public lost the right to enjoy provisioning from it freely. Even the recent remedial dredging of PCB hot spots by GE has not provided a sufficient remedy – one should still eat few or no fish from a river that is brimming with them.

Electrofishing for American eels in the heavily dammed Bronx River, a tributary to the Hudson Estuary, to assess the effects of the barriers on the fish's upriver migrations.

The Hudson Estuary has had a sweeping and inconstant history, which has left conflicting perceptions of it scattered along its arc, like images with different depths of field. Some optimists persisted in seeing flourishing life in the estuary even when most people had written it off entirely. Even at its most polluted, the Hudson had its aficionados, people I refer to affectionately as river rats. These enthusiasts couldn't spend enough time exploring the waters and were unafraid of getting a little oil or sewage on their hands. In a landmark 1969 volume, *The Hudson: A Natural and Unnatural History*, Robert H. Boyle – perhaps the Chief Hudson River Rat – wrote, "As of now, the biological productivity of the lower Hudson is staggering. Fishes are there by the millions . . . . All told, the populations of fishes utilizing the lower Hudson . . . comprise the greatest single wildlife resource in New York State."

Conversely, as the river began to recover in the ensuing decades, other New Yorkers remained completely oblivious of the changes. In the 1990s I was collecting fish via angling for a study of contaminants. One day, as I fished from a boat along the seawall of the East River, an obviously well-educated woman above me exclaimed, "You mean there are fish in this water?" – as if this great estuary could have become a biological desert.

Societal perceptions of the Hudson Estuary continue to evolve, but bulletins on the river's health are ever shifting and often confusing. The recovery of New York Harbor is being widely celebrated, but it is still almost impossible to get down to the water and actually wet your hand in it anywhere in Manhattan. Angling in New York City is being encouraged with the building of fishing piers, even though the Hudson's fish are still largely contaminated with PCBs. Health advi-

sories on consuming fish vary according to whether the fish was caught on the New York or New Jersey side of the river, even though it is the same fish and the same river. Oysters are being cultured and planted by students for ecological purposes in the Billion Oysters Project, yet some resource managers resist the resurrection of this fundamental component of the native biota because they are afraid of someone eating them and becoming ill. The Hudson has been colonized by numerous invasive species, including the ecosystem-changing zebra mussel, yet the government does nothing to neutralize the most dangerous avenue for creatures that don't belong: the Erie Canal. Swimming is permitted in some locations, but not if it has rained recently. And yet, despite these and other myriad conflicts and conundrums that complicate the development of a shared, strong identity, citizens of the New York City region were slowly readopting their river at the start of the twenty-first century – viewing it as a natural treasure and benign source of satisfaction.

Suddenly, though, attitudes toward the harbor shifted dramatically. On October 29, 2012, Hurricane Sandy came ashore at Atlantic City, New Jersey. Winds as powerful as ninety miles per hour blew relentlessly into the apex of the New York Bight. Waters riding on top of an already high lunar tide were pushed inland. Theoretically the New York City region was ready for the storm; it had been preparing for it for days. But the reality was far worse than people had expected. The southern tip of Manhattan was covered by fourteen feet of water. Fifty-three people in New York were killed. The hurricane caused $19 billion in economic damages.

Hurricane Sandy also damaged our collective psyche. The harbor's normally placid waters were now threatening. Sea-level rise was suddenly real; this single but harrowing episode of flooding that may or may not have been connected with climate change proved to be far more convincing to many people than a vast body of scientific evidence that the atmosphere, and hence the seas, were being dangerously affected by global warming. A disaster like this could happen again, and damages and deaths would probably be worse, as rising sea levels will enable smaller storms to have the impact of larger ones. In the aftermath of Sandy, the popular term "sustainability" was supplanted by new buzzword, "resilience." Even though "resilience" might fit semantically within a sustainability framework, the switch was as much psychological as strategic. Sustainability is a noble, optimistic goal: "Things are working, we like it as it is, let's keep it going." Resilience is pragmatically pessimistic: "We know we're going to get hit and knocked down. We need to make sure we can get up again."

Five years after Sandy, we are still grasping for solutions to prevent similar losses from future mega-storms. In the interim there has been some reasonable managed retreat and fortification of vulnerable infrastructure around the harbor, but two of the leading proposed solutions provide a striking dichotomy. One is a giant seawall stretching for miles across the Lower Bay that would permanently alter the water currents in the harbor, even if it were only closed completely when a threatening storm approached. Both the ecological and financial ramifications of such a fortification would be profound and potentially harmful. The other proposal is to coat low concrete barriers with oysters to slow down the incoming waves – an aquatic version of the speed bump – a strategy that reveals an almost delusional faith in a little bivalve to save us. So these are our choices: a wall, miles long and tens of feet tall, or a few inches of shell. Clearly we are now afraid of our harbor, and we don't know what to do about it.

Nonetheless, despite society's machinations, nature keeps pushing at the boundaries of the city. Shortly after the artificial circulatory system of the Gowanus Canal was restored in 1999, fish returned to its waters. And even more remarkably, seals were soon seen in it – right in the heart of Brooklyn. It also is instructive to revisit Danckaerts. Those porpoises? Back again. Eagles and other birds of prey? Ospreys and cormorants abound; bald eagles are nesting on Staten Island and have been seen from the Battery. A bay swarming with fish, both large and small? Large sturgeon, striped bass, and bluefish routinely glide through its depths.

And small fish? In 2015, for reasons unknown, there was a biblical production of young menhaden in the New York region, including in the Hudson. Menhaden, which feed on plankton, have been described as the "most important fish in the sea"; an oily, herringlike fish, they travel in dense schools and are pursued by all kinds of game fish. So many menhaden hatched that year that humpback whales were regularly seen filter feeding on them in the New York Bight.

In November 2016 boat captains, riverside strollers, and office workers in Midtown skyscrapers caught sight of one of these behemoths in the Hudson off Manhattan – likely preying on menhaden migrating down the river to the sea – just *one mile west* of Times Square. Most New Yorkers, however, were unaware of this miracle in their midst – just like the train riders under the Hudson that day, oblivious to the whale swimming over their heads. – John Waldman

Interrupted Landscapes: The Future of Bird Migration

Early on a May morning in the Ramble in the heart of Central Park, you might think yourself in a far more remote and wild landscape. New spring foliage obscures the buildings on the park's periphery, the sound of running water masks the city's noise, and the calls of the park's resident birds – the piping of the Tufted Titmouse, the ventriloquial French horn of the Blue Jay, the Northern Cardinal's husky "cheer-cheer-cheer" – add to the wood's music. If you have come to the park at that hour, however, chances are your focus is on the birds that are passing briefly through New York City on their way to more extensive woodlands and forests. They bear the colors we associate with their tropical winter haunts – orange on the Baltimore Oriole, brilliant red and black on the Scarlet Tanager, every shade of yellow arranged in bold patterns with blacks and greens on the many warblers. They, too, are singing – fluty notes from the oriole, a hoarse warble from the tanager, and a mix of high, thin, and buzzy tones from the various warblers. The arrival of these birds in Central Park following a night's flight with southwest winds is the high point of the spring migration – a migration that actually begins in February for other, hardier species and tapers off rapidly by early June.

Every spring I teach a class for some New York City fifth graders about bird migration. I start by asking them if they know anyone who goes to Florida for the winter and returns in the spring. Many hands go up. I ask if they know anyone who lives in New York and goes someplace else in the summer. Still more hands go up. From there it is an easy bridge to birds, although I do not point out a key difference – that the human migrants are those who can afford to move for the season, whereas the bird migrants are those that cannot afford to stay put. That information can wait until the kids are older.

