One Green Earth

Peter H. Raven

While I was lying in bed in the spring of 1944, recovering from measles at the age of seven, my mother entered my bedroom and handed me a bright orange book: *Six Feet* by Ruth Cooper Whitney. Once I had taken a look, I couldn't put the book down. It presented simple stories, illustrations, and poems about different kinds of insects. Its stories were so engaging that I couldn't wait to rush outside and see the insects for myself—even though I'd paid no attention to them previously. In our garden, built on the sandy flats of the Richmond District in San Francisco, I could find and rear cabbage butterflies; discover Jerusalem crickets, earwigs, tenebrionid beetles, bumblebees, and other fascinating creatures; and begin to catch a glimpse of how they all fit together. I soon began making a collection of butterflies but then switched to beetles. I accumulated a collection of several boxes of these mounted insects, which my parents would proudly display when guests visited.

As the years passed, it turned out that this book, an otherwise ordinary gift from my mother, provided the first major step towards my career as a botanist and environmentalist—a career that would culminate with a forty-year tenure as director of the Missouri Botanical Garden. During that career, I would see our global understanding of biodiversity expand far beyond what was known when I first began collecting insects in my childhood backyard. Yet, over that same period, researchers have shown how humans have increasingly pushed the Earth towards an environmental breaking point. Even as researchers are racing to name and describe new species, they are simultaneously racing to save species from extinction.

The spring after starting my backyard explorations, I discovered the existence of the Student Section at the nearby California Academy of Sciences in Golden Gate Park. The group offered activities after school and on weekends, along with occasional field trips to the

RAVEN, P.H. 2020. ONE GREEN EARTH. *ARNOLDIA*, 78(1): 32–41

surrounding countryside. The students also received a degree of access to the scientific departments at the academy, and by the time I was ten, I had become a regular visitor to the Entomology Department. There, I could compare and identify my beetle collections with the help of friendly curators, especially E. C. Van Dyke, a world expert on beetles who was always encouraging.

By the time I was twelve, in the summer of 1948, I had begun to switch my interest to plants, largely because of a book called *Manual of the Flowering Plants of California*, by the great University of California botanist Willis Lynn Jepson. With the aid of this book, I could identify almost every plant species that I collected and determine whether there was anything unusual about the place I encountered it or the characteristics of the individual plants that I found. There had been no such book available for beetles. For plants, Jepson's *Manual* made the world seem small and knowable—as if the different species in the Bay Area were parts of a large puzzle for me to discover and piece together. In the academy's Botany Department, curator John Thomas Howell ("Tom" to almost everyone who knew him) took me under his wing and taught me more each I time I visited him. I started helping in the department as a volunteer in 1948, and later that year, I was hired for my first job, sorting new collections that had come from people working with Tom around the state.

My Early Exploration

While I knew, even as a child, that botanists were still discovering new species of plants around the world, I had always assumed that plants in the region of California where I grew up were already well documented. Generations of earlier botanists had studied the flora, and it seemed as though all of the plants had already been named and included. My first personal experience with a new species began when I was in my final year at high school. Harlan and Margaret Lewis, who were preparing a monograph of the attractive native plant genus *Clarkia*, showed up at the academy. They were reviewing herbarium specimens of *Clarkia*, and they had come across an unusual one that I had collected a couple of years earlier on a slope of serpentine rock in the San Francisco Presidio. They wanted to grow it for their research, but it took me two years to find the colony again. When I finally sent them the seeds, they invited me to work with them at UCLA the following summer, between my junior and senior years at Berkeley. Following that experience, it was only natural for me to begin graduate work with Harlan in 1957. The unusual *Clarkia* eventually proved to be an unnamed species: *Clarkia franciscana*—now a federally endangered species. While I maintained a lifelong interest in insects, I never looked back.

At UCLA, I prepared a dissertation on a group of desert plants that were, like *Clarkia*, members of the evening primrose family, Onagraceae. At the age of twenty-two, I married a girl I had met at the student section, Sally Barrett, and the following year, somewhat to the consternation of my graduate advisors, we had our first baby. We had our second child, Elizabeth, in 1960, while we were living in London, where I had a postdoctoral fellowship at Kew Gardens and the London Museum of Natural History.

