

arnoldia

The Magazine of the Arnold Arboretum

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Front cover: During a plant exploration trip in northern Sichuan, China, last September, Curator of Living Collections Michael Dosmann photographed these colorful naturally terraced ponds above a temple in the Huanglong (Yellow Dragon) Valley.

Inside front cover: The lovely double flowers of *Prunus* 'Shogetsu' (accession 451-2010-A) open blush pink and fade to snowy white. Photo by Kyle Port.

Inside back cover: *Sensei*, a forest bonsai of Austrian pines (*Pinus nigra*), was created and donated to the Arboretum by Martin Klein of Andover, Massachusetts. The trees on the right appear more open because they have recently been pruned and wired, which will allow careful arrangement of the branches. Photo by Nancy Rose.

Back cover: On February 20, 2015, a perfect cap of snow remained on a weeping purpleleaf beech (*Fagus sylvatica* 'Purpureo-Pendula', accession 78-98-A) following a 16-inch snowfall on February 15th, the fourth major snow event within less than a month. Photo by Kyle Port.



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CAMPAIGN FOR THE
LIVING COLLECTIONS

The Campaign for the Living Collections is well under way at the Arboretum. In the last issue we presented the document that guides the Campaign, and in this issue we get to the action—how does the Arboretum curatorial staff prepare for and carry out plant collecting expeditions? Curator of Living Collections Michael Dosmann and Manager of Plant Records Kyle Port provide insight and share photographs from their recent trips.

The Art and Act of Acquisition

Michael S. Dosmann and Kyle Port

Plant exploration combines a love of plants with adventure. Over its nearly 145-year history, the Arnold Arboretum has harnessed these passions by leading or supporting more than 150 plant collecting events across 70 countries. As knowledge of the plant kingdom has evolved, so have the Arboretum's living collections, placing even greater demand on deliberate and strategic collection planning. As described in the previous issue of *Arnoldia* (Friedman et al. 2016), the new 10-year Campaign for the Living Collections articulates a number of broad goals that, when met, will preserve the collections' singular legacy and advance it well into the future. For example, there is a call to strengthen the species representation within genera such as *Viburnum* and *Taxus* that are useful to the study of biogeography. As a means of broadening the number of genera in the collections, several marginally hardy taxa like *Daphniphyllum macropodum* and *Nothofagus dombeyi* have been identified as species worth trying to grow here. And, because of the great threat of extinction, numerous conservation-status species are highlighted before they disappear from the wild.

The Arboretum will meet these collections goals through the acquisition of nearly 400 target taxa, or desiderata, with each fulfilling at least one (and typically several) goals. For many of the taxa on the list, the Arboretum needs several unique acquisitions (e.g., from multiple locations), so what is initially a list of 395 blossoms into a vibrant garden of 720 actual targets. Each of these targets will require its own acquisition plan and approach. A few might be purchased from nurseries, some may be acquired from cooperative institutions and repositories, while others will be sought out and obtained through the Arboretum's network of colleagues. However, the majority will be obtained on specific plant expeditions in which an Arboretum staff member leads or participates. With the vision and goals in place, a new generation of explorers, horticulturists, and other Arboretum friends and associates are rallying to collect from the temperate flora and cultivate these plants in the Arboretum.

Few endeavors are as rewarding and exciting as seeing plants in their wild habitats, collecting seeds or other propagules, and then bringing them back home to cultivate. As botanical garden professionals, we also value the role plant exploration plays in other aspects of collections manage-



Smoke from dynamic forest fires cloaked the Alpine Lakes Wilderness in the central Cascade Mountains of Washington as Kyle Port's flight descended into the region at the beginning of his plant collecting trip to northern Idaho last fall.

ment. The important pre-trip planning and post-trip follow-up lead not only to better executed expeditions, but to more individual (and thus institutional) knowledge that can be applied to the long-term stewardship of the species collected. In this article, we shed some light on a number of aspects of plant collecting based on some recent trips and our shared experiences. It is not our intention to be encyclopedic on the subject, however, as many resources exist that cover in greater depth. (For more details on the philosophy, mechanics, and best practices of plant exploration see Ault (2000), ENSCONET (2009), and the special 2010 issue of *Arnoldia* (Volume 68, Number 2) commemorating the 20th-Anniversary of the North America-China Plant Exploration Consortium [NACPEC].

For the majority of the expeditions that will be conducted by the Arboretum over the next decade, the various desiderata will dictate where (and how) we collect them. Simply put, as the individual targets are marked on maps, regions that contain the most "dots" become obvious sites for exploration. A region with just a single species might be best left to a contrac-

tor or other means. With respect to the Campaign, Living Collections Fellow Robert Dowell has been tasked with conducting species audits to identify these ideal collecting localities. For the inaugural expeditions that marked the Campaign's launch in the autumn of 2015, we (the authors) preselected regions based on our prior knowledge of the areas and confidence that they would yield quality material listed as desiderata. Kyle collected in northern Idaho from August 24 to September 4, 2015; Michael participated in a NACPEC expedition in central China focused on paperbark maple (*Acer griseum*) from September 1 to 18, and then struck out with another set of colleagues in northern Sichuan from September 18 to 29.

BE PREPARED

In many respects, a trip's success—both short- and long-term—is proportional to the amount of planning. Once a general region for an expedition has been selected, the trip participants hone their knowledge about the target species' biology, including their identification, phenology (e.g., what time of year mature seeds are

NANCY ROSE



Gathering information for planning the next where, when, and how of Arboretum expeditions may require everything from a library's collection of printed floras to online herbaria databases to direct correspondence with botanical observers in the field. Living Collections Fellow Robert Dowell uses multiple resources to conduct species audits that help pinpoint probable collection sites.

MICHAEL DOSMANN



One step in planning expeditions is determining when seeds of target species are likely to be mature. The Brenton Arboretum's Andrew Schmitz displays a handful of ripening white ash (*Fraxinus americana*) seeds collected during the 2011 Twin Tier Expedition to New York and Pennsylvania (Michael Dosmann was also a participant).

likely to be present), preferred habitats, and specific areas where they are known to occur. Online resources aid information gathering, and we've found the surge of herbarium specimen data uploaded to regional, online floras to be very useful in selecting collection locations.

It is important to create lists of natural areas and localities that are home to target species, ideally multiple species for the sake of efficiency, although for a high-priority target there is nothing wrong with going well out of your way to get it. While the desiderata certainly guide the expedition, it's worth reviewing what other species may occur in the area and might be of interest to collect opportunistically. Lastly, for both foreign and domestic collections, it's essential that all of the proper permits to access the sites and collect material are acquired. These permits are different from those required to import plant material into the United States.

Collaborating with local experts who can share their knowledge is a very important part of the planning process. Not only will they know the local flora (and may be able to scout plants in advance), but they can also be helpful in obtaining permits. Those same contacts can play an invaluable role during the actual expedition as full-fledged trip participants. Both the regional and visiting participants can share expertise on topics ranging from the local flora to germplasm collecting techniques. And, for practical purposes, additional hands make lighter work, so having another participant on board is great. We've found that a complement of three or four people is ideal for clear definition of tasks and division of labor during the trip.

The first step in assigning roles is to designate a trip leader, who will create an itinerary that includes daily destinations and likely targets, places to lodge at night, and contact information for collaborators on the ground. When scheduling, it's very important to build in more than enough time to travel between destinations, and to leave some flexibility in case of inclement weather or delays. Flexibility can be beneficial for other reasons, too, as a locality may end up being far more fruitful (literally) than anticipated and worth staying an extra day. It's also essential to include time for processing herbarium specimens and preparing propagules

ANTHONY S. AIELLO



Local collaborators are invaluable on expeditions. (Left) Kang Wang, from the Beijing Botanical Garden, has acted as liaison for a number of expeditions including the 2015 NACPEC trip that concentrated on paperbark maple (*Acer griseum*). Michael Dosmann, Kang Wang, and Kris Bachtell (left to right) sort and organize *Acer griseum* leaves that will later be subject to DNA extraction. (Right) Paul Warnick, from the University of Idaho Arboretum and Botanical Garden, collaborated with Kyle Port on the 2015 North Idaho Expedition. He's seen here with a collection of devil's club (*Oplopanax horridus*) in the Selkirk Mountains, Kaniksu National Forest, Idaho.

KYLE PORT



What's a Collection?

The word “collection” can refer to a group of living plants, like the Lilac (*Syringa*) Collection at the Arboretum. But on plant collecting expeditions, “collection” is also the term used for the products of each unique act of collecting. For example, if both seeds and herbarium vouchers are collected from a tree, a single collection number is assigned to both since they came from the same plant. When the seeds are distributed to other institutions, each institution will assign an accession number from its own system, but the original collection number will be included in the accession information so the original source can always be traced.



Anthony S. Aiello measures out seeds of *Ostrya japonica*, collection number 24 from the NACPEC 2010 trip, prior to packaging and shipping them back to the United States.

MICHAEL S. DOSMANN



Larry Hufford, Professor and Director at Washington State University's School of Biological Sciences and a member of the Living Collections Advisory Board, collects seed from Lewis' mock orange (*Philadelphus lewisii*) on the bank of the Clearwater River, Nez Perce tribal lands, Lewis and Clark Trail. This western North American native bears fragrant white flowers.

