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An exceptional symposium explores plants on the edge

By Gary A. Krupnick

The 19th Smithsonian Botanical Symposium, co-hosted by the Smithsonian's Department of Botany and the United States Botanic Garden (USBG), made a welcome return to the National Museum of Natural History's (NMNH) Baird Auditorium on May 13, 2022, three years after the last time the event was held in person. The Symposium, "Life on the Edge: Exceptional Plants in Exceptional Places," was a hybrid event, bringing together five engaging speakers to present their research to both in-person and virtual audiences from around the world. The invited speakers included scientists specializing in conservation, ecology, systematics, and genetics whose research explores plant adaptation and survival in extreme parts of the natural world. The speakers talked about their research on plants (and lichens) growing in exceptional environments, from the tepuis of the Guayana Shield and the steep cliffs of Hawaii to the South African Fynbos, the Mojave Desert, and even New York City. They spoke about natural history and evolution, and the challenges plants endure in the face of climate change and increasing pollution.

Eric Schuettpelz, NMNH Chair of Botany, welcomed the audience to the symposium and Rebecca Johnson, NMNH Associate Director for Science and Chief Scientist, provided opening remarks. In her comments, Johnson talked about a project, "Life on a Sustainable Planet," currently in development at NMNH, and she tied the project to the theme of the symposium. She described the new project as, "understanding, explaining, and amplifying the reach, relevance, and impact of the work here at the Smithsonian," and the relevance to the tens of thousands of species 'on the edge'. Susan Pell, USBG Deputy Executive Director, also provided opening remarks and gave an orientation to the USBG, including a description

Continued on page 2

> **"Wish to be wrong, because when you are wrong that's when the questions come. If you want to be wrong, you become a better scientist."**
>
> *- Fabián Michelangeli, in answering the panelist question, "what advice would you give botany students just starting out?"*

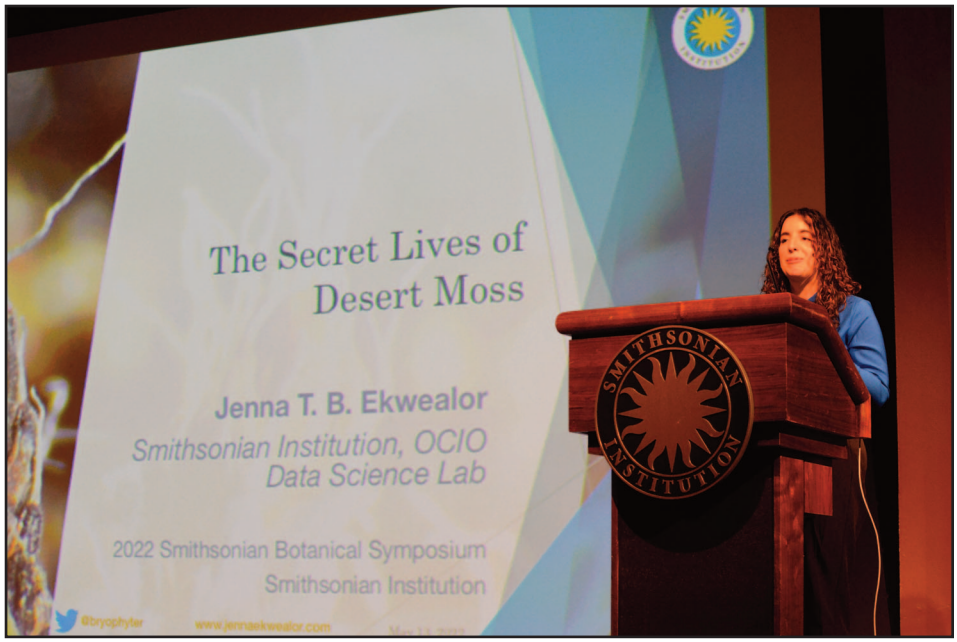
Symposium

Continued from page 1

of the living collections, current online and in-person programming, and their scientific and conservation partnerships.

