The Resilient Species

In Ruth DeFries' long view, human ingenuity has always prevailed.

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ILLUSTRATIONS HYE JIN CHUNG

A few years ago in the midst of research, Ruth DeFries came across a curious hand-drawn illustration. It was in an obscure paper called "The Human Population," written by an ecologist named E.S. Deevy for *Scientific American* in 1960. It showed human population levels as a series of steep climbs, coinciding with advances in technology such as the development of tools and the creation of agriculture. Between the surges in population were long flat periods.

As DeFries looked at the population curve, one thing about it particularly caught her eye: It never went backwards. It was almost as if the cosmos held a giant ratchet that only turned in one direction, and during brief moments of technological innovation it gave it a big, universe-sized crank. "We tend to think of population growth as a linear process, but this made me think that it isn't. It's related to these technological leaps," says DeFries, Engr '80 (PhD). Deevy's paper didn't explain what it was that caused the human population to rise so rapidly at various points in history. Nor did it explain why the global population never seemed to plummet.

Of course, there has been localized depopulation due to famine, war, or depletion of resources. Take one

famous example: the Irish potato famine of the mid-19th century. For 300 years, the Irish population had been sustained by the potato, a wonder crop imported from South America that was easy to grow and packed with nutrients. But the potato had a fatal flaw—since all potatoes sprout from other potatoes, they are genetic clones, the ultimate monoculture. All it took was one scourge in the form of a potato blight in 1845 to wipe out the crops of an entire nation, causing a million deaths (more than 10 percent of the population) and a mass exodus from Ireland to America.

Stop there and the potato famine seems like an unmitigated disaster. But DeFries looks at history with a longer lens. As a geology undergrad at Washington University in St. Louis, she became accustomed to thinking in epochal periods of time. As a geography doctoral candidate at Johns Hopkins, she zoomed out over global distances. As a specialist in remote sensing by satellites at the University of Maryland, she zoomed out to the ultimate degree: looking down on the earth from orbit. Seen from all of those perspectives, the Irish potato famine, tragic as it was for Ireland, was a blip on the big stage. Within a few decades, the country's population decline began to level off, and by the mid-1900s it started to rise again as farmers planted new crops, including blight-resistant species of potato. Never again would Ireland rely on one crop so completely.

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"When you produce more food, you ratchet up the number of people you can support, but you are also committing civilization to feed those people," says DeFries, a professor in the Department of Ecology, Evolution, and Environmental Biology at Columbia University. The pattern has repeated itself for centuries, she says. Human beings come up with ingenious new technology that increases the food supply and ratchets up the population. Eventually, when resources can't keep up with the increase in people, localized areas experience starvation and collapse. DeFries calls that "the hatchet." But human beings soon develop new ingenious technologies that allow them to avoid the full brunt of that collapse and restore population. DeFries calls that "the pivot."

In her new book *The Big Ratchet: How Humanity Thrives in the Face of Natural Crisis* (Basic Books, 2014), DeFries investigates a series of ratchets, hatchets, and pivots throughout the centuries. Sometimes we humans pivot before the hatchet takes a major toll, and sometimes we don't, but it always takes hard work to come up with the next big idea. Never has that been more the case than now, argues DeFries, when technological advances in this century have combined to create a Big Ratchet the likes of which has never been seen before. Had Deevy been alive to see it, the leaps in his population curve before the second half of the 20th century would seem like bumps compared to the explosion in population of the last 50 years. But along with that ratchet, says DeFries, we are facing a hatchet the likes of which we've never seen before—for the first time, our problems may not come from scarcity, but from overabundance—in food, in fertilizer, and in fossil fuels. The question is whether we can pivot in time to avoid them.

DeFries was a teenager in northern Virginia during the 1970s explosion of interest in environmental issues. "You could say I was an Earth Day adolescent. I got very involved in the environment during those teenage years." She still looks the part, sitting down in a conference room at Columbia University, dressed simply in a black scoop-neck T-shirt and casual turquoise button-up shirt, with wireframe glasses and curly salt-and-pepper hair pulled back in a ponytail. In spite of weighty topics like looming environmental collapse, she smiles infectiously, talking about the doom of civilization in a disarmingly genial way.

