

Prunus is a model clade for investigating tropical-to-temperate transitions

By Richie Hodel

For over a century, biologists have observed a latitudinal gradient in species diversity in many clades across the Tree of Life, with greater species richness near the equator. However, we lack consensus about the cause of this biogeographic pattern and several hypotheses have been proposed. The tropical conservatism hypothesis (TCH) is one explanation for the observed latitudinal gradient; the TCH states that the relatively high biodiversity of the tropics is explained primarily by the geographic extent of tropical taxa during the past ~55 million years and the subsequent evolutionary conservation of environmental niches.

Recent large-scale phylogenetic studies using over 10,000 angiosperm species identified general trends describing how the latitudinal species gradient affects plant diversity. Notably, few lineages transitioned from tropical environments to temperate ones, which may be explained by the difficulty of acquiring the substantial adaptations necessary to tolerate the cooler conditions in temperate zones. One of the goals of my postdoctoral work at the National Museum of Natural History (NMNH) is to use the genus *Prunus* (Rosaceae) to test the TCH.

Prunus contains approximately 250-400 evergreen and deciduous species occurring throughout the temperate regions of

the northern hemisphere and in the tropics and subtropics. Phylogenetic studies of *Prunus* have used several chloroplast and nuclear loci and produced key insights, but many questions remain. The phylogenetic position of *Prunus* within Rosaceae is uncertain, and phylogenetic relationships within *Prunus* are not yet fully resolved. Discord among chloroplast, nuclear, and morphological phylogenies suggests ancient polyploidy and/or hybridization may have impacted the evolutionary history of *Prunus*, and more data are needed to resolve the phylogeny (see figure on page 2).

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Because of its size, distribution, and an existing base of knowledge, *Prunus* will be an ideal clade for testing the tropical conservatism hypothesis and investigating the processes that shape the latitudinal species gradient once phylogenetic relationships are resolved.

Prunus

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A phylogenomic analysis of *Prunus* using hundreds of nuclear loci is needed to resolve uncertain relationships, address the role of ancient hybridization and/or allopolyploidy in the evolution of *Prunus*, and serve as a framework for downstream analyses. One consequence of phylogenetic uncertainty is that the biogeographic history of *Prunus* remains uncertain, and subsequent analyses, such as tests of the TCH, are challenging. Because of its size, distribution, and an existing base of knowledge, *Prunus* will be an ideal clade for testing the TCH and investigating the processes that shape the latitudinal species gradient once phylogenetic relationships are resolved. Moreover, because of three documented tropical-to-temperate transitions in *Prunus* (solitary, corymbose, and racemose groups – see specimen images below), this genus represents a model system for investigating the dynamics and evolutionary implications of such transitions.

We are currently using targeted enrichment (Hyb-Seq) to generate hundreds of nuclear loci and entire chloroplast genomes for virtually all species in the genus. Jun Wen and collaborators have an extensive collection of tissue samples, which will be supplemented by field collections in

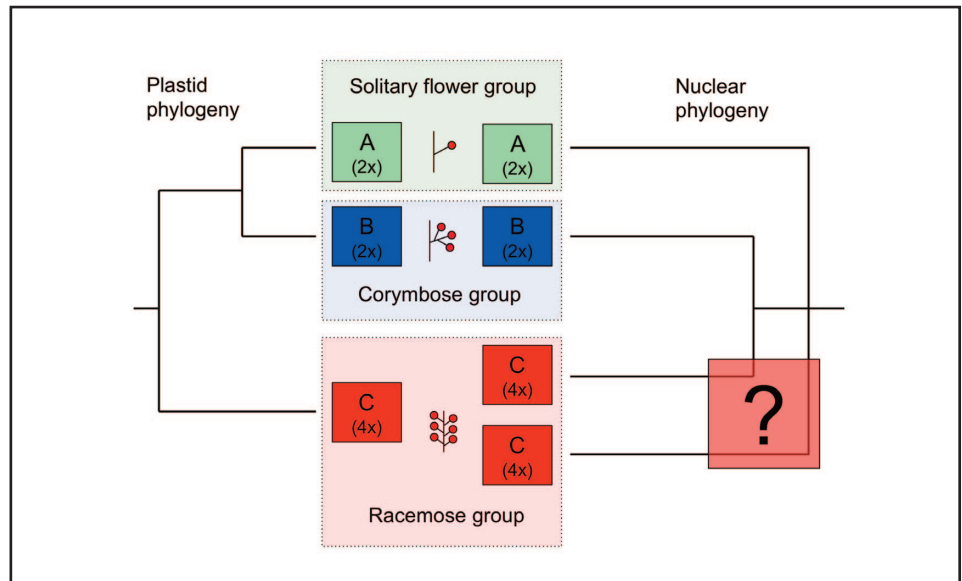
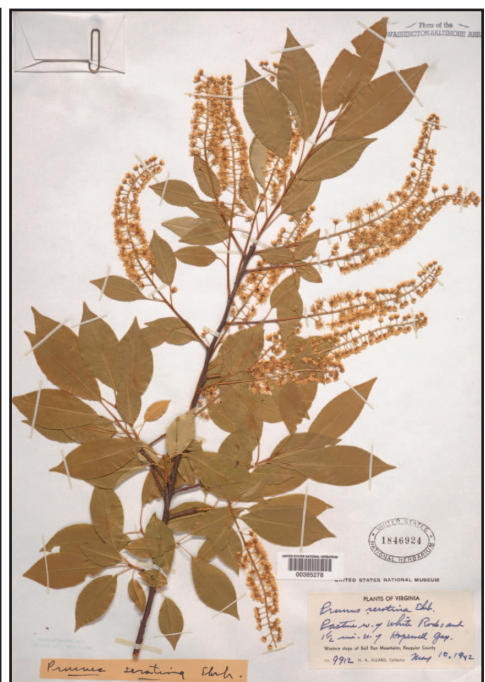


Figure 1. Cytonuclear discord in *Prunus*: the plastid phylogeny (left) infers a monophyletic racemose group, but the nuclear phylogeny (right) yields a paraphyletic racemose group. ‘A’ represents taxa in the *Prunus*-*Amygdalus* group, ‘B’ shows taxa in the *Cerasus* group, and ‘C’ depicts the polyploid racemose *Prunus*, which includes *Laurocerasus*, *Padus*, *Pygeum*, and *Maddenia*. The question mark shows the location on the phylogeny where ancient allopolyploidy may have occurred, leading to uncertain phylogenetic relationships in the racemose *Prunus*. Figure modified from Chin et al. 2014 and Zhao et al. 2016.

southeast Asia, tentatively planned for early Fall 2020. Obtaining a complete-as-possible phylogeny of the genus is a critical first step. We will use the genomic data and the rich fossil record for this group to generate a time-calibrated phylogeny and infer

diversification rates within *Prunus*. Geo-referenced distributional data will be combined with inferred diversification rates to investigate why tropical lineages diversify more rapidly than temperate clades.

We will also reconstruct the bioge-

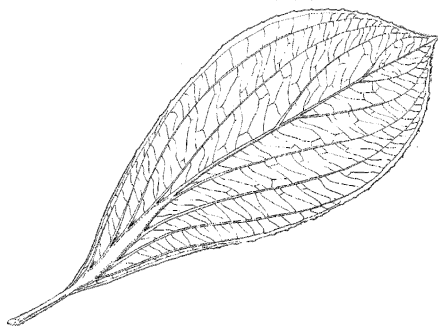


Herbarium sheets from the U.S. National Herbarium representing examples from (left to right) the solitary flower group of *Prunus* (*P. persica*; peach), the corymbose group of *Prunus* (*P. avium*; sweet cherry), and the racemose group of *Prunus* (*P. serotina*; black cherry).

graphic history of *Prunus*, which will be possible with a fully resolved phylogeny with complete taxon sampling. Next, we can use the biogeographic results to define the patterns and processes of the tropical-temperate transitions. Ecological niche modeling analyses using geographic distribution data, phylogenomic data, and niche models derived from bioclimatic variables will be used to trace niche evolution in *Prunus* to test if differences in niche conservatism among lineages determine their current geographic distributions.

