Chapter 1

Squandering Our Natural Wealth

Any foolish boy can stamp on a beetle, but all the professors in the world cannot make a beetle.

—Arthur Schopenhauer

Thousands of people travel around the world each year and pay vast amounts of money to witness one of nature's most awesome dramas: the great migration on the East African plains, from the Serengeti into the Masai Mara and back. Over 2 million wildebeest and other ungulates and their predators migrate with the seasonal rains, and Earth itself seems to shake with the sheer weight and force of wild animals on the move. Looking on from a safe distance, we suddenly feel small. We marvel at the power of nature. Few people realize that such massive migrations of wild animals once took place all across the world, as recently as a few decades or a few centuries ago.

While living in Kenya for almost 10 years, my family and I witnessed firsthand how nature is still breathtakingly rich. However, we also realized how the former continental-scale migration arena for wildlife such as the African elephant has shrunk to a few haphazardly connected national parks. I remember visiting Amboseli National Park during a prolonged drought and seeing a large herd of elephants, numbering over 100 animals, shuffling around in the bone-dry soil, and kicking up enormous dust clouds. In past centuries, they would have migrated north or west during droughts

until they reached a more suitable habitat, returning to the foot of Kilimanjaro only with the next rains. However, in East Africa today, there are few migration corridors left, and many elephant families have lost the experience of migrating long distances and the knowledge of the best routes. The matriarchs of these families once possessed a deep understanding of the migration routes and the wisdom of when to make a move, which they had accumulated over the course of their long, migratory lives. In recent decades, poaching, habitat fragmentation, and human-wildlife conflicts have severely limited their range, not only geographically but also mentally: They have lost the knowledge of how to navigate in landscapes that are now full of fences, roads, and settlements. Their loss of a mental map limits how far they dare to venture.[1] Africa is not the only place where nature is just a shadow of her former diversity and abundance.* Much of our natural heritage has disappeared across the Americas, Europe, Asia, and Australia, and we no longer remember how immensely rich we once were.

Restoration in One Generation

Despite all we have lost, with the right political will, finances, and knowledge, we can regain a diverse and abundant natural world within one generation. This is our generation's moonshot or, rather, our "Earthshot," as Prince William fittingly calls his global initiative to award innovators in this space. Ecosystem restoration is not about a longing for the past. Rather, it is the only way forward that will allow us to enjoy a life in abundance and diversity

*Careful readers will note my use of female pronouns, "her" and "she," for "nature" and "Mother Earth." As I discuss in more detail in Chapter 5, using "it" would indicate that nature is a thing or a commodity, which nature most definitely is not.

for generations to come, because our wealth, health, and well-being all depend on nature. We are the first generation that has the global perspective, knowledge, and tools—including sufficient finances—to rebuild nature as our most critical planetary infrastructure. Yes, there are some trade-offs between space for wildlife and space for humans. But there are far more win-win opportunities where more biological diversity creates more abundance for both wildlife and humans. We read about some of those cases in the second half of this book. And ecosystem restoration is as much about people as it is about nature. Countless examples show where the degradation of nature has impoverished people and where ecosystem restoration will trigger a restoration of local communities and the economy.

Innovation, imagination, and collaboration are the keys to this collective challenge. Despite the moonshot analogy, there are some key differences between restoring Planet Earth and the Apollo space program. The legendary inventor, architect, and futurist Buckminster Fuller once said that "there is one outstandingly important fact regarding Spaceship Earth, and that is that no instruction book came with it."[2] While I appreciate Fuller's quirky humor, Earth is in fact nothing like a spaceship. Earth is more complex, sophisticated, and marvelous than any spaceship we could ever build. Earth is a living system, and we are a core part of that system. The good news is that Earth's systems are not only self-contained but, for the most part, also self-repairing. Earth has immense self-healing powers. To activate them, we need to understand the basic principles of Earth's systems and life cycles. Because, for better or worse, we are the crew of Spaceship Earth, and we need to learn more about this tiny blue and green marble, our only home on which we are hurtling through space. Escaping to Mars is not an option.

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Squandering Our Natural Wealth

Before we can move on to build a new relationship with nature, we must take a hard look at the damage we have done and continue to do. Our study of Spaceship Earth begins with an understanding of nature's original wealth and abundance. In the next section, we look at lessons from stories of some ecosystems and species that are disappearing under our watch.

Nature Gone Bust

If you had been a passenger on one of the many ships that took European settlers to the New World in the 17th or 18th century and you were headed to the Caribbean or New York, your ocean passage would have been accompanied frequently by pods of dolphins swimming alongside your vessel and different species of whales spouting at all longitudes—from sperm whales to gray whales, humpbacks, and North Atlantic right whales (named, by the way, for being "just right" for commercial hunting: large, moving slowly, and staying afloat when harpooned).[3] Getting closer to shore in the Caribbean, your sleep would have been constantly interrupted by the thuds of sea turtles crashing into the wooden hulls. The Spanish priest Andrés Bernáldez (1450–1513), a chronicler and contemporary of Christopher Columbus, for instance, wrote in 1494 about Cuba's sea turtles: "The sea was all thick with them, and they were of the very largest, so numerous that it seemed that the ships would run aground on them and were as if bathing in them."[4] So plentiful were these magnificent creatures at that time that ships carried limited provisions of meat because they could easily catch large numbers of sea turtles and store them on board, scooped up from the sea or caught on islands during their journey.[5] Kept alive on board, their meat would stay fresh.