(seeds, cuttings, plants) for shipping back to the Arboretum. This is not something to leave until several hours before boarding the plane to return home! For international trips, incomplete seed cleaning efforts will likely result in precious germplasm failing inspection and ending up in the incinerator.

IN THE FIELD

There is a destiny which makes us brothers; none goes his way alone. All that we send into the lives of others comes back into our own.

—Edwin Markham (1852–1940)

Oregon's poet laureate sums up the joy and adrenaline rush of botanizing for the Arboretum; no wonder plant exploration is so addictive. Eventually, all of the planning and preparation is complete, bags are packed with gear, and field work is about to begin. After arriving and taking care of the initial logistics (which often means adjusting to a new time zone), the group makes its way to the first collecting site. Sometimes the entire trip is spent at one location. At other times, the expedition may cover great distances and necessitate staying in a new place just about every night (as was the case for the 2015 *Acer griseum* expedition), which can make for a rather harried excursion. Typically, though, the team stays in one location for several days, which was the pattern during the 2015 North Idaho Expedition.

Before the first day of collecting, all trip participants are assigned specific responsibilities (and the appropriate tools and materials needed). The duties for a typical team of three may be divided into trip recorder, germplasm collector, and herbarium voucher collector. The trip recorder assigns a unique number to each collection and records field notes and observations. Often referred to as passport data, these describe not just the plant's characteristics but also the habitat, associated species, and other key data such as GPS coordinates. We find that using field note

KYLE PORT



MICHAEL DOSMANN

(Left) David Port (Kyle's father), raised in the Idaho hamlet of Troy, played many roles over the course of the 2015 North Idaho Expedition, including lugging the pole pruners to the edge of Lake Pend Oreille and to the high elevations around Roman Nose Lakes. (Right) Pole pruners also came in handy during the 2014 Ozarks expedition, where they were used to collect these fruit capsules of red buckeye (*Aesculus pavia*) in Arkansas.

forms, printed on waterproof paper, is best for all weather situations. The recorder must have a keen attention to detail, be thorough, and, of course, have excellent plant knowledge. Memories always fail, so it's important to capture the information immediately. Sloppy or partial records at this point can create a cascade of problems for days if not decades to come. Even if the propagules that are collected never survive, the data (and the herbarium vouchers) will. The germplasm collector is responsible for collecting propagules, which typically are in the form of fruits, although cuttings and even entire seedlings are also an option. This person should have a good understanding of how to treat the collected material, from estimating seed viability and determining if the collection is warranted to selecting the right kind of bag. For example, oil-rich seeds like acorns can generate a lot of heat through respiration, so cloth bags are used to keep them from overheating. Rhododendron capsules, however, are best gathered in small glycine bags to prevent the tiny seeds from escaping. In addition to regular pruning shears, a set of pole pruners is very handy to have since they can extend an extra 10 to 12 feet (3 to 3.7 meters), often eliminating the need to climb trees.

The herbarium voucher collector collects samples of plants that are then pressed and

dried for future documentation and study. Collecting a voucher (often with several duplicates) is a critical part of the process because it captures the maternal plant's traits at reproductive maturity. Once deposited in a herbarium, the voucher will serve as evidence of what was growing in that location. During the trip, vouchers are kept in wooden plant presses, which, when tightly clamped down and ventilated, will yield high-quality pressed and dried specimens. Wooden presses can be used in the field but they are heavy and bulky, requiring extra time to pack and repack with each collection. Instead, some collectors use a plastic bag (the modern day version of a botanist's vasculum), which is a lot quicker to use. However, if not labeled properly specimens can get mixed up, and they can dehydrate by day's end. We prefer to use canvas field presses loaded with newsprint and corrugated cardboard. These presses are light weight, can be quickly loaded, and begin the pressing process immediately. By the end of the day, all of the specimens collected are transferred to the full-fledged wooden press, which can be tightened more effectively than the canvas press.

While each of these activities may be assigned to a single point person, in reality it becomes a group effort. For instance, everyone might pitch in to call out associate species' names or other plant details to the trip recorder. Gather-

It's All in the Numbers

A question often is asked: From how many mother plants do you need to collect? The answer depends. If the goal is to capture as much genetic variation of that species' population as possible, particularly if the seeds will be banked long-term in a repository, then the answer is "many." The actual number depends on that species' breeding system (e.g., can it self-pollinate or is it forced to outcross), some technical assumptions based upon the population, including its size, and other details. The seeds from multiple mother plants can be bulked in the field (keeping track of how many were sampled), or each sample can be kept separate, which is important in cases such as the collection of conservation-status plants. If the goal is simply to produce a few living plants, then the focus may be less on capturing the full genetic variation of the population and just a few (or even just one) maternal plants can be sampled. Sometimes the sampling regime is dictated by realities in the field—there might just be one plant encountered, or maybe there is not enough time to hunt for and collect from a dozen separate individuals. And, for international collections, we ship seed back in smaller quantities (using "small seed lot" permits), so it may be prohibitive to collect from large numbers of maternal trees.

Another question often posed is: How many collections are enough to call the expedition a success? This answer, too, depends on a number of factors. A garden that is in the expansion phase may have a lot of room to accommodate hundreds of new collections from a single expedition. However, for the Arnold Arboretum, where our goals for development are focused, fewer well-documented, high priority collections are more the norm. In fact, some trips may even be focused on just a single species. This can require practicing a bit of "collection restraint" to pass by plants that may be dripping with ripe fruits. However, it's also important to be open to "opportunistic collections" when a species of value—even though not a target species—is encountered. For example, while making our way towards a large *Acer griseum* in southeastern Shaanxi in September 2015, our multi-garden team stumbled upon a massive *Corylus fargesii*. After genuflecting and hooting and hollering, we all agreed that it would be worth making a collection of this paperbark filbert for our respective institutions. Sometimes an opportunistic species is of value to just one of the gardens, prompting a discussion about whether the group should collect it or not. If the decision is made to collect it, even if just for one of the participants, it is important to treat it just like all of the other collections and properly catalog, document, and voucher it. Supplemental or extra collections made on the side can end up being a nightmare to track later on if not documented and assigned an official collection number! Also, sometimes an important species is found, but without any fruits. An official collection of it can still be made, since the herbarium voucher and documentation are of value, perhaps enabling a collector to return in the future.



PHOTOS BY MICHAEL DOSMANN



The team made an "opportunistic collection" when this massive paperbark filbert (*Corylus fargesii*) was encountered in Shaanxi, China.

KYLE FORT



Larry Hufford prepares a voucher specimen of Douglas hawthorn (*Crataegus douglasii*) found east of Feather Creek in the St. Joe National Forest, Idaho. Herbarium specimens of nearly all of the 42 species collected during the 2015 North Idaho Expedition have been submitted to the Harvard University Herbaria for long term storage and scientific study.

ing fruits often falls to the full crew after other tasks are done, particularly if some of the seed extraction happens in the field. While typically all the participants are busy snapping photos, it is good to either assign the official task to one of the members, or at least make sure the recorder is jotting down which participant captured that collection's fullest complement of shots—habit, leaves, fruits, habitat, etc. A final photo swap at the end of the trip is a good way to cover all the bases.

In some cases, X marks the spot and target species are found exactly where expected. But sometimes there's only the suggestion that the species occurs in the general area, requiring the entire group to pay close attention to the surrounding habitat for clues to the target's presence. For example, perhaps it is a drought-tolerant tree more often found on the western or southern exposure of slopes, or it is a shade-loving shrub found in a mesic forest. Even with the team's expertise and a local collaborator

TIM BOLAND



In Arkansas, during the 2014 Ozarks Expedition, Michael Dosmann (left) and Polly Hill Arboretum's Ian Jochams (right) arrange a voucher specimen of overcup oak (*Quercus lyrata*) in a canvas field press.

in tow, plant identification in the field can sometimes be tenuous, so a trusted field guide is worth its weight in gold. These books can feel as heavy as gold when toted in a backpack, but luckily technology has come to the rescue. Michael reports that on multiple occasions he has been able to access the online version of the *Flora of China* from his phone, even while in remote sites in central China. What would E. H. Wilson think of that? And, since the team collects herbarium vouchers, further keying out can occur in the evenings or even after the expedition is concluded for some pesky and challenging species.

EVENING ACTIVITIES

At the end of the day's excursion all of the germplasm and herbarium vouchers are unpacked and double checked to make sure that collection numbers are properly assigned to each. Fruits are readied for drying or preparation, such as letting fleshy *Viburnum* fruits soak



High above the Snake River in Idaho, the northern slopes of Wild Horse Butte (5,458 feet) and Wild Horse Ridge host a number of species of interest to the Arboretum including *Pinus ponderosa* and *Spiraea betulifolia* var. *lucida*. Both species were collected within the Nez Perce National Forest in view of the breathtaking Hells Canyon Recreation Area.

in water to make them easier to clean. Maple (*Acer*) samaras may be green or wet when collected, and need to dry—small wicker baskets are great for this task, and paper plates also work. Respiring seeds might be packed in a bit of sphagnum moss to prevent them from losing too much of their moisture. The vouchers, once transferred to the wooden presses, need to be inspected frequently to ensure they are drying properly. Having a spare set of blotters to swap out will facilitate this. Also in the evenings, the trip recorder or others will typically work to get the hand-written notes into digital form, often using a computer template or spreadsheet.