In some plants, key morphological characters are typically associated with tropical environments, such as entire leaf margins; in contrast, temperate species often have toothed or lobed leaf margins. Tropical and temperate members of *Prunus* have different leaf margin morphologies and may represent an opportunity to investigate how certain morphological characters facilitate tropical-to-temperate transitions. We will leverage digitized herbarium specimens from the U.S. National Herbarium for traditional morphological analyses and a machine learning approach developed by other researchers in the NMNH Botany Department to identify morphological characters important in key transitions in *Prunus*, including tropical-to-temperate transitions, diversification rate shifts, and niche evolution.

The COVID-19 pandemic has put some portions of this project into a holding pattern, such as lab work and collecting specimens in southeast Asia. I am currently working on a phylogeny to resolve the evolutionary history of cherries (subgenus *Cerasus*) using publicly available genomic resources. I am also working to assemble datasets of images from the U.S. National Herbarium to be used in machine learning analyses for identifying key characters associated with tropical-to-temperate transitions.



Botanical research in the age of COVID-19

By Julia Beros

Life does not exist alone. It's 12:30PM and the only indication of my coworkers is how slow shared documents begin loading in my remote desktop. During this time of great uncertainty, misinformation, and vulnerability, it can be a challenge to normalize and re-create the habitual, it can even be an insult to the desire to be more "useful." But developing faith in our shared and now virtual community necessitates that we keep on keepin' on. The speed at which the Smithsonian Institution reacted to the velocity of COVID-19's approach in preparing ourselves to transition from a day-to-day routine working physically with specimens and collections to exclusively accessing them remotely and continuing research in the face of unknown challenges is not only impressive but admirable to see our passions overcome the immediate fight or flight reactionary instinct. It is clear as well, that as we log in from our various homes to access the collections, that the continued efforts of digitization at the Smithsonian are a true asset to research and maintaining continuity with the ever-changing infrastructure of our world.

Like much of the world right now, the conveyor belt, photographing specimens and creating up to 4,000 images a day, has paused, and so have the dedicated contractors who facilitate the process. In this moment of reflection we can see everything that the team accomplished thus far: of a projected 5 million botanical specimens, 2.83 million have been imaged and or recorded in the database (not including those digitized by the Botany IT team previous to the installation of the conveyor belt, or historic photographs and other media), making them available through the online catalog. With the effort of Open Access the information of our specimen image collections is not only digitally safeguarded, but it is accessible by the public for free to look at, use, and download. Nearing our last phase of imaging, the team had just begun digitizing the Poaceae (grasses). Previously about 24,000 bamboo specimens along with the type collections, were digitized, leaving an estimated 500,000 unimaged grasses of which we have already made headway with over 100,000 specimens. At our respective

homes, the team continues working on a backlog of specimen data (as we are still inundated with the roses and mustards), checking for completeness and accuracy, uploading to the database, and making the data searchable to expedite access to the collections.

Slightly inconvenienced by my new at-home workstation, I find myself still in awe, still inspired, and still feeling giddy as I scan through the U.S. National Herbarium's historic collections. Seeing an *Allium* or *Apiale* specimen come up that happens to be the same kind that I tended to in the garden this morning, or looking at a Rosaceae collected in 1800 and seeing a related species beginning to leaf and bud along the fence in my yard in 2020, is like time-travel giving me a link to the past. Reading the names of women botanists like Emma Lucy Braun and Agnes Chase paving the way for plant research and dis-

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The Plant Press

New Series - Vol. 23 - No. 2

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Cover image: Sweet cherry (*Prunus avium*).
(photo by R.A. Howard)

The age of COVID-19

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covery with their observant and patient collecting while circumnavigating sexism, fills me with hope. Seeing the names of Roosevelt and Cook's collectors, along with those of Henry Hurd Rusby, N.L. Britton, J.N. Rose, and Rupert Barnaby pop up and imagining the worlds they were collecting in, the trajectory of their work and its lasting impact on today's research—feeling the weight of history in this single moment where we as a global community are now asked to observe the world we share and become more keen to each other's needs, it's hard not to feel humbled by the magnitude of life.

With practically every major art and science institution across the world closed to the public right now, digital collections have become instrumental in serving the public and researchers. This is perhaps one of the first instances where museums have reconfigured to continue sharing their data and collections with the public while a



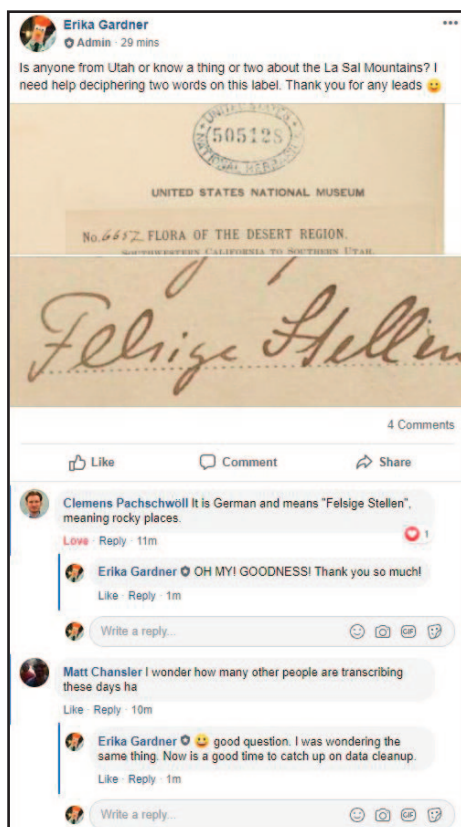
Members of the Department of Botany meet over Zoom on March 30, 2020, for a departmental afternoon tea. All were welcome to participate, including researchers, collection staff, administrators, fellows, and associates. The National Museum of Natural History in Washington, DC, remains temporarily closed to support the effort to contain the spread of COVID-19.

global crisis is actively impacting the day-to-day operations of every society. During WWII, art collections were highly vulnerable to destruction and theft, and were locked deep into storage to keep them safe. Though with tumultuous circumstances outlasting the war, many collections remained in storage and were not visible for many years, rendering them unusable and potentially putting them at risk of damage or decay (or to be lost with only the hope of rediscovery). At this very moment, the Smithsonian, encompassing 19 museums, the National Zoo, all its libraries, archives and research centers, have openly viewable exhibits online, as well as distance learning tools and educational activities (available through their webpages). Around the world, museums continue to share their rich collections via Instagram, Twitter, and other social media, and encourage the public to keep engaging with the arts, sciences, and history whilst practicing social distancing.

Feeling at times like it is not of primary importance to be able to know the difference between vascular and non-vascular plants, or what type of leaf shape is a dead giveaway for *Sassafras*, I remind myself that Botany not only *has* played a critical role in humanity, it will continue to serve us. With a rapid resurgence in “victory gardening” and more people taking daily hikes in abundantly forested seclusion,

botanical and horticultural knowledge continues to support the needs and curiosities of humans, helping them engage in their physical world and actively participate in their food cycle. Perhaps this is a chance to regain perspective of our role in life: including ourselves in nature not just as those (negatively) affecting it, but ourselves being affected by nature. The speed at which information is disseminated is astonishing in both the biological and technological landscapes: bacteria can transcribe DNA and replicate their own population size exponentially; with the click of a button an entire website can go live on the internet and be read by anyone with WiFi; and a virus can spread globally via the air we share. As we cultivate more tools and broaden our capacity to engage in our world virtually, we also amplify the speed at which information (and misinformation) travels, making work in data-checking and database management all the more essential. This also poses a challenge: as these become necessary tools to navigate our world, making access to digital infrastructure truly egalitarian becomes a requisite.