The birds moving north that are the highlight of the May mornings also return through the park in autumn. They leave our latitudes each fall because they depend on food sources that vanish with the change to colder weather, just as the birds that join us for the winter have left places where that season is longer and colder than ours, with even fewer hours of light in which to find sustenance. These seasonal shifts animate the landscape, and – for those of us who remain in one place – link us with the entire Western Hemisphere. Over

Northern Cardinals (*Cardinalis cardinalis*), once unique to the South, began spreading northward in the 1940s as mostly forested landscape became more suburbanized, thereby approximating their natural habitat. They are now permanent residents as far north as southern Canada. Photograph by Dave Alter.

the course of a year, we see birds from the Arctic tundra, birds that spend months in the Amazon rain forest, birds heading for the Argentine pampas, and birds traveling everywhere in between. The migrations also link us through time with evolutionary forces that have operated for millions of years; some of the birds around us originated in the ancient continent of Gondwanaland, and others attained their current form during the last southern thrust of the glaciers in the Pleistocene era.

A few days after the class, I take the kids into the park to see some of the birds – both resident and migrant – we have discussed. Since nearly all birds are new to them, robins on a nest, Mallards swimming in the Ramble's Azalea Pond, and Downy Woodpeckers digging into a tree are as exciting as the transient warblers. When I was their age, growing up in New York, I was already hooked on birding; I spent hundreds of hours on these same paths, learning my way around the Ramble and discovering the other places in the park that were best for birds. Ironically, thanks to the Central Park Conservancy, today the park is more luxuriant and attractive to birds than it was in my childhood.

Frederick Law Olmsted wrote in 1863 to the park's chief landscape gardener that he wanted the Ramble's plantings to give "a sense of the superabundant creative power, infinite resource and liberality of Nature." Ten years later, some of that vision had already been fulfilled, when the young Edith Wharton was taken regularly into the Ramble by her mother to pick violets and hepaticas. The first list of birds found in Central Park was published in 1886; New York City newspapers carried articles on the subject even earlier.

By the twentieth century, the park had become well known all over the birding world as one of the best places to see the songbird migration every spring and fall. As the city grew and the entire region became increasingly paved over, Central Park and the other big parks in every borough became oases for the birds that had few places to land after their long flights. In the early mornings Central Park hosts not only Manhattan birders but also others who have left their suburbs before dawn because they know they'll see many more birds in the heart of the city than in their own neighborhoods. Keen birdwatchers from more distant regions and even other hemispheres come here too to witness this distinctive spectacle. On a perfect May morning, one can see more than a hundred species, and goodly numbers during the rest of the spring and fall. Nearly three hundred species have been found in Central Park, and some two hundred pass through annually.

Today, however, the nature of bird migration is changing, and when I am with the fifth graders, I wonder what it will have become when they are old enough to teach others. Migrating birds depend on a succession of landscapes as they move north and south, but now the forests, meadows, wetlands, and coastlines in which these birds evolved are everywhere being degraded and transformed. Considering only the birds that pass through big city parks – mostly songbirds such as the orioles, tanagers, and warblers, plus thrushes, sparrows, finches, and others that feed on insects, fruit, and seeds – we must remember that they evolved to exploit the forests that originally covered much of eastern North America. Now, the once-unbroken Eastern forest survives in large swaths only in the Appalachians, Adirondacks, and a few other places far from centers of human activity. Where most Americans live, forests occupy relatively small patches.

Baltimore Orioles (*Icterus galbula*) are one of the few migrants from the tropics that nest in large urban parks. Their woven basket-shaped nests hang from the tips of tree twigs, often over water or roads where they will be safest from squirrels. Photograph by Frances Maas.

Many of the birds that nest in forests require larger blocks than they can now find. Exposure to the forest periphery leaves them vulnerable to the crows, jays, and other predators that thrive there and consume the eggs and young from the nests of woodland birds. Another bird of open areas that can penetrate the increasingly fragmented forests is the Brown-headed Cowbird, which lays its eggs in the nests of other species; the host's own young usually starve because the larger cowbird chick gets most of the food. Studies monitoring nests in small forests and near forest edges have found that most birds nesting there lose their young before these have fledged. Such forests are considered "sinks," because they do not increase or even maintain the population of the birds using them.

The taming of the American landscape that eliminated all its large predators from most areas near people has had a cascading effect on the natural areas that remain. White-tailed deer, at one time exciting to see in the woods, are now overabundant suburbanites that browse on all the vegetation they can reach and thus prevent trees and shrubs in the forest from regenerating. The absence of an understory eliminates the habitat used by many birds; even the birds that live entirely in the canopy suffer because, as the older trees die, far fewer saplings are growing to replace them. Ground-nesting birds and others in the low understory are especially vulnerable to another threat: domestic cats. An estimated 2.4 billion birds are killed each year in the United States alone by feral cats and house cats let outside.

On migration most songbirds aren't too fussy about their temporary habitat. When they are resting and refueling for a day or two, almost any grove of native or ornamental trees that has insects or fruit may meet their immediate needs. Places like Central

Park, too open to match the forests many of these birds nest in, do the job. But these birds can fly only so far from one stopover to the next. If you yourself ever fly into one of the New York City airports from the south or west, look down at that long stretch of New Jersey highways, housing developments, refineries, etc., and see if there is a place you'd want to land if you were a bird. And, if your plane takes you over New York or any other city, remember that migrating birds will be flying much lower than you and usually at night; the skyscrapers rising beneath you are big bird killers. We'll never know how many birds lose their lives when, confused by lights or reflections, they hit buildings; most tall buildings have setbacks onto which the birds fall, to be discreetly removed and never reported. Only a tiny portion lie dead on the street, but every spring and fall in New York I find the bodies of warblers, thrushes, and other small migrants on the sidewalk. Birds do not perceive glass, so they fly into it. There is now window glass that birds can detect, and, thanks to the advocacy of the American Bird Conservancy, a few cities, including Toronto and San Francisco, have begun requiring use of this new glass in certain places. But much more needs to be done – especially to reduce collisions by migrating birds flying at skyscraper level.

The Scarlet Tanager (*Piranga olivacea*) is the northeasternmost representative of a tropical American family with over 250 species. In autumn it returns to the eastern foothills of the Andes from Colombia to Bolivia. Photograph by Kelly Colgan Azar.

The winter destinations of many of the songbirds that pass through Central Park include the Caribbean, Mexico, Central America, and northern South America. There they settle into very different landscapes that until recently were almost entirely forested. The destruction of these forests for firewood, ranches, and subsistence or industrial agriculture is happening at a much greater rate than in contemporary North America. In the eastern United States, in fact, much of the farmland abandoned in the nineteenth century when the prairies became the American breadbasket has since reverted to forest. Unfortunately, the impact of land conversion in the Caribbean and Latin America may be greater than the present transformation of North America, because the total land area used in winter by most migratory songbirds is only one-seventh the extent of their collective breeding range. Thus every acre lost in the tropics is the equivalent of seven acres lost in northern forests.

In addition, most of the highly migratory songbirds spend more of the year in the tropics than in the north where they nest. Many establish and defend a territory all winter – just as they do when breeding – and return to it year after year. In the tropics, though, each territory is for one bird only, unlike in summer when a pair uses its territory to raise young. In many species, adults, especially males, claim the territories in the thicker, moister habitats that will have more insects and fruit, while many females and most birds born that year will make places for themselves in drier, less productive areas. Whether this habitat partitioning is due to the alteration or loss of so much original vegetation in the tropics or instead evolved long ago is unknown – scientists were not present to observe such preferences when these landscapes were relatively pristine. They have found, however, that when dominant birds are removed from preferred habitats, these vacant territories are quickly taken over by birds from nearby inferior ones, or by individuals that were "floaters" with no territory at all.