When collecting domestically, it's possible to bring entire fruits back to be further cleaned and

processed by the propagation staff—although they are always happy to receive cleaned seeds. For international trips, it is essential that the seeds are fully cleaned in order to import them into the United States. Thus, the typical evening routine is to process that or previous day's bounties, including careful inspection for any evidence of insects (acorns are notorious for housing weevils, and rose hips are rarely absent a maggot or two). Once the seeds are fully clean they are measured into discrete quantities and placed into small sealable bags, each labelled with the species name and unique collection number. At the end of the trip, these are all organized, included in an official manifest, and shipped directly to an inspection station that is

KYLE FORT



Propagules are bagged for shipment in specific ways: transplants, fleshy fruits, and cuttings are held in damp plastic bags while cones and seeds are placed in paper bags. Regardless of the container, handwritten notations including the name, collection number, and trip name are always applied and correspond to entries in a notebook or other form. These collections were made during the 2015 North Idaho Expedition.



Dug from a nurse log beneath 400-year-old virgin timber in Hanna Flats, this Western red cedar (*Thuja plicata*) is the Arboretum's first wild collected accession from Bonner County, Idaho.



Hiking above 6,000 feet, our search for *Larix lyallii* was another incredible experience. In waning daylight, facing a two-mile hike out, we gathered cones from a particularly fecund specimen above lower Roman Nose Lake, Kaniksu National Forest, Idaho. After finishing the collection, we turned to take in the view and were treated to the aerial display of two golden eagles (the black specks in the upper center of this photo).

KYLE FORT

KYLE FORT

KYLE FORT



KYLE FORT



The Arboretum's only living accession of bearberry (*Arctostaphylos uva-ursi*) is a cultivated variety, 'Massachusetts', sourced from Briggs Nursery in Olympia, Washington. Two new collections (fruit [above] and division [below]) from Idaho's Kaniksu National Forest add wild germplasm to our holdings that will be valuable for research and education.

part of the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (USDA). Once inspected by APHIS, they are then forwarded on to the Arboretum. Some collectors bemoan this step as unnecessary, and in some cases risky, since some items might be confiscated because of the presence of a pest or pathogen. For the Arboretum, this step actually provides peace of mind because it ensures that we are not importing the next invasive pest like Asian longhorned beetle or emerald ash borer.

While the individual collections are documented by the recorder and ample photographs are taken, there is much that occurs during the trip that can only be captured in narrative form, a duty that falls to the designated trip journalist. Although such journaling requires extra time, it's valuable to have a trip participant capture the names of people met along the way, make broad observations of the different sites and regions visited, and chronicle the events that make plant exploration colorful such as meals, wildlife, and other cultural items.

COMING HOME

The real work of an expedition begins when you return.

—Louise Arner Boyd (1887–1972)

When the newly acquired collections arrive at the Arboretum, the masterful hands of our propagators coax cuttings to root, encourage transplants to take, and stage the events leading to seed germination (be sure to read the next issue of *Arnoldia* for insights). The curatorial staff get to work processing herbarium vouchers and the products (e.g., images, field notes) generated by trip participants. Entering the passport information associated with each collection into our database is of utmost importance. From this central repository, data are used for labels, trip reports, and herbarium labels, and are also shared with the world through web applications and reports. As technology has improved, so too has the volume of information and objects our curators must consider and archive. To use one

example, the ease of creating digital images in the field adds to post trip responsibilities. In times past, when glass plates and film were the only options (yes, we are that old), there were fewer images to annotate. Now it is not unusual to have hundreds if not thousands of images to label. In the end, documentation is a labor of love and we revel in its detailed complexity.

Our passion for plants is manifest in the remarkable collections we steward. The Arnold Arboretum's 10-year Campaign for the Living Collections reaffirms a commitment to biodiversity discovery and the people engaged in plant exploration. In sharing our goals and experiences with you, we hope to inspire collaboration and exchange.

If we range through the whole territory of nature, and endeavor to extract from each department the rich stores of knowledge and pleasure they respectively contain, we shall not find a more refined or purer source of amusement, or a more interesting and unfailing subject for recreation, than that which the observation and examination of the structure, affinities, and habits of plants and vegetables, affords.

—Sir Joseph Paxton (1803–1865)

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IDAHO

Clockwise from upper left:

Red squirrels (*Tamiasciurus hudsonicus*) frequently scolded team members with sharp calls of “chickaree! chickaree!”, perhaps seeing us as competitors for seeds.

Seeds of *Holodiscus discolor*, a rosaceous shrub commonly known as oceanspray, were collected from this specimen in Farragut State Park.

Huckleberry (*Vaccinium membranaceum*), the state fruit of Idaho, is used in many edibles including pie, ice cream, jam, and wine, to name a few.

After a long day of seed collecting, we arrived after dark at the Coolin Motel on Priest Lake. The next morning, we were delighted to find and collect fruit from a Greene’s mountain ash (*Sorbus scopulina*) that was growing alongside the motel sign.

In a haze of wildfire smoke, Kyle Port collected cuttings from three willow species (*Salix lucida* ssp. *caudata*, *S. sitchensis*, *S. exigua*) along the Priest River. Photo by David Port.

Pages 14-15: All photos by Kyle Port unless otherwise indicated





Clockwise from upper left:

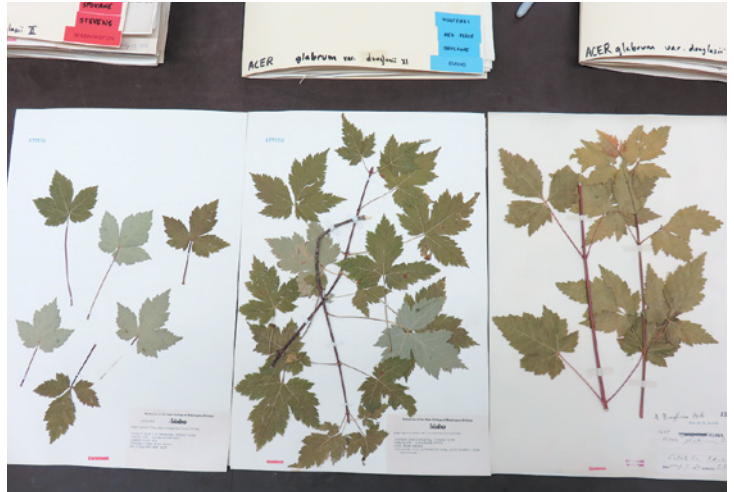
A striking stainless steel sculpture, *Allium Spring Chorus* by David Tonnesen, in McEuen Park, Coeur d'Alene.

Once a hub for dairy operations, this barn now holds equipment at the University of Idaho Arboretum and Botanical Garden in Moscow.

Specimens at Washington State University's Marion Ownbey Herbarium show the variation of leaf morphology in *Acer glabrum* var. *douglasii*, a species we collected.

In St. Joe National Forest we collected seeds from snowbrush (*Ceanothus velutinus*), notable for its glossy foliage and fragrant white flowers.

Master naturalist and Washington State University professor emeritus Steve Ullrich displays old man's beard (*Usnea* spp.), a lichenized fungi.





CHINA

Clockwise from upper left:

After a wet, cold, exhausting day in the field, nothing tastes better than steaming hot *jiaozi* (dumplings).

Meconopsis integrifolia, the yellow poppy that was the focus of E. H. Wilson's second trip to China for Veitch Nursery, blooms in Sichuan's mountains.

A portable heater came in handy to speed up the drying process of these wet lilac (*Syringa*) and ash (*Fraxinus*) fruits during the 2010 NACPEC trip.

Living up to its moniker, the "paper bark" of *Acer griseum* peels off in sheets and ribbons.

The superhighway gave way to a muddy dirt road as the NACPEC2015 team went from Shaanxi to Henan.

Pages 16-17: All photos by Michael Dosmann unless otherwise indicated





Clockwise from upper left:

Michael Dosmann measures the diameter of an *Acer griseum* in Henan Province (photo by Kris Bachtell).

Calcite deposits lead to the formation of amazingly colored iridescent pools, giving the Huanglong (Yellow Dragon) Valley in northern Sichuan its name.

We made an opportunistic collection of this *Hydrangea aspera* (note the large pink sterile florets) during the 2015 NACPEC trip in Sichuan.

Steep cliffs in Sichuan's Guangwushan Park were home to *Acer griseum*; although not visible in this image, one of the trees sampled grew just a few feet away from the precipice shown in the center-right of the image.

Autumn color was seen on *Fraxinus baroniana* growing along the Jialing River in Gansu on the 2015 NACPEC trip.



BOOK EXCERPT

Saving the World's Deciduous Forests: Ecological Perspectives from East Asia, North America, and Europe

Robert A. Askins

Editor's Note: In this compelling book, biologist Robert A. Askins examines the history and ecology of Northern Hemisphere deciduous forest ecosystems in East Asia, North America, and Europe. These forests have a common ancient origin but have evolved in now widely separated regions for millions of years. Askins writes clearly on the similarities among and differences between the forests, including the threats to the plants and animals they contain and the challenge of developing effective conservation methods for these unique ecosystems. The excerpt presented here is from Chapter 5, "Giant Trees and Forest Openings."