If you were bound for New York and you disembarked at what today is New York Harbor, your eye would have met crystal clear waters that were filtered at least once a day by giant banks of oysters,

covering almost 220,000 acres (90,000 ha)—about the size of 180,000 football fields—home to probably more than 300 billion oysters.[6] As one oyster can filter up to 50 gallons (190 l) of water daily, the oysters were continuously filtering the entire coastal ecosystem. They were also feeding the fast-growing local human population. The oyster reefs provided habitat and food to a vast diversity of marine life, including seals, dolphins, whales, crabs, striped bass, and huge shoals of herring. Hundreds of species in the harbor enjoyed the benefits of the vast oyster habitat. The oyster banks almost wholly disappeared after overharvesting, and they have been gone for more than a century now.[7]

In his book *The Big Oyster*, Mark Kurlansky writes:

> Before the 20th century, when people thought of New York, they thought of oysters. This is what New York was to the world—a great oceangoing port where people ate succulent local oysters from their harbor. Visitors looked forward to trying them. New Yorkers ate them constantly. They also sold them by the millions, supplying Chicago, St. Louis, Denver, and San Francisco, but also shipping to England, France, and Germany.[8]

Today, New York has to import its oysters. The city's last commercial oyster bed closed in 1927. Around the world, 85 percent of all oyster reefs have been lost over the last 200 years. Today's oyster populations in the Hudson-Raritan Estuary are less than 0.01 percent of what they once were in New York Harbor.[9] After the last oysters had been eaten and industrial shipping increased, the waters of New York Harbor and the mouths of the East River and Hudson River became murky because of untreated sewage. They are now almost devoid of life. With the disappearance of oyster reefs, the city and coastline have lost one of their most crucial storm and flood defenses. It takes a vivid imagination to see the lost universe of teeming life behind this now-lifeless

and polluted body of water. Most people visiting New York today probably think it has always been this way. In reality, the cycle of life has come almost to standstill in the waters around the city.

The Flywheel of Life

Nature basically works like a flywheel, which needs critical mass and speed. Nature becomes more powerful, stable, and resilient the more life and diversity we add. For the past few centuries, since the first Industrial Revolution, most of human efforts have been targeted at slowing down nature's flywheel for the purpose of controlling it. Monocultures, industrial agriculture, and overharvesting of natural resources all go against the fundamental principle in ecology that life and diversity produce more life and diversity. Therefore, the most important thing we can do for ecosystem restoration is to start the process of increasing the diversity and abundance of life. A local initiative is about to do just that for the oysters in New York Harbor. The Billion Oyster Project wants to restore oyster banks around Governors Island and other former sites around the Upper Bay and the river's estuaries. The project releases over 50 million small oysters each season, anchoring them in their former habitat. Millions of oysters have already established themselves in the wild. Despite obstacles such as bad water quality and a lack of funding, the project forges on.

And the momentum is growing, thanks to the enthusiasm of schools, restaurants, ecopreneurs, and investors. The Billion Oyster Project is now part of the curriculum, both in theory and in practice, of more than 100 public school campuses across New York City, mostly middle and high schools, as well as a growing number of schools in northern New Jersey. Once oyster populations become self-sustaining and begin to reproduce on their own in significant numbers, they will be able to form sustainable reefs that support

ongoing reproduction and habitat creation. They would start to filter large amounts of water, and their sturdy banks would once again provide storm protection, habitat, and food for fish, birds, and marine mammals. Once we make a strong and intentional start, nature herself will do most of the heavy work. Life could return to the waters around the Big Apple in breathtaking diversity and abundance. Let us now look across the Atlantic at another example of a drastic decline in once-abundant wildlife under our watch.

Meet the European Eel

For centuries, the European eel was the most important commercial fish species in European estuaries. However, following a loss of 95 percent of the entire population over just the past 30 years, the species has recently been categorized as critically endangered in the International Union for Conservation of Nature Red List of Threatened Species.

You might think of eels, if you ever think of them at all, as very slippery (they are!) and perhaps not very good to eat. They are, in fact, delicious, in particular as smoked eel on toast. Eels are medium-sized fish up to 3 feet (1 m) in length and can live up to 20 years in the wild. In my youth, I used to catch eels in a lake near our house. During summer, we would sit around a campfire and wait for eels to take our bait, triggering the little bells we had attached to our fishing lines. To understand what went wrong between us humans and the eel, it is worth a short excursion into the life of *Anguilla anguilla*, which has one of the most fascinating biological cycles in the animal kingdom.