"That doomsday message has been out there. It tends to turn people off," she says of the motivation for her new book. "I wanted to create a different way of looking at the narrative." That point of view has its roots at Johns Hopkins, where she studied under the tutelage of legendary professor Gordon "Reds" Wolman. Geography was then in a time of resurgence, moving past studying the nature of landscape to take a more comprehensive look at how humans interacted with the environment. Wolman was interdisciplinary a decade before it came into fashion, examining urbanization and water issues through the lens of politics, science, and sociol-

ogy. "Geography is a discipline that is all about the hyphen between humans and nature," says DeFries. "It's all about that intersection between the natural world and human society." For her doctorate, she looked at how land clearing by Europeans affected sedimentation patterns that changed the ecology in Chesapeake Bay. She became fascinated by how, alone among the earth's species, humans have enacted massive changes on the planet by hacking into the planet's physical and biological processes.

All the theories she'd been developing about the ways humans manipulate their environment came into new focus when she moved to India for several years with her husband, Jit Bajpai, whom she met at Johns Hopkins (and who later went on to become a director of the World Bank). Witness to new extremes of poverty and competition for resources on a daily basis, she saw close-up how people and the environment were connected in everyday life. Her lofty environmental goals faded against the reality of people scrambling for food and wood to fuel their cooking stoves. "When I first went to India, you couldn't find trash cans because there weren't any—everything was recycled," she says. "The relationship between the environment and people is always in your face."

Returning to the United States in 1983, she put that new awareness to use at the National Research Council. She worked on the U.S. Global Change Research Program, an effort to confront long-term environmental issues such as species extinction, deforestation, and the burgeoning threat of climate change. But after 12 years she wanted to get back to original research, telling program head Hal Mooney in 1991 that she was leaving to work at the University of Maryland in the emerging field of remote sensing with satellites. She hoped this would give her an even more global view of the world's problems. Mooney counseled her against it. "She was doing such a brilliant job popularizing and bringing this heavy-duty science together in an understandable way, I thought she'd get lost in such a vast, crowded field," he says. "But she rose very quickly up to the top." At a time when other researchers were using satellites to categorize broad land uses such as forest or agriculture, DeFries pioneered a more exact way to use smaller, discrete areas to show more subtle gradations in the way humans interact with their environment.

"She was really interested in the deep questions, and thinking on multiple levels," says Chris Field, a professor of environmental studies at Stanford University, who worked with her in a NASA-funded program. "And she was technically amazing, able to use the remote sensing data for things I didn't think possible." Others similarly took notice. In 2006, she was elected to the National Academy of Sciences. In 2007, she received a $500,000 MacArthur Fellowship for her study of deforestation. "It was 30 seconds of elation followed by five years of terror," DeFries recalls. "I kept thinking, 'I don't deserve this.'" With the MacArthur money, she set up a private foundation in India whose mission was to fund scientists working on sustainability issues. Her heightened profile caught the attention of Columbia, which was looking for a professor of sustainability studies. DeFries came instantly to mind, says Shahid Naeem, director of science for Columbia's Earth Institute Center for Environmental Sustainability, who was impressed with DeFries' ability to simultaneously see the world at village and satellite levels. "She is always scaling it way back up," says Naeem. "While others would be staying at the village, she is trying to connect the conversation she just had with the farmer with what she would see from space."

The Big Ratchet begins with a similarly cosmic view of the planet, starting with a discussion of factors, such as an elliptical orbit and plate tectonics, that allow the planet to support life. The book briskly moves on to examine how humans have evolved to manipulate the planet through an accumulation of social learning that allows ingenuity to be passed down to new generations. Then it settles into its real agenda: food.

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At its heart, *The Big Ratchet* is a food book, deserving a place on the shelf alongside work by the likes of Michael Pollan, Mark Bittman, and Marion Nestle that criticize our modern system of industrial agriculture. Where DeFries' book differs is in taking a broader view of the trade-offs that

occur in any system of food production. In her view, human beings' inexorable cycle of ratchet-hatchet-pivot always makes us the victims of our own successes. "This is our most recent experiment," says DeFries, "but we'll always be experimenting. There is no silver bullet. We are always manipulating nature to feed ourselves, and our solutions will always create more problems."

DeFries notes not just scarcity but overconsumption, which affects not just the developed world but is more and more common in developing countries.