Digitization of collections has long been of interest for museums, libraries, and archives, but it often takes a moment when collections access is limited to truly comprehend the benefits of this work. We already rely heavily on many digital tools:



A collective effort! Through crowdsourcing on the “Herbarium Junkies” Facebook page, a messy label written in German becomes clear and can be accurately transcribed.

in botany we use collaborative sites like Tropicos, IPNI, and World Flora Online to stay up to date with nomenclature and family changes, synonyms, and author names; we utilize the Index Herbariorum to find and connect with institutions throughout the world; and we even use herbaria list-serves and social media to query obscure encounters (often related to poor hand-writing on labels). As readership and visitation of digital collections is

going up, a big question has been circulating as to how to properly cite digital specimens in new publications. With more and more people being forced to use digital specimens for their research, there hopefully begins a shift in opinions about using these in lieu of physical ones. What previously took effort to defend the benefits, efficiency, and accuracy of sharing and using information through digital records is now proven, as shipping physical spe-

cimens out for loans and exchange is not the safest or most efficient way to share data during this time.

Feeling the solidarity of my fellow Smithsonian workers as they continue their research, continue to fact check and clean data, continue to make research tools and specimens openly and easily accessible, continue to collect local flora, press plants, and mount backlogged specimens, feeling infinitely grateful for our facilities,

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While writing and editing papers on grasses, researcher Robert Soreng uses JSTOR Global Plants, and Biodiversity Heritage Library daily to aid in his work. Updating literature and nomenclature in Tropicos, he confers with other researchers through email exchange. Hoping to find the original type specimen related to some fragments brought to the USNH by A.S. Hitchcock in 1907, Soreng reached out to curator Otakar Sida in Prague who was able to find a not yet uploaded image of the original type. Collected by Thaddaeus Haenke in the 1790s it was originally described as *Brizopyrum subspicatum*, which was transferred to *Poa subspicata* where it remains today. As Soreng notes, “Through digitization of specimens, such histories are documented in a useful way.”

Physical Distancing Telework Testimonial

By Erika Gardner

As someone who cares for the well-being and maintenance of the collection, as a part of the Core Collection Management team, I have been preoccupied with the following task while telecommuting. It pains me to not be physically in the collection but I am diligently working from home, updating transcriptions in the database, modifying and updating protocols which were last updated in 2016, and mounting unforsaken Poaceae specimens from home.

About 9 months ago I moved out of the heart of DC to the Maryland suburbs. We have a yard now and it is our

first spring in this new house! In between work breaks I have been out exploring our modest plot. I have decided that since I am the “land manager” I have the liberty to collect and press the flora from my backyard. So far I have collected a native violet, *Viola sororia* and a non-native *Vinca minor* (escaped from my neighbor’s yard into mine). I have a *Trillium* sp. on the verge of flowering! I can’t wait to see it in flower to figure out what species it could be. I am using a children’s mini plant press that I purchased from the National Gallery of Art as a stocking stuffer. Glad I bought this in December because I am getting a lot of use out of it while in quarantine.



Having moved from California five years ago, core collections manager Erika Gardner is collecting local flora and familiarizing herself with the names and distinctive characteristics of east coast native plants, resourcefully using a miniature plant press to press specimens in her neighborhood and utilizing the digital records to verify correct identification. Here she is pressing a native *Viola sororia* and a non-native *Vinca minor*. (photos by E. Gardner)

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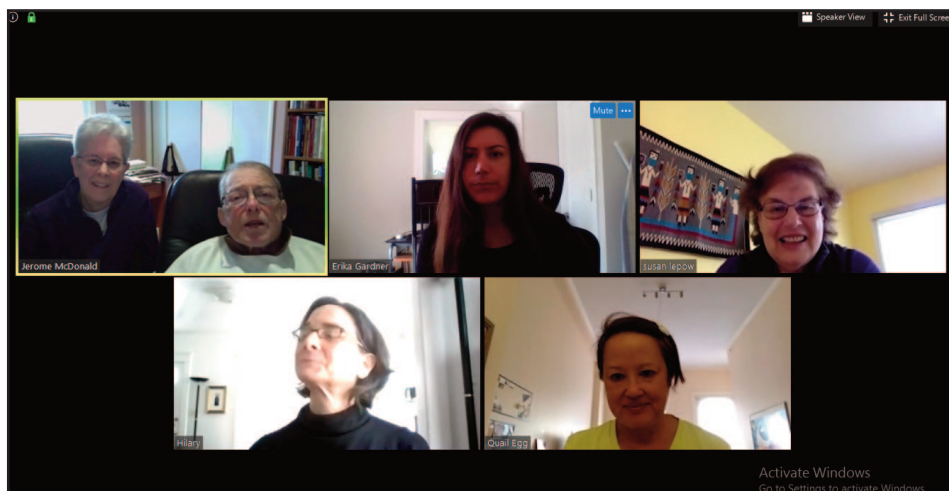
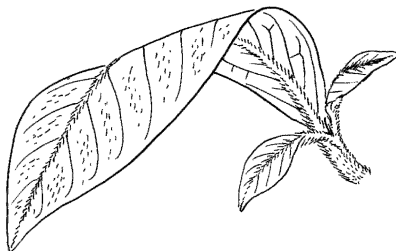
operations, and security staff continuing to show up to our museums and safeguard our collections and buildings, I am reminded of the importance of individual and solitary contributions to a shared goal. It is with the tools of art, history, and science that we are able to create solutions and innovate, solving problems that are unexpected and often self-provoked. Through the process of digitization and collections inventorying we can better assess our collections numbers and more accurately represent what is housed. Spending time editing and cleaning records, full days face deep in Microsoft Access sheets culling records for errors, we can more accurately represent the data that has been collected for hundreds of years. Plants collected decades ago, not with a clear intention of what discoveries they may incite or how they can inspire solutions to unforeseen challenges, just with the intention of preserving and sharing our natural history, take on new importance. With the continuing work of collections digitization, we make possible the enduring study of our world and inspire compassion through our shared curiosities.

It's 1:32PM and I've received an email reply that begins, "I'm eating too much, sleeping too much, watching TV too

much," from curator emeritus **Harold Robinson**. I asked him for a story:

Stories? Did I tell about the time I was walking past the Academy of Sciences building and outside the ivy-covered lawn was sticking up a squirrel's tail. I pulled it. Mistake. Small animals have a much more rapid reaction time than us big animals. It ran up my arm, sat on my shoulder and gave me a good scolding before it ran back down my arm and ran off. I don't recommend pulling a squirrel's tail. I was lucky it only chattered in my ear rather than biting it. It was just a brushy-tailed rat that chewed me out instead of chewing on me. I certainly felt like a nut.

Watching the squirrels outside is a practical distraction these days, but I also see the sweeping ephemeral blooms of magnolias, cherries, and lilacs, their warm scent a gesture of welcome, asking us to be observant and reminding us that our virtual realms still depend on the physical reality.



Each morning, core collections manager Erika Gardner guides her dedicated volunteers through virtual lessons in lieu of their regular mounting work. Beginning with a plant mounting demo and then continuing with a "botany crash course", Gardner is working to make interesting and useful courses for volunteers to grow their skillset while away from the Smithsonian.