Eels spawn only once in their lifetime, and it was a mystery for centuries where and how they reproduced. In 1922, Danish researcher Johannes Schmidt identified the Sargasso Sea in the western Atlantic as their spawning grounds. The Sargasso Sea is a vast ocean gyre located between Bermuda, the Bahamas, and

the southeastern coast of the United States, more than 3,100 miles (5,000 km) from the European coast. When eels sexually mature, their bodies turn a silvery color, and they start their journey from their freshwater and brackish habitats toward the Atlantic Ocean, never to return. Depending on their departure location in rivers, ponds, and lakes across Europe, some eels travel up to 6,200 miles (10,000 km) to get there. They migrate from the freshwater of lakes and rivers toward the coast, into the brackish water of estuaries, and then into the salt water of the ocean. It is assumed that they navigate by Earth's magnetic field. They can breathe through their skin and live on land for extended periods, moving like snakes across fields, preferably during rain or when the fields are still wet from dew. They often live in landlocked ponds and lakes, and to reach the ocean, they sometimes must travel long distances across land to migrate into rivers and streams, which has given rise to many folk tales about their supernatural abilities.

Once they reach the ocean, they start an epic journey westward across the Atlantic, which can take up to one year. During their journey, they no longer eat. Instead, their intestines are transformed into reproductive organs, which are not fully developed before they start their migration. Upon arriving in the Sargasso Sea, they spawn, often at depths of up to 500 feet (2,000 m) and then die. The tiny eel larvae now start an epic journey of their own: They drift with the Gulf Stream eastward, back toward Europe, a trip of up to 300 days. During their Atlantic crossing, they feed on plankton and other marine biomass and grow into small fish, but they are still translucent when they arrive at the southeastern coast of Europe and the Mediterranean, which is why they are called "glass eels" at that stage. From the coast, they start their journey back upstream into even the remotest freshwater bodies of Europe.

The more than 90 percent drop in population size over the past few decades did not happen due to sport fishing, such as my

occasional catch of an eel in my youth. Industrial fishing fleets in the Atlantic and Mediterranean catch the translucent glass eels in large quantities, mainly off the coasts of Portugal, Spain, and France, for export to aquaculture worldwide and in particular to Asia, where these eels are considered a prized delicacy. Prices for glass eels soared to 6,800 USD per pound (15,000 USD per kg) in Japan recently. So highly prized is this once-common fish that it has caught the interest of organized crime. The Convention on International Trade in Endangered Species places heavy restrictions on the export of eels, and the annual illegal trade in European eel is estimated to be worth up to 3 billion USD per year.[10] On October 28, 2019, French police arrested two people on their way to Kunming, China, with 300,000 live glass eels in their luggage, in water-filled plastic bags, weighing 200 pounds (91 kg) and worth over 110,000 USD (100,000 euros).

During my lifetime, from my childhood years fishing for eels in our local lake without a care in the world to today, a once-abundant wild animal has turned into a rare and smuggled commodity. Countless other species have met the same fate within the same short time. In the past, fisherfolk or hunters used to just move on to the next species, the next ecosystem, the next exploitation. However, we have reached the end of the road where we can recklessly consume nature to build more financial capital. The blank checks we issue on behalf of nature are starting to bounce. There are few pristine ecosystems left to plunder—the deep sea being one of the few. Yet even the deep sea is no longer safe from our liquidation of its natural capital. A concerted global effort is underway to erode a UN ban on deep-seabed mining, and industrial-scale mineral extraction plans exist across many ocean habitats.[11] The current plan to mine the deep ocean and the trawling of the bottom of the sea for the last remaining fish are in stark contrast to the fact that the ocean was once teeming with life.

Harvest Season

In my home region of northern Germany, much of the year's cultural calendar is based on former animal migrations. The mass migration of herring in their billions along the coast, for example, caused entire villages and towns to shut down for days because everyone was busy catching, drying, and wood-smoking enough fish to last throughout the year. For hundreds of years, the arrival of whales, dolphins, tuna, and sharks, which trailed the herring migrations, triggered a monthlong fishing frenzy among the human populations along the coasts of Northern Europe, North America, and northeastern Asia each spring. Fall and spring also marked the arrival of millions of migratory birds in the Northern Hemisphere. People caught them by the hundreds of thousands in specially constructed duck decoys, and they provided an essential source of protein. For example, in one specially constructed duck decoy in my home region on the island of Fohr in the Wadden Sea, an ecologically essential tidal estuary for migrating birds on the East Atlantic flyway, an estimated 3 million wild ducks were caught and killed between 1730 and 1983.[12] Dozens of such large-scale duck decoy constructions existed along the coast of the Netherlands, Germany, and Denmark.

In late spring each year, when the salmon run began, people would flock to the rivers and catch salmon and other migratory fish, such as the giant Atlantic sturgeon. This once-abundant fish is now critically endangered. Sturgeons can reach 20 feet (6 m) in length and weigh up to 880 pounds (400 kg). The last remaining large sturgeons in my home province of Schleswig-Holstein were caught in the 1950s.[13] Once a common sight and catch in the North Sea and all major European rivers, sturgeons are now so rare that they spawn in only one river in France. The decline of the sturgeon played out over several decades. The collapse of other species took centuries, so we often do not remember how rich our natural heritage once was.

We lack the ability to perceive the loss of nature at an intergenerational pace. Yet, for nature, it happens in a heartbeat. We are losing species too fast for nature to adjust, at an estimated rate 1,000 times faster than the natural rate of species extinctions, but apparently that is still too slow for us to notice. In Earth's geological history, there have been five confirmed mass extinction events, which basically sent evolution back to the drawing board. Some were caused by volcanic eruptions, some by meteorites, and some due to unknown causes. We are now entering the sixth geological mass extinction event, this time caused by us. Even when there is photographic evidence, as in our next story, we don't seem to notice the steady decline of nature until it might be too late.