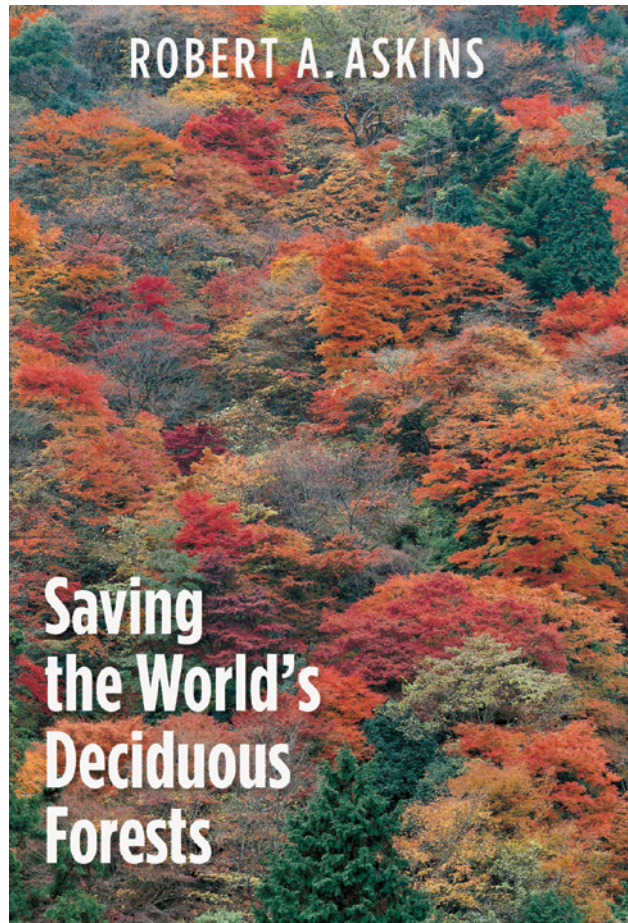
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CHAPTER 5

Giant Trees and Forest Openings

When land is no longer used for farming in the humid temperate zone, forests will eventually return. Unless the soil has been removed by strip mining, paved over, or poisoned by industrial toxins, the regrowth of the forest is remarkably swift, measured in decades rather than centuries. As a result, second-growth forests now cover large portions of the northeastern United States and the interior of Japan, and regenerating forest is beginning to appear on abandoned farmland in Europe. Does this represent a phoenix-like resurrection of temperate deciduous forests? A more pessimistic view is that the intricate and diverse primeval forests that were destroyed by agricultural clearing have been replaced with simplified and degraded woodlands. How do these new forests differ from the original forests?

To answer these questions, we need to determine the characteristics of the forest before agriculture spread throughout the temperate zone. As discussed in the previous chapters, we can create an imperfect picture of the original forest from historical accounts and from the pollen record in lakes and ponds. Another key source of information is ancient forests that were never cleared. Most patches of “virgin” or primeval forest in the temperate zone are small and isolated, but there are a few regions where landscapes are still dominated by ancient forests. Although never completely cleared, these forests inevitably have been affected by humans in various ways and to various degrees. Hunting has occurred in all of these forests, and in most cases large mammals have been extirpated, often leading to profound changes in the forest ecosystem. Also, relict patches of old forest were often subjected to periods of livestock grazing or selective timber harvesting. And particular species of trees have declined or disappeared in some ancient forests because of the spread of introduced insects or pathogens. Even though none of these forests have remained completely untouched by people, however, they are still our best source of information about how forest ecosystems functioned before widespread clearcut logging and farming.

A Remarkable Primeval Forest in Poland

To enter the Strict Reserve at Białowieża Forest in Poland, visitors walk along a narrow road through a large, sunny meadow filled with whinchats, common quail, and other grassland birds. At the edge of the forest they pass through an imposing wooden gate, entering the shade of gigantic oaks and limes. This is the heart of one of the largest expanses of forest in Europe, extending from Poland into Belarus. Parts of this region were never cleared for agriculture and have been heavily forested for thousands of years.

The aspect of the forest is distinctly different from the heavily managed forests in most parts of Europe. Instead of carefully managed stands of young trees that have been pruned, thinned, and cleaned up, the ancient oak-lime-hazel forest of Białowieża is a jumble of fallen logs, dead trees, and live trees of different sizes. The guided tours and guidebooks for Białowieża are geared to a European audience, so there is a heavy emphasis on the ecological importance of dead wood in all stages of decomposition, from standing dead trees to crumbling logs to mounds of organic soil that were once logs. Dead wood and its ecological importance are more familiar to visitors from forested parts of the United States and Canada, where virtually every nature trail has signs extolling the ecological value of snags (standing dead trees) and decaying logs. The role of dead wood is especially clear at Białowieża, however. Uprooted trees and fallen branches cover 12 to 15 percent of the forest floor.¹ Woodpeckers are not only common, but also remarkably diverse, with seven species regularly nesting in this forest.² They forage on dead wood, and some species build their nest cavities in snags. Standing and fallen trees also support a remarkable diversity of fungi, which is obvious from the wide variety of mushrooms sprouting out of logs. As logs decompose, they create a well-fertilized and protected site for the germination of herbaceous plants and tree seedlings.³

For visitors expecting an ancient forest to look like Muir Woods in California, with its clean columns of massive coast redwoods, the Białowieża forest is surprisingly complex and cluttered. Large oaks—300 to 400 years old—are scattered among younger trees with a wide variety of heights and trunk diameters. Enormous Norway spruces occasionally tower above the canopy of hardwood trees. The understory is open, with only scattered shrubs and saplings, but the ground is covered by a rich diversity of herbs and ferns. When one of the ancient spruces or oaks collapses, it leaves a large gap in the forest canopy. This results in a sunny area on the forest floor covered with a dense tangle of saplings and herbaceous plants. This mix of young and old trees is typical of ancient deciduous forests. It reflects a history of relative stability in which trees live for hundreds of years, then die and fall, opening the way for young trees to grow up into the canopy. Theo-



Clockwise from top:

An imposing wooden gate stands at the entrance to the Strict Reserve in the heart of Poland's Białowieża Forest.

The understory seen here is quite open, with little between the tree canopy and vegetation on the forest floor.

A view of the forest trail through the Strict Reserve. This photo shows the wide range of tree sizes (trunk diameters) in this old-growth forest where ancient trees stand along with middle-aged trees and young saplings.

retically, this could lead to an almost unchanging forest dominated by a few tree species that are best adapted to growing in the shade on the forest floor and then racing upward when a gap opens in the canopy. Most deciduous forests are still recovering from massive disturbance by humans, however, so we would not necessarily expect them to show this type of dynamic equilibrium in which old trees are consistently replaced by younger trees from the same set of dominant species, in the same proportions. Restoring this equilibrium may require hundreds of years. The best place to search for evidence of a steady-state system is in an ancient forest such as Białowieża.

It is difficult to believe that an extensive area in central Europe, in a region where empires have collided for centuries, could still have a large, intact forest that was never cleared. The pollen records from two peat bogs in the southeastern part of Białowieża National Park, however, confirm that some sections of the park have been covered with forest for thousands of years, apparently without interruption.⁴ At the end of the last glacial period the region was an open parkland or savanna with scattered pines. It became more tundralike during the Younger Dryas cold period, but after that it was continuously covered with forest. There is no evidence in the sediment record of frequent fires or of agricultural clearing in the region near the bogs. The composition of the forest changed slowly over thousands of years as the bogs, which had originally been lakes, filled in. Initially the landscape was mostly covered with pine with a few scattered birch trees. Later birch became more frequent and pine declined. Eventually a mixed deciduous forest dominated, but the species composition of the forest continued to shift as new types of trees spread into the region. Oaks, for example, arrived later than most other deciduous tree species, and common ash appeared even later. According to the pollen record, European beech never reached Białowieża, and it is not found there today. The composition of the forest has constantly changed, but the region has been covered with a deciduous forest with a diversity of tree species for 5,000 to 8,000 years.

Some other sections of Białowieża National Park are covered with coniferous forests (a mix of Norway spruce and Scots pine) rather than deciduous forest. These areas were covered with an open pine savanna in the 1600s and 1700s.⁵ Analysis of tree rings of living and dead trees reveals that during this period fires swept through these sites an average of every six years. Frequent low-intensity fires singed the trees (fire scars can still be seen in tree ring samples), but usually didn't kill them. The fires may have been ignited by human activities such as collecting honey from bee colonies in natural cavities in trees (which involves the use of fire and smoke to ward off the bees) and charcoal burning. After 1781 the frequency of fires

declined precipitously, and since then the pines have progressively been replaced with spruce, which is less tolerant of fire but more tolerant of shade (and thus able to grow up under a pine canopy). It is uncertain whether the open pine savannas were purely a result of fires caused by humans or were originally maintained by natural fires.

In contrast to these conifer forests, the deciduous forests in Białowieża National Park apparently were never subjected to frequent fires. Despite this, the vegetation of deciduous forests is also changing. This may reflect changes in the way these forests have been managed by people over the past two or three centuries.⁶ From the early 1400s until 1798 Białowieża Forest was protected as a hunting reserve for Polish royalty. Limited harvesting of timber and other forest products occurred during this period and continued after 1798, when Poland was partitioned and the forest became part of the Russian Empire. From 1888 until 1914 the forest was once again managed as a hunting reserve, this time for the Russian tsars. Intensive game management during this period had a lasting impact on the forest. Populations of red deer and bison were boosted by exterminating predators and providing hay to reduce winter mortality. During World War I, however, most of these large, herbivorous mammals were shot by soldiers and local people to provide food, and timber was harvested intensively in some parts of the forest.

