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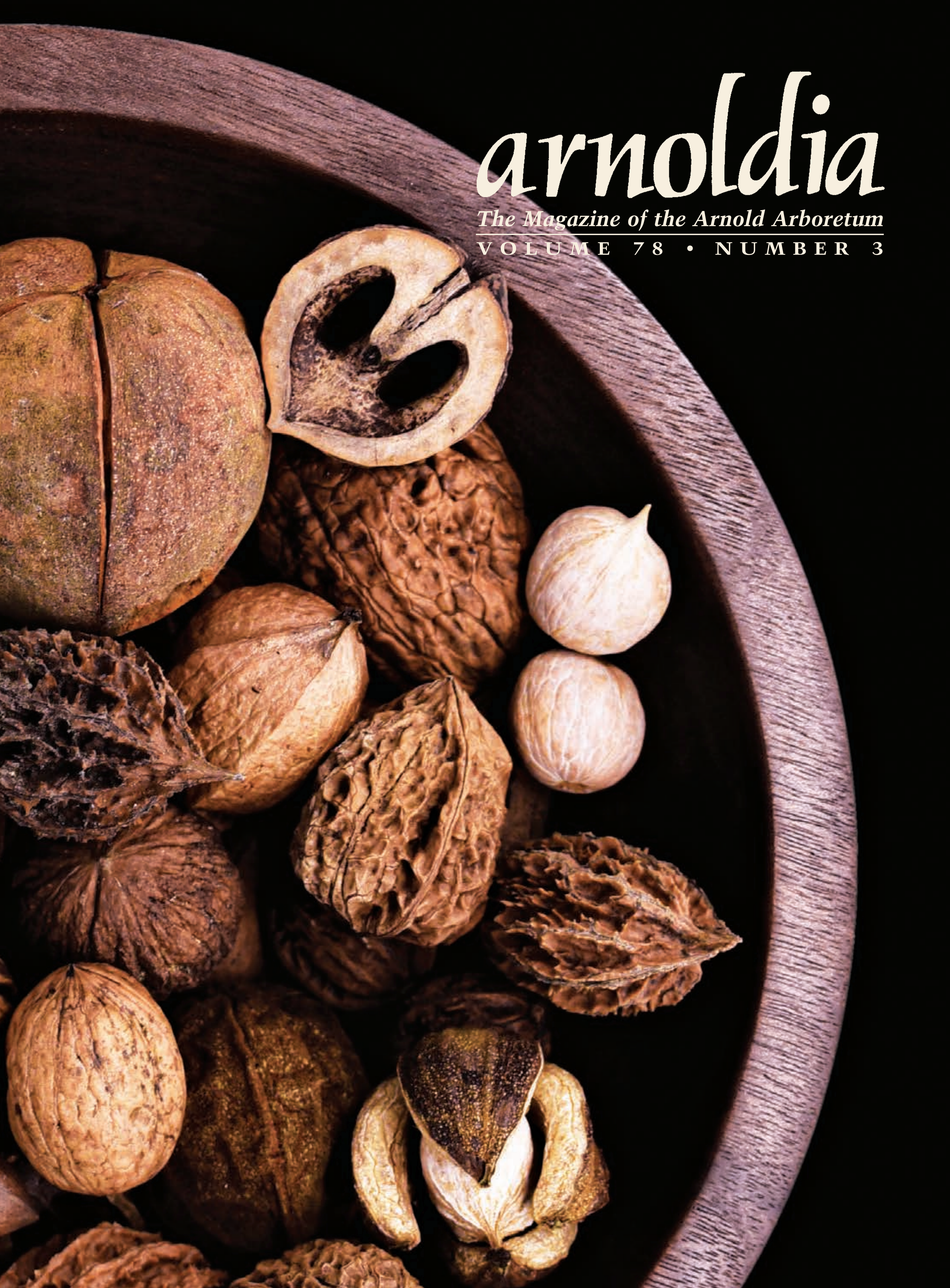
The Magazine of the Arnold Arboretum
VOLUME 78 • NUMBER 3



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VOLUME 78 • NUMBER 3 • 2021

Arnoldia (ISSN 0004–2633; USPS 866–100) is published quarterly by the Arnold Arboretum of Harvard University. Periodicals postage paid at Boston, Massachusetts.

Annual subscriptions are $20.00 domestic or $25.00 international, payable in U.S. dollars. Subscribe and purchase back issues online at https://arboretum.harvard.edu/arnoldia/ or send orders, remittances, change-of-address notices, and all other subscription-related communications to Circulation Manager, *Arnoldia*, Arnold Arboretum, 125 Arborway, Boston, MA 02130-3500. Telephone 617.524.1718; fax 617.524.1418; e-mail arnoldia@arnarb.harvard.edu

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Postmaster: Send address changes to

Arnoldia Circulation Manager
The Arnold Arboretum
125 Arborway
Boston, MA 02130–3500

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Front and back cover: Jonas Frei's collection of walnut family fruits includes a disc-shaped wheel wingnut (*Cyclocarya paliurus*, back cover) among other more familiar-looking species. Photo by Jonas Frei.

Inside front cover: Glyptostrobus pensilis is the only living member of a genus that was once widespread throughout the Northern Hemisphere. The illustration shows a *Glyptostrobus* fossil collected near Reading, England. From Gardner, J. S. 1886. *British Eocene Flora* (vol. 2, part 3). London: Palaeontographical Society. Biodiversity Heritage Library.

Inside back cover: The precision of Itō Jakuchū's observations is evident in *Old Pine*, an ink painting in which he fluidly captures the essence of a Japanese black pine (*Pinus thunbergii*). Painting: Harvard Art Museums, promised gift of Robert S. and Betsy G. Feinberg, ©photography: John Tsantes and Neil Greentree ©Robert Feinberg (TL42147.7). Photograph of Japanese black pine (11371*M) at Arnold Arboretum by Jonathan Damery.

Publication note: Volume 78 will comprise six issues published on the current quarterly schedule. Volume 79 will begin with the first issue published in 2022 and will include four issues.

CARSTENS, J.D. 2021. BUILDING A COMPREHENSIVE PLANT COLLECTION. *ARNOLDIA,* 78(3): 2–4

Building a Comprehensive Plant Collection

Jeffrey D. Carstens

Building a germplasm collection can take years or, more realistically, even multiple careers to assemble. The United States National Plant Germplasm System has nineteen stations around the country, and the goal is to acquire, conserve, evaluate, and distribute genetically diverse plant material. As a genebank curator at the North Central Regional Plant Introduction Station in Ames, Iowa, I'm responsible for managing collections of woody plants like ashes (*Fraxinus*) and chokeberries (*Aronia*), and also herbaceous plants. The collections arise from plant exploration by staff members (I typically make at least five collection trips per year), through exchange with other genebanks or public gardens, or by specific arrangements between a curator and an independent collector. The latter became more important than ever in 2020, as the coronavirus pandemic restrictions prevented normal travel.

One of our most notable collections from this unusual season occurred in the mountains of northeastern Tennessee. The story, however, began in June of 2018, when I sent an email to Roger McCoy, the director of the Tennessee Division of Natural Areas, looking for contacts in eastern Tennessee who might be able and willing to collect native *Monarda* species. *Monarda,* or the bee balms, is a group of herbaceous plants native to North America and Mexico and is represented by approximately eighteen species. Our *Monarda* germplasm collection in Ames currently includes fourteen species, represented by 164 accessions. In the last couple of years, we've acquired interesting samples, including three species that were first described by botanists within the past decade: *M. luteola,* found in northeastern Texas and southwestern Arkansas; *M. austroappalachiana,* endemic to the Southern Appalachians; and *M. brevis,* a dwarf, early-flowering species found in West Virginia and historically in Virginia.

McCoy connected me with Marty Silver, a park ranger at Warriors' Path State Park, who graciously volunteered to help. Silver stated he had "limited botanical skills" and was simply an "interested amateur botanist spending spare time in the field in various wild places in Tennessee." To ensure initial success, we selected *Monarda didyma* as the target from eastern Tennessee, since we had no holdings of the species from the region. The species also displays very conspicuous red flowers from July through August and is somewhat ubiquitous in the target area. This would make the plants relatively easy to locate. By the end of August 2018, Silver had documented several flowering patches of *M. didyma,* and that fall, he returned and successfully collected seed (accession Ames 34356). Despite living approximately an hour away from the sampling site, Silver conducted this travel and exploration on a volunteer basis.

As Silver and I communicated after the 2018 collection, he drew my attention to a very thorough floristic survey of the nearby Rocky Fork Tract, written by Foster Levy and Elaine Walker, published in 2016. Silver connected me with Levy, who brought our attention to several *Monarda* specimens from the area that were labeled *M.* × *media,* a taxon that was missing within our germplasm collection. We designated this hybrid as our next target.

Monarda × *media* is of potential interest for development as an ornamental landscape plant. Moreover, when I reviewed the published literature and herbarium specimens, I found a curious backstory for the taxon, suggesting that well-documented wild collections could also support taxonomic research. The taxon was described over two hundred years ago, in 1809, by the German botanist Carl Ludwig Willdenow, who published the name without the multiplication symbol. The symbol is used to indicate plants of hybrid origin, although it is not required in

***Facing page:* Collaboration is key for developing a plant germplasm collection. A recent seed collection of *Monarda* × *media* in northeastern Tennessee is a case in point.**

PLANT PHOTOS BY MARTY SILVER; SEEDS BY ASHLEY SONNER, USDA ARS NCRPIS


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a taxonomic name nor does authorship change in the event a name is later recognized as a hybrid. While Willdenow's description does not suggest that he recognized this taxon as a hybrid, he nonetheless noted an affinity to *M. fistulosa,* commonly known as wild bergamot. By 1901, Merritt Fernald, a botanist at Harvard, described observing numerous intermediate forms of *M. media,* making separation from *M. fistulosa* difficult.

Currently, *Monarda* × *media* is recognized as a variable group of plants with intermediate characteristics of *M. didyma* and either *M. fistulosa* or *M. clinopodia* or both. These numerous intermediate forms may stem from the various hybrid combinations, and thus, the name *M.* × *media* should ultimately be assigned to a specific combination (for instance, *M. didyma* crossed with *M. clinopodia*), with new names given to each of the others. Surprisingly, Willdenow did not designate a type herbarium specimen, which could make it more difficult to determine which combination should, in fact, retain the original name.

To correctly sample true-to-type specimens of *Monarda* × *media* in nature, Silver would need to mark populations in bloom, since *M. clinopodia*—a white-flowered species—and *M. didyma* are often found nearby; sometimes they are even intermixed with *M.* × *media.* This raises an interesting question about whether *M.* × *media* plants are stable in nature or whether they require the parents to constantly resupply them. Despite subsequent discussion about conducting reconnaissance and sampling for *M.* × *media* in 2019, Silver had other projects that left no time to acquire samples.

The following year, as implications of the coronavirus pandemic were becoming clear, I followed up by asking about the possibility of sampling a *Monarda* × *media* population. Silver quickly replied, "I am much more out and about in the field (outside and distanced) these days. If pointed in the right direction, I'll be glad to try and find populations within my limited taxonomic skills." While the pandemic quickly resulted in travel cancellations and restrictions (out of state, not to mention out of the country) across many agencies, Silver saw being in the field as an opportunity to be completely distanced while regaining a sense of normalcy.

Using Levy's herbarium vouchers, we identified a total of three potential sites, but since the specimens were described from a broad geographic area, their relocation was going to be challenging. A few weeks later, Silver reported finding *Monarda* × *media* while on a hike on his day off. His hike to get to these populations was three and a half miles (one way) with an elevation climb of over two thousand feet. He took notes, GPS coordinates, and photos. Making the hike once again in the fall, Silver relocated the five previously flagged flowering patches, but one patch had been completely destroyed and another patch was nearly decimated due to human disturbance. He collected seeds from the available patches and then shipped them to Iowa. I assigned them an accession number (Ames 35579) and deposited them into the repository's freezer, which maintains the seeds at 0°F (-18°C). This collection will be periodically monitored for viability, and when germination falls below a critical level, it will be regenerated using controlled pollination techniques ensuring the preservation of the genetic profile for the future. Since Silver sampled each clonal patch separately along with appropriate plant descriptions, the collections will be important resources for future research (including ecogeographic and phylogenetic studies). The collections might also be useful for selecting superior genotypes for the nursery industry.

Having one collection of this taxon is, of course, only a start—additional samples are desired. Yet Silver's collections demonstrate the critical importance of local assistance while assembling a comprehensive germplasm collection, especially given the amount of time and effort required to acquire even a single collection. In the end, I'll never forget Silver humbly labeling himself as an "amateur botanist with limited taxonomic skills," as his *Monarda* × *media* collection is one of the most exciting, well-documented samples of *Monarda* that I've accessioned in my nearly twenty-year career.

Jeffrey D. Carstens is the curator for woody and herbaceous plants at the North Central Regional Plant Introduction Station.


DAVID GREENBERGER

A Conservation SOS: *Polygonum hickmanii*

Holly Forbes

Plants with less-than-showy flowers tend to get overlooked, even by some of the sharpest botanists. When a plant is only a few centimeters tall and flowers later in the season than its more eye-catching neighbors, it can be even easier to miss. The Scotts Valley polygonum (*Polygonum hickmanii*) is a case in point. This tiny species was first described in 1995 and was already very rare. It occurs in a limited urban area in Scotts Valley, near Santa Cruz, California, where it is under pressure from development. Only 2,100 plants were observed in 1997, and in 2003, the United States Fish and Wildlife Service listed it as endangered under the federal Endangered Species Act.

As the curator of the University of California Botanical Garden at Berkeley, I work with the national Center for Plant Conservation and a coalition called California Plant Rescue. Each year we make an ambitious plan for conservation fieldwork in the greater San Francisco Bay Area, and for 2020, we planned a packed calendar. Most of our fieldwork was derailed by the restrictions put in place to limit the spread of COVID-19, especially given the timing of the restrictions. Annuals and herbaceous perennials on California's Central Coast tend to have a short spring cycle of growth and seed set. By the time permission was given to be in the field for just day trips, seeds had already set and been dispersed for many species.

Scotts Valley polygonum, in contrast, is an annual wildflower that typically starts to germinate in December, flower from May to August, and set seeds in August. The species is now known to occur on less than an acre of

In recent years, the endangered Scotts Valley polygonum (above) has been observed in only one wild population.