Shifting Baseline Syndrome

In the early morning of April 14, 1957, three tourists set out on a small chartered fishing boat, the *Gulfstream II,* from the docks of Key West. They were heading for the rich belt of coral reefs off the Florida coast, where they would spend the whole day fishing. For all we know, it was a successful and happy day, judging by the photos taken upon their return, with the day's catch neatly displayed on a special mount at the docks next to the beaming recreational fishermen. The happy hobby fishers and their skipper are posing proudly next to more than 20 large fish of several species hanging from the display board and lying at their feet, including a shark almost 6.5 feet (2 m) long and a goliath grouper larger and presumably heavier than the burly captain.

Over the next 50 years, the same charter company continued to operate fishing tours in the same waters, with the *Gulfstream II* being periodically refurbished. A photo of each trip was taken in the same way, proudly displaying the day's catch. In 2008, Loren McClenachan, a researcher from the Scripps Institution of Oceanography in California, had the opportunity to analyze the entire collection of photos from

1957 to the 1980s, and she took similar photos for comparison in 2007.[14] Her findings are striking. For the 13 groups of most frequently caught trophy reef fish, the average fish size declined by almost 90 percent from an estimated 44 pounds (19.9 kg) to 5 pounds (2.3 kg) over 50 years. Between 1956 and 1960, large groupers and other large predatory fish, including sharks over 6.5 feet (2 m) in length, were commonly caught (see Figure 1.1.). In contrast, by 2007, only small snappers with an average length of 1 foot (34.4 cm) were landed (see Figure 1.2.). Sharks were still caught occasionally, but their average length declined by more than 50 percent. Despite a drastic drop in fish size, variety, and numbers, the company still charged a high price for fishing trips, but customers paid for a much less valuable product.

Figure 1.1 Happy fisherfolk at Key West, Florida, in 1957. Credit: Monroe County Library

Figure 1.2 Happy fisherfolk in 2007 at the same location, with the average catch size reduced by 90 percent.
Credit: Monroe County Library/Loren McClenachan

What I find most striking about the long-term photo series is that the groups of fishermen and the occasional fisherwoman look equally happy in each photo. They all beam into the camera as if they had just landed the world's best and biggest catch. Imagine if the crew of another charter boat next to them displayed a much larger variety of fish species, at almost 10 times the average size. Our teams would demand their money back. But because there is no immediate comparison to what they have lost, they are blissfully unaware of the steep decline in our natural wealth. They look just as happy in 2007 as in 1957. If this delusion were just a case of a few people's—or even the general public's—complacency with the current state of nature, it might be more humane to keep everyone ignorant about how much we have lost. If you agree, you probably should skip to the next chapter.

A psychological phenomenon called the "shifting baseline syndrome" keeps us buffered from some of the grief or anger we might otherwise feel because of the immense loss of what once was ours and everyone's: seemingly unlimited natural abundance.

However, the shifting baseline syndrome is not merely a mental defense mechanism for coping with the effects of biodiversity loss. It is also a form of self-deception that can lull us into a false sense of security regarding the pace of environmental degradation. It makes us underestimate the looming tipping points at which sudden and drastic changes in ecosystems can occur. It leaves us in the dark about the immense original potential of intact nature and functioning ecosystems to feed, clothe, and shelter humanity as well as to contribute to our recreational and spiritual fulfillment. The shifting baseline syndrome is keeping us poorer, hungrier, and less healthy than we are supposed to be. It is time to reset our original baseline and our future expectations of natural wealth. We should both remember and demand a diverse, abundant world that is rich, fertile, and full of life, because that is how nature is supposed to be and is waiting to be again. Abundance is the true nature of our natural heritage.

Tipping Point

Most of us take the current degraded state of our environment for granted. We redefine what is "natural" with each generation, and our particular state of degradation becomes the new normal. But that is only part of the story. Ecology and ecosystems rarely work in linear ways. Nature moves in leaps and bounds, and Earth's complex life system has many known and probably even more unknown ecological tipping points. To better understand tipping points in nature, imagine a large round boulder resting in a slight depression on a hillside. The boulder represents an ecosystem, such as a forest. When something tries to move and dislodge it, such as a storm or a grizzly bear rubbing

against it, the boulder might shift slightly, but the depression it rests in keeps it in place. After minor disturbances, it returns to its resting place. That is called "resilience": bouncing back into a predetermined state of equilibrium. However, when the force moving the boulder is strong enough to push it over the slight edge of its depression on the hillside, the boulder will start to roll downhill with considerable speed and force, until it settles in a new stable location.