Meeting the conservation needs of migrant birds as they move from one region or country to another is a complex challenge, and it is made even more so by their distribution patterns. In many species, the population that breeds in one area also migrates to and winters in an area with birds from its home base. This is known as "connectivity." Wood Thrushes from New York and New England winter in Honduras and Nicaragua, while Wood Thrushes from farther west go to Mexico and elsewhere in Central America. Thrushes wintering in the Yucatan will never fill empty thrush habitat in New York. The Wood Thrush is in fact an exemplar of all the challenges facing migrants: it requires woodland interiors with an understory for breeding; it is frequently parasitized by cowbirds when it nests near edges; and it prefers mature forest in winter as well. Some individuals may get through the winter living in stream thickets and pasture edges, but they will be in poorer condition than those that secure forest territories. Based on breeding bird surveys, the Wood Thrush population has been declining by 2 percent every year since the mid-1960s. Cumulatively that is a loss of more than 50 percent.

How do all these factors play out at a familiar stopover like Central Park? In spring the tropical migrants, mostly travelling at night, come north in waves. They are numerous on days following winds from the southwest and scarcer during stretches of northerly winds that make flying more difficult for them. Today we continue to have a few waves when trees throughout the park seem decked in warblers, tanagers, orioles, and other colorful birds. But the troughs between the wave peaks are wider and deeper, with fewer birds than there were several decades ago. For many years, at least one pair of Wood Thrushes remained to nest in the Ramble of Central Park; their evocative, flutelike song could be heard every morning and evening in June and early July, long after the other migrants had departed. On July 5, 1852, Henry Thoreau presciently wrote in his journal, "The thrush alone declares the immortal wealth & vigor that is the forest." The Wood Thrush has not nested in the Ramble in this century.

Now let's examine the effects of climate change on the annual life cycle of most migratory songbirds. Birds wintering in the southern United States, such as seed-eating sparrows and other ground feeders, respond to the earlier onset of warmth at the end of winter by beginning their migration north. This is usually not a problem, as long as there is no cold snap in March that freezes the ground and covers it with snow, so the birds cannot find food. Migrants wintering in the tropics, however, receive no signals about local conditions in North America; their timetable has evolved to respond not to warmth but instead to changes in day length that match the advance of spring much farther north. Now that spring in North America is coming earlier and earlier, while the sun continues to rise and set as usual, the birds using the sun to schedule their departure may find on arrival that both the

The Magnolia Warbler's (*Setophaga magnolia*) bold black stripes separate it from the several other warblers with which it shares spruce/fir forests in spring and summer. It molts into a more subdued plumage before departing for Mexico and Central America. Photograph by Tom Benson.

leaves and the insects that consume them, upon which the birds depend for their survival, are too far ahead of "normal" to sustain them on their trip north. By the time they reach the latitude where they will nest, the birds may be even more out of sync with their prey. We've all seen how much earlier many plants are leafing out and flowering in spring; some birds are already unable to feed their young adequately because the caterpillars and other insects they consume have grown too fast.

In autumn the recent extension of summer warmth has slowed the southbound pace of tropical migrants. At the latitude of Central Park, September cold fronts, with winds out of the northwest, produce the waves of migrants birdwatchers hope for. Today, though, these are rare; migrants come through in a trickle rather than a wave. That may be a loss for the birdwatchers, but the shift has more significance for the birds themselves because – just as in spring – the migrants that return soonest to their winter range get the best territories. And, since the effects of global warming in tropical latitudes include a drier climate, the high-quality territories are becoming ever scarcer. Birds wintering in drier territories are in poorer condition by the following spring than those in moist ones. They depart later; arrive later in their breeding range, where they get the least productive territories; and fledge the fewest young, perhaps not even enough to replace themselves: a downward spiral.

Finally, we see the effects of climate change in the habits of the birds that winter wherever we are. Traditional harbingers of spring, like robins and bluebirds, are now year-round residents far north of where they were only a few decades ago. Other non-migrants, such as cardinals and mockingbirds, once symbols of the South, have in the last half-century expanded their range into southern Canada. These changes may seem benign, but they demonstrate how rapidly our familiar landscapes are changing. The warmer winters with little or no snow mean that the ground is receiving and retaining less of the moisture that fuels the growth of plants in spring. In due course, the basic ecosystem that has enabled these hardier birds to survive and expand over milder winters may weaken.

What can be done? Non-governmental conservation organizations in the United States are working with landowners to improve management practices for forests and other natural areas, so these will support more birds. They are also working with governments and NGOs in tropical countries to protect key landscapes – landscapes vital not only for migrants but for entire local ecosystems. Some forms of tropical agriculture, like shade-grown coffee, support much of the local fauna as well as migrants and are being promoted. Preserving forests also protects water tables and reduces runoff; communities are learning how to restore hillside forests to ensure they have a reliable supply of potable water.

Understanding how these larger systems interact and interlock is crucial. Sentiment for birds will not budge the position of many U.S. policy makers on wilderness, endangered species, or climate change, and governments in developing countries are thinking first about what to do with their burgeoning populations and the few rewarding forms of work available to them. This is why we must demonstrate that potential large-scale economic opportunities to be gained by confronting climate change and sustainably harvesting tropical forest resources vastly outweigh the alternatives of inaction and traditional practices. The challenge of protecting the diversity of life on the planet should unite people, businesses, and governments. While we are making that case, however, let us continue to appreciate the migrating birds that animate landscapes we know and link us to ones we may never visit. If we can teach fifth graders to recognize the song of the Wood Thrush, perhaps its music will still be heard by future generations. – Roger F. Pasquier

Living the High Life: Green Rooftops as a Biodiverse Frontier

I'm standing in a field of red and yellow *Coreopsis basalis* flowers, watching the sun set as bats fly overhead, quick strokes of black against the deepening blue of the sky. A few feet away, a glossy, yellow and black pollinator I can't quite identify ignores the downturned cap of a nearby columbine flower in favor of the bullseye-patterned tickseed blooms. I know it's not a bee; it lacks a buzz. I sink low into a crouch, level with the gently swaying plants. When I am still, the minute world around me moves more freely. The insect flies closer, pausing at length in midair above the open face of the tickseed flower. At last, it alights and stills. There: a syrphid fly – aptly called a hoverfly.

It is the longest day of the year. The landscape, like the daylight, seems infinite, but only if you squint. What appears as distant peaks is New York City's Midtown, built atop the Manhattan schist that is the mica-studded stump of a once-mighty tectonic mountain range. In actuality, the meadow I am standing in is Kingsland Wildflowers, a green roof five stories above Greenpoint, the northernmost neighborhood in Brooklyn, New York. This research and education site was built by Alive Structures on top of a film and television production facility owned by Broadway Stages, a company with a history of putting its rooftops to good use. One of its warehouses-turned-production studios is covered in over 50,000 square feet of solar panels, the largest privately owned solar array in New York State. A participant in the NYC CoolRoofs program, the company has another facility surfaced in a specialized white paint to reflect sunlight, cooling both the building and the surrounding neighborhood. In 2009 Broadway Stages worked with green roof installer Goode Green NYC to build the Eagle Street Rooftop Farm, the first green roof, commercial vegetable farm in the country, where I am the farmer. Kingsland Wildflowers, their second green roof, is the result of a partnership with New York City Audubon, the Newtown Creek Alliance, and the Greenpoint Community Environmental Fund (GCEF). When the newly built green roof began hosting public programming in September of 2016, visitors were able to see firsthand what Marni Majorelle, the owner of Alive Structures, first envisioned: the transformation of a bare roof into a thriving ecosystem.

This evening I am not alone in my observations. Dustin Partridge, whose research at Fordham University focuses on understanding the ecology of green roofs, is here, too, as part of his regular study of the roof under the auspices of New York City Audubon. A small box is mounted on a post in one corner of the roof, which Partridge explains is a bat-monitoring device. He has another system cued up to record the morning songs and calls of birds. Hidden throughout

the meadow landscape are colorful cups and strips of sticky papers, all insect traps. Later in the evening, we will walk downstairs to examine, with care and excitement, a small box of vials containing preserved insect specimens collected at Kingsland. While on the roof I'd noticed only one species of syrphid fly. Partridge's growing collection already contains over a dozen different species of insects.