We rarely think about how complex—or fragile—the global system of food production is that provides our daily breakfast. Even if we consider the network of farms and transportation that contribute to, say, producing the eggs and raising the wheat for our toast, we may not think about the scientists who created the pesticides and fertilizer, the dams that diverted the water, or the fossil fuels that powered the farm equipment. Yet each is an essential strand in the web that supports our system of food production. And each has been refined over centuries of ingenuity to support ever-vaster populations of people.

Take fertilizer, one of the little-considered technological innovations whose evolution DeFries traces. With the ratchet that came with domestication of agriculture 12,000 years ago, mankind quickly created a problem. Growing crops rob the soil of nutrients such as nitrogen that are necessary for later crops to thrive. "There had to be a way to get nutrients back, or the soil would be depleted and that's the end of civilization for a long time," says DeFries.

The earliest solutions to that potential hatchet came from returning the byproduct of human consumption to the fields. In China, for example, citizens perfected the art of carrying euphemistically termed "night soil"—human waste—back from the city to the fields at night. The slash-and-burn agriculture practiced by indigenous societies was a similarly low-tech way to return nutrients to the soil. Clearing forests for nutrients worked for a time in Europe as well, but by the 14th century, deforestation combined with a drop in temperatures that decreased crop yields contributed to agricultural shortfalls that led to famine, war, and disease.

In response, farmers pivoted with the new art of crop rotation, growing different crops in succession and sometimes letting the ground lie fallow to replenish essential nutrients. That worked to stave off famine for about 300 years, until another looming collapse in the 17th century due to drought and depleted fields threatened the ability to feed a growing urban population. This is when Thomas Robert Malthus famously articulated the doomsday point of view still cited by environmentalists today: Since the earth's resources grow linearly while the earth's population grows exponentially, human beings are doomed to outstrip the capability of the planet to support them.

Despite that dire warning, the hatchet in Malthus' own time never fell. Rescue came from the unlikeliest of places: islands in the Pacific Ocean covered in hundreds of feet of nitrogen-rich guano deposited by generations of seagulls. Europeans "discovered what the Incans had already known for a long time: bird poop is really good fertilizer," says DeFries. "And so there was a booming trade in bird poop. Here we go from human and animal waste cycling back to the countryside to this continental trade in excrement." For the following half-century, European countries competed to bring valuable guano halfway across the world, even starting wars over possession of contested rocks off the coast of Peru and Chile. After depletion of the guano supply, they turned to mining another South American commodity, saltpeter, which was also rich in nitrogen.

By the early 20th century, a fertilizer shortage was again looming on the horizon. That's when a German scientist named Fritz Haber perfected a new process to convert nitrogen to ammonia, making it nutritionally available to plants and ushering in the modern age of chemical fertilizer. "That was a really huge pivot," says DeFries. "Environmentalists like to think about carrying capacity as finite, and when we run out of resources, we drop off a cliff. But human beings are not like other animals—we are so adaptable—so you've got to take into account our ingenious ways of manipulating the planet."

As DeFries describes in the book, humans went through a series of similar ratchet-hatchet-pivot processes with other resources—developing irrigation and dams to channel water; breeding special hybrid seeds through natural selection to increase yields; and

perfecting pesticides to keep pests from destroying harvests. While each of these advances in technology could be considered amazing, together they have changed the face of the planet as never before. Sometime in the middle of the 20th century, says DeFries, they combined to create the Big Ratchet, a convergence of chemical fertilizer and pesticides, new hybrid seeds, modern dams, and oil-driven machinery. "It's a culmination of all of these different ratchets, and all of these constraints being lifted at the same time, which made it possible to have such abundance," says DeFries.

During this period, the amount of corn and rice produced worldwide each year tripled, and production of wheat more than doubled. Average lifespan rose, and with it the world's population—from 1.5 billion people in 1900 to 2.5 billion in 1950, and up to 7 billion today. (It's expected to level off at around 9 billion by 2050.) Despite more predictions of food shortages, the amount of food more than kept up with the number of mouths throughout the 20th century—from an average of 2,200 calories per person per day in 1960 to 2,700 calories today. Of course, that implies that food is evenly distributed around the world, which is not the case. Says DeFries, "We have more than enough food to feed everyone, but still we have people without enough food. That's a symptom we haven't figured out how to deal with."