The same thing can happen to ecosystems. When their initial resistance to disturbance is overcome and they are pushed over the edge of their natural resilience, they undergo rapid changes, referred to as "tipping points," and their new resting place is farther down the hill of ecological complexity, where they settle into a new equilibrium of birth, growth, and decay. When triggered, such tipping points can suddenly and sometimes irreversibly flip an ecosystem from a diverse and resilient state into a degraded state. The Amazon forest biome, for example, could flip from a moist forest ecosystem into the degraded state of a savannah woodland if it goes beyond approximately 25 percent of deforestation.[15] The warning signs that an ecosystem is close to a tipping point are often overlooked, such as in the case of New York oysters. For much of the 19th century, untreated sewage flowed directly into the waterways, smothering oyster reefs with sediment and toxic runoff. In the early 20th century, New York Harbor was a source of epidemics of typhoid, cholera, and other waterborne diseases due to sewage overflows and industrial waste.[16]

When it comes to the warning signs of our planetary life support systems, we are like the proverbial frog sitting in a pot of heating water. A frog thrown into hot water will immediately jump out again, but a frog that sits in a pool of cold water that is slowly being heated until boiling point will remain there until it dies. (I have not tried this experiment with an actual frog and hope you won't either.) We simply don't realize that we are headed for a point of no return, possibly leading to sudden collapse, because the change is too gradual for

our perception within human time frames until it dramatically accelerates. However, we now have clear indications that the intricate web of life is starting to tear at an unprecedented speed. The latest research highlights nine active global-scale ecological tipping points, including ice sheet collapses in Greenland and western Antarctica, the Amazon forest dieback, the permafrost thaw, and the potential collapse of the northern Atlantic Ocean circulation, which provides Europe with its mild climate. A 2025 study estimates a 62 percent average probability of triggering these irreversible tipping points unless we change current policies.[17] We should avoid at all costs letting these systems tip over the edge, which would be irreversible in human time scales. Even before we get there, the great unraveling of our planetary life support systems is already harming even nature's most versatile and resilient species: human beings. And sometimes we cannot return from a tipping point, as these next examples show.

Tipping Points of No Return

Although most of nature's once highly productive ecosystems can be set on a path to recovery—and many of them can even rebound surprisingly quickly, as we see in later chapters—some may be lost forever, or recovery is at least out of reach for many human generations. A study in 2008 predicted that a major population of Atlantic cod near Newfoundland, Canada, would essentially go extinct within 20 years, despite total fishing bans implemented after the collapse of the North Atlantic cod fishery in the early 1990s.[18] For centuries, cod fishing had been the primary economic driver of entire coastal communities. After decades of overfishing in the second half of the 20th century, the cod population suddenly collapsed around 1993, plummeting to less than 1 percent of its original size, which might be too small to recover despite the fishing bans. Even more than 30 years after fishing ceased, the population still shows no signs of recovery. It has gone

over a tipping point, and the marine ecosystem has reset itself into a new form of equilibrium. Rolling that giant boulder back uphill seems impossible for the North Atlantic cod, at least within our lifetime.

Another ecological tipping point that is becoming more frequent is the large-scale dying of coral reefs caused by marine heat waves. Spikes in ocean temperature can kill off entire reefs, turning them from lush, colorful havens of biodiversity into monochrome, dead rocks within a few weeks. According to Terry Hughes, a coral reef scientist at James Cook University in Australia, over 54 percent of the world's coral area experienced bleaching-level heat stress in 2023. And the highest ocean heat in four centuries is now even putting the iconic Great Barrier Reef at risk.[19] However, despite clear warning signs, it took the drastic step of UNESCO's World Heritage Commission putting the Great Barrier Reef on the list of World Heritage Sites in Danger to move the Australian government into action. The government is taking additional measures, such as banning gill netting and setting water quality targets. Whether that is too little, too late, or just in time remains to be seen.[20] What is certain is that without drastic emission reductions to slow down ocean warming caused by climate change, the future of the world's coral reefs looks bleak, and their death could happen fast if we let them tip.

Some tipping points unfold over years or decades, which is still lightning fast compared to nature's usual geological time frames. For example, as recently as 200 years ago, an estimated 60 million American bison once roamed the Great Plains of the United States and Canada, feeding and continuously renewing a grasslands ecosystem so rich and productive that it provided everything First Nations peoples needed, feeding hundreds of thousands before the arrival of European settlers. Because the American bison provided much of the food, hides for clothing and shelter, and horns and bones for tools for the traditional lives of Native Americans, military powers of the time recognized that for a clear and decisive victory over resisting tribes,

the buffalo had to be destroyed. Deliberate mass killings of buffalo were used as a weapon of war. The vast buffalo population was systematically exterminated until only 541 animals were left by 1889.

In his essay "The Frontier Army and the Destruction of the Buffalo," David Smits writes that the successive generals-in-chief of the US Army, William T. Sherman and Philip H. Sheridan, both recognized that "eliminating the buffalo might be the best way to force Indians to change their nomadic habits."[21] With nature's demise, indigenous peoples could be forced more easily into subjugation and settlements. The land that was thus "freed" by hunters armed with guns and by the military from both buffalo and Native Americans could become agricultural land. However, the large-scale plowing and tilling of the former Great Plains grasslands triggered another ecological and social tipping point a few decades later, resulting in widespread harm to the region's settlers and residents, as we see in the next section.