FORBES, H. 2021. A CONSERVATION SOS: *POLYGONUM HICKMANII. ARNOLDIA,* 78(3): 5–6

private land adjacent to a new housing development. The development company established a conservation easement to protect Scotts Valley polygonum and another endangered species, Scotts Valley spineflower (*Chorizanthe robusta* var. *hartwegii*). Both species are in the buckwheat family (Polygonaceae). In 2015, no Scotts Valley polygonum were found at this site, and it wasn't until 2020 that the number of plants went above four hundred, less than 25 percent of the population observed in 1997.

In the past, Scotts Valley polygonum has been documented at two nearby locations, but no specimens have been observed there in recent years. One of these locations is a special ecological preserve adjacent to Scotts Valley High School, where the polygonum has not been observed since 2015. The site is fenced and managed to support the species, but we have limited hope it will reappear on its own.

When my colleagues and I could finally return to the field, pandemic protocols required all participants to travel solo in vehicles and to maintain at least a six-foot distance from one another when working at the sites. I was fortunate to work with two other botanists, Kathy Lyons and Jaymee Marty, at the easement site on August 7. We declared ourselves free of COVID-19 symptoms and signed liability waivers for the landowner. The plants occupied an area of less than forty square feet, scattered across an undulating grassland. We worked for hours on hands and knees making a modest seed collection from the less than five hundred plants—all that is left in the world.

As we collected the tiny seeds from the plants (removing only a small percentage of the seed set), we remarked on how it almost felt normal to be in the field again, despite the pandemic. Travel restrictions had resulted in a huge reduction in the number of cars on the road, which meant that, as a side benefit, travel between Berkeley and Scotts Valley flowed along at the speed limit, instead of crawling through typical Silicon Valley gridlock. Travel each way took one hour instead of the usual three.

A few weeks after our work, the CZU Lightning Complex wildfire in Santa Cruz and San Mateo Counties blackened over eighty-six thousand acres, starting on August 16 and continuing through September 22. The evacuation zone included the two historic polygonum sites. The only extant site, from which the seeds had been collected, was on the margin of the evacuation zone, just across a four-lane highway. It could have easily been different. The fire burned so hot in places that any seeds present in the soil were cooked. During the fire we anxiously checked the maps. It was a great relief to learn that the polygonum sites did not burn.

Our purpose for collecting seeds was twofold: first, to create a conservation seed bank as a backup in case the population is lost for any reason, and second, to produce more seeds by growing plants in a nursery environment. This amplification of seed numbers may make it possible both to reestablish the plants at their historic sites and to augment the numbers of plants within the conservation easement.

In November, propagator Susan Malisch at the University of California Botanical Garden sowed one-third of the polygonum seeds from our seedbank. As of late January 2021, over 85 percent germination has been observed. Each seed was sown individually to minimize root disturbance when the plants are moved into larger containers. The plants aren't likely to grow larger than six inches tall and perhaps two inches across—giants compared to the plants in habitat, where they are crowded together and typically grow about one and a half inches tall.

We look forward to a successful crop of Scotts Valley polygonum in 2021. If all goes as planned, we will have thousands of seeds to use in saving this species from extinction. Wildfires and other threats still pose an incredible risk to the species, but with a robust conservation seedbank and the knowledge of how to grow the plants to reproductive size, we can safeguard its future. Botanists are paying close attention, and Scotts Valley polygonum is no longer overlooked. Next November, we plan to work with the federal Recovery Implementation Team—a team established by the Fish and Wildlife Service—to place seeds back into the habitat.

Holly Forbes is the curator of the University of California Botanical Garden at Berkeley. Support for the Scotts Valley polygonum project is provided by the Ventura Office of the United States Fish and Wildlife Service.

ENZENBACHER, T. 2021. AN UNUSUAL AUTUMN AT THE DANA GREENHOUSES. *ARNOLDIA*, 78(3): 7–9

An Unusual Autumn at the Dana Greenhouses

Tiffany Enzenbacher

October was quiet. The headhouse at the Dana Greenhouses was still, except for the dim hum of the radio, a necessity for an almost empty building. In previous years, the same location would have been marked with a cacophony of sounds, the door thrown ajar as Arnold Arboretum plant collectors eagerly arrived to unpack their hard-earned seeds and plants. Sieves and colanders would have rattled against the center worktable as plant production staff removed fruit pulp from each seed, and everyone would be talking about new and exciting acquisitions. Seed cataloging and cleaning is a departmental undertaking, sometimes lasting the entirety of fall and into early winter.

This annual activity has occurred at an invigorated level since 2015, when the Arboretum launched the Campaign for the Living Collections, a strategic ten-year initiative to increase the biodiversity and conservation holdings of our living collections by adding nearly four hundred wild-collected taxa that were not already growing in our landscape. As part of the campaign, staff organized and executed as many as five expeditions annually, traveling to locations in northern Idaho, central China, the country of Georgia, and elsewhere.

I have participated in two of those expeditions myself: one to the Ozarks and another to northern Illinois and Wisconsin. It was rewarding to engage in the full process, from planning

TIFFANY ENZENBACHER

The pandemic changed fall and winter routines at the Dana Greenhouses, providing an unplanned reprieve from processing new, wild-collected plant material. Chris Copeland (above) prepares grafts of a plum (*Prunus alleghaniensis*), one of hundreds of clonal propagations that are completed annually.

expedition logistics and obtaining permits to harvesting in the field and then processing seed back at the Dana Greenhouses. The collection that stands out most from my two experiences was of the endangered seaside alder (*Alnus maritima* ssp. *oklahomensis*). I collaborated with Kea Woodruff, then the Arboretum's plant growth facilities manager, to collect seed from two plants growing along the Blue River in Tishomingo, Oklahoma. We were guided by local experts. This subspecies of the seaside alder has only been documented in three other locations in the wild, all near the Blue River. (The two other subspecies also have extremely restricted ranges—one occurs in a single location in northwestern Georgia, the other comprises scattered populations on the Delmarva Peninsula of Delaware and Maryland.) For me, this collection brought home the purpose of the campaign and the urgency of preserving threatened taxa.

In the fall of 2020, however, those collections ceased due to the pandemic. Planned expeditions to China, Japan, and South Korea were postponed. In the headhouse of the Dana Greenhouses, the difference was striking. Only two or three members of the plant production department worked on-site on any given weekday, in an effort to de-densify our workspace and to allow staff to care for children who were completing schoolwork from home. This revised schedule continues into the new year. Other

TIFFANY ENZENBACHER

When new plant material arrives at the Dana Greenhouses, staff begin a detailed process of record keeping. New innovations have streamlined the process. Sean Halloran (above) readies softwood cuttings and will note rooting observations using a newly developed mobile application in spring.

nonessential staff are not permitted inside the building. Now, our team hears only the quiet sounds of greenhouse doors opening as we check the facilities, monitor plants for water, and scout for insect pests and diseases. We hear the clatter of containers being placed on potting benches as we prepare to transplant seedlings and the swish of cutting media components being mixed as we get ready for winter hardwood cutting season. We occasionally share the same workspace, but only brief, work-related interactions can take place. Our team meetings are now virtual.

The production cycle for plants already in the greenhouses and nurseries has not significantly slowed this year, although the headhouse tables are bare: no collection sheets from the expeditions strewn about, no bags of fermenting berries or cones to go through. During this altered time, as we have continued with usual greenhouse and nursery tasks, the plant production department has had the opportunity to refocus our direction on other activities. We have made enormous strides to integrate our workflows into the Landscape Management System, a new digital tool developed at the Arboretum, which combines horticulture and curation efforts through mobile applications and an internal website.

One component of this system, PropManager, will eventually replace the use of handwritten propagation cards, which are used to record treatments and results for propagation attempts, including for seeds that return from expeditions. Currently, when seeds arrive, staff record propagation methods and experiments on these cards. While some seeds can be sown immediately, others must undergo periods of cold or warmth. Others require treatments to weaken the seedcoat: sandpaper or an acidic solution. Data from propagation cards are then entered into BG-BASE, the Arboretum's plant records database. Then, as germination, transplanting, and other events occur, the cards are updated, corresponding data are input into BG-BASE, and the cards are refiled into a binder. PropManager will allow us to create a digital "card" on a mobile device and record events in real time. We observed how inefficient the physical card system was when Sean Halloran, our plant propagator, had to transport boxes of binders to and from his home as he toggled between remote and on-site work this spring.

Our team has also completed work that will help us to map, track, and communicate about plants in our nurseries using additional Landscape Management System tools. Chris Copeland, our greenhouse horticulturist, worked with members of the Landscape Management System team to acquire and upload locations of over 250 nursery plants. Specimens are now visible on a dynamic map, and we can easily picture spatial patterns and adjust maintenance of the next generation of Arboretum plants. Likewise, when horticulture staff inherit a tree after it has been transplanted into the landscape, they can use this new set of tools to determine noteworthy events that transpired during the tree's early life.

We are also working with Mike O'Neal, the director of BG-BASE, to analyze information about our repropagation attempts. Each year we duplicate hundreds of historic Arboretum plants through vegetative propagation—a process whereby resulting progeny are genetically identical to the original. Halloran and O'Neal are in the process of creating BG-BASE summary reports. The result will help determine whether the repropagation of a specimen in the landscape is complete. Instead of Halloran spending weeks at his desk writing code and manually sleuthing through BG-BASE tables, he will be able to run a quick query to have access to all the data needed.

The scene at the Dana Greenhouse is certainly different than it was in autumn 2019. That year, we processed over 150 seedlots and mailed surplus material to over a dozen collaborating institutions. Yet the unplanned reprieve from receiving campaign material has allowed our plant production team to collaborate on projects that would have otherwise progressed incrementally over multiple years. We are now better equipped than ever and prepared for the onslaught of new seed collected by Arboretum explorers who are eager to be back out in the field.

Tiffany Enzenbacher is manager of plant production at the Arnold Arboretum.

FREI, J. 2021. A BRIEF HISTORY OF JUGLANDACEAE. *ARNOLDIA,* 78(3): 10–17

A Brief History of Juglandaceae

Jonas Frei

When I first encountered butternuts on the ground of the arboretum here in Zürich, Switzerland, I was puzzled. The tree these nuts fell from must have died or been felled years ago, so I only had the seeds for identification. This North American species, *Juglans cinerea,* is rarely seen in European cultivation outside specialized tree collections, and I didn't recognize the ridged, oblong nuts. When I took a few home, they were not easy to identify within books on common park trees. After additional research, however, the butternut aroused my fascination and left me with questions about the whole walnut family (Juglandaceae). I had long been familiar with this group of plants, but the more I read about them, the more I realized that, in fact, I knew so little.

Like the butternut, many other members of the walnut family were absent in books that I had at home: hickories (*Carya*), wingnuts (*Pterocarya*), and platycarya (*Platycarya*). As I encountered each new species, new questions arose. After several years of intensive study, my pursuit evolved into a book project, *Die Walnuss,* which was published (in a German edition) in late 2019. My work with this unique plant family went far beyond scientific analysis; it also involved an artistic exploration of the unique variety of forms of this plant family. I wanted to make the knowledge hidden in scientific papers accessible through a language of drawings and photographs. These different approaches—science and art—offered new ways of observing and understanding the world of walnuts.

I live in a region with no native species of this widespread plant family. Here, you can occasionally find the North American eastern black walnut (*Juglans nigra*) planted as an ornamental tree in parks. The English walnut (*Juglans regia*) was most likely introduced by the Romans into the northern parts of Europe and can often be found growing as lone specimens on farms. But the number of these solitary trees has declined in the region since the industrialization of agriculture half a century ago. Walnut farms and orchards are relatively new in the German-speaking part of Europe, and walnuts bought in grocery stores here mostly originate from France (Périgord and Grenoble), the United States (California), or Chile.

Members of Juglandaceae, however, were once among the most common trees of alluvial forests in Central Europe. Fossils allow us to look back on a plant family whose greatest diversity and distribution preceded the ice ages in the Paleogene and Neogene. Many species disappeared only a few hundred thousand years ago. I became fascinated by this history. The fossil record reveals a long, slow story of evolution and shifting ranges, and it provides a counterpoint to the story of the family's rapid globalization in recent centuries.

Not far from Strasbourg, in the Rhine Valley of France, researchers and fossil collectors have discovered fossilized butternuts, described under the name of *Juglans bergomensis.* These fossils correspond so closely to the North American butternut that it is hard to find visual differences. The nuts must have fallen into the shallow water and sandy substrate of the Rhine five million years ago, but they still have almost the weight and feel of fresh nuts due to carbonization. In fact, this species had a wide distribution: its fossils have been reported in Italy, the Netherlands, and wider parts of eastern Europe and Russia. Similar fossils dating to the Neogene have been found in Japan and in the southern United States. Fossilized hickory nuts are also present in the Rhine sediments, including those of a widespread fossil taxon called *Carya globosa,* which is similar in appearance to the water hickory (*Carya aquatica*). Although all the European hickory species went extinct millions of years ago,

Facing page: **The walnut family is best known for nut-bearing species like the English walnut (*Juglans regia*), pictured here in the Thur Valley of Switzerland, but the family also includes notable wind-dispersed species.**

ALL IMAGES BY THE AUTHOR

the nuts look as fresh as if they were only a few years old.