That food inequality has led other environmentalists, including DeFries' colleague Shahid Naeem to see the history of the human race in bleaker terms than those espoused by DeFries. "The evidence of our success is the large number of individuals we have and the fact that we are spread all over the planet," says Naeem. "But if an alien entity came and gave us a report card, they'd see a billion hungry people, 2 billion people in poverty, and 3 billion people without sufficient water. I don't think they'd give us an A, I think they'd give us an F."

DeFries acknowledges food inequality as a sad consequence of our current system of production. She notes not just scarcity but overconsumption, which affects not just the developed world but is more and more common in developing countries. Obesity rates in Mexico are on par with the United States at around 35 percent, and the rest of Latin America is not far behind. Even in China, where overall obesity rates are

5 percent, they are as high as 20 percent in some cities. "Spreading obesity and unhealthy diets seem to be a big hatchet on the horizon—for individuals as well as society as a whole considering the spiraling health care costs," says DeFries. "What's different about this Big Ratchet is that the problems coming from it are much more about abundance than shortage. Previously the problems were how to overcome shortages. Now we have to overcome the problems that abundance creates." Run-off from fertilizer clogs streams and lakes with weeds, choking off water supply and hurting biodiversity. And there is the pollution from fossil fuels accelerating climate change—perhaps the biggest looming hatchet on our horizon.

Despite the obvious dangers of climate change, DeFries treats it only glancingly in her book as one of a list of looming environmental dangers that includes species extinction and a world shortage of phosphorus, a component as crucial in chemical fertilizers as nitrogen. While that might raise eyebrows with some readers, it's symptomatic of DeFries' seeming delight, at times, in upending conventional environmental priorities. She takes issue, for example, with some environmental evangelists who see the future in the locavore movement: eating only food produced within a short number of miles from home. While there might be good reasons to eat local food because it's healthier and supports local economies, says DeFries, that doesn't make it more sustainable. "It's not necessarily the way of producing food that leads to the lowest greenhouse gas emissions," says DeFries. "People focus on the transportation issues, but transportation is not always the greatest contributor to emissions." She adds that locavorism could contribute to worldwide inequality by depriving farmers in poor countries of export markets.

DeFries also parts ways with some environmentalists who have attacked genetically modified foods as anathema. "We have manipulated genetics for 12,000 years. This is really [just] a different way of manipulating genetics," she says. She sees GMO crops as part of a continuum by which humans have always selected for favorable characteristics in plants, and notes that early experiments with GMOs have reduced famine in developing countries. "The biggest problem right now is that they are in the hands of private corporations whose interest is not in feeding the poor but in making a profit. But I am not against them on principle."

In part, DeFries' take on controversial issues such as GMO foods stems from her long-lens view of the world. But she also sees it as an attempt to move beyond polarizing ideological debates to focus on practical solutions. "I wanted to present both sides, or rather multiple sides," says DeFries. "These issues are not black and white, and looking at them that way is what gets us into ideological stalemates between the doomsday people and the technological optimists, which isn't a productive way to move forward."

The one thing that today's problems share with past problems, says DeFries, is that they deny easy solutions. While the book stops short of being prescriptive, she praises recent initiatives to create more efficiency in the food system, including using less fuel, water, and fertilizers, noting that one promising trend in reducing use of fertilizer is in recovering sewage from cities and distributing it back to fields—a variation on the night soil concept developed by the ancient Chinese.

No solution is ever perfect. But by presenting the various trade-offs and consequences created by past solutions, DeFries hopes that she can challenge human ingenuity to pivot away from new hatchets before they fall. In some recent cases, she notes, we have done just that—for example, rapidly addressing the depletion of the ozone layer by restricting chlorofluorocarbons before that became a catastrophe. In other cases, such as climate change, the jury is still out on whether we will move quickly enough in the future. Modern humans, at least, have a huge advantage over our ancient forbearers, she says: modern science, which can help us identify and deal with problems before they become crises. That is, if we heed its warnings. "It's human nature to respond to what's immediately in front of us," says DeFries. "Science can identify the upcoming hatchet—and then it's up to society to determine how to respond."

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