Analyzing tree data to prevent extinctions

Sara Oldfield, Co-Chair IUCN SSC Global Tree Specialist Group

This year biodiversity and climate change will be in the headlines as politicians take stock of progress towards global targets and make plans for increasing concerted action. Tree species are of fundamental importance both as elements of biodiversity and in adaptation and mitigation measures addressing climate change. One way botanists around the world are contributing their expertise to support scaled-up environmental action is through the Global Tree Assessment (GTA). This is a global effort to assess the risk of extinction faced by each and every tree species by the end of 2020. The goal is to pull together all existing data on the conservation status of tree species and add conservation assessments to the IUCN Red List of Threatened Species for all previously unassessed tree species. This is a huge collaborative effort, managed and coordinated by Botanic Gardens Conservation International (BGCI) and the IUCN Global Tree Specialist Group (GTSG) working together with many national and local institutions and individuals. The Smithsonian Institution is contributing significantly to this global initiative which will be used to prioritize and significantly increase conservation efforts to ensure that no tree species goes extinct.

An initial task in the GTA was to produce the first global checklist of the world's tree species. This in itself was no easy feat given that plant habit is not routinely recorded in taxonomic checklists. The list of around 60,000 tree species with accepted names and country level distribution took two years to produce by consulting a range of plant databases, over 500 scientific references, and working with around 80 tree experts. The list is maintained online by BGCI as the GlobalTree-Search database <<https://www.bgci.org/resources/bgci-databases/globaltree-search/>>. It remains a dynamic resource reflecting taxonomic and nomenclatural changes and is a baseline for monitoring progress towards the GTA. GlobalTree-Search has also been connected to the World Flora Online, which is being developed as the open-access, web-based com-

pendium of all the world's plant species.

Evaluating the conservation status of tree species for the GTA follows the guidelines for applying the IUCN Red List Categories and Criteria. Each species is assessed by considering information on its area of distribution, population size and trend, habitat, uses, and threatening factors. Herbarium specimens and collection data continue to be of primary value in carrying out conservation assessments. Wherever possible these are combined with field knowledge of botanical experts. Often there is limited information on individual tree species and further fieldwork would greatly enhance our knowledge. Nevertheless, we need to use what information is currently available rather than waiting and, at the same time, identify those species which are poorly known and in need of further research. Concerns about loss of particular areas of forest and similar indirect information can form part of the species assessment process.

A species distribution map is required for each assessment and is very important in determining whether a species falls within the thresholds for IUCN threat categories. The Smithsonian's National Museum of Natural History (NMNH) has pioneered using plant specimen data to calculate distribution range for rapid conservation assessments, for example in published research on Caribbean species, and this work is taken fully into account by the GTA.

One particular approach taken by the GTA has been a rapid assessment of tree species considered to be Least Concern at a global level. These are species with a widespread distribution, not known to be exploited on a large scale as timbers or for other products such as medicines, and not known to be declining because of other significant threats. Lists of candidate species thought to meet these criteria have been sent to experts for review and/or reviewed through regional workshops. It is expected that around 20,000 tree species will be evaluated as Least Concern by the end of this year. Each species published as Least Concern on the IUCN Red List will meet the minimum required documentation standards for IUCN assessments.

Assessments of tree species more likely to be at risk because of their restricted distribution, inclusion in national or regional red lists, or known targeted use have been

undertaken in more depth than those that fall into the Least Concern category. A major priority has been to assess national endemics for countries which have particularly rich tree floras. Partnerships have been established with national organizations to undertake the tree assessments. Brazil has the most tree species of any single country, with over 9,000 species, and the most endemic trees. Currently over 3,000 endemic species are being assessed by Centro Nacional de Conservação da Flora (CNC Flora), a unit of the Rio de Janeiro Botanic Garden, and will be published on the IUCN Red List later this year. Over 20 other national partnerships are in place to help deliver the GTA. In Madagascar, the country with the highest percentage of endemic tree species, a collaborative effort over the past three years is yielding great results. The Red List of Dry Forest Trees of Madagascar is due for publication in April 2020 and all Madagascan tree species will be included on the IUCN Red List by the end of 2020.

In January this year a meeting was held at NMNH to plan an assessment for the trees of the Guianas. A rapid review of around 200 Least Concern tree species was initiated and a plan developed to assess 377 endemic trees of the Guiana Shield with no previous assessment using maps produced by NMNH's Department of Botany.

Some countries already have well-developed lists of threatened tree species. These are being incorporated into the GTA. The Smithsonian has been involved in assessing the conservation status of U.S. species since the 1970s contributing data from the US National Herbarium to both federal and non-governmental organization (NGO) efforts. Now this data for all tree species of the continental US is being converted for inclusion on the IUCN Red List for the first time. This initiative is being undertaken through a partnership, coordinated by the Morton Arboretum who are working with NatureServe and BGCI US. Linking back to GlobalTreeSearch, this work builds on the first definitive list of the native tree species of the continental US. Some of the US species assessed as part of the GTA are the *Fraxinus* (ash) species devastated by the Emerald Ash Borer. Six widespread and previously abundant North American *Fraxinus* spp. are now listed as Critically Endangered as

a result of predation by this beetle which was accidentally introduced through infested shipping pallets.

The results of the GTA will allow us to gain a clearer understanding of the threats faced by tree species on a global scale. It will be possible to analyze which species are in trouble through overexploitation for resources, general deforestation and the growing risk from climate change and exotic pests or diseases. Then it should be possible to plan for action. Conservation assessments for specific groups of trees are already guiding coordinated efforts to safeguard trees in well-managed *ex situ* collections providing materials for ecological restoration and helping to meet UN biodiversity targets. Ideally *in situ* protection for tree species can also be scaled up as part of conservation of healthy forests and other habitats, contributing for example to the planning of protected areas and sustainable forest management.

The GTA is the biggest species conservation assessment ever undertaken. It will summarize the best available information on tree species, highlight the gaps that need to be filled, and place tree diversity center stage in global discussions on biodiversity and climate change. For more information please visit www.globaltreeassessment.org.



***Talisia furfuracea* (Sapindaceae) is endemic to the Guiana Shield. This species is being evaluated for its conservation status as part of the Global Tree Assessment. (photo by Pedro Acevedo-Rodríguez)**

Growing pains in the Type Herbarium

By John Boggan

If you have looked for a type specimen recently in the United States National Herbarium (US), you may have noticed that things have changed...a lot. An ongoing rearrangement of the Type Herbarium has addressed two issues: overcrowding of the collection due to growth, and a phylogenetic arrangement that has become increasingly outdated.

A botanical type specimen is a physical specimen, usually a pressed herbarium sheet, designated by the author of a new taxon to serve as a permanent reference point for the published name. Type specimens are critical to research as they provide an unambiguous representative of the taxon, provide physical details that a written description may not, and allow subsequent researchers to study and understand how the name should be applied.

In my position as the Type Registrar, I assist the management and curation of the digital records in our Type Register and the physical specimens in our Type Herbarium, one of the largest and most impor-

tant collections of type specimens in the world. Our type collection is well-documented, with each specimen verified as a type by comparison with the original literature. Our types were among the first specimens in our herbarium to be bar-coded, inventoried, and photographed, a task made easier because, unlike some herbaria, our type specimens are segregated from the rest of the collection. All of our types were photographed in the 1980s and while these photos have since been superseded by digital photographs, I still occasionally refer to them on microfiche to document changes in the specimens (e.g., insect or mechanical damage) or to gather data from specimens that have since been lost (a rare occurrence, thank goodness). Under the direction of retired staff member **Ellen Farr**, our type collection was one of the first in the world to present both our digital records and images of our specimens online.