We returned to California, and in 1962, after a job at Rancho Santa Ana Botanic Garden, I started what turned out to be a nine-year stint on the faculty at Stanford University. Fortunately for me, Stanford had a combined Department of Biological Sciences in which I had plenty of room to learn and grow in many aspects of the life sciences. Working with these colleagues, I could expand my research beyond its original emphasis on the classification of a particular group of plants and begin exploring topics with a broader and more theoretical footing.

My closest colleague at Stanford was Paul Ehrlich, an entomologist and population biologist who has remained a mentor and friend for life. Comparing our thoughts on plants and butterflies, we recognized that the caterpillars of some groups of butterflies fed almost exclusively on one related group of plants. In these

Facing page: **A superbloom on the Carrizo Plain in California, with desert candle (*Caulanthus inflatus*) across the center of the image, the blue tansy phacelia (*Phacelia tanacetifolia*) in the foreground, and the hills beyond covered with hillside daisy (*Monolopia lanceolata*).**

PHOTOGRAPH BY ROB BADGER, FROM BADGER, R. AND WINTER, N. 2020. *BEAUTY AND THE BEAST: CALIFORNIA WILDFLOWERS AND CLIMATE CHANGE*. WINTERBADGER PRESS/CALIFORNIA NATIVE PLANT SOCIETY.

HENRY DOMKE

Monarch butterflies (*Danaus plexippus*) advertise their poisonous nature by their bright colors and thus warn birds to leave them alone or suffer the consequences. This group of butterflies takes the process of coevolution one step further, getting poisons from the milkweeds on which their caterpillars feed and using them to protect themselves.

cases, few other kinds of butterflies fed on the same groups of plants. Cabbage butterflies, for instance, which I had observed in my childhood backyard, were among a group of related butterflies that fed on plants in the mustard and caper families. Paul and I came to understand that the ancestors of these plants had, over time, evolved chemical defenses that deterred most other insects. Ancestors of the cabbage butterflies, on the other hand, had gained the ability to break down or resist those defenses, which meant a whole food resource was more or less exclusively available to them. Paul and I developed, published, and named this stepwise process coevolution, which turned out to be one of the most fruitful scientific discoveries that either of us ever made.

A couple of years earlier, my first Stanford graduate student, Dennis Breedlove had introduced me, through his fellow student and friend Brent Berlin, to a project that was being carried out in the Department of Anthropology. Professor A. Kimball Romney, one of the founders of cognitive anthropology and Berlin's graduate advisor, was working with colleagues to pursue various projects with the highland Mayans in the southernmost Mexican state of Chiapas. Together, the four of us conceived a project dealing with the names one group of these Mayans gave to the plants that grew in their area. Dennis moved to Chiapas for three years to carry out the botanical side of the study. We wanted to know what principles governed the way the Mayan community named their plants,

RICHARD MACK

Gunnera insignis **was among the many wonderful new plants the author encountered while teaching a course for the Organization of Tropical Studies in Costa Rica in 1967.**

and what regularities we could find in comparing their system with those employed by groups from elsewhere. This Mayan community did not use a written language, and it turned out, this meant individuals only keep something like a few hundred plant names in their active memory. Within this system, they divided the kinds of plants most useful to them into many more categories than others.

When this project began, the plants of southern Mexico were unfamiliar to me. Challenged with a rapidly growing number of herbarium cases filled with such plants, I had to find ways to name them in order to fulfill my part of the project. I eventually solved this problem with the help of many specialists, especially Jerzy Rzedowski, a Holocaust survivor who had become and has remained for many years the doyen of Mexican botanists, and the taxonomist Rogers McVaugh of the University of Michigan. On my next major collecting adventure in the tropics, where I served as an instructor for the Organization for Tropical Studies basic field course in Costa Rica during the summer of 1967, I was able to ship all the specimens to Bill Burger at the Field Museum in Chicago. He found a number of undescribed species among them and was quite pleased with what he received.