Kenneth Wurdack, NMNH Department of Botany, presented the annual José Cuatrecasas Medal for Excellence in Tropical Botany to Fabián A. Michelangeli, curator of tropical botany at the New York Botanical Garden in the Institute of Systematic Botany where he conducts research on Melastomataceae. Michelangeli, who did double duty as invited speaker and award recipient, accepted the award as a tribute to his advisors, colleagues, and "most of all, [his] students and postdocs that have helped [him] be a little bit relevant."

The first presentation of the symposium was delivered by Jenna Ekwealor from Smithsonian's OCIO Data Science Lab. Her talk, "The secret lives of desert moss," explored the vegetative growth and the sexual reproduction of these exceptional desert plants. Her talk focused on species in the genus *Syntrichia*, which includes many dryland specialists and the most desiccation-tolerant plants known. After finding a population of *Syntrichia caninervis* growing underneath rocks in the Mojave Desert, she set out to characterize this habitat including understanding the community composition, measuring and quantifying the light transmitting through the rock, and characterizing the hypolithic microclimate. She characterized the Mojave moss community as including *Syntrichia caninervis* (abundant both on the surface and under quartz rocks), *Tortula inermis* (more abundant under quartz rocks), and *Bryum argenteum* (found just once on the surface). She found that rocks buffer from extreme temperatures—cooler under the rocks during the day and warmer at night, except during snowfall where the rocks provide a warming effect during day and night. She found higher measures of humidity under the quartz, thus providing protection from desiccation. In measuring light intensity transmitting through the quartz, she found that mosses receive low light under rocks, but they also get different quality of light—bigger wavelengths and less ultraviolet radiation.



Jenna Ekwealor shares secrets about the lives of desert moss. (photo by Ken Wurdack)

In the second half of her presentation, Ekwealor spoke about an extreme sex ratio bias in *Syntrichia caninervis*. Studies show that phenotypic males are rare, with at least five females for every male. Many individuals of this species can be non-expressing without making sex organs. Do males express their sex less frequently or are males actually rare in this species? Ekwealor used a new restriction-fragment length polymorphism technique that amplifies a gene on the sex chromosome to determine genotypic sex in *Syntrichia*. She found an 18:1 ratio of females to males in non-expressing individuals, demonstrating that males really are rare in this Mojave population. The next step, she explained, is to understand why—is female clonal growth rate faster or is male mortality higher? She found evidence that both processes are present and said that more work is necessary to tease these hypotheses apart.

Fabián Michelangeli speakes about endemism and adaptations in tepui flora. (photo by Ken Wurdack)

Fabián Michelangeli from the New York Botanical Garden gave the second presentation, "Endemism and adaptations in the flora of the lost world." He began with some history about the first scientific

explorations of tepuis, table form mountains in the Guayana Shield. He also spoke about tepuis in popular culture, such as Conan Doyle's book, "Lost World", and Disney's movie, 'Up". In describing the geology, he talked about how these 40-45 summits were formed, and in describing the variety of plant environments, he talked about how tepuis are very biologically rich with about 2,600 plant species and 885 endemic species. A few species endemic to tepuis are found on multiple summits, but many more species are locally endemic to a single or a couple of summits. He explained that species richness correlates well with isolation and summit area, following classical island biogeography patterns, but more data is needed as sampling effort varies—some summits are easily accessible by hiking and have thousands of specimens in herbaria, whereas other summits can only be reached by helicopter and have not been sampled as frequently.

In describing the flora of tepuis, Michelangeli said that Orchidaceae, Melastomataceae, Rubiaceae, Asteraceae, and Bromeliaceae are the plant families with the most species. He expressed surprise that Fabaceae and Euphorbiaceae, two very large tropical families, are conspicuously absent from tepuis, and that the presence of uncommon families that are important elements of tepuis are dominant, like Xyridaceae and Rapateaceae. He explained that cosmopolitan tribes within families like Asteraceae that are very common in the Andes or the Amazon are not the same tribes that are common on the top of tepuis. While displaying stunning photographs of flowering plants, he explained that the combination of high elevation, high radiation, low pH, and few nutrients has created a unique tepui syndrome of plants with small thick leaves and few compound leaves. Low nutrients has also led to a diverse selection of carnivorous species that have evolved on rock environments and in bogs. He wrapped up his talk by speaking about the threats of mining and other illegal activities that threaten the flora of tepuis.