In their most basic iteration, vegetative roofs have been around for millennia. Sod rooftops insulated cottages at Skara Brae, a five-thousand-year-old settlement in Scotland. History shows that these roofs can open up a new landscape for opportunistic flora. In 1914 – well before the term "green roof" was coined – the Moos Water Filtration Plant in Switzerland installed a rooftop garden for insulation, using soil harvested from the ground near the building site. Today, with minimal care (as a traditional meadow, the roof receives a twice-annual mowing), the rooftop is a thriving meadow of approximately 175 plant species, all self-seeded. This includes several thousand individuals of a rare, endemic orchid found nowhere on the ground nearby.

Today, a "green roof" refers specifically to a rooftop overlaid with a waterproofing layer, a series of water-retaining membranes, and manufactured soil (referred to as green roof growing media) planted with vegetation. Green roofs receive deserved attention for their capacity to mitigate the heat-island effect, capture storm water, and provide an additional layer of insulation to buildings, which can contribute to lower energy costs. These environmentally beneficial qualities produce long-term financial benefits for both the building owner and the larger municipal landscape. A 2011 report by the U.S. General Services Administration (GSA) concluded that installing green roofs on the nearly six million square feet of rooftop in the National Capital Region of Washington, DC would provide public benefits worth almost $180 million, or $3.30 per square foot of building area, over a fifty-year period.

Research of the sort that Partridge is conducting will allow green roof owners and professionals to add "ecologically beneficial" to the list of advantages such roofs offer, with specific examples to speak to that claim. For instance, the New York City Department of Parks & Recreation is cataloguing the benefits of green roofs in support of the Million SQFT Initiative, a program with the ambitious goal of adding green roofs to over one hundred parks facilities across the city's five boroughs. Drafted by the Sustainable Facilities Division's Grant Justification team, the report summarizes research from the department's own green roof pilot initiatives and similar efforts conducted by other agencies and academic institutions. The financial value green roofs offer as a component of sustainable city infrastructure is listed alongside their boons for pollinators and commercial beekeepers.

How does a biodiverse community develop several stories up in the air? A bare rooftop, not surprisingly, offers very little biodiversity. But this changes with the addition of growing media, plants, and water. First there is the biota that comes with the rooftop growing media itself: bacteria, fungi, and more easily visible arthropods such as springtails and millipedes. A manufactured green roof media is different from ground-level soil. Designed to be lightweight without compromising volume, the media is made up of a blend of lightweight material with the appearance of gravel, such as expanded shale and clay particulates, and a much smaller amount of organic matter, such as compost. It's in the organic matter of a green roof soil blend that microscopic fauna hitchhike up to the rooftop. Additional biota may arrive with plants as well. Once the green roof is established, the next wave of insects and animals to arrive on the rooftop are the fauna that can find their way up, such as climbing, windblown, and flying insects, as well as birds. New species arrive; less hearty species are extirpated; but overall, diversity increases with time.

Each of these insects and animals uses the green roof in different ways. For some species a green roof is like an island ecosystem, entire unto itself. For others it is a stepping-stone habitat, a fragment in a larger matrix of surrounding green spaces. According to Partridge, the colonization and resulting biodiversity of a green roof results from an interplay between the rooftop and the green space around it. "The green roof is habitat in a larger framework. They change as the neighborhood changes," Partridge explains. "It's important to think of green roofs not in isolation, but as part of the network of landscape around them. The ecological community of a green roof will reflect nearby green spaces."

How do plant choices, the location of the rooftop, and its height inform its biodiversity? Three examples speak to the possibilities: the sedum-planted green roof atop the Jacob K. Javits Convention Center in New York City; the well-studied, broad range of flora thriving on the Chicago Botanic Garden's Daniel F. and Ada L. Rice Plant Conservation Science Center; and the dynamic landscape of ornamentals, edibles, and trees at the Battery Rooftop Garden, a residential green roof in Lower Manhattan.

In 2015 New York City Audubon's monitoring of the 6.75-acre green roof on top of the Javits Center in Manhattan recorded a diverse list of bird species. Among others, Eastern Phoebe, Eastern Kingbird, Ring-billed Gull, Peregrine Falcon, Common Raven, and Song Sparrow were all reported: excellent birds for any urban habitat, let alone a rooftop. During migration season a

In 2009, the Eagle Street Rooftop Farm became the first green roof vegetable farm in the country. An ecosystem including pill bugs and worms thrives in the soil of the three-story-high green roof.

Flying insects and birds are among the first colonizers of a green roof environment.

Palm Warbler also made an appearance there – the first Palm Warbler spotted atop a green roof.

What makes these findings particularly interesting is that, in contrast to the diversity of Kingsland Wildflowers, the convention center's rooftop is planted with sedums. Sedums are a "go-to" plant in the green roof industry, in large part because they suffer neglect with panache. With thick, water-retaining leaves, they're tolerant of the dry soil conditions often found on green roofs. Many species of sedums also overwinter well – a plus on a rooftop, as dead plant material can be a fire hazard. It's true that, while flowering, sedums are a sound source of nectar and pollen for pollinators. But how has a rooftop with so little plant species variety come to host such a wide range of birds?

Clearly, size is a factor: the roof is a massive green oasis in the sea of concrete that dominates the Hell's Kitchen neighborhood of Manhattan. So is its proximity to the Hudson River, which puts it within easy reach of birds such as Canada Geese and Herring Gulls – the latter a species that successfully hatched and raised chicks on the rooftop in 2015. It is also adjacent to the Hudson River Greenway and a few blocks from the last section of the 1.5-mile-long High Line Park, a refurbished, elevated train track planted with several hundred plant species.

Hypothetically, if the Javits were smaller but planted with a diverse array of flora, it is possible that it would host more insect and animal species than a sedum-planted rooftop. Or, if planted in sedums but located near a rich green space such as Central Park, the green roof might see more diversity in visiting insects and animals. Theoretically the most biodiversity would result if the green roof were larger, diversely planted, and near a thriving green space. "We know a bit about what drives green roof communities, but we still have a lot more work to do," Partridge admits. Regardless, from a conservation perspective, birds still benefit from large isolated habitats like Javits. "Even if it's not diverse in its planting, it may be the only thing available for migratory birds passing through that portion of the city," Partridge adds. "Biodiversity is a good measure of success, but it's not the only aspect to consider on a green roof."

In some green roof settings, the interplay between the rooftop and the surrounding landscape is even more obvious: for example, the 2011 discovery of nesting Killdeer (*Charadrius vociferus*) on the green roof atop the Daniel F. and Ada L. Rice Plant Conservation Science Center at the Chicago Botanic Garden. The nests of these graceful shorebirds were described by John James Audubon in the nineteenth century and appear exactly the same today: "various, some being merely a hollow scooped in the bare ground [encircled by] small pebbles and fragments of shells."

Upon completion of its new building in September 2009, the botanic garden began a five-year study of the 16,000-square-foot green roof's forty thousand individual plants. Five years later nearly all of them were still alive, despite shallow soils and the harsh conditions typical of a zone 5 growing climate. The study is tremendously detailed, offering a useful and dynamic plant list for four-season rooftop growers. Differentiating between two types of prairie dropseed, for example, project leader Dr. Richard Hawke calls *Sporobolus heterolepis* an "absolute standout."