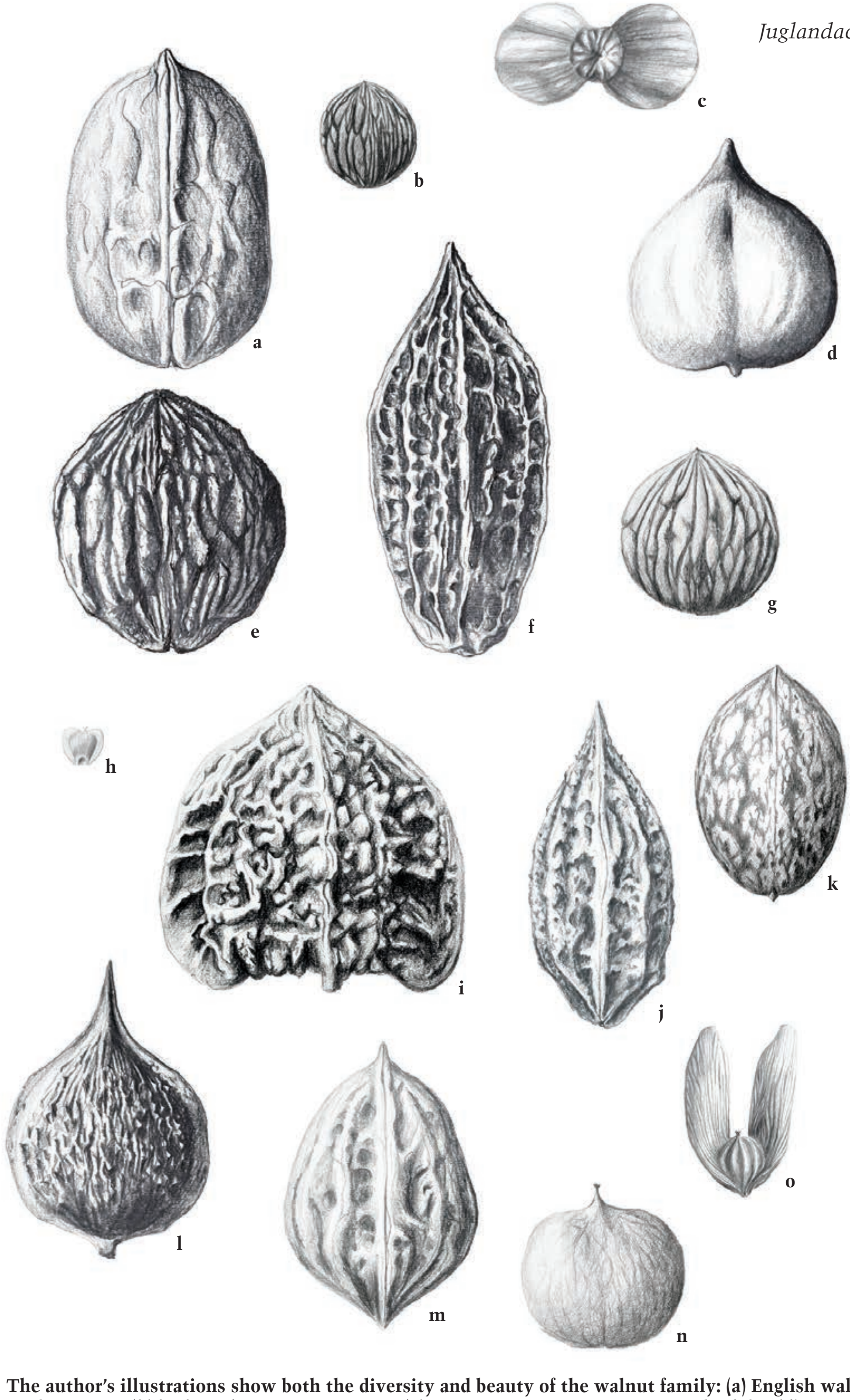
Walnut family species with large, animal-dispersed fruits are only part of the story. Wingnuts (*Pterocarya*)—a genus that is now known for six extant species—were once dominant trees here in Central Europe along rivers and in mountain slope forests. These are ancestors of the species we now call the Caucasian wingnut (*P. fraxinifolia*), which today runs wild in parks and gardens in Central Europe, its root sprouts forming dense stands. Some horticulturists have argued that we should cease planting this species in our gardens, given these invasive tendencies, but based on the fossil record, we could also view the wingnut as a returnee from another era. After all, wingnut leaf fossils in the Stuttgart region were found in sediments of the Holstein interglacial and date back only 325,000 years. The few remaining populations of this once widely distributed species are increasingly threatened in their last refuges in the Caucasus. Wheel wingnuts (*Cyclocarya*) and platycarya—both unusual wind-dispersed genera now found only in East Asia—are also represented in the fossil records in Europe.

The reason the walnut family went extinct in Europe while some species meanwhile survived in North America and East Asia is related to the geographical shape of the continents. Here in Europe, the Alps and the Mediterranean Sea form a barrier for the north-south migration of plant species. In cold periods, trees could survive only in the southernmost corners of Europe; therefore, while in America plant species could migrate according to climate conditions, many European species died out with every cooling and warming. The fossil record indicates that wingnuts survived this back and forth the longest of all Juglandaceae, but in the end, they vanished irretrievably, just like the European magnolias (*Magnolia*), kiwis (*Actinidia*), and sweetgum (*Liquidambar*). Other genera of woody plants, including maples (*Acer*) and ashes (*Fraxinus*), are now represented in Europe with only a few species but had much greater diversity before the Pleistocene ice ages that started about two and a half million years ago. The diversity of these genera in Europe was similar to their modern-day representation in North America and Asia.

The fossils reveal more than former distributions and long-extinct species—the record also documents how the walnut family evolved from an entirely wind-dispersed family to one with the charismatic nut-bearing species that we know today. Some of the oldest fossils of Juglandaceae fruits originate from the United States. Fruits of a wheel wingnut named *Cyclocarya brownii* have been found in different sites from the Paleocene, occurring shortly after the K-T boundary, the geologic marker that separated the Cretaceous and Paleogene a good sixty-five million years ago. This event of mass extinction was both the end of the era of dinosaurs and ammonites and the beginning of a new chapter for the walnut family.

Cyclocarya looks very typical for early members of the family, especially since its fruits are spread by the wind and not by birds or mam-

Fossils document the former abundance of the walnut family in Central Europe, where no members of the family naturally occur today. Hickory (*Carya*) fossils, shown above, were collected from sediments in the Rhine Valley, close to Strasbourg, France, and are around five million years old.



The author's illustrations show both the diversity and beauty of the walnut family: (a) English walnut, *Juglans regia*; (b) little walnut, *J. microcarpa*; (c) Japanese wingnut, *Pterocarya rhoifolia*; (d) Japanese heartnut, *J. ailantifolia* var. *cordiformis*; (e) black walnut, *J. nigra*; (f) butternut, *J. cinerea*; (g) Arizona walnut, *J. major*; (h) *Platycarya strobilacea*; (i) Ma walnut, *J. hopeiensis*; (j) Manchurian walnut, *J. mandshurica*; (k) nutmeg hickory, *Carya myristiciformis*; (l) buart hybrid, *J.* × *bixbyi*; (m) Chinese butternut, *J. cathayensis*; (n) bitternut, *C. cordiformis*; and (o) Chinese wingnut, *Pterocarya stenoptera.*

mals. Back in Paleocene, some fifty million years ago, mammals only started to specialize in the new ecological niches that became available after the extinction of the dinosaurs. Many other winged walnut species emerged. Some went extinct, but the descendants of others are now populating the tropics of the New and Old World: *Oreomunnea* in Central and South America, and *Engelhardia* in Southeast Asia and northern India. It was only with the diversification of mammals, especially squirrels, that some walnut species developed fruits that could be spread by animals.

Squirrels and other rodents drove the evolution of Juglandaceae in two different genera: walnuts (*Juglans*) and hickories (*Carya*), which evolved within separate lineages. Birds, especially the crow family, likely played a part in the distribution from the beginning as well. Because animals never find all the nuts they stash in their winter storage places, they contributed to the spread of these groups, and evidently, they were quite efficient. Walnuts and hickories spread through North America, Asia, and Europe, populating much of the Northern Hemisphere. In the case of the walnuts, this process must have taken place during the span of about ten million years. The oldest known fossil record of the genus, a species named *Juglans clarnensis,* was discovered in North America and dates back forty-four million years, while the oldest European specimen of *J. bergomensis* is around thirty-three million years old.

Later, humans helped with the worldwide spread of two major species: the English walnut and the pecan (*Carya illinoinensis*). Whereas squirrels and crows spread walnuts and hickories on three continents over several million years, humans extended the range of cultivation into all other suitable climatic regions within a few decades. The English walnut (a species of Eurasian origin) and pecan (from the southeastern United States) are now cultivated well outside their native range, including in parts of South America, northern and southern Africa, Australia, and New Zealand. So, the tasty kernels of the walnut became the main reason for this widespread distribution—a process started by squirrels many millions of years before the fossil records prove the evolution of humans.

Today, in Central Europe, almost forty species and hybrids of Juglandaceae are cultivated. During my research, I traveled to many parks and arboreta, looking for insight into the diversity of this family. I was driven not only by my scientific interest in Juglandaceae but also by my enthusiasm for the aesthetics of their habits, leaves, and fruits. The readers of my book should be able to make their own journey of discovery through the walnut family, on the tracks I have uncovered with my research.

Often, after days of traveling, I would find out that a tree I wanted to visit had been cut down or that a rare species was simply confused with an ordinary, oft-planted one. I created a collection of seeds of all the cultivated species and a leaf herbarium. The collection soon included hundreds of fruits and nuts from different locations in Europe, which made it possible to distinguish between the species and hybrids. Later, the collection became the basis for the illustrations of all species in the individual portraits of the book.

These trips through Europe searching for the different species of the walnut family also brought to light the stories of other humans—botanists and horticulturists—who moved the walnut family all over the world. While I could find many species within a day or two of searching, many researchers spent years traveling through the natural habitats in North America and Asia a few centuries ago. In the time of Carl Linnaeus, only three walnut species were known to European researchers. Besides the English walnut, Linnaeus included the North American butternut and the eastern black walnut in his *Species Plantarum,* published in 1753. The hickories—especially the Asian species—were documented much later.

The genus name *Carya* was proposed by the English botanist and plant collector Thomas Nuttall, who used the name, in 1818, in his work *The Genera of North American Plants.* He had borrowed this name from ancient Greek, where *karya* was a word for walnut. The valid botanical name for a genus or species should always be the one from the first official description, and in this case, Nuttall's proposal wrongly became the namesake of the genus. Ten years earlier,

The large kernels of walnuts and hickories have inspired animals to disperse the species widely: (a) English walnut (cultivar), *Juglans regia*; (b) water hickory, *Carya aquatica*; (c) shellbark, *C. laciniosa*; (d) Chinese hickory, *C. cathayensis*; (e) bitternut, *C. cordiformis*; (f, g, h) English walnut (cultivars); (i) butternut, *J. cinerea*; (j) black walnut, *J. nigra*; (k) Japanese walnut, *J. ailantifolia*; (l) Japanese heartnut, *J. ailantifolia* var. *cordiformis*; and (m) pecan, *C. illinoinensis*.

the hickories were described under the name *Hicoria* by the American polymath Constantine Rafinesque. These circumstances led various scientists to urge for reinstating the earlier name, but the change was never implemented. It would have been a respectful act, not only to honor the scientific rules but also because the Greek word *karya* refers to the English walnut whereas *Hicoria* is derived from the Algonquin word for a well-known hickory dish: *pocohiquara.* That name reveals an obvious fact: these trees have a cultural importance that far predates their scientific documentation.

Philipp Franz von Siebold was one of the first Europeans to collect plants in Japan. One of his great collections was *Platycarya strobila-*

cea, which was described in 1843. Some botanists initially thought it was a conifer due to its cone-like fruiting structures. In 1844, the famous English plant collector Robert Fortune also found *Platycarya* in China. Assuming that it was a new, not-yet-described species, he sent herbarium material and seeds to the Royal Horticultural Society in London. John Lindley, the secretary of the society, named the plant after its finder, *Fortunaea chinensis,* and called the species the most important new find of Fortune. Later, it became known that Siebold had described the species one year earlier, so today the name *Fortunaea* is only used as a synonym.

These scientific explorations—and those of other botanists—made it possible to describe, collect, and, of course, cultivate many of the species as ornamentals and orchard trees. But this era of Siebold and Fortune was not simply a time of great scientific discovery; it was also a time of European colonization, in which the gathering of knowledge on expeditions was often combined with ideological, cultural, and religious imperialism. This movement of plants around the world coincided with violations of ethical standards by European maritime powers and a merciless approach to other cultures. The relatively slow but efficient distribution of Juglandaceae by squirrels and mice seems innocent in comparison.

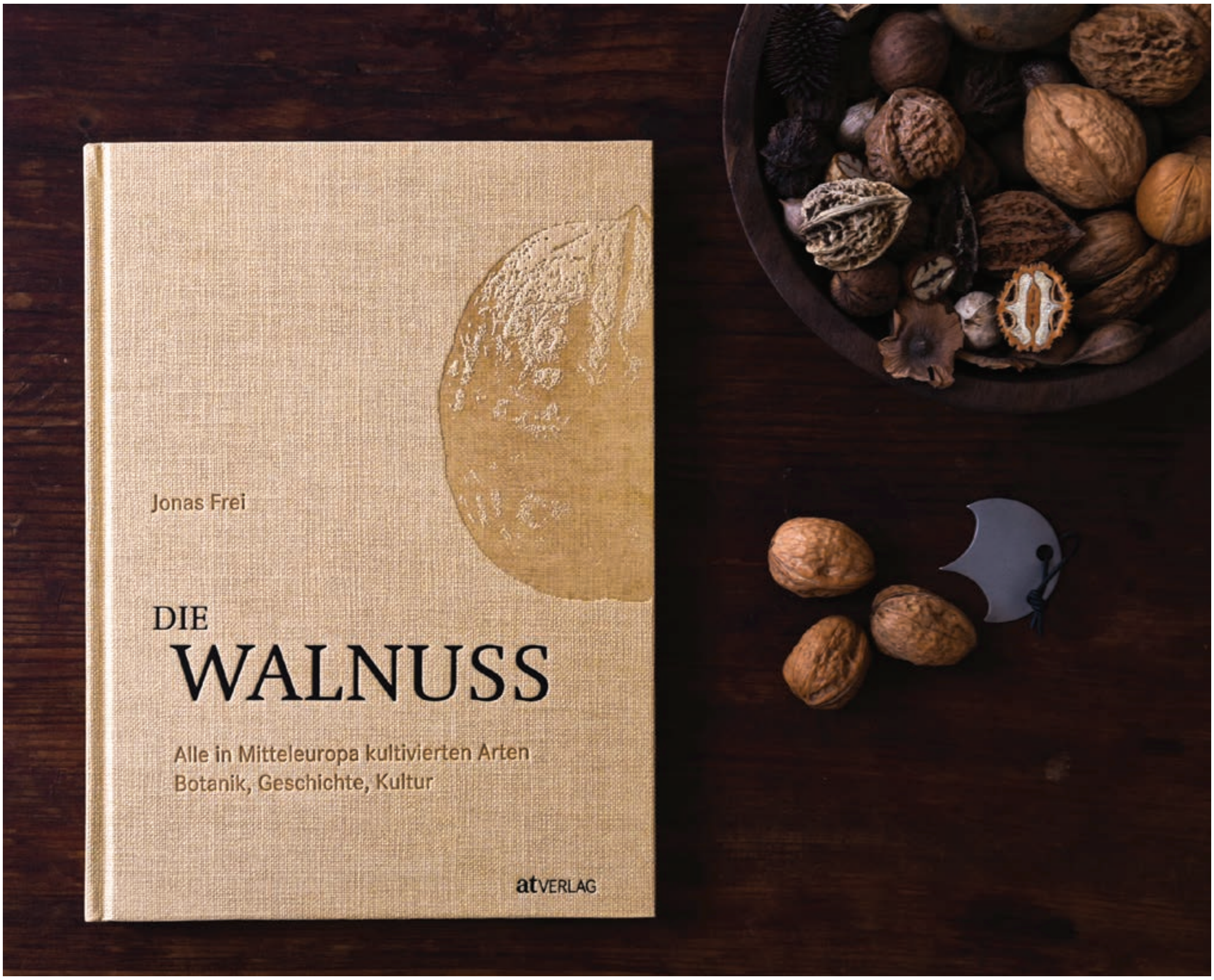
When the walnut family is viewed in the broad sweep of its evolutionary history, the speed of its recent spread is clearly unprecedented. As beautiful as it is to see the worldwide diversity of Juglandaceae close together in many parks today, the globalization of the family has also produced novel threats.