Step by step, my interest in and knowledge about plants was expanding globally. Considering that my parents were living in Shanghai when I was born, and that my mother's grandfather arrived in California with his Irish family

MARY LOU OLSON, MISSOURI BOTANICAL GARDEN

Seiwa En, the Japanese Garden at the Missouri Botanical Garden, was designed as part of a plan to deepen community interest in this venerable institution (opened to the public in 1859) and, at the same time, to encourage an international outlook among St. Louisans.

(Breen) as a member of the 1846 Donner Party, a global perspective had always been central to my family narrative. It seemed only natural that this perspective should be extended to plants.

Research Coordination

The mid to late 1960s were a tumultuous time for America, and all the more so for me. My wife, Sally, died of a sudden and unexpected health problem at age thirty. Our two young children were nine and seven at the time. This personal tragedy was compounded by the national unrest. These years were unsettling and extraordinary. This broader sentiment has been expressed well by Joan Didion, in her essay "Slouching Towards Bethlehem," in which she describes the countercultural movement that had taken hold in San Francisco. "Once we could see these children, we could no longer ... pretend that society's atomization could be reversed," she concludes towards the end of the essay. "This was not a traditional generational rebellion."

This period saw the Tet Offensive, the assassinations of Robert Kennedy and Martin Luther King, the riots and arrests at the Democratic Convention in Chicago, and eventually the Kent State shootings. Demonstrations became an everyday event on the Stanford campus, as they did at other universities throughout the country. All in all, I became deeply confused about where the world was headed and uncertain about what the future held for me and, indeed, for the world. In this period, I worked with Helena Curtis, another biology writer, in preparing the first edition of what turned out to be a very successful botany text, *The Biology of Plants*. I also remarried relatively soon, to Tamra Engelhorn, whom I had met on the Organization for Tropical Studies course in 1967. Notwithstanding these positive events, I remained deeply troubled about the future and, indeed, about the purpose of life.

My personal salvation came in the form of a sabbatical year in New Zealand, in 1969 and 1970. My intention in going there was to study the regional species of willow herbs, *Epilobium*,

the largest genus of the family Onagraceae. About a quarter of the roughly 160 species of the genus occurred in New Zealand and Australia, a strange fact considering the obvious New World origins of the family—why were there so many species of *Epilobium* in that part of the Southern Hemisphere? They were all herbs but widely varied in appearance. They gave the impression of having evolved relatively recently and rapidly in the varied habitats of the region.

As Tamra and I studied the *Epilobium*, we gradually regained our balance. New Zealand felt like a green paradise, and the people we worked with were level-headed, friendly, and helpful. One of them, Eric John Godley, the director of what was then the Botany Division at the Department of Scientific and Industrial Services, was of particular importance for me. We soon became fast friends. Nearly twenty years older than me, he calmly offered sound advice and joined us for enjoyable activities throughout our time in the country.

The theory that the position of the continents had moved over geologic time had been proposed half a century earlier by the German geophysicist Adolf Wegener. His theory was essentially validated in the years just before we reached New Zealand, and it opened important new ways to interpret the origins of the plants and animals in the region. I was quick to apply them to the patterns about which I was learning and to publish the results. For example, the ridge that included New Caledonia and New Zealand separated from Australia and Antarctica (then still joined) about eighty-five million years ago, and most of the plants in New Zealand (including *Epilobium*) reached their new home by blowing or floating across the intervening seas. In later years, I presented similar interpretations in a series of papers with my geologist friend (and former member of my doctoral committee) Dan Axelrod.

At our final dinner with Eric Godley, in the garden of his suburban home, he turned to me and asked what I was going to do next. He suggested that I might make the greatest contribution by emulating the great German botanist Adolph Engler, who, in the late nineteenth and early twentieth centuries, had led the production of the most important comprehensive works on plants, *Die Pflanzenfamilien* and *Das Pflanzenreich*. These works collectively described all the plants on Earth that were then known to science.