After World War I the best remaining ancient forest was protected as a national park. In 1921 the park covered 4,700 hectares, but subsequently it was enlarged to 10,500 hectares.⁷ The Strict Reserve within the national park has been carefully protected from human disturbance, and the vegetation and large mammal populations have been monitored since the 1920s. In contrast to many old-growth forests, the forests in the Strict Reserve are embedded in an almost continuous complex of natural forest reserves and managed forest that covers 1,250 square kilometers, more than half of which is in Belarus (where there is another large national park that protects ancient forest). This complex of forests supports an almost complete set of extant large European mammals, including red deer, roe deer, European bison, and moose (called elk in Europe), as well as predators of these large herbivores (gray wolf and lynx) and an active population of dam-building European beavers. As a result, Białowieża Forest represents our best opportunity to learn how European forest ecosystems worked before forests were heavily managed by people.

The Strict Reserve was protected because it lay deep within the forest where relatively little logging or other direct destruction of the forest occurred. This forest has all of the characteristics of a vibrant old-growth forest, with ancient trees nearing the end of their maximum lifespan and

vigorous seedlings and saplings in the understory and in forest openings. Is this really a steady-state system, however, in which each tree species is successfully producing the next generation?

In 1936 five vegetation transects were established within ancient forest in Białowieża National Park.⁸ Along each transect, every tree was identified and the diameter of its trunk was measured. These measurements were repeated approximately once every decade from 1936 to 1992. The overall structure of the forest did not change; the number of trees per hectare for different size classes (from small saplings to old trees that are more than one meter in diameter) was similar in 1936 and 1992. The species composition of the trees changed substantially, however, with major declines in Norway spruces, pedunculate oaks, Norway maples, birches, poplars, and willows. The decline in early successional species—birches, poplars, and willows—is not surprising, because these species only grow in relatively open, sunny areas. Large natural disturbances such as storms had not disrupted the canopy to create habitat for these species along any of the transects (although this has happened in other parts of the national park). Spruces, oaks, and maples are characteristic of mature forest, however, so it isn't as obvious why populations of these species declined. The situation with Norway spruce (the species that suffered the most substantial decline) is particularly perplexing because this is a shade-tolerant species that should be able to reproduce in forest conditions. Despite this, Norway spruce was replaced as the dominant species by three deciduous trees: European hornbeam, small-leaved lime (a relative of the American basswood), and common ash.

The best approach to understanding these changes is to investigate the survival of seedlings and saplings of various species of trees. Analysis of recruitment of new trees on the permanent vegetation transects in Białowieża Forest demonstrated that spruce, oak, and maple seedlings had high survival rates between 1916 and 1936, when the density of deer and other large ungulates was extremely low following intensive hunting during the First World War.⁹ In contrast, hornbeams showed the highest recruitment rates as the density of ungulates increased after 1936.

Hornbeams, in fact, thrived during this period of high ungulate densities. Ironically, hornbeams are a preferred food species for deer, but the saplings are especially tolerant of browsing because they quickly grow lateral branches when their tops are cropped off. They appear to survive despite high deer densities and may benefit from deer removing saplings of other species that compete with hornbeams for light and nutrients. Fenced plots that prevented browsing by deer and bison supported a diversity of saplings, including maples, elms, birches, and spruces.¹⁰ In contrast, nearby unfenced

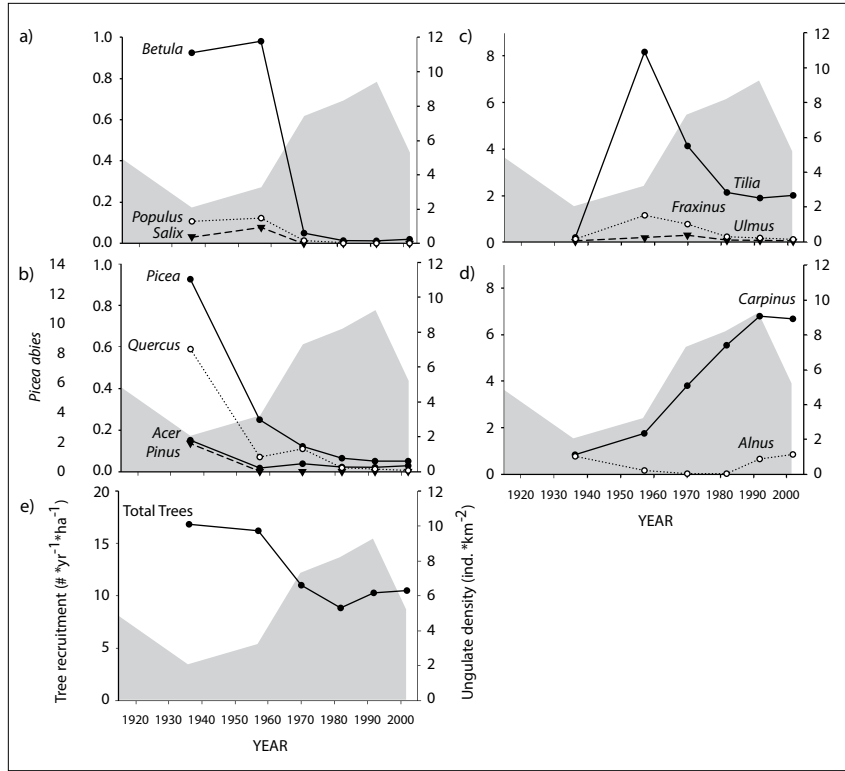


Figure 12. History of the abundance of ungulates (deer and bison) and of the recruitment rate (number of tree saplings per hectare per year) for different species of trees in Białowieża National Park, Poland. Note that spruces (*Picea*), oaks (*Quercus*), maples (*Acer*), pines (*Pinus*), and birches (*Betula*) showed high recruitment rates when ungulate densities were low. Only a few species, such as hornbeam (*Carpinus*) and limes (*Tilia*), reproduced successfully after ungulate density increased. (Kuijper et al., 2010a; reproduced with permission of John Wiley and Sons, Inc.)

plots were dominated by hornbeams. The implication is that browsing deer reduce the diversity of tree saplings by removing virtually all saplings except hornbeams.

The ungulate-exclosure experiments also indicated that tree regeneration is heavily influenced by other factors that affect young trees at different ages. The success of small tree seedlings is mostly determined by the density of herbs and ferns on the forest floor.¹¹ The maximum number of seedlings occurred in sites with intermediate herbaceous cover. For small saplings (bigger than seedlings but less than 50 centimeters tall), the greatest densities are found at sites with high soil fertility. It is only taller saplings (greater than 50 centimeters) that are heavily affected by the presence of browsing mammals. Thus, a tree seedling must survive a gauntlet of environmental conditions, each of which may favor one species over another. The combination of factors will determine which species of trees eventually

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Clockwise from upper left:

This large canopy gap in the Strict Reserve forest allows sunlight to reach young tree seedlings.

Dead wood—from standing snags to decomposing trunks—is an integral part of the forest ecosystem.

In Białowieża Forest, a black woodpecker (*Dryocopus martius*) clings to a snag where a nestling waits for food.

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reach the canopy.¹² For example, wych elm seedlings are greatly outnumbered by hornbeam and lime seedlings in most parts of the forest, but are virtually the only tree seedlings that successfully grow in sunny forest openings covered with dense stands of stinging nettles. In contrast, hornbeam and lime seedlings are particularly common in areas where wild pigs have plowed up the forest floor while rooting for food, removing most of the herbaceous cover. Other species of tree seedlings such as Norway spruce and European mountain ash grow especially well on top of decomposing logs.¹³

Although hornbeam is becoming increasingly common in the forest canopy, it may eventually be replaced by lime, which grows taller and lives longer.¹⁴ The hornbeam canopy could slowly be overtopped and shaded by the many young lime trees that are now present in the understory. Lime saplings were almost absent from the forest in the 1920s following a period of intense browsing by deer and bison, and a large age cohort of limes (trees with a diameter of 1–2 meters) is missing from the forest today because of a long period more than a century ago when there was little successful reproduction. This is the same period when many of the tall Norway spruces in the forest germinated. Thus, the composition of the forest may still reflect a period of several decades when bison and deer populations were artificially boosted for hunting by the Russian royal household.