After the first coffee break, Tanisha Williams from Bucknell University spoke about "Protecting the Fynbos: climate change insights from South Africa." After a brief introduction about the effects of climate change on global biodiversity, she turned her focus to South Africa, an exceptional place with a rich flora. Certain local regions of South Africa are already experiencing extreme levels of heat, droughts, and floods. A video she shared touched upon the Cape Town water crisis and the inequalities of water access on the local communities. Centering in on the Fynbos, a shrubland biome with a Mediterranean climate housed in the Cape Floristic Region, Williams spoke about the diverse flora and the various ways that plants have adapted to this ecosystem.

Tanisha M. Williams gives insights into the effects of climate change to the South African Fynbos. (photo by Ken Wurdack)

Using *Pelargonium* (Geraniaceae) as a case subject, Williams talked about how Fynbos plants are responding to rapid climate change. In her research she examined phenological records, conducted common garden experiments, and modeled species distributions. She shared herbarium records that showed a 12-day advancement of flowering over the past century. Her garden experiments showed that *Pelargonium* species exhibited significant levels of morphological variation in response to the environment, but responses by the plants were not favorable in hot and dry environments. Her species distribution maps showed that the species will respond to a precipitation gradient, with habitats shrinking through 2070. Williams expressed hope, though, that Fynbos species have the ecological and evolutionary tools to mitigate and respond to climate change.

Continued on page 4

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Web site:
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On the cover: The rich botanical diversity of Kaua'i as seen using drone technology. (photo courtesy of Ben Nyberg)

Symposium

Continued from page 3

She ended her talk by recommending Black Botanist Week <http://www.blackbotanistsweek.weebly.com>, a social media campaign that promotes, encourages, creates a safe space for, and finds more Black people who love plants.

Ben Nyberg from the National Tropical Botanical Garden followed with "A conservation airlift: applications of drone technology in plant conservation." He described the Hawaiian Island of Kaua'i as having a rich flora with nearly 90% endemism and 250 single-island endemic species within an area of 550 m^2. The island's most diverse plant families include Campanulaceae, Rutaceae, and Rubiaceae. With 90 species on the edge of extinction, Nyberg described how exploration, seed collection, and propagation are all important in conserving these exceptional species. Rare plant refugia models place hotspots for rare species in cliff environments, spots often too steep or difficult to reach. Nyberg described the use of drones for botanical surveys in these hard-to-reach areas. In describing his methods, he shared awe-inspiring high-resolution images and videos retrieved from drones showing rare and threatened species along precipitous Kaua'i cliffs. He spoke about his methods in assessing the images, tagging species, creating 3D maps, and developing models to locate other individual plants. He demonstrated these methods by showing how *Hibiscadelphus woodii*, once believed to be extinct, was rediscovered with drone technology. He then shared a table of 10 Critically Endangered species where, with the use of drones, the number of known individuals in each population was found to be double, triple or more.

Ben Nyberg describes the applications of drone technology in plant conservation. (photo by Ken Wurdack)

Nyberg also described how drone technology can assist in plant collecting and seed propagation. He shared images and videos of his team using drones to collect seeds and cuttings from inaccessible, cliff-dwelling species, like *Lysimachia iniki*, *Kadua st-johnii*, and *Isodendrion pyrifolium*. He spoke about finding undescribed species, such as a new *Schiedea*, and the ability to take cuttings from these plants to then grow them in greenhouses for further research. He explained that frequent extreme storms have led to landslides that have further degraded cliff habitat. To restore these habitats, he said that drones can be used to spray a hydro-mulch mix for plant propagation.

Jessica Allen describes urban lichens as a symbiosis in a built environment. (photo by Ken Wurdack)

After the second coffee break, Jessica Allen of Eastern Washington University gave the final presentation, "Urban lichens: symbioses in the built environment," which brought the conversation much closer to home for many audience members. She described urban environments as extreme, where it is hotter, drier, more disturbed, and with more pollution than surrounding natural areas. And yet, she said, densely urbanized areas are incredible living laboratories for studying biodiversity due to the detailed baseline for organisms that live there. She turned to lichens, in which she described as "not plants, but they are exceptional, an obligate symbiosis between fungi and algae, and both of those partners have to live together to form these beautiful and diverse organ-

isms." She detailed historic surveys of lichens in New York City, from J. Torrey's 1819 study (61 lichen species) and A. Halsey's 1823 study (191 species), to C.C. Wood's 1914 study (51 species) and I. Brodo's 1968 study (8 species). Allen conducted her own lichen survey in 2017 and counted 106 species. She explained that the fluctuation in species count is due to the changing built environment of the city and the shifting air quality.