As humans moved the walnut family around the world, fungi and pathogens often migrated with the species. In the United States, a fungal disease known as the butternut canker (*Sirococcus clavigignenti-juglandacearum*) has brought the butternut to the brink of disappearance. The fungus, which was once native to Asian walnut species, causes little damage to its original hosts, but it is often fatal to the North American butternut. The thousand cankers disease, meanwhile, is the result of the unfortunate encounter of a fungus (*Geosmithia morbida*) and a beetle (*Pityophthorus juglandis*) that formed in the western United States due to the proximity of the eastern black walnuts, cultivated in parks, and natural populations of the Arizona walnut (*Juglans major*). And the walnut fruit fly (*Rhagoletis completa*), which once lived inconspicuously on the black walnut species of North America, today spreads quickly in walnut orchards of Europe.

Meanwhile, the close planting of related Juglandaceae species leads to the formation of hybrid offspring. This has led to major changes in natural environments, especially in the case of the butternut populations in North America. Many of the butternut trees that can resist the butternut canker also carry the genetic material of Japanese walnuts (*Juglans ailantifolia*). Resistant hybrids have greater fitness, as they survive and have more offspring, which could be a blessing for the American butternut stocks that survive the strong fungal infestation. On the other hand, conservation of the "real" butternut becomes more complicated. This scenario reveals the cascade of unintended but profound environmental consequences of human actions, which cannot be easily resolved.

Of course, the walnut family experienced various climatic changes over the past fifty million years and therefore changed its distribution again and again. It is assumed that many of the species we know today are the result of hybridization between different populations that collided after a long separation due to climatic fluctuations and subsequent spread by squirrels and ravens. Genetic studies suggest that the English walnut originated from the hybridization of the black walnuts (section *Rhysocaryon*) and Asian butternuts (section *Cardiocaryon*). Also, the American butternut is said to carry some black walnut genes in addition to the genetic material of similar Asian species from the *Cardiocaryon* section. Given this history, one could say that many walnuts, as a lineage, will adapt to human-made influences, although it is unlikely all of the walnut species we know today will survive the pressure.

Recently, in a second-hand bookstore, I found a small booklet titled *Die Quaianlagen von Zürich,* from 1889. The author, botanist Carl Joseph Schröter, planned the tree collection at the arboretum where I first encountered the



The author's book *Die Walnuss*—currently available in a German-language edition—features drawings, photographs, and descriptions of the walnut family.

butternuts that started my interest in this exceptional plant family. He states that a butternut tree was planted in 1887 at exactly the spot where I found the nuts pressed into the soil. Now I know that these nuts, almost like modern-day fossils, are the remains of a now-rare species. The tree was planted long before butternut canker was imported to the United States, and before hybridization with imported species changed its natural populations rapidly.

If we did not have our own hands in all the processes that threaten species like the butternut, we could analyze the consequences from a scientific perspective and see with great fascination how some species emerge from this immense pressure and how others disappear, just like during the whole history of this family. But we also have a responsibility towards biodiversity, towards those species that exist now and that enriched the global ecosystem long before the arrival of humans. Today, as the pace of ecological change and movement continues to accelerate, we have to recognize that the story of the walnut family is now entwined with our own.

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Discovering the Majestic *Mai Hing Sam* of Laos

Gretchen C. Coffman

In early April 2007, less than three weeks after submitting my dissertation and receiving my doctorate at the University of California, Los Angeles, I got on a plane headed for Laos. It took four flights and more than twenty hours of flying time to get to the capital city of Vientiane. From there, I was bound for the Annamite Mountains: an eight-hour drive from Vientiane, then onward by truck, hand tractor (*tok tok*), and boat.

The remote Annamite Mountains run 680 miles (1,100 kilometers) along the border between Vietnam and Laos, reaching into northern Cambodia. This range divides the Mekong River Basin to the west from Vietnam's narrow coastal plain to the east. The mountains are home to exceptional biodiversity. After the Vietnam War ended, Laos closed to Westerners, but in the early 1990s, the borders began to open. Biologists began to document fascinating endemic wildlife, some new to science, including the enigmatic saola (*Pseudoryx nghetinhensis*), a critically endangered bovine that, due to its rarity, has been dubbed the Asian unicorn. Perhaps the most miraculous discovery was that of the endangered Laos rock rat (*Laonastes aenigmamus*), a rodent identified as a surviving member of a family (Diatomyidae) previously thought to have gone extinct about eleven million years ago.[1]

Plant biodiversity in this mountain range is exceptionally rich as well, and many new species have been documented.[2] When I initially arrived in the foothills, I could not have imagined that I would become part of one of these discoveries: the first biologist to collect samples of the majestic Asian swamp cypress (*Glyptostrobus pensilis*) growing in the country. This critically endangered species—locally known as *mai hing sam*—is currently documented in only two other heavily degraded populations, both in Vietnam. The *mai hing sam* in Laos are the only old-growth specimens in the world, and in recent years, the stands have been increasingly threatened by agricultural development and poaching for the luxury timber market. The protection of the few hundred remaining individuals in Laos has become my mission.

Arriving in Laos

My journey to the Annamite Mountains had begun four months earlier, when a member of my doctoral committee, Phil Rundel, emailed me with a proposal to work on a project in an especially remote part of Laos. I was immediately intrigued by the biodiversity, and the thought of getting away from my computer days after finishing my dissertation was alluring. Yet, I was hesitant. The opportunity involved working as a restoration ecologist on a World Bank hydropower project. As a wetland and riparian ecologist by training, I had always focused my research and professional work on protecting rivers and streams, not damming them.

Rundel encouraged me to research both points of view—pro- and anti-hydropower dam. On my breaks from dissertation writing that winter, I read articles and websites from advocates and opponents (including, among the latter, International Rivers and other nongovernmental organizations). I also corresponded with wildlife biologists who would be working on the project. The work was part of mitigation actions for the Nam Theun 2 Hydropower Project and supported the development of a national park in the reservoir's headwaters. At more than 1,300 square miles (3,500 square kilometers), this protected area is one of the largest remaining contiguous areas of forests on the Indochinese Peninsula.[3]

Ultimately, I made a pragmatic decision: there was no stopping the dam, but I could work for the wildlife by helping to develop a conservation plan. I would work closely with

Facing page: **The author was the first researcher to document the critically endangered Asian swamp cypress, *Glyptostrobus pensilis*, growing in Laos. This old-growth specimen, photographed in 2015, is locally known as the "mother tree."**

PHOTO BY DAVID MCGUIRE

ASSOCIATION ANOULAK

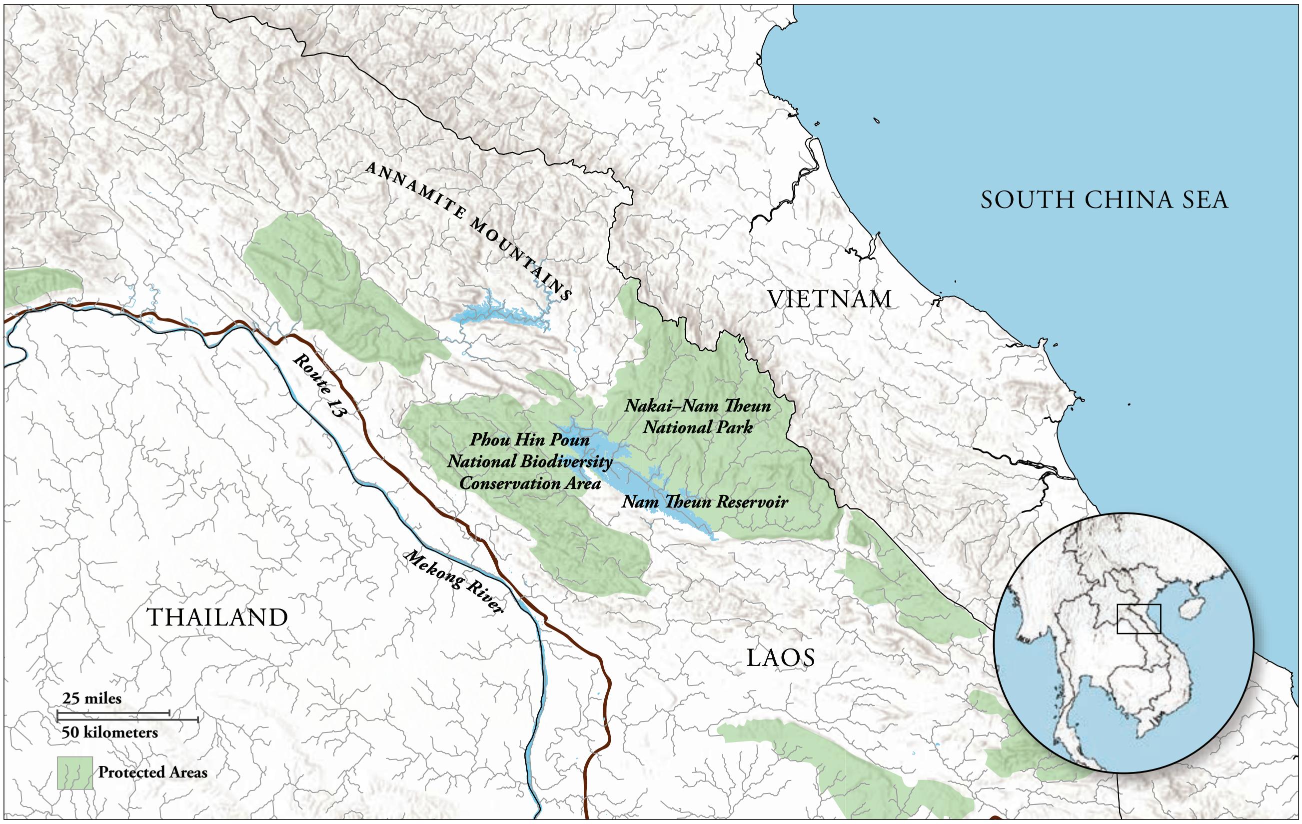
The Annamite Mountains—known for complex topography, geography, and climate—harbor some of the most-contiguous moist forests in Indochina.

James Maxwell, a renowned botanist from Chiang Mai University in Thailand, along with a team of wildlife biologists from a multitude of disciplines. Our mission was to assess wetland habitat on the Nakai Plateau—located high within the Annamite Mountains—before it was flooded by the reservoir. We would document the wetland vegetation and develop a wildlife management plan that included the restoration of habitat within an area known as the Nakai–Nam Theun National Protected Area. Little did I know I would be acting as field coordinator once I arrived, a task that I was comfortable with from fifteen years of managing restoration projects in the United States but not nearly as easy in this new landscape and culture.

The Discovery

The Annamite Mountains contain some of the last relatively intact moist forests in Indochina, unique due to the region's complex geology and climate, and relatively inaccessible due to the steep topography. Initially, working with Maxwell proved extremely difficult. He could not understand why I had been hired on this project, since all my botanical experience was in the United States. He was standoffish and focused on collecting rare wildflowers he encountered. As we settled into the work, however, we bonded. He proved to be an exceptional mentor and friend, and in the years to come, I would stay with Maxwell and his wife in Thailand on multiple occasions.

Our standard workdays were reminiscent of my first fieldwork experiences in the hot, humid wetlands of coastal Georgia, where I had grown up. When we arrived in Laos, it was the height of the dry season and unbearably hot in the late afternoons. We started at sunrise to avoid the heat, first eating a bowl of pho, a noodle soup loaded with fragrant mint, crunchy cabbage, long beans, and assorted leathery forest leaves. In the field, we lugged our plant presses everywhere, as everything we collected



ARNOLD ARBORETUM, ESRI, GARMIN, AND GIS COMMUNITY

The author located *Glyptostrobus pensilis* within the Nakai–Nam Theun National Park. The discovery was made while assessing wetland habitat and developing a wildlife management plan for the Nam Theun 2 Hydropower Project.

went immediately into the press. The afternoons were sticky and oppressive in the open wetlands. We ended around four o'clock when we couldn't take the heat anymore, giving us time to process our plant specimen and clean up our notes. At that point, the plants went directly from the presses into rice sacks with alcohol for preservation.

We surveyed all the herbaceous wetlands across the Nakai Plateau. These wetlands intermingled with rice paddies and were often used as grazing pasture. We began our collections in large, easy to access wetlands on the south side of the Nam Theun River. To guide us, we used paper topographic maps. We then made our way to more forested wetlands and riparian forests, northwest towards the dam site and onward to an area that was nicknamed Thousand Islands because of how the landscape flooded during the monsoon rains. From there we continued east, across the river, near the foothills of the Annamite Mountains.

The first potential wildlife habitat restoration site we visited was northeast of Thousand Islands, near the Nam Xot tributary to the Nam Theun River. Our colleague Pierre Dubeau, a geospatial scientist who had sited these potential restoration areas, exuberantly walked downstream through the forested wetland toward an area with large wetland grasses (*Neyraudia reynaudiana*). Maxwell and I followed Dubeau and wildlife biologist Rob Timmins, who was carrying an umbrella in the sprinkling warm afternoon rain. We agreed that this would be a great open location, ideal for wildlife habitat restoration. As we trudged back among a mucky mess of the forested wetland swamp, I stumbled over something and fell to my hands in the soggy soils. I slowly got up, shook off the fall, and investigated what I tripped over. It looked like a pneumatophore—the cypress knees I knew from my childhood in coastal Georgia, where bald cypress (*Taxodium distichum*) are a dominant feature of the swamps.