Although gigantic old pedunculate oaks are a prominent component of the ancient forest, oak saplings are infrequent in the understory because they do not grow well in shade. Some oak seedlings may successfully grow in the small openings caused by tree falls, but they grow best in much larger openings with full, direct sunlight.¹⁵ Areas adjacent to the ancient forest where farming was abandoned 40 years ago already support a developing oak woodland with a mix of mature trees and saplings. Numerous oak saplings survived in fields despite browsing by deer and other native ungulates. The immense oaks of the ancient forest may have originated in similar large openings that were caused by either natural or human disturbances.¹⁶

Frans Vera argued that open woodland dominated by oaks was widespread in Białowieża long before agricultural clearings were made in the forest.¹⁷ This is confirmed by pollen records from sites in a depression on the forest floor and in a bog in the northern part of the forest.¹⁸ Although the concentration of oak pollen increased during the past few hundred years, oak pollen is present in the pollen record for the past 1,200 to 1,500 years. Vera hypothesized that large grazers (especially aurochs, the ancestor of domestic cattle, and tarpans, a type of wild horse) maintained parklike woodland similar to the traditional wood pastures of Europe (such as those in the New Forest in England). According to Vera's hypothesis, the presence

of grazers allowed young oaks to grow successfully in competition with faster growing, more shade-tolerant limes and hornbeams that would normally out-compete them. All tree seedlings suffered high mortality because of grazing, but oaks were more likely to survive because they have an exceptionally large taproot with stored food that they can use to grow back after their shoot is nipped off.¹⁹ Equally important, acorns are efficiently transported into favorable growing spots in open woodland by Eurasian jays, which bury them in order to have a stored food supply for the following winter, spring, and early summer.²⁰

Aurochs and tarpans survived in Białowieża Forest long after they were extirpated from most of Europe, but they finally disappeared in the seventeenth century.²¹ After their disappearance, the wood-pasture landscape may have been sustained by domestic livestock, especially domestic cattle and horses, because some grazing was permitted in the hunting reserve. Oak regenerated during this period, but stopped regenerating as grazing of domestic livestock was increasingly restricted by forest regulations. According to Vera, the decline of domestic grazers initiated a transition from open, heavily grazed wood pasture to closed-canopy forest, which in turn led to the decline in young oaks. Vera contends that this explanation applies not only to Białowieża Forest, but also to most oak-dominated lowland forests of central and western Europe.

Although it was never completely cleared to create extensive farmland or converted to tree plantations, the structure of Białowieża Forest has still been heavily influenced by human activities. After a longer period of protection from human disturbance, perhaps the mix of tree species in the forest will return to some ancient steady state. Another possibility is that the mix of trees has always been in flux as a result of natural disturbances (windstorms and fires) and changes in climate and animal populations.²² If there is a steady state, it may take the form of more general structural characteristics of the forest, not the particular tree species that make up the forest canopy. The steady state may be characterized by a range of trees of different sizes, from seedlings to ancient giants, with a complex forest floor interrupted by decomposing logs, massive roots of tipped up trees, and open, sunlit patches where trees have fallen. Tall trees emerge above the canopy, and there are several layers of vegetation below the canopy. The mix of species making up the forest layers may shift over time while the overall structure changes little and consistently provides the full range of microhabitats needed by the rich diversity of lichens, mosses, insects, birds, and other forest organisms. Perhaps some areas within a large expanse of forest support pine savanna and open oak woodland. It may be the overall structure of the forest—not the dominant tree species at any particular time—that best defines the steady-state conditions of an old-growth forest.

This hypothesis is supported by research on old-growth forests in eastern North America, many of which were never subjected to major human disturbances. Between 1976 and 1991, for example, there was relatively little change in the overall structure of numerous old-growth forests in eastern North America.²³ The total diameter of trees and the density of trees changed very little. Larger trees showed a higher mortality rate than small trees, but their death was compensated for by the growth of smaller trees. Trees died at an average rate of 1 percent per year, providing a constant source of snags for animals that require dead trees. Although the basic structure of these forests did not change much at these sites, there was often a substantial shift in the species composition of canopy trees. Most notably, the proportion of American beech either increased or decreased at most sites. In some sites, American beeches were replaced with sugar maples. These changes were not due to pathogens killing the beeches or other obvious causes, and may reflect basic environmental shifts (such as climate change) that favored one species over another. Although these subtle changes might be caused indirectly by human activities, they might also be natural changes of the sort that occurred long before the advent of agriculture or industrial pollution.

Young Trees in Old Forests

Old-growth forests are characterized not only by giant trees and large amounts of decomposing dead wood, but also by openings in the tree canopy that support tree saplings and early successional species. These canopy gaps are more frequent in old-growth forests than in younger forests because old-growth forests have numerous old trees. Windstorms frequently blow down giant trees that have been weakened by age. Also, when a 300- or 400-year-old oak dies, it leaves a large hole in the canopy, particularly if it takes other trees down as it collapses. In old growth hemlock-hardwood forests in the Great Lakes region, the size of canopy gaps and the total percentage of the forest covered by canopy gaps increase steadily with the age of the forest as the average size of dead trees increases.²⁴

In old-growth forest in Białowieża National Park, trees fall at an annual rate of 200–450 per 100 hectares.²⁵ The resulting openings drive a cyclical change in the forest.²⁶ During the first 60 years canopy gaps are dominated by saplings that grow quickly, competing for space in the forest canopy 35 meters above the ground. From 60 to 200 years the restored canopy remains closed as trees slowly grow larger, but after 200 years the canopy thins and new gaps begin to open up, allowing another set of tree seedlings to grow on the forest floor. Eventually this initiates a new cycle.

Andrzej Bobiec and his colleagues mapped the distribution of these three stages in the cycle at sites in ancient forest in Białowieża National

Park.²⁷ They found that 40–48 percent of the forest was covered with open canopy gaps or stands of young trees less than 60 years old; 32–40 percent was closed-canopy mature forest, and 20 percent was old forest where trees were dying and the canopy was beginning to open up. This mosaic of patches is a key feature of old-growth forests. Thus, the biological diversity of old-growth forests depends not only on the vertical complexity created by multiple layers of vegetation and dead organic matter (from leaf litter to tall snags), but also on the horizontal complexity encountered as one moves from canopy gaps to stands of old trees to younger mature forest. The exceptionally high diversity of birds nesting in Białowieża Forest, for example, is partially due to this mosaic of habitat patches.²⁸

Natural disturbances produce canopy gaps of different sizes, resulting in both small and large patches of low vegetation. In canopy gaps in 14 old-growth forests in North Carolina, Tennessee, Ohio, Pennsylvania, and New York, the percentage of land immediately under forest openings ranged from 3 percent to 24 percent.²⁹ The rate of gap formation could be estimated based on the approximate age of the gaps. Gaps formed in 0.5–2 percent of the forest canopy each year, so any particular point in the forest would be subject to a canopy gap every 50 to 200 years. This is shorter than the maximum age of many of the trees in the forest, but gaps can occur repeatedly at some areas while other areas remain undisturbed for long periods, allowing some trees to survive for hundreds of years. The picture that emerges is not of a timeless, unchanged forest of ancient trees but of a constantly shifting mosaic of young and old forest patches.

The forests that grow on abandoned farmland are “even-aged,” meaning that most of the trees started growing at the same time. Even when these forests become mature, they are more homogeneous than an ancient forest. Most of the trees are about the same height, and there is relatively little dead wood and only a few vertical layers of vegetation. Because the trees are still young and vigorous, canopy gaps are infrequent and small. If a tree dies, the gap is usually filled by the horizontal growth of branches of neighboring trees. It is well known that these forests do not support species that require large snags or logs. In addition, they may be missing species that depend on forest openings caused by tree falls.

Canopy Gap Specialists

One of the most elegant sights in the deciduous forests of North America is a male hooded warbler fluttering through the understory. It moves gracefully from branch to branch, repeatedly fanning its tail to reveal bright white patches. When an insect is startled into flight by these rapid movements, the warbler flies after it and deftly captures it with an audible snap

of the bill. As the warbler moves into a patch of sunlight, its yellow body and face glow in striking contrast to the velvety black head and throat.

Hooded warblers build their nests and search for insects in the understory, so they are most common in forests with a dense layer of shrubs and small trees. They are common in young, regenerating forests where the canopy is still open and shrubs have not been shaded out.³⁰ As the tree canopy becomes denser and more continuous, however, hooded warblers decline and disappear. The closed canopy shades out shrubs and saplings, causing many to die. After the forest has grown for 150 or 200 years, however, canopy gaps are large enough to permit the growth of dense clusters of shrubs and saplings, providing new habitat for hooded warblers.³¹ Some European bird species may display a similar pattern. In a comparison of 50 canopy gaps and 50 sites within closed-canopy forest in Białowieża National Park, Robert Fuller found that several species of forest birds (particularly dunnock, blackcap, and chiffchaff) were concentrated in canopy gaps.³²

Much of the landscape of eastern North America is now covered with young, closed-canopy forest that provides little appropriate habitat for species like the hooded warbler. As these forests age, canopy gaps will become more frequent, providing sufficient habitat. This transition will require decades if not centuries, however. In the meantime, selective harvesting of trees can be used to create artificial openings filled with shrubs and saplings that attract hooded warblers, boosting their breeding populations.³³ In regions dominated by young forest, selective harvesting of trees or small groups of trees may be a reasonable way to sustain habitat of canopy-gap specialists until the forest is old enough to produce a sufficient number of natural canopy gaps.

Thus, the loss of old forest threatens not only species that require big trees and complex, multilayered forests, but also species that thrive in forest openings. The clearing of most of the bottomland hardwood forests in the southeastern United States in the late 1800s and early 1900s affected both types of species. The ivory-billed woodpecker disappeared as the forest was logged because it needed extensive old-growth forests with giant dead trees for feeding and constructing nest cavities. In contrast, the Bachman's warbler probably became extinct because it nested in forest openings caused by tree falls.³⁴ Although Bachman's warbler may have benefited from the early stages of logging when selective removal of the most valuable trees created many openings, it declined along with the ivory-billed woodpecker when the forest was completely cleared.