When I called to inquire what among the outstanding plants or landscape features had attracted the Killdeer to the green roof, I learned that the regularly nesting pair had made a very simple swap. In previous years, the birds nested in the gravel that provided drainage for the plant trial beds alongside the new facility. Upon discovering an equally suitable habitat one story up, they'd simply relocated. In fact, Killdeer are somewhat notorious for green roof habitation. The 10.4-acre green roof above the Ford Motor Company's River Rouge Truck Plant, for example, is a sedum-planted rooftop constructed in 2003 as part of the company's reinvestment in its outdated manufacturing facility, built in 1917. Within a year of the green roof installation, a photographer espied the small, speckled eggs of a Killdeer nestled carefully among the gravelly growing media, a shallow blend only 1.5 inches deep. Within two years, three more nests were found.

Soil, plants, and water provide the foundation for biodiversity. What happens when a green roof grows higher up? Fred Rich's Battery Rooftop Garden in Lower Manhattan, at approximately 2,000 square feet, has all the elements of a garden capable of harboring both visiting and resident insects and animals. In 2010 Rich hired landscape architect Mark K. Morrison to create a stunningly varied garden, featuring over 150 plant species. Originally the extensive green roof hosted 3-inch deep growing media and a basic plant palate of sedums and hardy seaside shrubs such as bayberry (*Myrica pensylvanica*). Rich and Morrison took advantage of the building's steel-reinforced roof deck to increase the depth of the growing media significantly – in some places up to twenty-four inches. The green roof's design offers shelter in the form of trees, shrubs, and dynamic topography. There is a water source in the form of two small fountains that insects and animals may use. An area of open patio planted with creeping thyme releases aromatic oils underfoot; a southern corner of the rooftop is landscaped with a small collection of alpine plants, including prickly pear, native to the region. Over the structural support columns, trees such as *Stewartia* and contorted larch were planted in open-bottomed containers, allowing their roots to spread across the entire green roof. Espaliered fruit trees fence in the rooftop's western parapet. Almost immediately, a (likely delighted) Mockingbird (*Mimus polyglottos*) took up residence.

But the Battery Rooftop Garden is thirty-five stories high. Does biodiversity drop off at such a height? During the 2012 growing season, Jeremy Law, a graduate student in the Ecology, Evolution and Environmental Biology Department at Columbia University, measured the diversity and abundance of arthropods on the sky-high garden to find out.

Despite the garden's altitude, pollinators such as honeybees, bumblebees, and – a favorite of the organic gardener interested in pest management – braconid wasps (all Hymenoptera) were recorded in high abundance. Members of the brush-footed butterfly group fluttered up. Law identified fifteen orders and a mini-

Green roof blenders such as rooflite, shown here, have matured with market demand. Many now produce compost-rich media in lieu of the sand, gravel, or Styrofoam blends of the past.

mum of thirty-five families of arthropods. There were predator-prey relationships, a strong indication of a functioning ecosystem. Spiders and ladybugs dined upon aphids and thrips at well over 350 feet in the air. While it is likely that pill bugs hitchhiked their way onto the roof via the rich organic matter in the soil blend, the presence of such insects as a Tule bluet, a species of damselfly (*Enallagma carunculatum*), came as more of a surprise. That same year I spotted a green darner (*Anax junius*) in the garden, a migratory insect that travels from as far as Mexico and Texas to New York City.

A mixed plant palate of flora (here at Goode Green in Soho: sedums, wildflowers, and edibles) provides a richer landscape for fauna.

With such heartening reports of biodiversity on all types of green roofs, one can conclude that the more green roofs, the merrier. The growth of the green roof industry depends, in large part, on what measures are taken to support – or strong-arm, as the case may be – the costs of green roof installation (these days, around fifteen to twenty dollars per square foot), how navigable the permitting process is locally, and what resources exist nearby. Because installations occupy a mix of public and private spaces, it can be difficult to get an exact number on how many square feet of green roofs are installed each year. Studies of satellite imagery, such as the City of Chicago's map of existing city green roofs (last edited in November 2012), are quickly outdated.

What about looking to the market for rooftop soil to get the dirt on industry growth? A rising demand for green roof growing media would suggest an increase in green roof installations. To check, I called Joe Donnelly, Director of National Sales for rooflite, a green roof growing media manufacturer. Donnelly confirms that the company has observed growing interest in green roofs nationwide over the last decade. Rooflite continues to expand its network of licensed blenders (companies that it works with to make regionally-sourced growing media). While the Mid-Atlantic and Chicagoland regions lead the market, rooflite has footholds in Colorado, the Saint Louis region, and the Pacific Northwest. The company has also set up shop in Southern and Central California. ("It was interesting to talk to the design team at one of our sites in California," Donnelly adds wryly. "They asked if we'd ever worked in an active seismic zone.") Miami and Orlando are calling, too. Rooflite used to get a call a year from Florida. That, too, is changing. "Last week alone I had three requests from Florida, which makes it worth getting serious about growing our blender network there."

To explain how cities incentivize green roof installation, Donnelly points to two locations rooflite contracts with regularly, New York City and Washington, DC "Every project in DC has storm water management components built into it. The civil engineers mention it in their design. The city uses a cap-and-trade agreement to allow green roof owners to sell their storm water credits. On the other hand, New York City offers tax rebates. That's the carrot. Washington, DC has a high storm water fee. That's the stick."

Donnelly identifies megahospital complexes as a notable area of growth. Children's Hospital of Philadelphia, University of Florida Health Shands Hospital in Gainesville, and Nemours/Alfred I. duPont Hospital for Children in Wilmington all recently installed green roof healing gardens for their clients. Often more varied in their landscaping choices than typical sedum green roofs, these gardens are highly likely to provide dynamic shelter for insects and birds.

The green roof I'm responsible for is an organic vegetable farm. I'm a ground-level green thumb by training, but in 2008 I cofounded the Eagle Street Rooftop Farm in Brooklyn, New York. It was my first experience with the green roof industry. The building owner, Broadway Stages, contracted Goode Green, a Manhattan-based green roof company, to transform the rooftop, with its silver tar finish, into a thriving vegetable farm. Over the course of an unusually hot morning in late April 2009, Goode Green guided two hundred thousand pounds of growing media, delivered in forty-four specialized, soil-carrying "super sacks," from street level to the three-story-high warehouse rooftop.

I was not immediately sold on the notion that green roofs made for a great vegetable-growing landscape, but I was intrigued enough by the concept of überlocal food to give it a shot. In early conversations I fretted that green roof growing media would not provide the robust organic matter and the accompanying biota necessary to grow healthy vegetables. (What would I do without worms?!) Working with Goode Green, whose representatives in turn navigated the conversation with rooflite, our growing-media supplier, we adjusted the typical green roof blend to incorporate a much higher ratio of organic matter to particulates without exceeding the load the rooftop was capable of supporting. Today, rooflite sells a similar blend under the brand name "rooflite agriculture." A popular product, the blend is used by a wide range of rooftop farming projects, including the two acre-plus archipelago of rooftops run by the green roof farming company Brooklyn Grange.

In eight seasons our 6,000-square-foot farm has produced more than just vegetables. The farm hosts volunteers and students. Over one hundred people have matriculated from our training program. They have grown into careers ranging from urban agriculture to grass-fed animal farming; from flower growing to floral design; and pursued advanced degrees to sharpen their skills further. We've given up on growing moisture-loving and space-hogging watermelon. But we grow incredible chili peppers, marketed in the form of a hot sauce – Awesome Sauce – making them both a practical product to grow and a fun one to eat.

And, I'm happy to say, we have worms in our soil. In 2010 I added several hundred *Eisenia fetida* to our compost system, and they made it onto the farm as part of the fall season's

topdressing. The worms seem happiest in the areas of the green roof that retain the most moisture: underneath the planting of perennial herbs, near the wooden barriers that form the perimeter of the farm, and wiggling in the moist, manure-enriched soil produced by the "chicken tractor," the small coop we use to rotate a half dozen domestic egg layers (*Gallus gallus domesticus*, for those still keeping track of bird sightings) around the farm for added soil fertility. Along with worms we have aphids and ladybugs, leaf miners and lacewings. In short (besides groundhogs, for whom the stairs and Brooklyn location remain barriers), many of the same pests and beneficials I'd come to expect on the ground.