I looked up to find the tree it might be attached to, and sure enough, an enormous conifer towered above me. I looked up at this red-barked giant and saw something wonderfully strange and familiar. It looked like a cross between the bald cypresses that I knew from Georgia and the coastal redwoods (*Sequoia sempervirens*) from California, both members of the cypress family (Cupressaceae). I found several other knees as I walked up to inspect the tree. This, I proclaimed to Maxwell, must be a very special tree! Maxwell, however, like many other tropical botanists, was not as interested in conifers as much as the epiphytes that might grow on them. He thought nothing of it. Meanwhile, I collected the samples of small cones, foliage, and bark of this tree, which I sent to conifer expert Philip Thomas at the Royal Botanic Gardens, Edinburgh, for identification.

Documenting the Mai Hing Sam

Conifers are dominant or codominant parts of primary- and secondary-growth evergreen forests throughout the Annamite Mountains. In Vietnam, for instance, the mountains host a particularly rich assemblage of thirty-three conifer species, of which the cypress family (Cupressaceae) has seven.[4] When I asked people in the neighboring Lao communities about the enormous tree that I had encountered, they provided a name: *mai hing sam. Mai* means "tree," *hing* is a modifier for the kind of tree, and *sam* means "swamp," or what ecologists would describe as a forested wetland.

As it turned out, the *mai hing sam* was, indeed, special. When Philip Thomas replied to my email, he identified the species as *Glyptostrobus pensilis* (known as the Asian swamp cypress), which the International Union for Conservation of Nature has classified as critically endangered.[5] In 2007, the scientific community was aware of only 250 individuals of this species in the wild in Vietnam, where most were spindly, unhealthy young trees, growing in two small stands in the middle of coffee and corn plantations. Other stands in China were presumably planted.[6] Due to its rot-resistant wood, *Glyptostrobus pensilis* is highly sought after in the luxury timber market and is used for a variety of structural and boat-building uses by local communities. It is threatened (like so many endangered species) by illegal logging.

As I learned more about the two populations in Vietnam, I realized how remarkable the *mai hing sam* in Laos really were. The trees in Vietnam grew very close together and, like those in China, appeared like they could have been planted. Boardwalks had been built within the stands to get around. Dams located beneath each of the stands were used for agricultural irrigation and raised the water levels for the trees significantly. In contrast, the trees that we observed in Laos were erect and widely spaced, as expected for a wild population. The crowns of the *mai hing sam* in Laos were only found in the top third of the trees, with no limbs below for us to climb to the seed-bearing cones. In the Vietnam population, perennial and annual branchlets were numerous along the main bole, appearing to be epicormic growth. This form suggests that the trees in Vietnam were responding to stress from inundation. Also, some of the trees in Vietnam were cut down years ago and had resprouted.[7]

I immediately told my colleagues about the *mai hing sam* discovery so that we could develop a strategy to describe and protect this stand. I also informed the Nam Theun 2 Power Company (NTPC) of the discovery and asked to spend time describing the tree and its ecology and to have a surveyor document their elevation relative to the proposed reservoir footprint. I was not allowed time to document this stand properly, however, and I was only able to record the number and size of the trees and basic soil characteristics. There were approximately one hundred trees in the stand, and many were three feet in diameter at breast height. We only had very rough elevation information from our GPS units, but it was clear that the trees—along with many others that we were unable to document—would likely be within the reservoir footprint.

In desperation to protect these rare trees, I contacted the Nam Theun 2 Panel of Experts, an audit group that was in charge of assessing

Facing page: Forests in the Annamite Mountains are rapidly disappearing due to forestry, agriculture, and hydropower development, along with other causes. Philip Thomas (right) stands beside _Glyptostrobus pensilis_ within a rice paddy.

PHOTO BY DAVID MCGUIRE

the environmental and socioeconomic impacts of the dam, during their visit to the Nakai Plateau in August 2007. One of the members, the American conservation biologist Lee Talbot, joined me on a tour of this newly discovered *mai hing sam* stand. Nothing seemed to come of the visit, however, and unfortunately, I didn't find anything about the trees in the panel's next report.[8] I proposed to my contacts at NTPC to collect as many seeds as possible and try to propagate and grow more trees. NTPC thought it was a great idea and gave us the go-ahead.

Developing a Restoration Protocol

At the time, *mai hing sam* had never been successfully propagated from wild-collected seed. As a result, several critical facts about restoration protocol were unknown to scientists: What time of the year do the seeds mature in the mountains of Laos? How long is their seed viable? Do they produce seeds every year? Did we need to treat the seeds before sowing them? Under what conditions would they propagate and survive? What we did know was that all conifer seeds are wind dispersed, so we hypothesized that their dispersal is probably connected to the windy part of the year, which occurs toward the end of the monsoon season.

Our first challenge was logistical: how would we collect seeds from cones high in the canopies, sometimes one hundred or more feet high. Maxwell—who, by this point, had returned to Thailand where he lived—often hired local tree climbers to make collections. But this method requires low branches or woody vines growing up the trunk, as the climbers do not use any specialized equipment. We put our heads together and came up with an unusual plan. We placed large tarps under the trees and hired boys with slingshots to shoot rocks up into the canopies of the trees so that the seeds would fall onto the tarps. We tried this method, and miraculously it worked. We got thousands of cones and hundreds of thousands of minute winged seeds.

The next challenge was to clean and propagate the seeds. This process was not managed by a conifer expert like Philip Thomas, as I had hoped. Rather, NTPC hired a commercial contractor to propagate the seeds in a local nursery. The contractor had no familiarity with this sensitive species, and only twelve seedlings germinated. Of those, only four grew to maturity. In restoration and horticultural propagation, this rate is not considered successful, but it was a start.

In 2008, NTPC planted the four trees at the confluence of two small streams behind the house occupied by the director of the Watershed Management and Protection Authority. This area was somewhat protected and easy to monitor, although soil characteristics were not similar to the natural conditions of the peat swamps in which the trees naturally grew. In 2015, when I first observed these trees, they were about six feet in height, and on my last expedition, in January 2020, they had reached over sixteen feet. The key to the survival of these four trees, I believe, was sustained high soil moisture during their establishment period and protection using sturdy exclusion fencing to fend off the cattle and water buffalo that munch on the succulent foliage.

Threats to Wetland Habitat and Endangered Species

After my contract was completed in 2009, I returned to California, where I became an assistant professor at the University of San Francisco. I vowed to go back to look for more *mai hing sam* in the Nakai–Nam Theun National Protected Area. Southeast Asia is experiencing rapid habitat loss, biodiversity declines, and risk of species extinction primarily due to unsustainable harvesting of forest resources and conversion for agriculture. Lack of enforcement and pressure to develop rice paddies has led to the decline of wetland habitat and continued poaching in the protected areas.[9] Nearly every species of softshell turtle, terrapin, or tortoise is threatened with extinction. Populations of exceptionally rare species, such as the saola, are too low and fragmented to be viable.[10] Considering these threats, I knew that we needed to mount a concerted effort to document and conserve *mai hing sam* in the region.

Phil Rundel, who had first encouraged me to participate in the project in Laos, recommended that I apply for National Geographic funding. I spent two years getting collaborators on board

PHOTOS BY DAVID MCGUIRE

In 2015, the author partnered with other researchers and local collaborators to locate more than six hundred previously undocumented *Glyptostrobus* in the Nakai–Nam Theun National Park. The author (at right) measures tree height using a clinometer, and a tree climber ascends to the upper canopy.

and finding out from contacts if there were any other trees in the national protected area. Maxwell and I corresponded regularly during this period. Likewise, Philip Thomas was a huge source of support and encouragement. Finally, in the spring of 2014, my collaborators and I received funding, and we went on to get permits and work on the expedition plan that summer.

With the help of National Geographic funding, we were able to document more than six hundred other *mai hing sam* between ten and thirty miles from the original stand. These plants occurred in the newly renamed Nakai–Nam Theun National Park, an area that has been under the management of the Watershed Management and Protection Authority since 2005. The trees in the oldest stand are more than three feet in diameter at chest level and five hundred to more than one thousand years old. Many of them are over six feet in diameter, and the largest is over ten feet. (We recorded 11.2 feet—3.4 meters—but it's difficult to get the measuring tape behind all the woody vines and strangler figs on the trunk.) The neighboring communities call the largest tree the "mother tree." It is more than 138 feet (42 meters) in height. We believe it could be two thousand years old, but it is not the tallest tree: that claim goes to one we documented at 184 feet (56 meters) tall.

While these trees are protected in the park, illegal activities still occur. Sometime between September 2015 and February 2016, two hundred *mai hing sam* were logged, leaving the total known population at approximately four hundred individual trees. This event was deeply upsetting, especially because, as I later learned, the individuals responsible were aware of the conservation importance. The Laos government took the event seriously and not only arrested the local Lao poachers but aggressively pursued the company in Vietnam that had hired them. Fortunately, the neighboring communities protected the mother tree from the poachers. Another factor that might have contributed to its protection is that the oldest trees are often hollow at the base, much like coast redwoods in California. The younger trees have solid trunks that are more desirable to poachers. This event shifted our project's goals and objectives to focus on community-based restoration program and to identify and protect other unknown stands in the region.

GRETCHEN C. COFFMAN

The author (right) plants a *Glyptostrobus* seedling on National Tree Planting Day in May 2019. More than one hundred Laos government officials participated in the event, including Axay Vongkhamsao, head of the environmental division at NTPC (left); Khamthone Vongphachanh (center); and Thong Eth Phayvanh (second from right), the deputy general director of the Department of Forestry and director of the Watershed Management and Protection Authority.

Each November, between 2017 and 2020, we collected seeds from the remaining stands. In the first two years, we propagated two thousand seedlings; however, many of these did not survive. We have learned a lot about propagation from these trials, and our team is actively developing improved propagation and planting techniques to restore stands of the *mai hing sam* in strategic areas of the watershed. We are excited to collaborate with colleagues in Vietnam and China to restore populations there as well. The urgency is clear: after the poaching occurred, the government intervened before the logs were removed from the forest. Some of the fallen trees were more than a thousand years old, and now those trunks remain as warnings on the forest floor. With these threats in mind, our work continues, sustained by the promise of the small seedlings.

Endnotes:

1 To learn more about recently documented mammal species in the Annamite Mountains: Dawson, M. R., Marivaux, L., Li, C., Beard, K. C., and Metais, G. 2006. *Laonastes* and the "lazarus effect" in recent mammals. *Science,* 311(5766): 1456–1458. doi:10.1126/science.1124187; MacKinnon, J. 2000. New mammals in the 21st century? *Annals of the Missouri Botanical Garden,* 87(1): 63–66. doi:10.2307/2666208

2 Recent botanical discoveries in the Annamite Mountains include many new orchid species. Also, Brendan Buckley, from Columbia University, documented remarkable old-growth specimens of another cypress family species, *Fokienia hodginsii,* growing in Vietnam's Bidoup Nui Ba National Park. The oldest specimens he found are more than twelve hundred years old, and the tree-ring data have supported Brendan's research on long-term climate change in the region, including primary evidence for the fall of the Angkor civilization. Sano, M., Buckley, B. M. and Sweda, T. 2009. Tree-ring based hydroclimate reconstruction over northern Vietnam from *Fokienia hodginsii:* eighteenth century mega-drought and tropical Pacific influence. *Climate Dynamics,* 33: 331–340. doi.org/10.1007/s00382-008-0454-y

3 Robichaud, W. G., Marsh, C. W., Southammakoth, S., and Khounthikoummane, S. 2001. *Review of the National Protected Area System of Lao PDR.* Vientiane, Lao PDR: Lao-Swedish Forestry Programme, Department of Forestry and IUCN; Scudder, T. 2020. A retrospective analysis of Laos's Nam Theun

2 Dam. *International Journal of Water Resources Development,* 36(2–3): 351–370. doi:10.1080/07900627.2019.1677456

4 Of the thirty-three conifer species documented in the Annamite Mountains in Vietnam, thirteen are members of the pine family (Pinaceae). The cypress and yellowwood families (Cupressaceae and Podocarpaceae, respectively) include seven species each. The yew family (Taxaceae) has five species, and the plum yews (Cephalotaxaceae) have one. In particular, the Da Lat Plateau in central Vietnam has sixteen species of conifers, representing the highest conifer diversity in Indochina. Ninety percent of these, however, are nationally threatened. Loc, P.K., The, P.V., Long, P.K., Regalado, J., Averyanov, L.V., and Maslin, B. 2017. Native conifers of Vietnam—A review. *Pakistan Journal of Botany,* 49(5): 2037–2068.

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7 It is interesting to note that pneumatophores of the trees in Vietnam measure about 2 feet (0.6 meters) tall on average, similar to those in Laos; however, the pneumatophores were more abundant in Laos, sometimes numbering dozens per tree and usually much shorter.

8 McDowell, D., Scudder, T., and Talbot, L.M. 2007. *Twelfth Report of the International Environmental and Social Panel of Experts for the Nam Theun 2 Hydro Project.* Vientiane: Lao People's Democratic Republic.

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The map in this article was created using Esri, USGS, USFS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, lntermap and the GIS user community.

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Dedication

I dedicate this manuscript to the late James Maxwell (1945–2015). He was an intrepid botanist, fervent collector, a character like no other, exemplar taxonomy mentor, and trusted friend.

GRETCHEN C. COFFMAN

James Maxwell in 2007

FAISON, E.K. 2021. BACKYARD CLIMATE SOLUTIONS. *ARNOLDIA,* 78(3): 28–37

Backyard Climate Solutions

Edward K. Faison

Carbon dioxide levels in the Earth's atmosphere stand today at 415 parts per million, which is significantly higher than concentrations have reached for at least the past eight hundred thousand years. Throughout this time, levels oscillated between 180 and 280 parts per million, until the mid-nineteenth century, when they began an inexorable rise. By the end of the century, if business as usual continues, carbon dioxide levels could be higher than at any time in the past fifty million years.[1]

Like many other concerned citizens, I have wondered what one person can possibly do to help stem the rise of carbon dioxide levels, warming temperatures, and accompanying species extinctions that characterize our Earth in the twenty-first century. Carbon is a two-part problem: we must simultaneously reduce combustion emissions and increase the removal of atmospheric carbon dioxide. As an individual, I can take action to reduce emissions (use more efficient LED bulbs, drive a more efficient car less often, use airplanes sparingly), but what about the other side of the equation? I have increasingly come to recognize that, as a landowner, the way I steward the vegetation on my property can make a difference to both sides of this problem.