When I first started working with our types in 2003, we had about 95,000 type specimens catalogued. Since then, we have added about 20,000 new types for a current total of about 115,000 types, representing a 21 percent increase. Beginning in 2007, with a substantial grant from the Mellon Foundation, the Botany Department hired several contractors to work on the Latin American Plant Initiative (LAPI) (see *The Plant Press* 10(3): 1, 6-7; 2007). Originally devoted to finding, recording, and imaging type specimens from Latin America, this project eventually grew to encompass all types throughout our herbarium. A series of contractors over the years, notably **Shruti Dube**, combed through each and every specimen throughout the entire herbarium to find and record all potential types. This was a monumental job as it required not only the verification, inventory, and imaging of each new type specimen, but also the evaluation and re-filing of thousands of specimens that proved not to be types. Since this project began in 2007, we have added about 17,000 new types to the Type Register and the Type Herbarium.

Although the flood of new types has abated somewhat, they continue to come to me. Types are received as gifts from



The type specimen of *Guatteria alticola* Scharf & Maas (Annonaceae). This specimen was collected by H. David Clarke in 2001 from Mt. Ayanganna, Guyana. It is one of about 115,000 type specimens in the U.S. National Herbarium.

other institutions, specimens come back from loans newly identified as types, and visitors and staff members continue to find overlooked types in the herbarium. All new types are packaged in special type folders that provide better protection than the old type folders (which were notorious for allowing fragments to fall out) but take up slightly more space. All types returning from loans, and all types that come to me with new annotations to be recorded, corrections, or any other kind of work, are being placed in these new folders before being returned to the Type Herbarium. Placing type records and images online has greatly reduced the number of type specimens being loaned, and the number of types present at any particular time has increased.

We have several different type herbaria within the department. The largest are the "pteridophytes" (ferns and lycophytes) and the spermatophytes (seed plants). The smaller type collections of diatoms, lichens, and "bryophytes" (liverworts, hornworts, and mosses) are scattered



The type specimen of dawn redwood, *Metasequoia glyptostroboides*, collected by C.T. Hwa in 1947 from Szechuan, China. An endangered conifer, the dawn redwood is the sole living species of the genus, which was first described from Mesozoic fossils.

among a handful of cabinets. Many bulky type specimens (particularly bamboos) are also scattered within the herbarium, simply because the Type Herbarium cannot accommodate them.

Pteridophyte types, now occupying nine herbarium cases, have historically been curated separately from the rest of the vascular plants. This type collection underwent its own radical rearrangement in 2014, shortly after **Eric Schuettelpelz** arrived as the new fern curator. Most of my own work involves the spermatophyte collection. In recent years it became increasingly clear that the collection needed more space. The last time the Type Herbarium was given new cabinet space, in the early 2000s, the collection was decompressed, with room for future expansion allocated within each herbarium case. That space has long since been filled.

In late 2019, 24 additional herbarium cases were added to the Type Herbarium, in addition to the 147 it already occupied. This may seem like a generous 16 percent increase, but it does not quite match the 21 percent increase since 2003. Shifting the specimens to decompress them could have been a simple (if time-consuming) task,

but before moving any specimens, I decided to use the opportunity to address the second issue: the new phylogenetic arrangement of the herbarium.

Since the early 20th century, the U.S. National Herbarium has followed a phylogenetic arrangement that is now well over a century old and increasingly archaic. Genera are arranged by numbers originally assigned in 1900 by Dalla Torre & Harms in their *Genera Siphonogorum*. This reference listed and numbered all known genera and placed them in numeric order following the phylogenetic system of famous German botanist Adolf Engler. US has largely followed this system ever since, with occasional tweaks and new genera squeezed in along the way.

Changes in classification have accelerated since cladistic methodology met molecular phylogenetics and begat an entirely new understanding of plant relationships. The last two decades have seen an upheaval in plant classification at all taxonomic levels. With some of the dust finally settling, particularly at the rank of family, a major overhaul of the entire herbarium is now underway to arrange the flowering plants into an entirely new phylogenetic system. This new family arrangement, spearheaded by **Mark Strong**, follows the most recent phylogenetic sequence proposed by the Angiosperm Phylogeny Group (APG IV).

The new system does not simply put the existing families in a different order. While some families have proven monophyletic and their circumscriptions remain unchanged (e.g., Poaceae, Melastomataceae, Asteraceae), most families have lost or gained a few genera and some family circumscriptions have changed dramatically. Amaryllidaceae and Liliaceae, long a problematic pair of families, have had their genera reshuffled into each other and into numerous other families. Scrophulariaceae has become a much smaller family, with many of its former members now placed in Plantaginaceae. Some families do not exist anymore. Turneraceae is now included in Passifloraceae and the genera of the former Flacourtiaceae are now distributed among Salicaceae, Achariaceae, and several other families. The result is a modern, up-to-date system that reflects our current understanding of flowering plant relationships and makes phylogenetic sense.

The Type Herbarium has always fol-

Type specimens at the United States National Herbarium*

- **Diatoms: 400 types**
- **Algae: 5,800 types**
- **Lichens & Bryophytes: 5,400 types**
- **Pteridophytes: 5,600 types**
- **Spermatophytes: 97,600 types (including 16,000 grass types)**

*all numbers are approximate

lowed the broad outline of the main herbarium, with one major difference: each type is filed under the name it typifies, not the currently accepted name of that taxon. The arrangement is otherwise similar, with genera arranged numerically and species arranged alphabetically within each genus. If you knew the typified name and its genus number, finding the specimen was easy.

Expanding and shifting the Type Herbarium into new space provided an opportunity to update and reorganize it into the same new phylogenetic arrangement as the main herbarium. From late 2019 to early 2020, I began to shift the type specimens into their new families, and the families into their new herbarium cases. Between assigning genera to their proper updated families, and then physically moving the specimens, this process took about four months. The result is that, while types remain in numeric order within a family, their family assignment will also be required to find them.

In the short term, type specimens are going to be a little more difficult to find. To complicate things further, our understanding of the relationships of genera within the families has also changed. In parallel with the family rearrangements, genera in every family are being re-numbered to reflect these new understandings. The new genus numbers will have two parts, with the first indicating the family number and the second the genus number within that family (e.g., 018-074 for the Annonaceae genus *Guatteria*). This is an ongoing task in the main herbarium, and most families in the Type Herbarium have not yet been updated with the new genus numbers.

Continued on page 10



Among the oldest type specimens in the US collection is *Banksia integrifolia*. It was collected along the eastern coast of Australia (then called New Holland) by Joseph Banks and Daniel Solander during Captain James Cook's first voyage of the ship *Endeavour* (1768 - 1771).

Type Herbarium

Continued from page 9

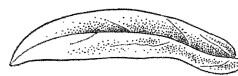
How does one find a type? The first piece of information is the typified name. Knowing that, you will need two additional pieces of information: the current family assignment of the genus and the corresponding genus number. Taxonomic records in EMu (the department's collections management software) are being updated, but the new family circumscriptions can be found online at the Angiosperm Phylogeny Website, <http://www.mobot.org/MOBOT/research/APweb>. Several of the major online resources like Tropicos, IPNI, and Plants of the World Online have already updated their records to reflect new family assignments. Wikipedia is another surprisingly good source for information on the new classifications. Genus numbers can be found by looking up the name in the taxonomy module of EMu, or by checking the genus number database on the Botany Department's Intranet (accessible on Smithsonian computers only). Genera are still arranged numerically within each family, and species are arranged alphabetically within each genus. (One exception is Poaceae, in which types have always been filed alphabetically by both genus and species.) To help find the new location of a family, a list has been printed and posted in various locations around the herbarium. I am also available in person to provide assistance in finding type specimens.