The Great Dust Bowl

Humanity has learned important lessons from several large-scale ecological tipping points in recent history. One of the best examples of a tipping point caused by human mismanagement, which was later at least partially mitigated and restored by human intervention, is the settling of the American Great Plains Region. The Great Plains covers a portion or the entirety of 10 of the United States: Texas, New Mexico, Oklahoma, Colorado, Kansas, Nebraska, Wyoming, South Dakota, North Dakota, and Montana. These areas were settled by immigrant farmers mostly in the second half of the 19th and the early 20th century. The Homestead Act of 1862 granted 160 acres of land to settlers who would live on and cultivate it for five years. This act, along with the Kinkaid Act of 1904 and others, spurred hundreds of thousands to claim land across the plains. However, the plowing of

grasslands, which held the soil in place, greatly disturbed the delicate equilibrium of this vast ecosystem.

In the late 1920s, massive sand and dust storms started to occur over the Great Plains region of the United States, plunging the region into a health and food crisis. Widespread soil erosion due to a combination of severe drought, poor farming practices, and overuse of agricultural soils was causing an ecological disaster that would, over the next two decades, cause one of the largest internal human migrations in US history.[22]

The Great Plains are an ecosystem that has evolved over thousands of years with a balance of grazing, fire, and renewal of grasses. The grasses, such as buffalo grass, are mostly perennials, with deep and complex root systems that could survive prolonged drought, occasional fire, and heavy grazing pressure while at the same time stabilizing the soil. A tiny bit of soil is added each year through dissolving bedrock and through the decomposition and mineralization of organic matter. Forming fertile soil is a process that can take hundreds or even thousands of years, especially in dry conditions, and yet, if the land is not taken care of properly, large amounts of topsoil can be eroded by wind or water in mere hours or days.

In the late 19th and early 20th centuries, the US government encouraged settlers to move west into the Great Plains and plow the grasslands to plant annual crops, such as wheat or corn. This plowing destroyed the deep-rooted, complex underground structure that kept the soil in place. When a severe drought hit the region in the 1930s, the exposed fertile topsoil was swept away by powerful winds, creating massive dust storms. The area hit worst by wind erosion centered around the Oklahoma and Texas panhandles, covering 16 million acres (6.47 million ha) of farmland,[23] an area the size of the US state of West Virginia. The "Black Sunday" storm of April 14, 1935, for example, brought visibility down to near zero and total darkness in the middle of the day across much of the state of Oklahoma.[24]

The economic and social damage from this mismanagement of nature remains immense. Based on the assumption that half of fertile soils on an area the size of Iowa were lost in the 1930s and since then only partially recovered, it is estimated that the United States has lost at least half a trillion US dollars in economic output between 1930 and today.[25] This significant, transgenerational loss resulted from the lack of basic ecological literacy among decision makers. Ironically, the prairies could have been sustainably settled by a large number of farmers if they had practiced no-till agriculture and rotational grazing. Instead, the ecological tipping point was quickly followed by a negative social tipping point: As the ecological foundation for society crumbled, lives and livelihoods were severely disrupted, causing widespread human suffering.

Beyond the direct economic damage, the human suffering and property damage caused by the ecological mismanagement of the Great Plains in the 1920s and 1930s were immense. In addition to the erosion of fertile topsoil, the dust storms buried homes, businesses, and roads; killed livestock; and caused widespread respiratory problems, including the so-called dust pneumonia that affected an estimated half a million people during the Dust Bowl.

In his iconic novel *The Grapes of Wrath*, John Steinbeck describes the plight of a family of sharecroppers, the Joads, who leave their home in Oklahoma and migrate to California, where they face severe hardships in the harsh economic climate of the Great Depression. Almost 2.5 million people who migrated during the Dust Bowl from the Great Plains to the American West, mainly to California, may have faced a similar tragic fate.[26] I stress the link among the economy, human suffering, and ecology here because the Dust Bowl is one of the best-documented and most extensive case studies where basic ecological literacy could have saved and improved millions of lives and secured trillions of US dollars in economic value. Numerous similar examples in our past exist from all regions of the world.

Present-day examples include the ongoing destruction of the world's rainforests and destructive overfishing and pollution of the ocean, against all long-term economic reasons. Running our economy without basic ecological literacy is like driving at night without headlights at high speed and hoping not to crash into anything.

On the positive side, the Dust Bowl disaster also ushered in an era of increased understanding of soil conservation and focused government action. Techniques such as contour plowing, planting hedgerows to limit wind erosion, and using native grasses all helped to stabilize soils. The Great Plains Shelterbelt project began in 1934 to stop wind erosion with rows of trees, and, by 1942, it had planted 220 million trees, covering 18,600 square miles (48,000 km^2) in a 100-mile-wide zone from the Canadian border to the Brazos River in Texas.[27] All these actions helped to slow the degradation of additional areas. The Dust Bowl offers many valuable lessons for the threat of climate change we face today, including how fast and effective concerted government action can be if we muster the political will. If we learn from the ecological disaster of the 1930s and heed ecological alarm signals early enough, we can repair and maintain the health and functionality of natural carbon and water cycles, particularly in the soil. How we manage soils, given their fundamental role in the global water and carbon cycles, can either stabilize our Earth in its distress or send us even faster into a tailspin. We return to the essential role of soils for humanity in Chapter 8. Let us now dive into the critical role of the ocean for Planet Earth.