I live in a small, residential neighborhood in an otherwise rural part of Connecticut. My property comprises a one-and-a-half-acre lot, about two-thirds wooded. The other third includes a yard (where the kids can kick a soccer ball), the house, and a gravel driveway that can accommodate several cars. Plants on my property, like those growing anywhere else, remove carbon dioxide from the atmosphere during photosynthesis and store it as carbon molecules in wood, roots, and leaves—a process known as carbon sequestration. Yet it's surprising to learn just how much carbon dioxide is removed by the Earth's natural vegetation: about 30 percent of all carbon emitted each year globally. With changes in the way we manage vegetation, this percentage could increase dramatically.[2]

Trees are key. An acre of temperate grassland and an acre of temperate forest store a similar amount of carbon in the soil, but a forest stores as much as seventeen to twenty times more carbon in the vegetation than does a grassland.[3] Compare an acre of forest to an acre of lawn, and the carbon storage disparity is far greater. When we replace natural forest with fields, lawn, and other less-natural land covers (like roads, parking lots, and buildings), not only do we release huge amounts of carbon once stored in the trees into the atmosphere but we also sequester significantly less carbon going forward.

The Carbon in My Trees

I became curious about the role of my property in sequestering carbon and how much of a difference simple management decisions could make towards this end. How much carbon is stored in the trees on my property? To answer this question, I measured the diameter of every tree at least five inches in diameter at breast height and then used carbon estimation ("allometric") equations devised by the United States Forest Service and researchers from Harvard Forest to estimate the total biomass in the trees.[4] Plant tissue contains about 45 to 50 percent carbon, so dividing total biomass in half is a good approximation of the carbon storage in the plants.[5] The results: 226 trees storing 84.3 tons of carbon total, including a forty-inch-diameter black oak (*Quercus velutina*) and a red oak (*Quercus rubra*) of nearly the same dimension. These big oaks comprise less than 1 percent of the trees on my lot but store a remarkable 13 percent of the carbon. The big oaks are not idle reservoirs of carbon either. A healthy red oak forty inches in diameter may add two-tenths of an inch to its trunk

Facing page: **Homeowners can take action on climate change by making simple management decisions that leverage the carbon-absorbing power of trees.**

ALL PHOTOS BY THE AUTHOR

diameter each year—an imperceptible increase to even an observant naturalist—but a layer of carbon equal to adding an entire six-inch-diameter tree.[6]

The amount of carbon stored in the trees across my property is over 50 percent higher than in an average acre and a half of forest in Connecticut.[7] The elevated levels can be attributed to the relatively high density of large trees in my woods, for which I have the past owners to thank. In addition to the two large oaks, seven other trees exceed twenty-seven inches in trunk diameter. A typical acre and a half of forest in Connecticut currently contains only one or two trees of this size.[8] Ironically, the forest edge associated with residential properties appears to contribute to large tree growth. Trees within one hundred feet of a forest edge (which many of mine are) grow faster and thus are often larger—and store more carbon—than those in a forest interior because of reduced competition for light and greater leaf area.[9] Hence, smaller residential properties can be surprisingly important contributors to carbon sequestration.

Natural Climate Solutions

As a property owner, I have many different options for how to manage the vegetation growing on my lot to increase the removal of carbon dioxide from the atmosphere and to reduce emissions. These practices are collectively referred to as natural climate solutions.[10]

By choosing not to convert the forest on my property into lawn or field (a practice known as avoided conversion), I refrain from emitting the carbon stored in those trees into the atmosphere as carbon dioxide: 310 tons of it. (Carbon dioxide emissions can be calculated by multiplying organic carbon—in this case, 84.3 tons—by 3.67). Three-hundred-ten tons of carbon dioxide is equivalent to the annual emissions of sixty-one cars.[11] These are not insignificant numbers, and when multiplied across hundreds of thousands of small properties, the potential for avoided emissions is notable.

When retaining a forest, I have a range of management decisions that will affect the amount of carbon stored in my woods. At one extreme, I could remove all the adult trees and regenerate a young forest. At the other extreme, I could remove an occasional tree for firewood, a practice that falls within the category of reduced impact forest management, or, by practicing wildlands management, I could remove no trees at all. Not surprisingly, the latter scenarios result in a significantly greater amount of carbon storage in my woods than the former scenario. In fact, any tree removal on a property like mine reduces carbon storage below the potential maximum for that site (although it is also true that if I leave all my trees standing, which I mostly do, and obtain my firewood from another source, I transfer that carbon loss to another property). Hence, reduced impact forest management—retaining more trees, particularly large ones, for more time—can make an important difference in the amount of carbon that is retained in a forest.[12]

Decisions about tree retention in residential areas often involve mitigating risk to power lines. A few years ago, for instance, the power company asked for my permission to cut three healthy trees on the edge of my previous property: a red oak, white oak (*Quercus alba*), and pignut hickory (*Carya glabra*), all with trunk diameters of more than thirty inches. Removing three trees would not have resulted in any forest conversion on my property—indeed, there are young, small trees growing underneath these big ones—but the carbon stored on my property would have been reduced by about eight tons, equivalent to the annual emissions of almost six cars. A large tree thirty inches in diameter also removes about seventy times the quantity of pollutants (including carbon monoxide, ozone, nitrogen dioxide, and particulate matter) as a tree three inches in diameter.[13] I decided that the trees were a relatively low risk to the powerlines and would provide more benefits if I allowed them to continue to grow and sequester carbon.

Wildlands management, the decision not to cut or mow any trees, has obvious limitations near houses, but it can be applied to more removed areas. In the relatively small number of wilderness areas and strict nature preserves in the northeastern United States, the trees store a disproportionately large amount of carbon

Individual trees sequester more carbon the larger they grow: A forty-inch-diameter red oak (left) adds about two-tenths of an inch to its trunk diameter every year, but this new layer of biomass stores approximately the same amount of carbon as an entire six-inch-diameter tree elsewhere in the author's backyard forest.

relative to the region's total forest area.[14] Wildlands also have the potential to sequester much additional carbon. Because of a lengthy land-use history of forest clearance and intensive logging, northeastern forests are, on average, only about 20 to 30 percent of their maximum potential age (80 to 100 years versus 350 to 400 years) and store only about half their potential carbon. An eighty-year-old forest today can, in most cases—barring a major disturbance such as a windstorm or insect infestation—continue to accumulate carbon for at least the next two hundred years in live and dead trees and in the soil.[15]

Another management option I have is reforestation: allowing an existing field to return to forest. I have begun reforestation on a small section of lawn along the edge of my property. Over the next fifteen years, this patch of regrowing forest may store as much as twenty-five times the aboveground carbon as the grassy lawn it replaced.[16] Hence, reforestation has tremendous potential to sequester additional carbon on little-used pastures, agricultural fields, vacant lots, municipal fields, and small lawns on residential properties.[17] There is a good reason for this potential: a site in which the trees have been removed—either recently or long ago—is in a deep carbon debt because the land stores a fraction of the carbon it once stored as a forest.

Energy Use

Trees, of course, also have other climate-related implications for my property. Trees standing within sixty feet of my house reduce home energy expenditure and carbon emissions by cooling the house in summer and insulating it from cold winds in winter. Not surprisingly, large trees provide significantly greater energy reductions than do small trees. A thirty-inch-diameter red maple located on the west side of a house would reduce carbon dioxide emissions by almost seven-fold compared to a two-inch-diameter red maple that is similarly placed.[18]

One caveat is that trees, especially conifers, located on the south side of a house increase winter fuel use by blocking solar radiation; but the drawbacks are generally offset by the substantial year-round benefits of trees located on the other three sides of a house. For example, if a thirty-inch white pine was growing on the south side of my house, it would increase winter fuel use slightly, while still providing some summer cooling, resulting in an estimated 10 pounds of additional carbon dioxide emitted annually. But the same tree on the north side of the house would reduce winter fuel use—and provide greater summer cooling—resulting in the reduced emissions of an estimated 335 pounds of carbon dioxide annually.[19] Trees, therefore, play an important role not only in sequestering and storing carbon but also in reducing household carbon emissions.

Habitat and Biodiversity

Natural climate solutions can also provide important forest habitat. Trees, as they age and grow larger, provide nesting and denning sites for a host of birds and mammals.[20] They create deadwood that provides food for insects and develop large crowns that supply an abundant seed source. Even scattered trees with trunks at least sixteen-to-twenty inches in diameter in an urban setting can have outsized effects on bird diversity and abundance—a role that has caused researchers to describe large urban trees as "biodiversity hotspots."[21]

Reforestation of fields and lawns can provide additional young forest habitat (when the trees are fifteen years of age or younger), an ephemeral and uncommon habitat in the northeastern United States. Several species of birds (like chestnut-sided warbler, prairie warbler, indigo bunting, and brown thrasher) and the rare New England cottontail prefer dense, low woody vegetation found in young forests, shrublands, and disturbed open woods and are generally not found in closed forests.[22]

Depending on how many trees are retained or regrown on a property, and where the property is located, a small parcel may serve as a green oasis in an otherwise developed environment, or as an uncommon vegetation structure in a landscape of mostly mature forest or field, or as an extension of a larger forested patch. My property best exemplifies the last scenario, as it abuts one hundred acres of contiguous forest. I frequently see and hear wood thrushes, veeries, barred owls, and pileated woodpeckers on my property. These species generally prefer mature forests or are associated with larger trees, and the wood thrush is listed as globally "near threatened" by the International Union of Conservation of Nature.[23] Such species would almost certainly avoid my property if I converted my woods into lawn. Given that North America has lost almost 30 percent of its total bird population in the past fifty years, the natural climate solutions presented here applied across a multitude of small properties could make a real difference in stemming these population declines.[24]

Management for Natural Climate Solutions

In general, the less I manage my property, the more climate benefits it will provide. Some tending, however, is important to allow trees to continue growing to their full potential. Lianas like the non-native oriental bittersweet (*Celastrus orbiculatus*), which thrive in the edge habitats characteristic of residential properties, are best cut and removed when they are growing up trees and over shrubs. Bittersweet will reduce the growth rate (and carbon uptake) and eventually kill trees by intercepting much of the sunlight in the canopy and by strangling the

Regrowing forests can quickly store far more carbon in the vegetation than lawn grass—as much as twenty-five times more in only fifteen years—while also providing superior habitat. With this in mind, the author has begun a small reforestation project in an area previously maintained as lawn.

trunk.[25] The native poison ivy (*Toxicodendron radicans*) and grape (*Vitis* spp.) are generally more benign than bittersweet, but they function similarly and can proliferate in edge habitats, so I generally cut these vines at the base of my trees to give the trees every advantage to remain healthy and sequester the most carbon.

With less management, tree branches inevitably grow close to my house and into my driveway and need to be trimmed periodically. After trimming, I deposit the branches in a brush pile or scatter them into the woods rather than chipping them or carting them away. Brush piles serve as cover and den habitat for a variety of small animal species such as red-backed salamanders, red-spotted newts, wood frogs, wrens, white-throated sparrows, juncos, and box turtles.[26]

Trees will also die over time from insects, pathogens, and other causes and can be a hazard if houses, cars, or recreational spaces are in the fall zone. Common sense dictates that these should be cut down. But if dead trees are not a hazard, they provide considerable benefits if left standing and are not an indication that the forest is "unhealthy" and needs to be fixed. Though no longer sequestering additional carbon, standing dead trees continue to store existing carbon, often for decades, as the carbon is released slowly via decomposition.[27] Dead trees also provide habitat for cavity-nesting birds and mammals and serve as an abundant source of insect food for woodpeckers and other bark-gleaning birds like nuthatches. On my property, a standing dead elm tree (*Ulmus americana*)

is used each year by a pair of yellow-bellied sapsuckers as a nest site.

When I need to remove a dead tree that poses a hazard, I move it into the woods after cutting it. Similarly, when large branches and trees fall during storms, I move them off the driveway and lawn and into the woods and use some for firewood. I also resist cleaning up downed branches and trees in the woods. Downed logs serve as habitat for a host of animals, replenish nutrients and carbon to the soil, act as germination sites for new tree seedlings, and store large amounts of carbon, often for decades.[28]

Reforestation also requires little to no management. Tree growth is the default process in the Northeast, and the vegetation will naturally self-organize into a forest over time if a landowner simply stops mowing a lawn or field. The cessation of mowing will also add to the carbon benefits of reforestation by eliminating a significant source of emissions.[29] A tall grass layer will inhibit tree growth because of competition and shading, and therefore shrubs, even thorny invasives like multiflora rose (*Rosa multiflora*), will generally facilitate tree seedling growth by reducing the grass layer and protecting the seedlings from deer browsing.[30] In most cases, tree seedlings will eventually grow above the shrubs and reduce shade-intolerant shrub species; however, in some instances, a dense shrub layer can suppress further tree growth beneath it.[31] In such cases, selectively removing some shrubs can be beneficial. Planting trees can supplement and speed up natural reforestation, but it can be expensive and labor-intensive, and is ultimately unnecessary unless a homeowner is interested in an immediate screen planting or a particular species that does not grow nearby.

The Final Look

Ultimately, implementing natural climate solutions is an exercise in restraint and may challenge a homeowner's sense of aesthetics. Indeed, given the choice, many homeowners prefer a relatively open, tidy property, with a few trees, long views, and unobstructed sunsets. But a property stewarded for natural climate solutions can offer a beauty not found in more open landscapes. On my property, I appreciate the delicate beams of light that pass through the foliage and columnar tree trunks in the early or later parts of a summer day; the brilliant reds, yellows, and oranges that envelop the property each autumn; and multitudes of snow- or ice-covered branches on a winter day. For six months of the year, when the leaves have fallen from the deciduous trees, the views lengthen and sunsets emerge. Even during the growing season, I enjoy surprisingly long views because most of the foliage on the large deciduous trees is above rather than below the sightlines.

In the small area where I have begun reforestation, sightlines are reduced and the brushy patch of tall grass, young trees, and shrubs look unkempt compared to my neighbors' adjacent, close-cropped lawn. Yet this management decision comes with other aesthetic rewards: insects busily foraging on the tall goldenrods that bloom in late summer and the flash of goldfinches and white-throated sparrows drawn to the seed source in this brushy new habitat.