Ultimately, what sold me on green roof farming are the same key benefits that green roofs provide, regardless of the plants they host. On any sunny summer day at the Eagle Street Rooftop Farm, the silver tar roof adjacent to the green roof farm is perceivably hotter, often by a difference of ten degrees or more. During heavy rain, including the dramatic precipitation that accompanied Hurricanes Irene and Sandy in 2011 and 2012, I watched the torrents cascading down the gutters of the building's rooftop slow to a trickle as they made landfall on the green roof and passed through the absorbing and filtering layers of the growing media and green roof membranes. I'd read statistics about a green roof's capacity to retain storm water, but seeing it in action was astonishing. And after years of spotting birds like House Finches (*Haemorhous mexicanus*) in the fall and Dark-eyed Juncos (*Junco hyemalis*) in the winter, picking through our seeds, I started an eBird account and used the easy app installed on my phone to track the growing numbers of birds making use of the new green space. The Common Starlings (*Sturnus vulgaris*) made perennial use of the building's wall cavities to nest, but I was pretty sure from a citizen-science perspective that it was our green roof that had piqued the interest of the dozen or so new bird species that frequented the garden.

One afternoon in July while I'm taking a much-needed drink of water, a butterfly lands on a flowering yarrow plant next to me. With a gentle cupping motion, I bring my hand down over it like a net. When it rises to take flight, I draw my fingers closed, and the butterfly is caught. Its wings beat furiously against my palm. To call a butterfly delicate is relative. In proportion to their size, insects are absurdly strong.

I open my fingers carefully. The hind wings are a warm brown with red edging; the forewings the same warm brown with a meridian red stripe, then black. At the top of each wing, there is a large white spot attended by a trim of smaller speckles. I have caught the Red Admiral butterfly, *Vanessa atalanta*. Atalanta, my childhood heroine, was the swiftest warrior-princess of all the Greeks. She married Hippomenes after he outran her, and they had a very lively sex life until the gods turned them into lions when they were caught making love in a temple. (It was a punishment meant to chasten: as every good Greek naturalist knew, lions could not mate with their own kind, only leopards.)

I open my loose fist. In a moment the Red Admiral lifts into the air and is quickly busy among our small patch of waving *Coreopsis grandiflora* blooms, four stories above Brooklyn's streets. In both Europe and North America, *Vanessa atalanta* migrates south when cool weather arrives in the fall. The migration isn't as famous as that of *Danaus plexippus*, the Monarch Butterfly. But it's notable enough that during boom years (about every decade or so), a local paper might write about the steady stream of Red Admirals, moving in twos and threes, fluttering by like a ticker-tape parade as temperatures start to drop. Typically, they'll pull a quote from a longtime resident commenting on the last time they witnessed such a spectacle. Typically, too, they'll note that the numbers of these butterflies are declining.

Like many insects, the Red Admiral is suffering habitat loss as the cost of our habitat gain. Two short centuries ago, Audubon's home in the Washington Heights neighborhood of New York City, Minnieland, was described by George Bird Grinnell, the founder of National Audubon, as "a dense forest of white pine and hemlock, with tidal ponds along the river, full of ducks and snipe." In Audubon's time, Red Crossbills and Passenger Pigeons feasted in dogwood trees while Bald Eagles landed on the Hudson River's ice floes.

When I'm on a green roof, squinting at a skyline until it blurs into the semblance of a mountain range, I experience a sort of mental whiplash, stunned anew by how quickly humans can transform an ancient landscape. The loudest rooftop landscape I've ever visited was a private residence in Chicago whose plant palette evoked the prairie landscape that predated the city's construction. As I stood surrounded by tall grasses fifty feet above street level, the air vibrated around me with the bisbigliando of bugs. Eye level with the oak tree canopy surrounding the brownstone, I listened to the sonic landscape that had dominated the Midwest for millennia.

Martha, the last known Passenger Pigeon, expired at age 29 in 1914. Minnieland was razed in 1931. The winters when the Hudson River freezes over are few and far between. But many of the birds and insects that continue to fly overhead provide the thread that weaves together our landscape's long evolutionary past and the quickly changing present. Replacing bare rooftops with green roofs can keep that thread from snapping. – Annie Novak

Exhibitions

Jardins
Paris, Grand Palais
March 15 to July 24, 2017

Infinite Garden: From Giverny to Amazonia
Metz, Centre Pompidou-Metz
March 18 to August 28, 2017

How does a museum do justice to the inexhaustible theme of the garden within its four walls? In *Jardins*, the seeming absurdity of attempting to truly represent a garden inside a museum is overcome by exploring their shared essential goals: the pursuit of beauty, knowledge, and pleasure.

The setting is the Grand Palais – a Beaux-Arts pavilion of glass, steel, and stone built for the Exposition Universale of 1900. This elegant exhibition, which is arranged in a linear fashion, uses the basic elements of the garden to lead the visitor from the *Seuil*, or threshold, through discrete spaces titled after fourteen fundamental garden features: "Humus," "Mixed Border," "Belvedere," "Promenade," and so on. It opens with a fresco of a garden scene (100 BCE–100 CE) from the House of the Golden Bracelet, Pompeii. Next up is *Soil Library/Loire* (2017) by Koichi Kurita, a five hundred-centimeter-square installation of four hundred soil samples. This juxtaposition sets the pattern of the exhibition, which intermingles two thousand years of gardens. The transitions between rooms containing historic materials are gracefully punctuated with thematically linked, showstopping works by contemporary artists. Indeed, it is hard to pull away from each object or group of objects, all of which have been thoughtfully selected for the highest quality and significance. But the show is vast, and one's eye is caught by carefully choreographed viewpoints ahead.

The three hundred-odd works in the exhibition range from a diminutive gouache of violets by Dürer (ca. 1490) to Emile Claus's life-size portrait of a gardener (1885) to a room devoted to Yann Monel's photo essay of fifty-three garden views (2017). The

pleasure of standing a nose-length away from wall-size portraits of châteaux and Italian villas by Utens, Brueghel, and Bellotto – landscapes of infinite detail, hung at eye level – is intoxicating.

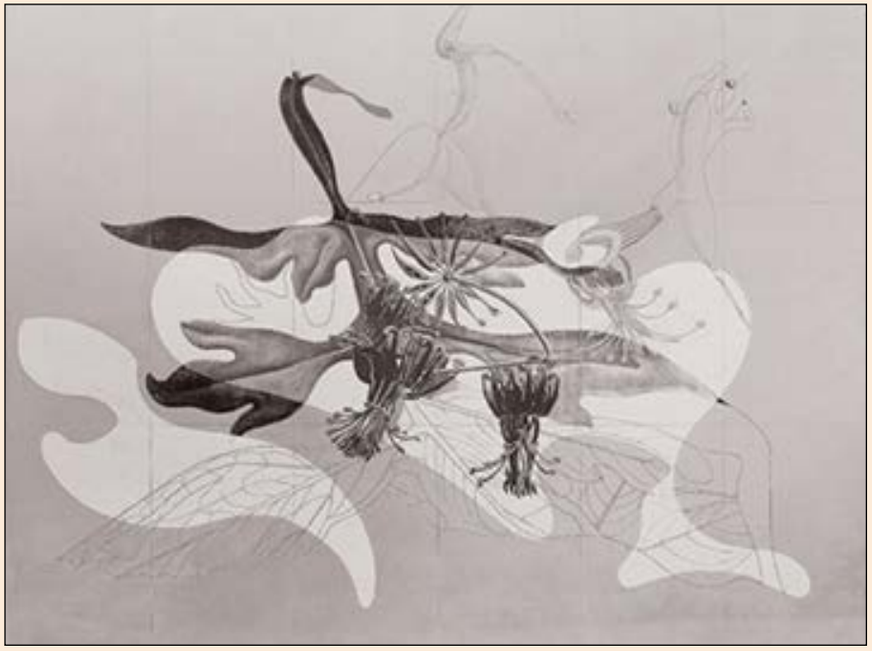
Almost exclusively European in geographic terms, the objects are mostly fifteenth century to contemporary and relate to the art and science of gardens. While familiar paintings by Picasso, Monet, Fragonard, Cezanne, and Matisse will catch everyone's attention, it is the less predictable inclusions – drawings by anonymous botanical artists; Rousseau's herbaria sheets; Gertrude Jekyll's boots depicted in oil by William Nicolson; mechanical botanical figures; gardening tools; cleverly used dioramas, models, and film excerpts – that pull the visitor into this brilliant meditation on garden space, structure, and meaning. The result is a history of representation that moves across time, uniting objects as diverse as Le Nôtre's plan for the Château de Maintenon (1662–67) and Paul Klee's *Garten-Plan* (1923) to illustrate how three-dimensional design has been conveyed through artistic means.