The pteridophyte types have always been curated separately from the rest of the vascular plant types. They were formerly arranged phylogenetically, according to the currently accepted name of each type, using an arrangement devised by former curator **Dave Lellinger**. This arrangement made types difficult to find and to file. Schuettpelz decided to arrange the pteridophyte types alphabetically by genus and species and this has proven to be a much easier arrangement to maintain. The grass types have similarly been filed alphabetically. Based on the demonstrated ease and convenience of finding and filing types in these two groups, the Collections Committee has given its approval to arrange all types alphabetically – a project for the future.

Several tasks remain. First, we are working to update the taxonomic records

in EMu with new family assignments and new genus numbers. All type folders in the Type Herbarium need to be updated with the new family assignment and genus number. At some time in the future, types will be arranged alphabetically within each

family. Finally, several of our smaller type collections have been neglected for decades, notably the lichen and bryophyte types. Both groups need extensive curation, but we currently lack curators actively working with these groups.



ForestGEO network welcomes three new plots

ForestGEO, a Smithsonian-led global network of large-scale, long-term forest research sites, is pleased to welcome three new plots to its ranks. The Ailaoshan plot is in a montane forest in subtropical China; the Niobrara plot and the Indian Cave plot encompass the forest-prairie transition zone in Nebraska, USA. There are now 70 ForestGEO research sites.

Min Cao, Principal Investigator for the new Ailaoshan plot (and also for Xishuangbanna, an extant ForestGEO plot), established the site with his research and field crew teams in 2014. They have undertaken two censuses of the 20-hectare plot and report over 44,000 free-standing stems (of plants with a diameter at breast height (dbh) ≥ 1 cm) that span 104 species – the most dominant species being within the *Fagaceae*, *Theaceae*, and *Lauraceae* families.

Sabrina Russo has long been an active member of the ForestGEO network, notably through her mentorship at ForestGEO's annual analytical workshops, and now as the principal investigator for Niobrara and Indian Cave. Niobrara is a 20.16-ha plot located at the northern border of the Nebraska-South Dakota border. The field crew finished its first census in July 2019 and noted the presence of both paper birch (*Betula papyrifera*) and Ponderosa pine (*Pinus ponderosa*), a rarity for Nebraska. The crew was poised to complete Indian Cave's first census in the spring of 2020. The 18.40-ha plot contains eastern redbud (*Cercis canadensis*), two cherry species (*Prunus virginiana*, *P. serotina*), catalpa (*Catalpa speciosa*), and pale dogwood (*Cornus amomum*). It is located in the south-east corner of the state.



Buffalo amble by on the prairie's edge at the Niobrara plot. (photo by Sabrina E. Russo)

New plant species named in honor of Vicki Funk

A new species from the Ecuadorian Andes, *Xenophyllum funkianum* J. Calvo, was recently described and named in honor of **Vicki A. Funk** (1947–2019) who greatly contributed to the understanding of the family Compositae worldwide. It grows in the dry superparamo at elevations of 4100–4300 m in the provinces of Bolívar and Chimborazo. The species was

first collected by Funk and Mauricio Bonifacino in the Mt. Chimborazo area in April 1818. The species is described in a recent publication written by Joel Calvo and Vicki Funk (*Phytokeys* 139: 29–38; 2020). The publication includes a second new species, *Xenophyllum lorochaqui* J. Calvo & V.A. Funk, endemic to the Argentinian Andes.

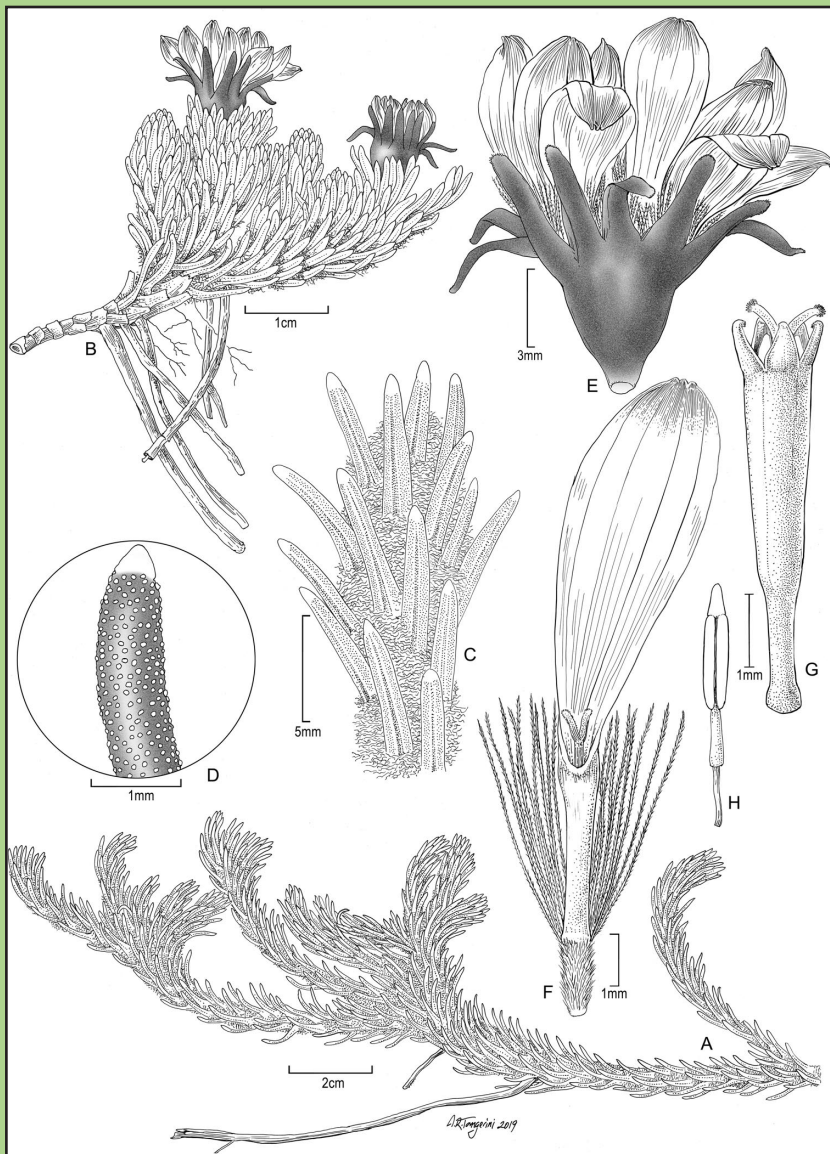


Illustration of *Xenophyllum funkianum* by Alice Tangerini. Tangerini corresponded multiple times over email with Joel Calvo to highlight key characters in the drawing. One key character she emphasized is the very dark involucres on the head.

The Digitized State Plants of America

Smithsonian Learning Lab has uploaded a set of postcards created by the Digitization Program Office (DPO). Each state and the District of Columbia is represented by a herbarium sheet of a plant collected in that state. The postcards are available at <http://learninglab.si.edu/q/ll-c/oMrY7y1Wdt46GRwC>. These were made possible through the herbarium digitization project done at the National Museum of Natural History in partnership between the museum and the DPO. As of March 2020, the U.S. National Herbarium has digitized 3.7 million plant specimens, which are free to view and download from the Botany Collections webpage at <https://collections.nmnh.si.edu/search/botany/>.



The Maryland postcard, represented by the state flower Black-Eyed-Susan (*Rudbeckia hirta*), is just one of 51 postcards made by the Smithsonian Digitization Program Office (DPO). Each postcard features a specimen from each state of the USA and the District of Columbia. The specimens were digitized as part of the Herbarium Digitization Project by DPO and the National Museum of Natural History.