In the end, there is a natural beauty that accompanies the climate and biodiversity benefits of leaving more vegetation intact. Faced with runaway carbon dioxide levels and a rapidly warming climate, property owners can leverage the carbon-absorbing power of trees by keeping them standing and growing and by allowing an existing field to revert to forest by not mowing. In this way, we can play an important role in the solution by doing *less* and letting nature do *more.*

Endnotes:

1 Current carbon dioxide levels are posted on https://www.co2.earth/. The long history of carbon dioxide levels on earth are discussed in Lindsey, R. 2020. *Climate change: Atmospheric carbon dioxide.* NOAA Climate.gov. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide; and in Kolbert, E. 2014. *The sixth extinction: An unnatural history.* New York: Henry Holt and Company.

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***Facing page:* Trees continue storing carbon long after they have fallen. Therefore, retaining logs and branches on the forest floor provides additional climate benefits and also adds new habitat types.**

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[7] Data on average carbon storage in Connecticut forests was calculated using the USDA Forest Service, Forest Inventory and Analysis Program EVALIDATOR tool. Retrieved from http://apps.fs.usda.gov/Evalidator/evalidator.jsp

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[11] The emission of the entire 84.3 tons of carbon (310 tons of carbon dioxide) into the atmosphere assumes that all cut trees would be chipped and burned and none would be used for wood products. If the trees were used for wood products, approximately 20–25 percent of the tree carbon would be stored in wood. See: Nunery, J.S., and Keeton, W.S. 2010. Forest carbon storage in the northeastern United States: Net effects of harvesting frequency, post-harvest retention, and wood products. *Forest Ecology and Management,* 259(8): 1363–1375; United States Environmental Protection Agency. 2019. *Greenhouse gases equivalencies calculator – Calculations and references.* Retrieved from https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

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The author standing in his backyard forest.

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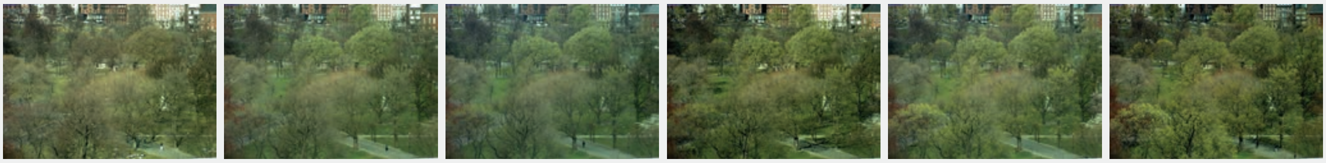
ALLEN, K. AND OSWALD, W. W. 2021. A NEW LOOK AT BOSTON COMMON TREES. *ARNOLDIA*, 78(3): 38–41

A New Look at Boston Common Trees

Kelsey Allen and W. Wyatt Oswald

MARCH 19 MARCH 24 MARCH 29 APRIL 3 APRIL 8 APRIL 13

2012

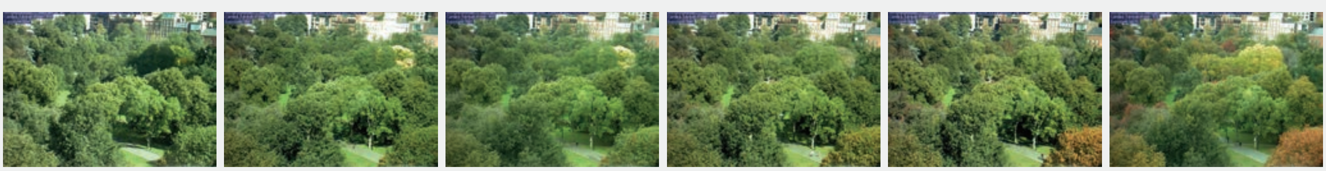


Technology changes how we see the world: think of Antonie van Leeuwenhoek's microscope or Jacques Cousteau diving with a video camera and bringing the movements of ocean life to the silver screen. For the past decade, a digital camera mounted on the roof of a ten-story building has taken photos of the Boston Common every thirty minutes. The camera is a simple consumer model, but the resulting set of photographs, numbering well over two hundred thousand, compresses time in a way that turns everyday changes within the tree canopy into meaningful patterns and trends. Within this set of images, forty seasons can be viewed as a flipbook. If you visit the Boston Common in April, you will see light-green leaves unfolding on elms (*Ulmus*) and the warm glow of red maples (*Acer rubrum*) bursting into flower, yet only in an image set like this could you determine how these hour-by-hour moments in the life of a tree correspond to seasons past. Ten years can be viewed simultaneously. Seasonal shifts can be visualized in a way that surpasses our on-the-ground experience. Moreover, thanks to image-analysis software, data can be extracted from the photographs, allowing researchers to quantify the "greenness" of the canopy as it changes through the growing season and from year to year.

We know that global climate change is impacting plant phenology. Already, for instance, researchers have described discernable differences between flowering times for herbarium specimens that were collected one hundred years ago and those that have been collected in recent years. So far, however, the photographs of the Boston Common have shown relatively consistent leaf-out times in the spring, with the exception of 2012. The sequence of photos from that year shows the details of the springtime green-up, when anomalously warm temperatures in March triggered leaves to emerge two to four weeks earlier than other years. The elms turn green first, but not because of leaf emergence; in fact, we are seeing

OCTOBER 5 OCTOBER 10 OCTOBER 15 OCTOBER 20 OCTOBER 25 OCTOBER 30

2018



APRIL 18

APRIL 23

APRIL 28

MAY 3

MAY 5

MAY 13

the maturation of samaras, the elms' winged fruits. Leaf out of the elms, along with the Common's red maples, lindens (*Tilia*), oaks (*Quercus*), and scholar trees (*Styphnolobium japonicum*), follows over the next few weeks. As trees on the Boston Common respond to climate change in the future, ongoing photography may reveal that years like this become less anomalous.

At the other end of the growing season, the deciduous trees of the Boston Common start to prepare for winter by breaking down their photosynthetic machinery during the second half of October. The timing of those changes has not varied much over the last ten years. In the set of photos from 2018, for instance, we can see the visual transformation of the landscape that occurs each fall, with the faded greens of early autumn giving way to patches of gorgeous color, including yellow elms and reddish-brown oaks. Then, by the last week of November, the leaves have all fallen, exposing the scaffolding of branches that held them aloft all summer long. And at the tips of those branches are buds, poised to burst open in spring and start this cycle anew.

Further reading

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NOVEMBER 4

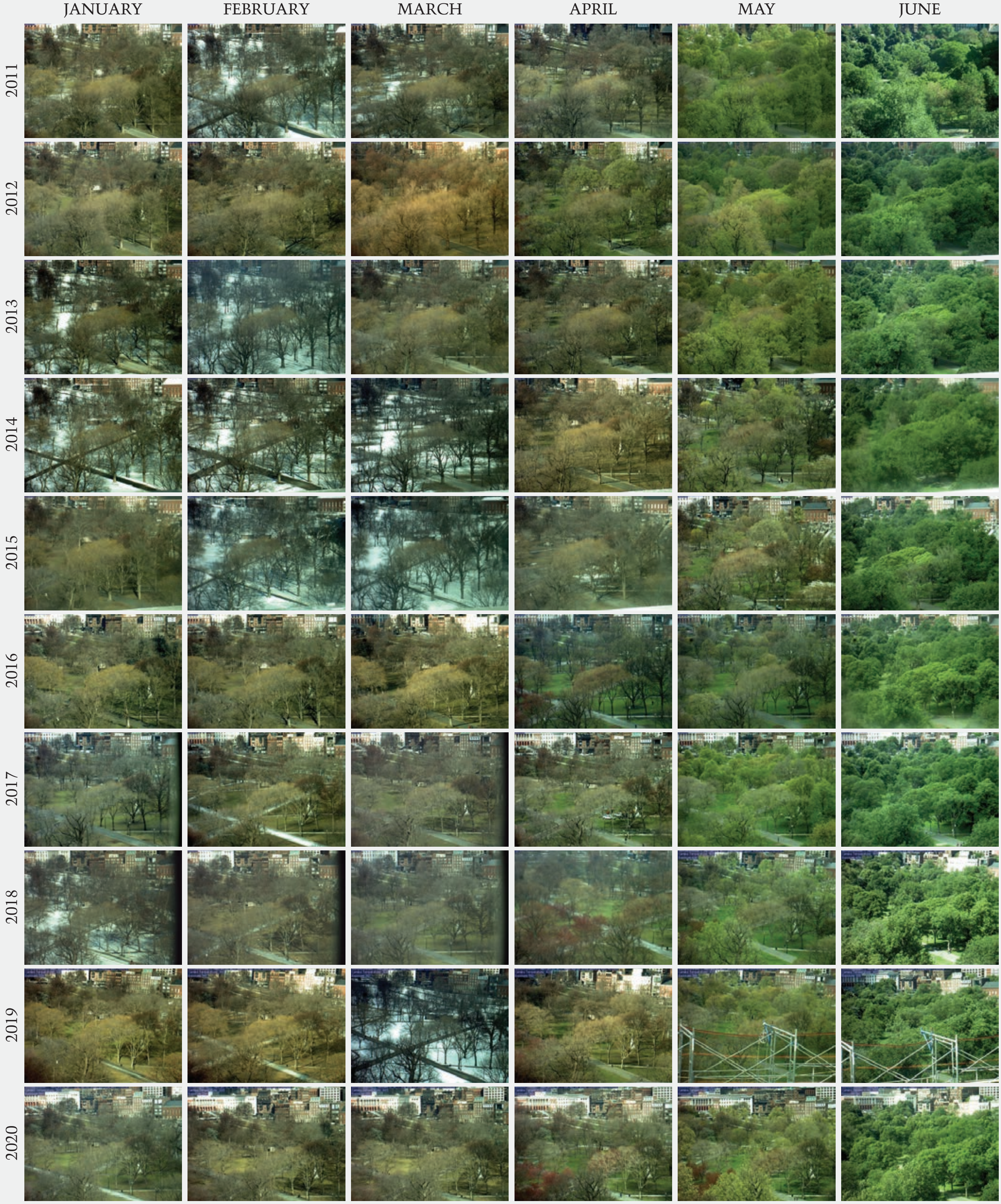
NOVEMBER 9

NOVEMBER 14

NOVEMBER 19

NOVEMBER 24

NOVEMBER 29


JANUARY
FEBRUARY
MARCH
APRIL
MAY
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2011
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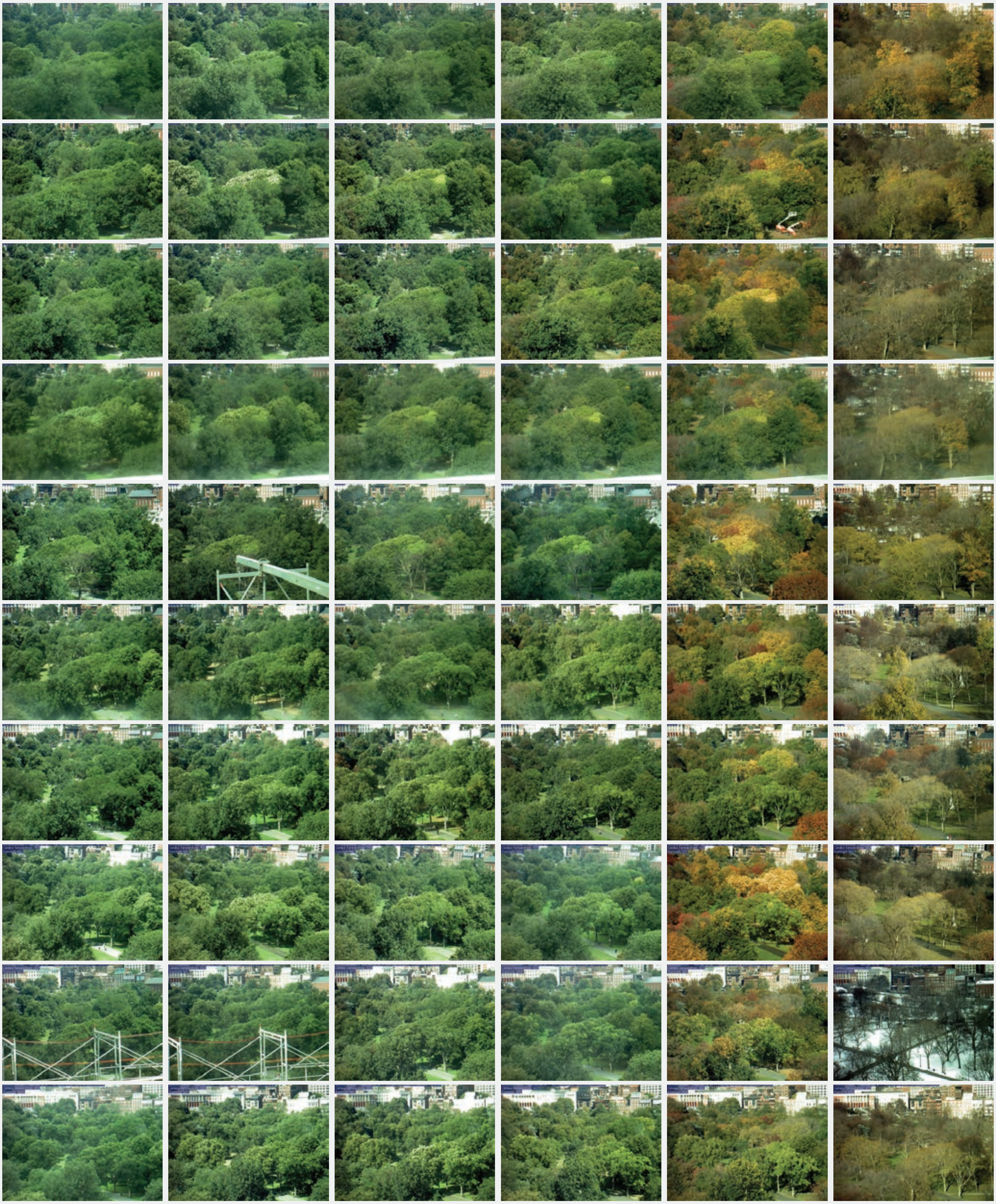
JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER



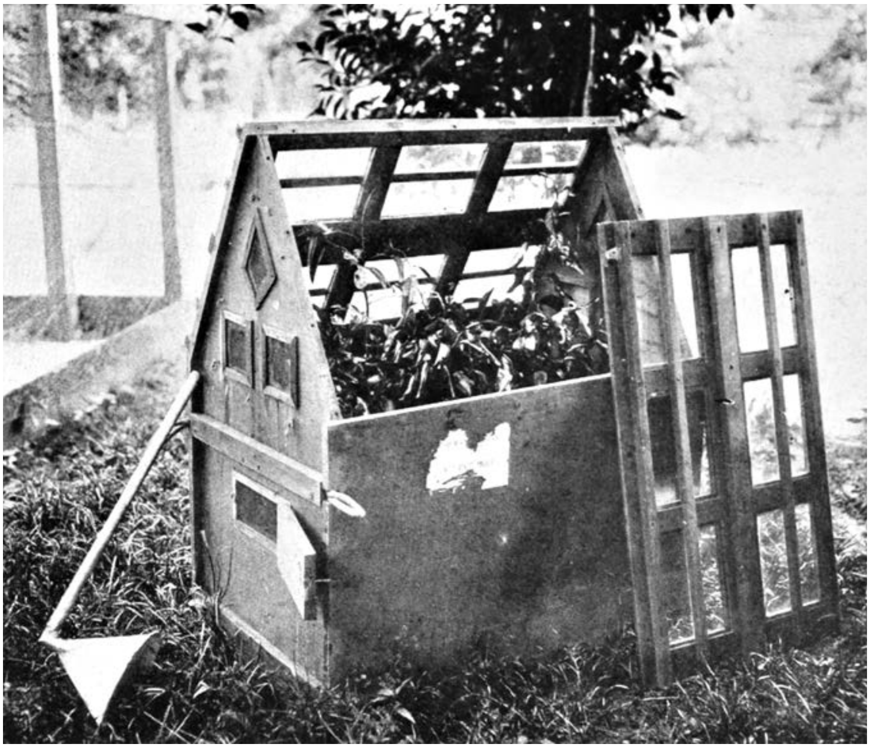
ALL PHOTOS BY W. WYATT OSWALD

Each column shows the Boston Common during the first week of the month—revealing differences year over year.