Returning to Stanford, I kept Eric's advice in mind: I looked for a pathway to become a leader in encouraging others to undertake major projects, rather than simply continue to do my own research. The need for synthesis became obvious to me, and it has turned out over the years that instead of the roughly 250,000 species of vascular plants we had thought existed then, the actual number approaches twice as many. With these broader horizons in mind, I applied for the open position of director of the Missouri Botanical Garden in St. Louis during my single year back at Stanford. As matters turned out, I was successful. There I soon realized my efforts in coordinating and enabling the studies of others were more important than the results I could achieve as an individual, regardless of how useful and interesting the results of my efforts might prove to be.

Global Collaboration

The Missouri Botanical Garden is the oldest public garden in the United States. I had visited several times earlier to consult its excellent herbarium. On my arrival in 1971, the garden's only major research project, and the only one it had ever conducted abroad, was the *Flora of Panama*, which was being published serially as exploration and writing proceeded. My experience in Chiapas had taught me that to inventory the plants of a particular area properly it was necessary to live there and work with them daily. It seemed logical to find parts of the world that were of particular interest botanically, not being studied in detail by others, and to concentrate there. We began to hire staff with the help of several grants from the National Science Foundation and the support that accompanied the increased local interest in the garden that we were building.

As the years went by, we were able to sponsor scientists to live in Nicaragua, Costa Rica, Ecuador, Peru, Bolivia, the Democratic Republic of the Congo, Madagascar, and Vietnam, and to form strong partnerships with a number of other countries. We established a branch office

WILLIAM MCNAMARA

Libing Zhang (Missouri Botanical Garden), Hong Deyuan (Beijing Institute of Botany), Peter Raven, William McNamara (Quarryhill Botanical Garden), and Fu Chengxin (Zhejiang University), on the summit ridge of Huangshan (Yellow Mountain), in Anhui Province, China, on April 6, 2008. The field trip occurred a few days after a meeting of the *Flora of China* Editorial Committee, held at Zhejiang University. Hong and Raven were coeditors of the forty-nine-volume project.

for studying African plants in the herbarium at the Muséum National d'Histoire Naturelle in Paris. Overall, these efforts led to the *Flora Mesoamericana,* a modern account of all plants between the Isthmus of Tehuantepec in southern Mexico and Panama; the revival of the *Flora of North America,* which covers the United States and Canada; national floras for many of the countries; and an online checklist of the plants of the Americas, a massive collaboration with institutions and researchers around the world that is headed by Carmen Ulloa Ulloa and Peter Jørgensen.

I also helped to start and then coedit the *Flora of China,* a forty-nine-volume work that treats the more than thirty-two thousand species of plants found in the country where I had been born. This important and personally enjoyable project lasted for some three decades and was the product of a major cooperative effort between dozens of institutions and hundreds of individual botanists. It brought the botanists of China, taking up their new opportunities as the effects of the Cultural Revolution receded in the late 1970s, into cooperative contacts with botanists all over the world. The volumes were jointly published by Academic Press in Beijing and the Missouri Botanical Garden.

Robert Woodson, the originator of the *Flora of Panama,* had told me in the course of a visit to St. Louis, back in 1961, that he thought they had accounted for nearly all of the species in the country. As our studies continued, however, we have reached the point where we now list approximately twice as many species from Panama as were known at that time. Everywhere botanists looked—not only in Panama, but in North America, China, and around the world—masses of new species turned up. Through this collective research effort, we were just beginning to grasp the magnitude of the Earth's biodiversity.

The Need for Conservation

When I was a young field biologist, in California, my studies were predicated on the assumption that the world would pretty much stay as it was. But in the 1960s, at Stanford, I started to

WILLIAM LAURENCE

Tropical forests are being destroyed rapidly all over the world, as the 2011 clearing of primary forest for wood pulp in central Sumatra illustrates.

become aware of the rapidly increasing destruction of nature around the world and the need to do something about it. California's population was then less than a quarter of its present 40 million, and the global population was less than a third of its present 7.8 billion, headed for 10 billion by the middle of the century. I began to worry about the severe effects of DDT and other pollutants—Rachel Carson's *Silent Spring* appeared in 1962—and I came to understand Paul and Anne Ehrlich's emphasis on population growth as a factor driving the destruction of ecosystems globally. In an effort to influence the 1968 presidential election, Paul and Anne published *The Population Bomb*, a real wake-up call about problems that were starting to become obvious.