Whales to the Rescue

In the 21st century, we may be further removed from an abundant natural world than at any point in human history. Blue whales, for example, the largest animals ever to live on our planet, number only about 25,000 in the world today. Historical blue whale population numbers are hard to quantify. Still, we know that an estimated

360,000 of these majestic animals were killed in the first half of the 20th century alone, almost driving the species to extinction.[28] Blue whale numbers are slowly increasing again since commercial whaling was largely banned in 1986, but it will take many generations for the population to reach more than the current small fraction of about 1 percent of its former population size before the beginning of large-scale commercial whaling in the 17th century.[29]

The disappearance of most blue whales and other large whales from much of the ocean has triggered a ripple effect on the entire marine ecosystem, an effect we have only recently begun to understand. Whales are *ecosystem engineers*: an essential species that shapes entire landscapes and seascapes and on which many other species depend. Whales distribute nutrients and carbon from the depths of the ocean to the surface, and vice versa. They spread essential nutrients and minerals like iron from the relatively small areas of high nutrient upwelling in the open ocean or near seamounts to the vast nutrient-poor ocean deserts that make up the majority of open water. Whales feed in areas where upwelling occurs. When they migrate away from these ocean meadows, they fertilize other areas with feces and urine. In a fantastic feature of over 3.5 billion years of evolution, phytoplankton, the base layer of much of the ocean's food chain, need precisely the mix of nutrients present in whale excrement. This biological stirring of the ocean stimulates and feeds an entire ecosystem of plankton, fish, seabirds, and marine mammals. The whales create islands of life spread across the open ocean.

The loss of whale populations and their migrations across the ocean led to the loss of a critical biological pump of nutrients and carbon, both across the expanse of the ocean and from its depths to the surface. We have lost much of the former richness of many fishing grounds, let alone their vital function of binding carbon dioxide (CO_2) in the ocean depths. Living whales accumulate tons of carbon

in their bodies. When a whale dies and sinks to the ocean floor, the dead whale binds many tons of carbon for decades and feeds an entire deep-sea ecosystem. Whales also bring nutrients back up to the surface. Sperm whales, for example, dive up to 6,500 feet (2,000 m) deep, hunting for squid and other cephalopods. And whales spread nutrients when they defecate on their migrations across the ocean. The growth of phytoplankton caused by these nutrients is a highly effective way to draw down CO_2 from the atmosphere. The ocean already absorbs almost one-third of all annual CO_2 emissions through the photosynthesis of phytoplankton, drawing carbon down into the ocean depths when the plankton dies and sinks. Whales were once the primary catalysts for this marine cycle of life by distributing the nutrients for a vast carpet of phytoplankton across the ocean as the foundation for much of marine life. The absurdity of our common human mindset of scarcity versus the reality of nature's approach of abundance is demonstrated by the fact that, to this day, in some areas of the world, whales and dolphins are hunted because they are seen as competitors to human fisherfolk. In fact, they are one of the main reasons that there are fish in the first place.

In a 2023 study, Heidi C. Pearson from the University of Alaska and other scientists estimated that the direct and indirect carbon sequestration, fixation, and storage contribution of the world's great whale population each year is more than the equivalent of 90 million tons of CO_2, or roughly the same as the annual carbon sequestration of Germany's entire forest area. However, the same study estimates that historic whale populations, which were significantly larger, helped to absorb over 30 times more CO_2, a stunning 2.5 gigatons of CO_2e each year.[30] (A gigaton is 1 billion tons, an enormous volume of CO_2.) In other words, about 5 percent of all our current annual greenhouse gas emissions could be eliminated if we allowed whale populations to reach their historic numbers again. Only a few nations still hunt whales, and most whale populations show signs of

recovery. Unfortunately, whale species reproduce relatively slowly, and it will be many decades, if not centuries, before we reach a point where whales once again can give life to the entire open ocean and draw down carbon at a significant scale. The whale pump shows the immense power of nature to regulate and run Earth's carbon cycle—and the enormous risk we are taking by allowing our ecological life support systems and wildlife populations to plummet to their current levels. Our global economy seems to be on a self-destructive autopilot, aiming to extract as much monetary value from the living world as possible, until nothing is left. That autopilot has led us to disregard that we are losing altitude fast and are headed into dangerous territory. We can still take back the controls of Spaceship Earth before it is too late. Instead of escaping to Mars or plundering the deep sea, the last large, untouched ecosystem on Earth, let us rewrite the next chapter of our human drama and give it a happy ending, starting with ecosystem restoration.

Resilience Starts with Us

Even if you don't care about European eels or other recent examples of dwindling wildlife populations caused by overfishing, overhunting, or habitat destruction, you might care about the indirect impacts that our disregard for nature and ecology has on our lifestyle. The supply chains of everyday commodities, such as coffee, cocoa, and timber, are starting to disintegrate. After three years of bad harvests in West Africa due to drought induced by climate change, cocoa prices reached almost 10,000 USD per ton in 2024, five times the price of 2020. Other agricultural commodities are coming under similar pressure across the world. To continue to thrive as a civilization, we have to replenish our natural "bank account" and start to live off the interest that accrues from nature rather than burning through humanity's only true source of wealth and abundance.