It is impossible to summarize the achievement of an exhibition of such ambition in this brief review. The challenge of celebrating gardens in museums has been attempted more and more frequently as interest in the environmental humanities grows. The curators of *Jardins* – Laurent La Bon and Coline Zellal, both from the Musée National Picasso-Paris, and Marc Jeanson, from the National Herbarium at the Muséum national d'histoire naturelle – and the exhibition designer, Laurence Fontaine, have mounted a *Gesamtkunstwerk* that raises the bar for garden exhibitions. Sadly but not surprisingly, due to its scale, the exhibition will not travel. And here is another characteristic that the museum exhibition and garden share: they are ephemeral arts. I can recommend, however, the equally comprehensive and beautifully produced catalog.

The much smaller but still important and provocative exhibition, *Infinite Garden: From Giverny to Amazonia*, is at the Centre Pompidou-Metz, a striking building opened in 2010 that was designed by Japanese architect Shigeru Ban and French landscape architect Jean de Gastines. For this exhibition, the museum's immense nave/atrium is filled with *Leviathan-Main-Toth* – "hanging gardens" constructed from Lycra netting by Brazilian artist Ernesto Neto. Neto's piece signals to the visitor that this is not going to be a conventional "history of the garden" exhibition but rather a recognition of the garden as a point of departure for artistic inspiration.

This point is clearly made with the opening work, Max Ernst's *Pétales et jardin de la nymphe Ancolie* (1934), a stunning, mural-scale painting Ernst based on a print found in *La Flore des serres et des jardins d'Europe* by Louis van Houtte, a twenty-three-volume botanical journal published between 1845 and 1880 that was famous for its hand-colored engravings. Ernst's version, the largest work he ever did (415 × 531 cm), is made of synthetic resin paint transferred to wood panels.

If history and fine arts characterize *Jardins*, fantasy and political debate might best describe the nature of *Infinite Garden*, curated by Emma Lavigne and Hélène Meisel, both from the Centre Pompidou-Metz. The designer was the Brazil-based, Catalan artist Daniel Steegmann Mangrané. An environmental and conceptual artist, he has long been concerned with formal oppositions of culture and nature. For this project, he laid out two interior galleries – one dark, one light – and, breaking further with conventional exhibition design, used the exterior of the building for installations as well.



Max Ernst, *Pétales et jardin de la nymphe Ancolie* (Mural), 1934. Oil on plaster transferred to block board panels, 163.5 x 209 inches. Kunsthaus Zürich, ©ADAGP, Paris, 2016.

The first gallery, "Cosmic Spring," evokes a nocturnal garden walk through a series of village houses and small squares. The visitor's experience in the darkened gallery is directed by narrow spaces with focused views. Sections of the exhibition are dedicated to themes such as "Metamorphosis," "The Primordial Garden," "Pollination," and "Intoxicating Gardens." Multimedia works by Yayoi Kusama, Joseph Beuys, Jean Dubuffet, Thierry de Cordier, Richard Long, Isamu Noguchi, and Derek Jarman depict the degradation of the environment wrought by humans and the consequences of that interaction. Their subjects are strikingly relevant.

The second gallery, "From Giverny to Amazonia," is conceived as an open space, like a park or the outskirts of a city, with straw-colored carpeting that gives the sense of walking in a field; the pile gets taller as you walk the length of the exhibition on the subtly rising and falling floor. This light-filled gallery provides visitors with sight lines that extend through the installations and also outside, beyond the windows, where three other gardens were commissioned for this exhibition. In *Garden*, set in front of the Centre Pompidou, Loïs Weinberger pursued the phenomena of spontaneous vegetation by arranging hundreds of plastic pots filled with earth in the open air and leaving them to the random sowing of wind, insects, and birds to produce a garden. In a similar vein, Hans Haacke's work of living art, *Directed Growth* (1972), is an elongated planting bed with green beans growing up strings attached to the windows. It recalls, as do many of the exhibition's works, Haacke's manifesto of 1965, in which he called for "time-based, dynamic, natural, indeterminate art," and evokes the environmental art movement of the 60s and 70s. Thus, the exhibit closes with a "light" open-ended message in contrast to the "dark," and sometimes even threatening, mood of the first half of the show. This exhibition has two associated publications: the catalogue, *Jardin infini*, and *Anthology*, a collection of related essays, literature, and poetry.

– Therese O'Malley

The Power of Flowers: Pierre-Joseph Redouté 1759–1840
Paris, Musée de la Vie Romantique
April 26 to October 29, 2017

To complement the two recent Gardens/*Jardins* exhibitions in Paris and Metz that presented an astonishing range of objects documenting European garden history, the Musée de la Vie Romantique has dedicated an exhibition to the illustrator, engraver, and painter Pierre-Joseph Redouté (1759–1840). Redouté's exceptional talents both expanded and transformed the art of botanical illustration, an evolution that promulgated a new appreciation of flowers and bridged a long-established gap between the arts and botanical sciences. The exhibition displays a remarkable selection of works on loan, chiefly from the Muséum national d'histoire naturelle. One only wishes that the relevant historical information so carefully gathered for the accompanying catalogue had been better integrated into the exhibit itself, which would have enhanced the visitor's appreciation of the rare works on display.

The museum was once the home of the Romantic painter Ary Scheffer (1795–1858), and the guest curator Catherine de Bourgoing has evocatively exploited the intimate spaces of Scheffer's former ateliers, where the dark blue walls, wooden display cases, and glass ceilings are reminiscent of Redouté's own era. The first of the four rooms testifies to the rich history of botanical exploration with a selection of manuscripts, herbaria, and printed editions – such as François André Michaux's *Histoire des Arbres Forestiers de l'Amérique septrionale* (1810–1813), which brought thousands of American plants to Europe. In the same room, *Vase with flowers* (1785) by the Dutch painter Gerard van Spaendonck (1746–1822) demonstrates the established conventions of flower painting during this period. Van Spaendonck was a professor at the Jardin du Roi and mentored Redouté. Several of Redouté's earliest illustrations of succulents are on display here also, establishing his precocious talents as a botanical illustrator.

The second room displays Redouté's drawings and vellums, including several unfinished sheets that demonstrate the artist's profound sensitivity to detail, color, and shadow. Unfortunately, the labels on the walls are lacking in the information that would have permitted a deeper understanding of the works they accompany; visitors must read the catalogue essays by Catherine de Bourgoing, Denis Lamy, and Pascale Heurtel to obtain the necessary historical context.