Highlights from a winter after-school botanical workshop

On the 16th, 23rd, and 30th of January, and the 6th of February, a botany after-school workshop was led by **Gabe Johnson, Liz Zimmer, Richie Hodel, Mónica Carlsen-Krause, Shruti Dube, Steven Canty, Erika Gardner, Julia Steier, Alice Tangerini, Marcos Caraballo Ortiz, Aleksander Radosavljevic**, Nicole Webster, Heather Richardson, Juan Pablo Hurtado Padilla, and Lee Coykendall in the Q?rius Science Education Center at the National Museum of Natural History. This class was an introduction to botany for local teenagers across the greater Washington, DC metro area. The overarching theme of the class was 'orphaned' crops and floristic changes incurred by global climate change. The workshop was focused around Araceae because it contains a number of understudied crop plants that are grown in areas threatened by sea level rise.

On the first evening, students learned about collections-based botanical research, the value of voucher specimens, and the importance of herbaria around the world.

Students received a tour of the herbarium led by Canty and Dube. During the tour, Caraballo showed his collections of parasitic plants and explained how some specimens are bottled in alcohol. Radosavljevic showed several new legume species that he described from collections housed at the US National Herbarium. Tangerini explained the process of botanical illustration using the drawings she made of Radosavljevic's new species as an example. In the Q?rius lab, students placed slices of pineapple and malanga coco (*Xanthosoma sagittifolium*), cooked and uncooked, onto Petri plates of gelatin to observe protease activity in the pineapple fruit and determine if such protein digesting enzymes are also present in the corm tissue of malanga coco. With a basket of local grocery store produce, the students learned the difference between a tuber, a bulb, and a corm; each student received a taro (*Colocasia esculenta*) or malanga coco corm to plant in a cup and watch sprout in the Q?rius growth chambers during the course of the 4-week workshop.

The following week the students received an introduction to the scientific process from a wider perspective. It was emphasized that scientific investigations are rarely a linear progression from problem and hypothesis through results and discussion; rather, science is a multifaceted approach where ideas are tested in response to discoveries made through exploration and feedback from peers in the community to address issues ranging from everyday curiosities to global social dilemmas. Examples of this holistic view of the scientific process were given by Hodel, a postdoctoral researcher who just arrived at the Smithsonian one week prior. Hodel explained the various challenges he encountered and the discoveries he made researching mangrove reproductive biology around the Florida peninsula. Returning to Araceae, the students were given a simple, six couplet dichotomous key to identify some common aroid houseplants. After doing so, the students were given two ad-

ditional plants, *Epipremnum aureum* and *Philodendron hederaceum*, and were asked to rewrite the key to include these taxa. After discussing their creative solutions to this problem, each group of students was assigned a different aroid species from which to collect tissue and press a voucher specimen.

The third class opened with an introduction by Carlsen-Krause, a world expert of Araceae, research associate in the Botany Department, and currently Assistant Scientist and Education Coordinator at the Missouri Botanical Garden. Carlsen-Krause inspired students as she recounted how she chose to become a botanist and the importance of botanical research in the 21st century. She taught the class the elements of a herbarium label and had them write labels for the houseplants they pressed the previous week. After mounting their specimens on herbarium sheets, the students observed the morphology of their assigned aroid species under the stereoscope. Each group also prepared a wet mount of macerated petiole tissue from their plants to observe the raphide phytoliths under polarized light microscopy. The students met with teenagers taking the Microscopy After School Workshop and used SEM to observe the subtle geometric differences in raphides of different aroid species. At the end of the class, they observed their proteinase assay plates and observed the buds sprouting from their potted taro and malanga coco plants.

The workshop concluded the last week with a visit to the U.S. Botanic Garden. Student groups were paired with a botanist mentor and given a dichotomous key (developed by Carlsen-Krause, Dube, and Johnson) to the aroids of the Garden's Tropical House. The name signs for the various aroids in the garden were covered with neon pink number signs, one through forty-five, and the students were asked to correctly identify as many as possible. This activity gave students a real opportunity to wrestle with the morphological concepts and characters used to identify aroids in the field. Afterwards, over a snack of taro chips and poi, the students discussed their identifications and discoveries. USBG education specialist Coykendall explained the garden's history and mission as well as the biology of one of its most charismatic, yet



Students from a winter botany after-school workshop visit the U.S. Botanic Garden to identify a number of aroids using a dichotomous key. (photo by Lee Coykendall, USBG).

noisome, aroids, *Amorphophallus titantium*. The students were invited to smell a jar containing its saprocantharophilic scent.

The students left this workshop with a deeper appreciation for plant diversity and the methods scientists use to understand them. Many who take these after school

workshops in Q?rius go on to become teen ambassadors in the Q?rius space during weekends and over the summer months. Here, they interact with their peers and orient visitors to the many wondrous collections in its cabinets and display cases. The fluency and accuracy with which these

teen docents discuss botanical collections with Q?rius visitors is in part thanks to the selfless dedication of staff members in the Botany Department who volunteered to make this After School Workshop happen.



NEW FACES

Richie Hodel started as a Peter Buck Postdoctoral Fellow in the Botany Department in January 2020. Hodel is working with **Jun Wen** and **Liz Zimmer** to use phylogenomic approaches and collections-based deep learning technologies to resolve phylogeny, assess ancient polyploidy, and infer the biogeographic history of *Prunus* (Rosaceae). Hodel studied the comparative phylogeography of Neotropical mangroves (genera *Avicennia*, *Laguncularia*, *Rhizophora*) for his doctoral work at the University of Florida

with Doug and Pam Soltis, completed in 2017. He recently finished his first postdoctoral appointment at the University of Michigan with Lacey Knowles and Stephen Smith studying the comparative phylogeography of montane sedges (genus *Carex*), and working on phylogenomic methods development. His research interests include the comparative phylogeography of island taxa, biogeography and niche evolution, and tropical-to-temperate transitions.

STAFF ACTIVITIES

From February 1 to March 17, **Robert Soreng** traveled to South Africa and Lesotho to collect grasses and study high elevation grasslands in the Mulati-Drakensberg Mountains with Steven Sylvester (Nanjing Forestry University, China), Mitsy Sylvester, and Vincent Ralph Clark (University of the Free State, South Africa). The team made over 350 collections of grasses from 41 genera. Sets were left for the South African National Biodiversity Institute (PRE) and the University of KwaZulu-Natal's Bews Herbarium (NU); the U.S. National Herbarium (US) set is expected to be shipped to Plant Protection and Quarantine (PPQ). They also conducted vegetation surveys of over 220 plots. The team visited PRE herbarium in mid-March. Soreng flew home early to the United States from South Africa the day before the airports closed down due to travel bans related to the COVID-19 virus. The Sylvester family is stuck in South Africa indefinitely.



Drakensberg Mountains, South Africa, with a view of Sentinel Peak (right) and Devil's Toothpick, (narrow pinnacle in center). A botanical team made over 350 collections of grasses from this area, a place that was used in filming the fictional land of Wakanda in the 2018 movie *Black Panther*.

TRAVEL

Manuela Dal Forno traveled to Berlin, Germany (2/29 – 3/28) to attend the 9th Programming for Evolutionary Biology Course at the Freie Universität Berlin and to visit the Botanischer Garten und Botanisches Museum to work on lichen specimens from the Philippines and revise *Dictyonema* (Hygrophoraceae) material with Robert Lücking.

Laurence Dorr traveled to Philadelphia, Pennsylvania (2/28 – 3/1) to visit the herbarium of the Academy of Natural Sciences of Drexel University to search for type material.

Laurence Skog traveled to Sarasota, Florida (1/27 – 1/31) to continue working at the Marie Selby Botanical Gardens on the Wiehler collections of Gesneriaceae and to examine specimens for Flora Mesoamericana.