Fortunately, with a recent global move beyond gross domestic product and toward measuring the true value of nature as part of inclusive national wealth and a growing movement to invest in nature conservation and restoration, this shift is starting to happen, as we see in Chapter 4. Nature-friendly and regenerative growing techniques, such as agroforestry or shade-grown cocoa and coffee, exist for many of our agricultural products. Regenerative agriculture holds the opportunity of higher nutrition, more farmer income, and greater food production on restored soil. We return to the topic of agriculture and our globalized, industrialized agri-food system throughout this book, because that system is the main driver of nature loss. At the same time, agriculture has the potential to become the greatest driver of nature restoration. Due to our current agri-food system and other drivers of nature loss, we live at a fraction of the natural wealth and health we and life on Earth are entitled to.

A 10 Percent World

Across all ecosystems and all biomes, we have lost most of the world's natural abundance in just the past 500 years. Today, only about 4 percent of the world's weight of mammals are wild animals; the rest are livestock and humans.[31] Since 1492, the world has been in an accelerating race to use up, or "liquidate," nature for short-term economic gain. We have burned, eaten, and chopped our way through much of our natural wealth: clean water, clean air, forests, wildlife, and fish. So much, in fact, that the share of nature per person on the planet has dropped by over 40 percent just between 1990 and today.[32] An estimated 66 percent of ocean ecosystems are now damaged, degraded, or modified, and one-third of all commercial marine fish populations are fished unsustainably.[33] Natural abundance, wildlife populations, and biodiversity today are only a shadow of the world's former natural wealth. In his wonderful essay "A 10 Percent World,"

J. B. Mackinnon explores the emerging field of historical ecology.[34] He argues that we live in a "10 percent world" when comparing today's natural abundance with Earth's recent geological past.

This statistic is not meant to be precise. From the perspective of the many species that have gone extinct since humans emerged, we live in a zero percent world. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services estimates that up to 1 million species may be threatened with extinction.[35] Some wildlife populations today are well below 10 percent of their natural range, and some are even below 1 percent. And a few are starting to make a cautious comeback, such as beavers, bison, and wolves in Europe, or the bald eagle in the United States, which had a phenomenal comeback through better protection after near extinction in the 1970s.

It is hard to determine a precise percentage of loss across all types of ecosystems and all species. Coral reefs are dying back at record rates and might completely disappear with global warming reaching 2°C or more, the upper limit for global warming that was set in the Paris Agreement on Climate Change, somewhat arbitrarily, as a "safe limit" for human civilization to operate on Planet Earth. Yet more than 50 percent of the world's original forest cover still exists from before the Agricultural Revolution, thankfully, and forest area is on the increase in Europe, China, and other regions, even though forests are still being lost at an alarming rate in most of Africa and South America.[36]

Providing a precise global statistic for the status of all of nature is not the point here. As J. B. McKinnon points out, "Imagination is not a game best played between columns of data. What is the taste, smell, and feel of a wilder world?" We currently live on a fraction of nature and our own potential, and I use the term "10 percent world" as a metaphor for our self-inflicted nature poverty. Living in a 10 percent world severely curtails human creativity, health, and well-being. It clearly limits our economic and social development.

We can move from a 10 percent world—a world where only a skeleton of our natural riches remains, and we are picking at the bones—to living once again in a 100 percent world. It is the only way for us to maintain a life in abundance in the long term. Fortunately, there is some cause for optimism.

Staging Nature's Comeback

One piece of good news is that nature conservation and restoration are highly effective when done right. Recently, there have been signs of some species recovering, particularly mammals. A study in 2023 by the Zoological Society of London, BirdLife International, and the European Bird Census Council revealed that of 50 European species studied (25 mammals, 24 birds, and 1 reptile), almost all showed an increase in population size and range. The most stunning recovery was observed in European beaver populations. Once hunted almost to extinction, the beaver population has increased by 16,000 percent (160 times) over the past 30 years in the 95 locations that were studied.[37] Similarly, Eurasian wolves, European bison, and red deer are all making a comeback. At the global level, a study in *Science*, the world's most respected scientific journal, showed that conservation efforts are working in two out of three cases when the researchers reviewed evidence from 665 trials from 186 studies conducted between 1890 and 2019 across various countries, oceans, and species.[38] Although that is good news for some mammal species, we still see downward trends in insect populations, with an up to 75 percent drop in the last five decades across Europe, and half of all the world's bird species are now in decline.[39,40] We still have a long way to go. But we can—and we will—rebuild our natural world. Restoring nature at a planetary scale is an idea whose time has come.

It is clear that the world of the future will look very different from today's world. Our future world could either become,

by degrees, worse: warmer, less diverse, and more violent both in weather extremes and in human interactions. Or the future world can become orders of magnitude better than today's world: more resilient, more connected, more diverse, healthier, and wealthier. This positive change will be made possible by an intentional choice to embrace the power of nature and combine it with human ingenuity, technology, and political will to create a world of abundance. Which is the future we choose? How can we get from a 10 percent world to a 100 percent world? Once we have realized that we are undermining humanity's most important relationship, how do we make peace with nature? Before we attempt to answer those questions, let us dive deeper into the story of one of the most underrated scientific disciplines of our time: ecology.