I was also becoming aware of the extensive destruction of tropical forests that was taking place; once I reached St. Louis this became a major issue for me in planning my personal activities and those of the garden. At the request and with the sponsorship of the National Science Foundation, I chaired a National Research Council study of priorities in systematic and evolutionary biology (Raven, 1974). By that time it had become obvious that the tropics were the most poorly known part of the Earth biologically and that the estimate for the number of species globally (then, with 1.5 million named, placed at 2 million) was much too low. Only five hundred thousand of the named species were tropical, yet two-thirds of the total number of species in well-known groups like plants and terrestrial vertebrates occurred there. It became clear that the actual number of species was at least 3 to 4 million—and now we would probably say 20 million, with only 2 million of them yet named. In view of these new estimates and the fact that we had a sense that major habitat destruction was going on in the tropics, we selected focused research in the tropics as a top priority. We knew a lot less than we thought we did.

Several years later, Bill Sievers, a program officer at the National Science Foundation, challenged me to head a study on setting specific research and conservation priorities in the

tropics. I felt that we first needed a more comprehensive understanding of the degree and rate of destruction that was going on in the tropics. This information would help us set the most critical priorities during our study. It seemed to me that the man for the job was Norman Myers, an imaginative English ecologist and conservationist. He had gone to Kenya in the British Colonial Service and stayed on after independence, working as a teacher, guide, photographer, and consultant. By the late 1960s, Norman had become one of the very first to recognize that we were entering a major extinction event and to write about it. To conduct the study of tropical forest destruction for us over an eighteen-month period, he visited all of the major tropical areas and many tropical forested countries, consulting a great deal of "gray literature" and conducting interviews. His report, published in 1980, proved to be a bombshell, documenting rates of deforestation much higher than were generally assumed at the time. It spurred us all to higher levels of action, given the urgency of the task facing us.

Once these relationships had become clear to me, I decided to devote a large part of my energy and available time to accomplish what could still be done while our present wealth of organisms and their ecosystems still exist. I had the opportunity to present the case for action at the American Association for the Advancement of Science annual meeting in Chicago in 1987. It was a large audience, and many people told me later that they had heard about the problem of mass extinction for the first time then (Raven, 1987). Even at the lower estimates of species numbers with which we began, we learned that for every twenty species of plants, animals, and other organisms in a given forest, nineteen were still unknown. So when an area of tropical forest is cleared, the overwhelming majority of species were disappearing without being documented by scientists. The problem was becoming generally obvious.

Today, more than a quarter of the tropical forests standing when the Convention on Biological Diversity was ratified, twenty-seven years ago, have been cleared. The rate is only increasing. Few researchers project that any substantial stands of tropical forest will remain by the end of this century. At the same time, the world climate is warming rapidly, with no strong international agreement in place to slow it down. Biologists can still hope to fill out a relatively complete picture of species numbers and distribution for vascular plants, terrestrial vertebrates, and a few other groups of organisms. But carefully constructed sampling protocols afford the only hope for learning much about groups such as nematodes, mites, and fungi, for which we have recognized fewer than one in a hundred species yet. At least a quarter of all species, most of them unknown, are predicted to disappear from the face of the Earth by the close of this century. What we find and save now will be all we can pass on to those who come after us. We have a moral obligation to do so. As University of Pennsylvania biologist Daniel Janzen has remarked, "If we don't save it now, we can't save it later."