Case of the Anthropocene

Jonathan Damery

Luke Keogh. *The Wardian Case: How a Simple Box Moved Plants and Changed the World.* The University of Chicago Press and the Royal Botanic Gardens, Kew, 2020.



BIODIVERSITY HERITAGE LIBRARY/FROM US BUREAU OF ENTOMOLOGY (1913) *BULLETIN* NO. 120

Wardian cases moved plants around the world, along with insects and other organisms.

On December 18, 1994, three cave explorers squeezed into an opening of a cliff overlooking the Ardèche River in southern France. At the back, a whisper of cool air prompted them to prize stones from a narrow passage and worm forward headfirst. After ten feet, they encountered a thirty-foot drop into a large chamber. Beneath them, as it turned out, the cave walls were covered with paintings. Some appeared almost fresh. First, the explorers found a mammoth drawn in red pigment, then woolly rhinoceroses, cave lions, and compositions made entirely of human handprints.

Researchers would later determine that a landslide sealed the main entrance to the cave, now known as Chauvet Cave, twenty-eight thousand years ago, safeguarding hundreds of paintings and wall engravings. Eighteen thousand years later, glaciers had retreated from much of Europe, and many of the animals depicted in Chauvet Cave had gone extinct. Humans in Mesopotamia were domesticating wheat and barley. Fast forward another nine thousand years to the completion of the first recorded circumnavigation of the globe in 1522.

Eventually, in the summer of 1833, an English sailing ship departed London, bound for Australia. On the upper deck, the captain diligently monitored two sealed glass cases planted with ferns, grasses, and mosses. About six months later, the ship arrived in Sydney with all but three of the plants still alive. The case was opened only once; moisture cycled naturally inside the enclosure. On the return trip, the cases were packed with ferns that survived air temperatures fluctuating between twenty and more than ninety degrees Fahrenheit. In fact, the cases were so effective that stowaway seeds germinated in the soil.

A shipment of plants between the antipodes might seem like a minor historical footnote, but in a new book, *The Wardian Case: How a Simple Box Moved Plants and Changed the World,* historian Luke Keogh describes the shipment as a profound inflection point in the history of the Earth. Keogh first became interested in these enclosed glass cases while curating an exhibit at the Deutsches Museum in Munich. The exhibit opened in 2014 and focused on the Anthropocene, a term for our current geologic era that acknowledges the enormity of human-caused environmental change. Millions of years from now, our present moment will appear in the geologic record as an abrupt transition characterized by rapid climate change, sea-level rise, and mass extinction—an imprint far more permanent than the markings at Chauvet Cave. The unprecedented biotic exchange ushered in by the experimental plant shipments between London and Sydney is a piece of this story.

The experiments had been orchestrated by an affable English physician named Nathanial Ward and the nurseryman George Loddiges. Previously, it had been exceptionally difficult to ship live plants over such long distances. In addition to the general perils of sea travel (salt spray, tempestuous weather, foraging rodents), fresh water was a scarce resource and could seldom be spared for plants. In a backyard experiment, Ward discovered that plants could be sustained within an enclosed glass container for long periods without supplemental water. When such cases were used aboard ships, they solved many of the persistent problems associated with long-distance plant transport. In a follow-up experiment in 1834, Ward sent six cases to Egypt and Syria, and when the plants were received, scarcely a leaf was reported missing.

Keogh follows the Wardian case as it became a commonplace tool, not only for moving botanical curiosities but also for transporting crops (including tea, *Camellia sinensis*, and rubber, *Hevea brasiliensis*) that supported the endeavors of Western empire-building. Also, because Wardian cases contained soil, the plants invariably arrived with insects and pathogens in tow. "To move plants was to move ecosystems," Keogh writes. Some of these newcomers proved devasting, including coffee rust (*Hemileia vastatrix*), which erupted in Ceylon (now Sri Lanka) in 1869 and subsequently decimated plantations in many coffee-growing regions around the world. Altogether, this global churning—which continues in a post-Wardian world—accumulates to dramatic effect. Keogh, for instance, cites a study suggesting that approximately nine out of ten invertebrate pests in the United Kingdom arrived on live plants.

Certainly, the Wardian case was just one innovation within the broader scope of the Anthropocene. The case gained traction at a moment of enormous industrialization and fossil fuel use. While the first Wardian cases were transported on sailing ships, steam power soon predominated. Carbon dioxide levels in the atmosphere would mount. Moreover, industrial agriculture favors monocultures, which are especially susceptible to pests and pathogens (like coffee rust) that spread rapidly in the Wardian era. In a curious twist, Keogh recounts how, in the early twentieth century, entomologists used Wardian cases to intentionally transport insects to control invasive plants and other pests that had been imported in earlier shipments.

By the 1920s, plant quarantines and import restrictions slowed the use of Wardian cases, but it was the airplane that finally rendered them obsolete. Now live plants can be moved without soil, wrapped in plastic, and mailed directly to inspection sites before being admitted into a country, assuming importers follow the rules. Yet pests and pathogens continue to spread. The emerald ash borer (*Agrilus planipennis*) was first identified in the United States in 2002 and likely arrived burrowed within wood shipping materials. The Asian longhorned beetle (*Anoplophora glabripennis*) arrived in a similar fashion before 1996. In this light, the Wardian case was only one contributor to this dramatic biotic exchange. Not only has the admixture continued to the present but humans began moving plants long before Nathaniel Ward arrived on the scene. Ward's main innovation, Keogh stresses, was the enclosed system. Also, not insignificantly, Ward was a charismatic individual who used his social connections to promote the case.

For Ward, awaiting news on his inaugural shipment to Australia, the long-term implications of his cases would have been impossible to imagine. Thinking about consequences two hundred years in the future is almost beyond the realm of comprehension—almost as unlikely as the painters at Chauvet Cave imagining researchers studying their work more than thirty thousand years later. Yet the concept of the Anthropocene asks us to think even further ahead. In 1833, the captain of the ship to Australia penned a congratulatory letter to Ward: "Your experiment for the preservation of plants alive … has fully succeeded." The case of the Anthropocene challenges us to reconsider the meaning of our own small successes.

Jonathan Damery is the editor of *Arnoldia.*

Planting Edo: *Pinus thunbergii*

Rachel Saunders

In February 2020, we opened our largest ever exhibition at the Harvard Art Museums, never anticipating that, a month later, the doors of the museums would close due to the pandemic. *Painting Edo: Japanese Art from the Feinberg Collection* features 120 paintings arranged as an immersive, in-person experience. At the onset of the closure, when I rushed about my office gathering books and papers, I expected to be away for only a few weeks, but as our exile from the galleries continued, we adapted to virtual close-looking through an online exhibition and Zoom events. What I hadn't realized was how significantly this new form of looking would alter my own vision of Edo painting.

One work that I came to see differently was *Old Pine* by the eighteenth-century painter Itō Jakuchū. It is by no means a fresh observation that artists of the Edo period (1618–1868) were extremely interested in the natural world. Jakuchū is celebrated today for the magical hyper-realism of his polychrome paintings of flowering plants, aquatic animals, and especially chickens, which he is said to have kept so that he could observe the complexity of their feathers daily. *Old Pine,* by contrast, is executed in gestural monochrome ink. The painting is modestly sized, but the radical proximity from which the tree is painted—so close that it cannot be contained within the picture plane—makes an encounter with it feel as overwhelming as standing beneath an enormous conifer.

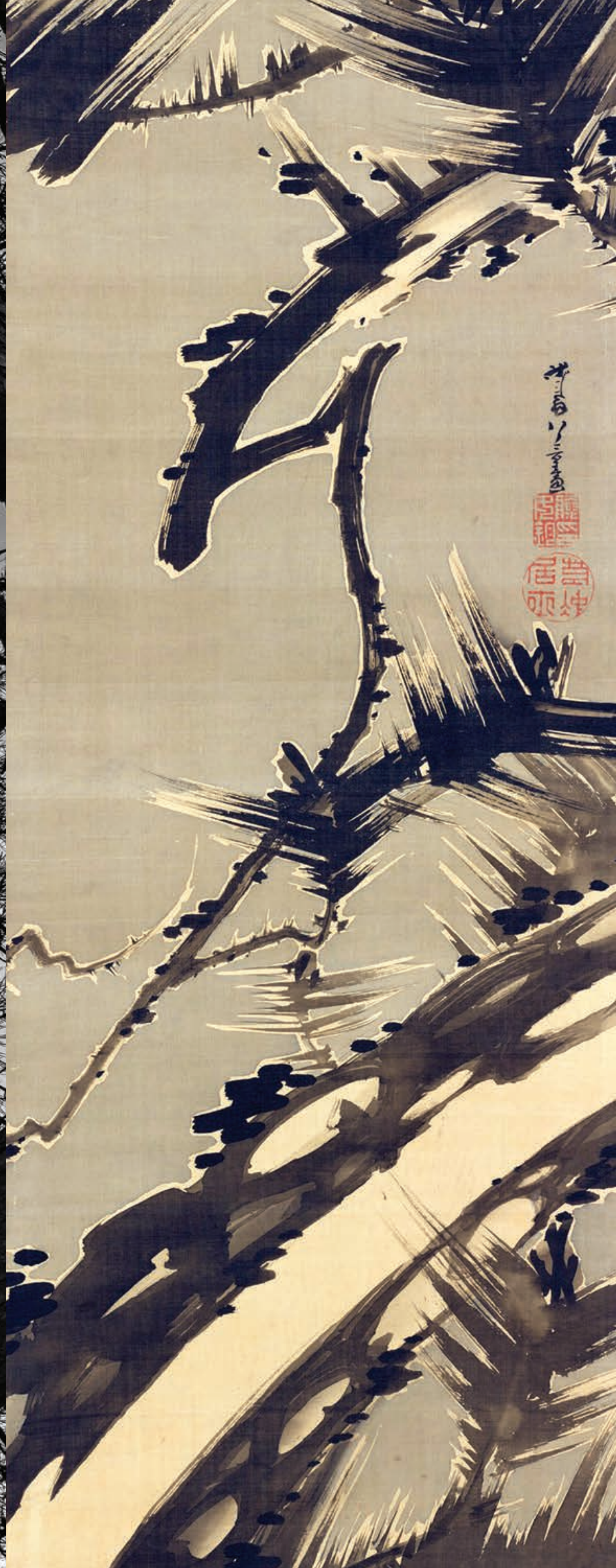
Pines have a long history in East Asian art and are among the primary subjects of ink painting. In the vocabulary of this spare, highly intellectualized mode of painting, pines represent resilience, longevity, and the integrity of the upright scholar-gentleman. Identification of a painted tree as "a pine" is all that is sufficient to trigger these associations, since ink painting valorizes capturing the essence of a thing over mere verisimilitude. Jakuchū had clearly captured an individual arboreal essence, but it was not until a botanist's eye was turned upon it that the true level of Jakuchū's observation emerged.

With Zoom, the distance between the painted plants in the galleries and their living counterparts at the Arnold Arboretum melted away. This enabled a new privilege of simultaneously looking at living and painted plants with the Arboretum's Michael Dosmann and Ned Friedman. Our conversations led to a series of public virtual events. With this botanical view, the eccentrically angled branches, plated bark, and textured twigs of Jakuchū's "pine" resolve almost immediately into features of a "black pine," or *Pinus thunbergii* (*kuromatsu* in Japan).

When we view the painting, a major limb—covered, dragon-like, in scaled bark—thrusts up from the bottom left-hand corner, only to disappear beyond the right-hand border. It curves back into the frame at the top right, from where an angular branch, brushed in several switchback strokes, descends. This dramatically contorted form echoes the Japanese black pines growing at the Arnold Arboretum (see accession 11371), and so, too, does the orientation of the painted needles: spiky lateral marks from a wide brush that flare from axial twigs. But the precision of Jakuchū's observation is evident beyond these most prominent elements. A variety of lichen-like dots peppers the branches, the largest pressed from the side of an inked brush, and the smaller nubby marks from its tip. What I had read as an anomalous abundance of moss-like texture strokes, Ned's eye revealed as the closely observed characteristic texture of black pine twigs, formed by the unusual persistence of bracts, which can remain for up to two years after their sets of paired needles fall.

In an inscription brushed in 1755, Jakuchū wrote: "Flowers, birds, grasses, and insects each have their own innate spirit. Only after one has actually determined the true nature of this spirit through observation should painting begin." *Old Pine* shows just how thoroughly Jakuchū took this dictate, not only in his obsessively observed and painstakingly detailed polychrome paintings but also, we can now see, in the spare and immediate genre of ink painting.

Rachel Saunders is the Abby Aldrich Rockefeller Curator of Asian Art at Harvard Art Museums.



The ARNOLD ARBORETUM of HARVARD UNIVERSITY