Robert Soreng traveled to South Africa and Lesotho (2/1 – 3/17) to collect grasses and study high elevation grasslands in the Mulati-Drakensberg Mountains.

Ken Wurdack traveled to St. Louis, Missouri (1/22 – 1/28) to do research in the herbarium of the Missouri Botanical Garden.

VISITORS

Peiwu Xie, Guangdong Academy of Forestry, China; Herbarium research (8/28/19-8/28/20).

Myoung-hai Kwak, National Institute of Biological Resources, South Korea; Herbarium research (9/3/19-3/3/20).

Santos Miguel Nino and **Daniela Canelón Barraez**, Universidad Nacional Experimental de los Llanos Ezequiel Zamora, Venezuela; Flora of Guaramacal (10/29/19-1/31/20).

Steven Sylvester, Royal Botanic Gardens Kew, United Kingdom; Poaceae (12/4/19-1/4/20).

Fred Barrie, Missouri Botanical Garden; Flora Mesoamericana (1/6-1/17).

Amanda Chunco and five students, Elon University; Plant conservation and herbarium tour (1/14).

Krissa Skogen, Chicago Botanic Garden & Northwestern University; Onagraceae (1/17).

Fabian Michelangeli, New York Botanical Garden; Melastomataceae (1/20-1/23).

Emily Beech, Botanic Gardens Conservation International, United Kingdom, **H. David Clarke**, University of North Carolina Asheville, **Neil Cox**, IUCN District of Columbia, **Bruce Hoffman**, Amazon Conservation Team, Suriname, **Nina Marshall**, Critical Ecosystem Partnership Fund, and **Sara Oldfield**, IUCN SSC Global Tree Specialist Group, United Kingdom; Global tree assessments (1/21).

Yubing Wang, Three Gorges University, China; Herbarium research (1/28-2/26).

Rafal Gutaker, New York University; *Oryza* (Poaceae) (2/6-2/10).

Marc Baker, Arizona State University, and **Michelle Cloud-Hughes**, Desert Solitaire Botany and Ecological Restoration; *Cylindropuntia*, *Grusonia*, *Echinocereus*, other assorted Cactaceae (2/10-2/15).

Bertrand Black, University of Vermont; Ferns (2/14-2/18).

Nelson DeBarros, Fairfax County Park Authority; *Juncus* (Juncaceae) and *Potamogeton* (Potamogetonaceae) (2/14).

Jacques Florence, Museum National d'Histoire Naturelle, France; Flora of French Polynesia (2/18-3/9).

Thomas Heller, Royal Botanic Gardens Kew, United Kingdom; Caribbean *Zanthoxylum* (Rutaceae) (2/18-2/19).

Nareerat Boonchai, Florida Museum of Natural History; Fossil and modern woods (2/19-2/21).

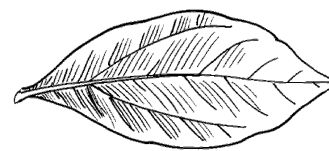
Paul Berry, University of Michigan; Euphorbiaceae (2/26-2/27).

Jonathan Flickinger, Florida International University & Fairchild Tropical Botanic Garden; Neotropical Myrtaceae (2/26-2/28).

Ivan A. Valdespino, University of Panama; Ferns (3/2-3/12).

Diane Winters, Academy of Natural Sciences; *Melosira complexa* (Melosiraceae) (3/10).

Caroline Mitchell, Manaaki Whenua Landcare Research, New Zealand; Plant population genetics (3/16-3/20).



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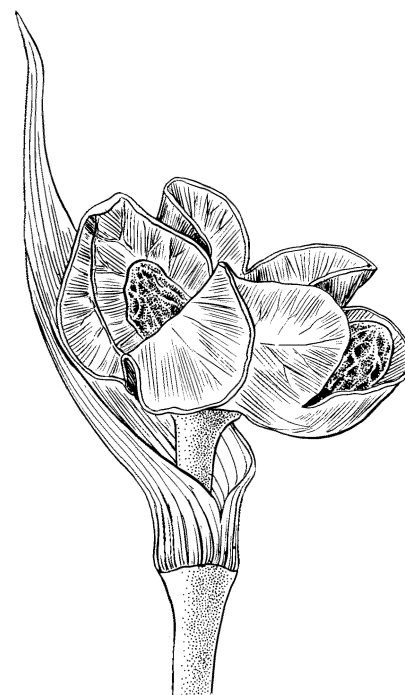
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ART BY ALICE TANGERINI

Prunus polystachya (Hook.f.) Kalkman

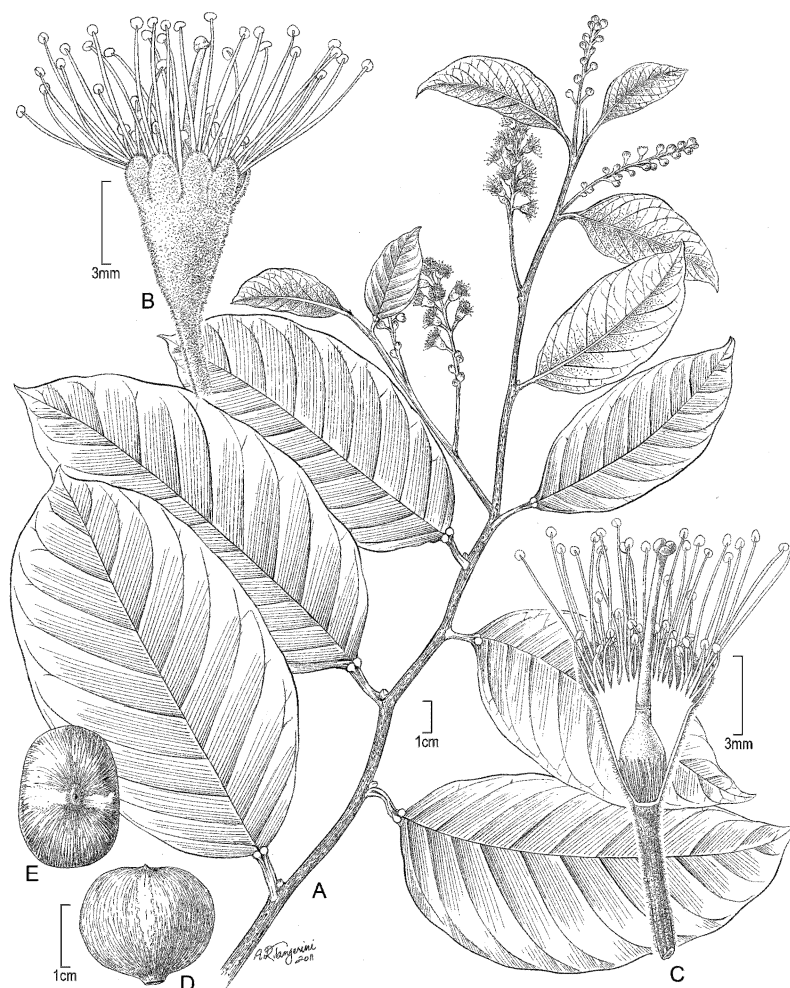
Prunus polystachya (Rosaceae) is a tree that grows up to 35 m high with deeply hollowed leaf glands.

A species from the Malaysia, Singapore, and Indonesia region, it has the common name “bat’s laurel”, yet field

observations show pollination by hover flies.

Alice Tangerini drew this illustration of *Prunus polystachya* for a forthcoming *Prunus* taxonomic revision. It

was pointed out to Tangerini the importance of the arrangement of stamens in the flower, so a longitudinal section of the flower was included to show the arrangement.



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