Born to a family of artists in Belgium, Redouté arrived in Paris in 1782 and attended classes at the Jardin du Roi. Here he was introduced to Charles-Louis l'Héritier de Brutelle (1746–1800), who taught him the principles of botanical description. L'Héritier followed the recently established Linnaean systems of classification and taught Redouté to draw the entire plant, transcribing the shape of the stalks and petals, and supplementing them with details of the stamens and pistils. Redouté's fame derived from his capacity not only to provide precise scientific information but also to capture the flower at its fullest bloom, endowing it with an almost three-dimensional tangibility that was unique at this time.

L'Héritier gave Redouté his first commissions in 1784–85 and then invited his protégé to accompany him to London in order to illustrate his catalogue of plants from Kew Gardens (1786–87). During this London sojourn, Redouté met the engraver Francesco Bartolozzi (1727–1815), who taught him how to combine color washes with stipple engraving techniques that allowed for greater tonal graduations. Upon his return from London, Redouté would add watercolor to his engravings, thereby creating the style that has made his work so recognizable and appreciated today.

As Redouté improved his techniques, his reputation increased, attracting the attention of not only the scientific directors at the Jardin du Roi but also Marie-Antoinette, who awarded him an honorary position as draftsman of her gardens at the Petit Trianon. In 1792 he was named Dessinateur de l'Académie des Sciences. In this position he continued to produce botanical illustrations, seemingly impervious to the upheavals of the Revolutionary decade. The following year, when the Muséum national d'histoire naturelle was founded, Redouté successfully competed to become one of the official painters of the "velins du roi," which were now dedicated to the Republic. (He contributed to this project until his eightieth year, first drawing and then hand-painting over 600 vellums for the new national collections.) The golden period of Redouté's career, however, was still to come, under the exceptional patronage of the Empress Josephine (from 1802 until her death in 1814). The exhibition does not highlight this singular relationship, yet several essays substantiate how her patronage enabled Redouté to reformulate the art of botanical illustration and reach a wider audience.

Josephine's passion for the natural sciences began around 1800, when she started to collect and acclimatize plants at her gardens at Malmaison in friendly competition with the natural history museum. In 1802 she commissioned the botanist Étienne Ventenat (1757–1808) to record the species that flourished under her patronage in a luxury volume, *Jardin de la Malmaison* (1803–1805), which included 120 engraved watercolors by Redouté. This work was followed by *Description des plantes rare cultivées à Malmaison et à Navarre* (1812–1817), by Aimé-Jacques-Alexandre Goujaud, called Bonpland (1773–1858), which contained 152 plates by Redouté, including the Chinese peony *Paeonia moutan* and the *Cactus speciosus*. The drawings of both plants are on display.

These commissions enabled Redouté to launch his own highly ambitious project, *Les Liliacées:* over 486 engravings of lilies and other species published in eight volumes from 1802 to 1816 and dedicated to the empress, who purchased the original vellums and underwrote the subscription for the printed edition. Redouté oversaw a team of eighteen engravers, who created remarkable prints – including an image of a March lily named *Amaryllis Josephine*. These prints, which are considered his masterworks, demonstrate how Redouté transformed illustration into an art form that appealed to a wide audience interested in flowers as symbols of nature's diversity and beauty. A bilingual electronic copy of *Jardin de la Malmaison* and an edition of *Les Liliacées* are on display in the fourth room of the exhibition.

Following Josephine's death, Redouté faced financial difficulties. He offered subscriptions to *Les Roses*, thirty albums that appeared from 1817 to 1824, to preserve the empress's legacy of her favorite flower, but this venture did not benefit from the sort of royal

patronage that had assured the financial success of his earlier works. In order to sustain his publishing projects, Redouté offered private painting lessons to the Queen Marie-Amélie and other members of the Orléans court and sold paintings of bouquets of flowers, in addition to performing his duties at the museum. At the end of his career, he turned to lithography as a less expensive means to publish his works; nonetheless, he was forced to sell his properties, including his own garden, to alleviate his debts.

While Redouté's personal fortune declined, his influence grew. His engravings inspired his fellow painters and spurred the dissemination of floral motifs in the decorative arts. In the third room of the exhibition, a wide variety of objects – including fans, Sèvres porcelains, luxury textiles, and amazingly delicate *porte-bouquets* – attest to the fact that Redouté's publications contributed to the rejuvenation of French manufactures. The final room of the exhibition is dedicated to the development of the silk industry in Lyon under the direction of Jean-François Bony (1754–1825). The floral motifs that served as models for both textiles and wallpapers are displayed in a number of formats, and their significance is fully developed in the catalogue by Audrey Millet.

Redouté's delicate gouache of *Rose trémières, raisins et le lori cramoisi* (1836) testifies to his mature artistic accomplishments; ironically, despite his participation in the annual Paris Salons, his gouaches did not receive official recognition by the artistic community. After 1824, however, Redouté offered annual classes at the natural history museum that encouraged the next generation of flower painters – many of whom were women. Essays by Nicole Biagioli and Séverine Sofio effectively suggest that Redouté's legacy can be traced to this generation of women painters, who entered career paths in the applied arts and disseminated floral imagery.

Two works on display also demonstrate his effect on his peers. Pierre Paul Prud'hon's depiction of the Imperial crown flower in *Portrait of the King of Rome* (1811) was surely influenced by Redouté's illustration of the same plant, and in *Flora caressed by Zephyr* (1802), Francois Gérard's precisely painted blooms were clearly inspired by Redouté's example. *The Power of Flowers* and its erudite catalogue vividly demonstrate Redouté's singular contribution to both botanical illustration and flower painting, reminding us why he is celebrated today as the Raphael of Flowers.
– Susan Taylor-Leduc

Contributors

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Dan Flores is a professor emeritus of history at the University of Montana and the author of ten books – most recently *Coyote America* and *American Serengeti*, both published in 2016. *Coyote America*, a *New York Times* best seller, won the Sigurd F. Olson Nature Writing award and was a finalist for PEN America's E. O. Wilson prize. *American Serengeti* received the 2017 Stubbendieck Distinguished Book Prize. Flores is a resident of the Galisteo Valley near Santa Fe, New Mexico.

Roger F. Pasquier grew up playing in Central Park. He studied art history at Columbia and the University of California, Berkeley. A lifelong bird-watcher, he spends hours in Central Park all through the year. During a career in ornithology and conservation, he has worked at the American Museum of Natural History, the Smithsonian Institution, the Environmental Defense Fund, the National Audubon Society, and other national organizations. In addition, he has written several books on birds and art history – most recently *Painting Central Park*, which is about the many major American painters who have been inspired by the park's landscapes and recreational activities. Pasquier is currently writing a book on the ecology and behavior of birds in winter.

Annie Novak is founder and director of Growing Chefs, a field-to-fork food-education program; the manager of the Edible Academy at the New York Botanical Garden; and co-founder and farmer of Eagle Street Rooftop Farm in Greenpoint, Brooklyn. She is the author of *The Rooftop Growing Guide: How to Transform Your Roof into a Garden or Farm*, published by Ten Speed Press. Her current project is an illustrated book about the nocturnal migration of birds.

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Frederic C. Rich, former partner and now of counsel to the law firm Sullivan & Cromwell LLP, is the author of *Getting to Green: Saving Nature: A Bipartisan Solution* (Norton, 2016). His 2013 dystopian novel, *Christian Nation* (Norton), forecast that a demagogic populist would defeat Hillary Clinton in the 2016 presidential election. He serves on the advisory board of a bioethics think-tank, The Hastings Center. His next book, a novel, involves the de-extinction of a Neanderthal.

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John Waldman, Ph.D., is a professor of biology at Queens College in New York City. Previously he had a twenty-year career at the Hudson River Foundation for Science and Environmental Research. He is the author of *Heartbeats in the Muck: The History, Sea Life,* and *Environment of New York Harbor* and *Running Silver: Restoring Atlantic Rivers and their Great Fish Migrations*, and the editor of *Still the Same Hawk: Reflections on Nature in New York*.

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