Canopy gaps are also important for foraging bats, which often concentrate along the edges of forest openings.³⁵ In South Carolina, bats were more active in these openings than in the interior of the closed-canopy

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A white-backed woodpecker (*Dendrocopos leucotos*) brings an insect larva to a nest cavity in Poland's Białowieża Forest.

forest.³⁶ Canopy gaps may have a higher insect density or they may simply be a more efficient place to catch insects while flying because of the lack of obstacles. When automatic recording devices that detect the ultrasonic calls of bats were placed in a large number of natural openings in deciduous forest at Tomakomai Experimental Forest in Japan, bat species with short, rounded wings were detected in small canopy gaps more frequently than in large forest openings.³⁷ Unlike these agile, short-winged species, bat species with long, pointed wings foraged in the center of large openings in the forest or above the forest canopy.

The importance of canopy gaps is widely recognized for old-growth tropical forests.³⁸ They are also important for deciduous forests in the temperate zone, but their ecological role has not been as widely recognized. Most research on forest ecology in the temperate zone takes place in highly managed forests or in fairly young second-growth forest rather than in old-growth forests, so it isn't surprising that the key role of canopy openings is often overlooked.³⁹ They play a central role in forest regeneration and enhancing biological diversity only after the forest is hundreds of years old.

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(NOTES AND REFERENCES LISTED ARE FOR THIS EXCERPT ONLY)

NOTES

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2015 Weather Summary

Sue A. Pfeiffer

JANUARY began with seasonal temperatures. A warm front moved through on the 4th, bringing an inch of rain and a high temperature of 51°F. But the warm weather did not last long; the coldest temperature of the month occurred on the 8th, dipping down to -3°F as an arctic front moved in. Temperatures returned to seasonal and there were a number of small snow events, none with accumulations of more than an inch. Rain returned on the 18th and 19th as a second warm front brought temperatures in the high 40s and low 50s. Up until that point, we had received only 3 inches of snow from 6 separate events. Although some were enjoying the snowless winter, many were wondering when the snow would arrive. Our first plowable snow came on the 24th when 5 inches fell, followed by rain, leaving a heavy, wet snow that blanketed the landscape and created a beautiful winter scene. This snow turned out to be just the tip of the iceberg. Cold temperatures returned as a blizzard rolled in on the 27th, burying the grounds with 28 inches of light, fluffy snow. As storm cleanup was well under way, we received some light rain to finish out the month.

FEBRUARY was record setting for both snow accumulation and cold temperatures. Snow started falling on the evening of the 1st and by mid-morning on the 3rd an additional 16 inches of snow was on the ground. Temperatures dropped to below freezing on the 6th. Just as snow clearing was wrapping up, a third sizable

KYLE PORT



Skiers venture into the Arboretum through heavy snow showers on February 2nd.



SUE PEPPER

No staff were lunching on the patio behind the Weld Hill Research Building on February 17.

storm arrived on the morning of February 8th. The storm brought an additional 20 inches of snow, bringing the Arboretum's snow total to over 4 feet. Frigid conditions remained. With few places left to put the snow, the Arboretum crew spent many hours using large equipment to push snow banks back in order to clear roads and allow for access. Between the 1st and the 12th, 42 inches of snow fell, just surpassing the record for snowiest Boston February on record. The grounds were buried and many shrubs were completely covered, no longer visible under the thick quilt of snow. The final winter storm, a blizzard with high winds, dumped an additional 16 inches of snow on the 15th. By now, we were all exhausted from snow removal and were dreaming of spring. The idea of green grass, flowering snowdrops, and blooming magnolias seemed like an impossibility as snow banks of unprecedented size created a barrier between the roads and the collections. Sunny conditions returned and snow began to melt. There were a few smaller snowfalls over the following week and the temperature finally hit 41°F on the 22nd; it had been 33 days since it last reached the 40s. Warmer conditions were short-lived and the temperature plunged to -5°F on February 24th, the coldest recorded temperature of the year. The remainder of the month saw numerous sunny days as the snow pack slowly started to melt. Overall, February was extremely cold with lows in the single digits or below on 19 days. The average temperature for the month was 17.5°F, the second coldest February in recorded history. Highs were 10 degrees below average while lows were 15 degrees below average. Snowfall from January 26th to February 15th totaled 86 inches; snowfall for the month totaled 64.7 inches, the snowiest month ever recorded at the Arboretum.

MARCH was cold and drier than usual, but enough snow fell this month to set a new record for snowiest winter ever recorded. Meteorological spring arrived on March 1st with almost three feet of snow still on the ground. Sunny and cold conditions persisted and, in spite of an additional two inches of snow falling over the first few days, melting was underway. Temperatures warmed in the subsequent

Arnold Arboretum Weather Station Data • 2015

	Avg. Max. (°F)	Avg. Min. (°F)	Avg. Temp. (°F)	Max. Temp. (°F)	Min. Temp. (°F)	Precipi- tation (inches)	Snow- fall (inches)
JAN	32.6	16.8	25.0	52.3	-3.0	3.75	36.6
FEB	27.6	7.5	18.5	41.0	-4.7	4.58	64.7
MAR	41.9	24.0	32.8	58.9	6.9	3.02	6.0
APR	56.6	39.4	48.0	70.9	24.9	2.34	
MAY	75.5	50.3	62.7	89.9	35.9	1.19	
JUN	73.9	55.5	64.8	88.2	43.5	5.67	
JUL	83.3	63.6	73.3	93.9	55.2	2.50	
AUG	84.0	63.5	73.2	93.9	55.9	1.75	
SEP	79.2	57.5	67.9	96.5	39.0	3.41	
OCT	61.8	43.1	52.2	77.6	27.0	2.31	
NOV	55.9	37.9	46.9	75.0	21.2	2.02	
DEC	51.5	37.4	44.0	69.6	23.9	4.50	1.5

Average Maximum Temperature	60.5°F
Average Minimum Temperature	41.6°F
Average Temperature	51.0°F
Total Precipitation	37.04 inches
Total Snowfall in 2015	108.8 inches
Snowfall During Winter 2014–2015	107.3 inches
Warmest Temperature	96.5°F on September 8
Coldest Temperature	-4.7°F on February 24
Strongest Wind Gust	40.3 mph on March 18
Last Frost Date	30°F on April 5
First Frost Date	27°F on October 18
Growing Season	196 days
Growing Degree Days	3166.5 days

week, peaking at 59°F on the 11th and allowing for exceptional snow melt and the reappearance of once-buried plants. Seasonal temperatures remained in the 40s and a spring shower on the 14th dropped just under an inch of rain. Snowdrops (*Galanthus nivalis*) finally peeked through the snow around the Hunnewell building on the 17th. A cold front moved in on the 18th, bringing cold temperatures and high winds with gusts over 40 mph. Cool, dry conditions lingered until a warm front brought above average temperatures in the 50s and just under an inch of rain on the 26th. The last measurable snow (2 inches) for the season was recorded on the 28th. By the end of the month, bare ground was visible in sheltered areas and a mere 5 inches of snow remained on open sites.

APRIL temperatures were average, but precipitation was again well below normal. The month began with a few warm days, reaching 62°F on the 2nd, and the first growing degree day (a measure of heat accumulation) was recorded on the 3rd. The last frost for the year occurred on the 5th. As the deep snow finally melted, damage from the harsh winter was revealed; signs of desiccation were evident on plant tissues above the 4-foot snow line, while rabbit and rodent damage was apparent on lower limbs below the snow line. A front passed through on the 8th and 9th, bringing cool temperatures and light flurries, which quickly turned to rain followed by high wind conditions on the 11th with gusts reaching over 39 mph. A stable warm front moved in the following day bringing temperatures in the 60s and low 70s, it certainly felt like spring! Warm conditions continued until the 19th; a rumbling thunderstorm arrived early on the 21st, bringing cold, windy, and rainy weather. The remainder of the month was seasonal with minimal precipitation.



KYLE PORT

Japanese sweet coltsfoot (*Petasites japonicus*, accession 648-2008-MASS) and Siberian squill (*Scilla siberica*) were in flower near Goldsmith Brook on April 13th, not long after the deep layer of snow finally melted away.

SUE PEIFFER



A dwarf lilac (*Syringa vulgaris* 'Prairie Petite', accession 39-97-A) was blooming beautifully on May 11th.

MAY was warm and extremely dry; it marked the third consecutive month with below average rainfall. The month started with several cold days before unseasonably warm, summerlike conditions arrived. Temperatures in the high 70s and 80s persisted until the 12th, peaking at 90°F on the 10th to celebrate Lilac Sunday. These conditions, coupled with the lack of precipitation, lead to flagging and the need for supplemental irrigation of newly planted accessions. Temperatures declined over the following ten days, remaining below seasonal and ranging from the mid 60s to 70s. Warm conditions returned in the last week of May with steady temperatures in the 80s. Through the 30th, only a quarter inch of rain had fallen and supplemental irrigation was needed throughout the landscape. A slow-moving storm arrived on the final day of the month, bringing much needed precipitation.