Collective and Individual Action

When I was lying in bed recovering from measles at the age of seven, nearly eighty years ago, it would have been impossible for anyone, and certainly for me, to imagine the tremendously difficult problems we are facing now. Estimates by Global Footprint Network, based on United Nations statistics, reveal that human demand on natural resources in 1961 corresponded to about 73 percent of what Earth could renew at the time. Our demand has risen to 175 percent currently (Lin et al., 2018; Global Footprint Network, 2019). In other words, by July 29, 2019, humans had demanded as much of the Earth's resources as those ecosystems could regenerate in the entire year. Taking this depletion on a per-person basis, we find the averages in the United States, Gulf Countries, and Western Europe are the highest. In contrast, the averages within countries that lack ecological resources and purchasing power reflect very low demands, indicating extreme deprivation and difficult material prospects for their residents (Wackernagel et al., 2019). Huge inequities also exist within nations. Schemes for conservation imposed by wealthier nations tend to be massively unjust towards poorer nations, which have far fewer resources to devote to them than their wealthy counterparts. If the richer nations

PHOTOGRAPH BY CAMILLE PARMESAN, EDITED BY HENRY DOMKE

Pat and Peter Raven by the side of the rapidly receding Portage Glacier in Alaska, on a trip with scientists and Evangelical Christians to study climate change in early May 2007.

would partner with them and help financially, the schemes could work, but there is little sign of such mutual respect and the love that it would require to generate such help.

During my career, I have become convinced that only global collaboration and understanding can give us hope for sustainable life on Earth. Any such collaboration must be based on social justice and a spirit of love and understanding between people everywhere. Yet global success ultimately requires individual action, and it can exist only in a socially just world. Each of us must learn as much about the world, and especially about the poorer parts of the world, as we possibly can. We must live as sustainably as possible. We must vote for politicians who try to understand what's going on beyond their own short terms of office and who recognize the critical importance of arresting and then reversing global climate change. We must support the preservation of the species and ecosystems living today. We must also find ways to gradually lower our population to a level that the planet can support, instead of continuing to pretend that our global resource consumption doesn't matter. All of these actions are predicated on a fundamental need for us to find ways to love and appreciate one another. Our civilization is very young and vulnerable. Our ingrained habits of selfishness and competition were doubtless beneficial in a world where the total human population numbered in the hundreds of thousands, but they have become a sure pathway to destruction now. It is clearly time for us to act.

Acknowledgments

I sincerely thank Mathis Wackernagel, Global Footprint Network, for his suggestions, and acknowledge the exceptionally fine work of Jonathan Damery, the editor.

Literature Cited

Global Footprint Network. 2019. 2019 edition of the National Footprint and Biocapacity Accounts. Retrieved from https://data.footprintnetwork.org.

Lin, D., Hanscom, L., Murthy, A., Galli, A., Evans, M., Neill, E., Mancini, M.S., Martindill, J., Medouar, F.-Z., Huang, S., et al. 2018. Ecological footprint accounting for countries: Updates and results of the National Footprint Accounts, 2012–2018. *Resources*, 7(3): 58. Retrieved from https://www.mdpi.com/2079-9276/7/3/58.

Myers, N. 1980. *Conversion of tropical moist forests.* Washington, DC: United States National Academy of Sciences.

Raven, P.H. 1974. Trends, priorities, and needs in systematic and evolutionary biology. *Brittonia*, 26: 421–444.

Raven, P.H. 1980. *Research priorities in tropical biology.* (P.H. Raven, Chairman, Committee on Research Priorities in Tropical Biology, National Research Council.) Washington, DC: United States National Academy of Sciences.

Raven, P.H. 1987. *We're killing our world: The global ecosystem in crisis.* MacArthur Foundation Occasional Paper; reprinted in *Missouri Botanical Garden Bulletin*, 75: 3–7.

Wackernagel, M., Lin, D., Evans, M., Hanscom, L., and P.H. Raven. 2019. Defying the Footprint oracle: Implications of country resource trends. *Sustainability*, 11(7): 2164. https://doi.org/10.3390/su11072164

Peter H. Raven is president emeritus of Missouri Botanical Garden, in St. Louis. In 2014, he received an honorary doctor of science degree from Harvard University. His autobiography, *Driven by Nature: A Personal Journey from Shanghai to Botany and Global Sustainability*, will be published by the Missouri Botanical Garden early in 2021.