JUNE was slightly warmer than average with higher than normal precipitation. The month started out cool with temperatures in the high 40s. A lingering storm moved out on the 3rd after dropping over 2 inches of rain. Temperatures remained in the 60s, more than 10 degrees below the average for this time of year, until the 8th when beautiful clear skies and temperatures in the 80s returned. Conditions on the 15th were cloudy and cool as a storm dropped half an inch of precipitation. The remainder of the week saw seasonal temperatures return before a fast moving storm delivered heavy downpours on the morning of the 21st. Temperatures in the 80s with intermittent thunderstorms ensued over the following four days before a cold front moved in. The lingering front dropped temperatures into the low 70s and a steady rain on the 27th and 28th delivered almost 2 inches of precipitation. Temperatures on the 28th were in the 50s, more than 20 degrees below average. The additional rain was welcome in the collections.

JULY was a dry month with seasonal temperatures. Intense thunderstorms on the 1st delivered three-quarters of an inch of rain in two separate downpours. Perfect summer conditions prevailed for most of the month; highs remained in the 70s and 80s, dipping to 69°F on one occasion and into the 90s on a few days. Heavy rain in the early morning of the 10th resulted in wash-outs on paths and in mulched beds. Warm conditions with clear sunny skies persisted with temperatures rising to the 90s on the 19th and 20th before a heat wave (three or more consecutive days with temperatures of 90°F or higher) arrived on the 27th, peaking at 94°F on the 29th. We received only an additional third of an inch of precipitation during the latter three weeks of the month, most of which fell during five brief overnight rain events. Lack of rainfall made supplementary irrigation necessary again.

AUGUST was very dry and slightly warmer than normal. July's heat continued into August with temperatures hitting 91°F on the 3rd. These hot and humid conditions lead to the loss of numerous large limbs on established trees. The heat wave came to an end on the afternoon of the 4th as a cold front marching eastward swiftly turned the sky ominously dark before erupting in deafening cracks of thunder and torrential downpours. Golf-ball-sized hail pelted the ground and lightning illuminated the sky as temperatures plunged 20 degrees in a matter of minutes and winds whipped through the landscape. Despite the conditions, the collections suffered very little damage. Temperatures remained well below normal for the following week until an all-day rainfall on the 11th soaked the landscape. Temperatures soared following the storm and temperatures in the 90s occurred from the 15th through 19th with scattered thunderstorms dropping a total of half an inch of rain. Temperatures returned to seasonal on the 22nd and the month finished with sunny, dry conditions and temperatures in the high 80s. Additional irrigation was once again a focus since we received less than 2 inches of precipitation for the month.



JON HETMAN

Arboretum visitors enjoyed the lush greenness of the collections along Meadow Road on July 6th.



Arboretum Working Foreperson Jim Papargiris mows a section of the Meadow on October 28th, with some fall foliage color visible. The Meadow is mowed periodically to prevent woody plants from becoming established in it.

SEPTEMBER was warm and mostly dry. Warm weather continued until the 4th when more seasonal highs in the low 70s returned. The reprieve from the heat did not last long as a four-day heat wave arrived; new records were set on the 8th and 9th at 96°F (the hottest temperature for the year) and 93°F, respectively. A cold front moved in on the 10th, bringing with it cloudy, cooler conditions along with almost an inch of rain. Sunny, hot, and dry conditions with temperatures in the mid to high 80s followed as summerlike weather stayed around until the 20th. Dry, seasonal weather returned until the end of the month when a storm arriving on the evening of the 29th brought steady rain that totaled 2 inches by the time it ended on the 30th. This storm included some of the most intense downpours of the year, which resulted in an abundance of acorns and nuts on the ground below many oak (*Quercus*) and hickory (*Carya*) species, evidence of a mast year (a year with especially abundant seed production) for these majestic trees.

OCTOBER was a dry month with slightly warmer than average temperatures. As the September rain moved out, temperatures dropped more than 20 degrees, bringing cooler weather in the mid-50s until a warm front moved in on the 6th. Two rain events on the 9th and the 13th delivered a quarter inch of rain each as temperatures rose into the 70s. Seasonal conditions returned on the 15th and heavy frosts on the 18th and 19th brought the growing season to an end at 196 days. A fast moving warm front passed through on the 22nd, bringing a warm, sunny day with a high of 74°F. Up until the 29th there had been less than three-quarters of an inch of rain, so high-volume sprinklers were out in full force to ensure that the collections received adequate water. A storm on the evening of the 29th dropped over an inch and a half of much needed precipitation.



No jacket required: Arboretum Horticulturists Rachel Brinkman (left) and Sue Pfeiffer (right) spread soil amendments in the collections on the 10th of December, a month with temperatures that were well above average.

NOVEMBER was a warm month and the 7th month of the year with below average precipitation. During the first week of November, temperatures hovered 15°F above normal. This atypical weather combined with the ongoing dry conditions made leaf blowing and pickup easier, but leaf mulching was far dustier than usual. Fall temperatures returned with rain on the evening of the 10th and into Veteran's Day, accumulating over half an inch of rain. Dry weather returned, allowing fall clean up and soil amendment applications to continue smoothly. An early morning storm on the 20th brought almost an inch of rain, as the front moved out, cold air moved in and temperatures dropped to the 40s for five days straight. We finished out the month with warm weather and an additional quarter inch of rain.

DECEMBER was very warm and wet with temperatures 10 degrees above normal and with frequent precipitation events. The first day of the month was cooler than normal and a storm dropped half an inch of rain before moving out on the 2nd. Temperatures slowly climbed and from the 10th to the 15th averaged in the high 50s, well above average. An overnight rainstorm on the 14th/15th cooled conditions. Four additional rainfall events between the 17th and the 23rd totaled over an inch and a half of precipitation before an extremely warm front moved in. From the 22nd to the 26th, low temperatures were well above the expected highs for this time of year. The highs peaked at 69°F on the 24th, 30 degrees above the historical average. A number of systems moved through before year end, one on the 29th bringing us our first inch and a half of snow before turning to rain. The temperature the following day was barely above freezing, leaving a sheet of ice on untreated surfaces. With such a mild December, and memories of last winter still fresh in our minds, we yearned for a more tranquil winter in the coming months.

Sue A. Pfeiffer is an Arboretum Horticulturist at the Arnold Arboretum.

Sensei: An Austrian Pine Forest Bonsai Comes to the Arboretum

Stephen Schneider

Each dwarfed tree in the Arnold Arboretum's bonsai and penjing collection offers its own unique story. With the recent addition of ten new bonsai to this esteemed group, several interesting tales have been added to our archives. One of the new bonsai, an Austrian pine (*Pinus nigra*) forest, is of particular interest since it represents both a genus and a style that have never before been in our bonsai collection. Created and donated by Martin Klein of Andover, Massachusetts, this group of seven plants, meticulously sculpted over the past twenty-five years, takes its mound-like shape on what is known as a "ciment fondu" (a calcium aluminate cement) slab, also formed by the same artist.

At first glance, one can't help but get the sense that this group of seven struggling stems represents nature on the edge of survival. Clearly competing for the most basic of resources—light, water, nutrients—these tiny trees capture a snapshot of what their full-sized, earthbound counterparts contend with in the wild. This miniature forest receives daily care within the the Arboretum's comfortable urban setting, so it is all the more impressive that Martin's patience and steady hands created the successful illusion of ancient trees subjected to the vagaries of nature.

Austrian pine, also known as black pine or European black pine, has a native range stretching from Austria to the Crimean Peninsula, south to Turkey and west to Morocco and Spain. It has been cultivated in the United States for at least 250 years. This two-needled pine grows 50 to 60 feet (15 to 18 meters) tall in the landscape and has characteristic dark green foliage and dark gray, furrowed bark. Austrian pine is quite adaptable, thriving under various soil and climate conditions (though unfortunately it is susceptible to diplodia tip blight, a fungal disease). It has a variety of uses including windbreaks, remediation plantings, and fast-growing property screens. Its tolerance of dif-

ficult growing conditions makes it ideal for the pressures exerted through bonsai.

The story of this bonsai forest began in 1991 when Martin purchased a bundle of ten Austrian pines from a local nursery for \$25.00. Out of that bundle, seven plants were selected for the project. Emulating the work of bonsai master John Yoshio Naka, whom Martin had trained under during his early years of interest in bonsai, the concept of a forest began to take shape. Naka's famous bonsai, *Goshin*, a forest of eleven Foemina junipers (*Juniperus chinensis* 'Foemina') on permanent display at the United States National Arboretum, inspired Martin to create a forest of his own using his newly acquired pines. The forest bonsai began in a training box where the young trees were pruned to develop trunk taper and wired for early form development. The forest then graduated to a Tokoname bonsai pot, and eventually moved to its final display on the ciment fondu slab. Mosses, lichens, and ferns were batted to the understory and have now all grown together, creating an emerald carpet speckled with many different textures and shades of green.

At over four feet (1.2 meters) tall and with a spread of more than five feet (1.5 meters), this miniature forest creates a massive impact within the collection. On display for the first time this season, Arboretum visitors will find their imaginations challenged: To what distant land does this group of seven beckon them? Is this forest in a secluded mountain valley, or perhaps on a tiny island in the middle of a calm lake? As with all art, part of this bonsai's beauty lies in the perspective of the viewer.

In memory of his former teacher John Yoshio Naka, Martin Klein has appropriately named this bonsai *Sensei* (teacher). As the fortunate recipient of this masterwork, the Arboretum will retain the name in the accession's passport data and proudly display our new treasure in the bonsai and penjing pavilion.