Allen recounted which species have been lost, such as *Usnea strigosa* (not seen since the 1800s), which ones have persisted, such as *Cladonia caespiticia*, and which ones have recolonized the city, such as *Flavoparmelia caperata*. She described an unsuccessful transplant study in which she attempted to bring back to the city *Cladonia subtenuis* and *Usnea mutabilis*. She argued that assisted recolonization is challenging and that lichens need to come back on their own. She concluded her talk with a list of outstanding questions in urban lichenology, from whether there are specific genotypes adapted to urban conditions to which genes are under selection in urban populations.

The symposium ended with a panel discussion moderated by Susan Pell (USBG) with questions from the in-person and virtual audiences to the five speakers. Questions included: where do you think we are on the discovery curve of understanding plant dynamics in extreme environments?; how do you advocate outside of the botanical community for the conservation of the species or habitats that you study?; what advice would you give to botany students just starting out?; how do plants and lichens adapt to climate change?; what are synergies that you see between water conservation engagement and land conservation engagement?; where does horticulture overlap with botany and how do we create more collaborations?; and in a 30-second elevator pitch, what's the most fascinating aspect of your research or what would you want everybody to take away from your presentations here today? To hear the fascinating responses to these questions by all five speakers, a video of the panel discussion is available on YouTube <https://youtube.com/playlist?list=PLQmxS2U3B6KYwtkGdb9YrI1F95dSs04tZ>.

"Even these little, tiny mosses that are in the desert and seem very niche are actually really fundamentally connected to all of us."

- Jenna Ekwealor, during the panel discussion in giving a 30-second elevator pitch about what she would want everybody to take away from her presentation

The symposium attracted nearly 400 people. Those who viewed the proceedings online watched from 20 countries from around the world. All speaker presentations, opening remarks, the presentation of the José Cuatrecasas Medal, and the roundtable panel discussions were recorded and are available for viewing at NMNH's Natural History for Scientists YouTube <https://www.youtube.com/channel/UC6ebFzi3b6IZtTrbyUz35iQ> page.

The 20th Smithsonian Botanical Symposium is scheduled to take place at the National Museum of Natural History and the U.S. Botanic Garden on Friday, May 19, 2023. The topic is still to be determined. Check the Department of Botany's website for updates.

Susan Pell (far right) moderates a panel discussion with the symposium's speakers: (from left) Fabián Michelangeli, Tanisha Williams, Jessica Allen, Jenna Ekwealor, and Ben Nyberg. (image from Zoom)

Michelangeli receives the 19th Cuatrecasas Medal

The José Cuatrecasas Medal for Excellence in Tropical Botany is named in honor of Dr. José Cuatrecasas, a pioneering botanist and taxonomist, who spent nearly a half-century working at the National Museum of Natural History. Cuatrecasas had a distinguished career devoted to systematic botany and plant exploration in tropical South America, especially in the Andes, and this award serves to keep vibrant his accomplishments and memory. The Department of Botany and the U.S. National Herbarium present this award at the Smithsonian Botanical Symposium to a botanist and scholar of international stature who has contributed significantly to advancing the field of tropical botany. The award consists of a bronze medal bearing an image of José Cuatrecasas on the front with the recipient's name and date of presentation on the back.

This year the 19th José Cuatrecasas Medal for Excellence in Tropical Botany was presented to Fabián Michelangeli.

Michelangeli earned a Bachelor of Science in Biology in 1993 from the Universidad Central de Venezuela in Caracas and a Ph.D. in 2000 from Cornell University for research on *Tococa*, a genius of ant plants in Melastomataceae. Since 2004 he has been a curator in the Institute of Systematic Botany at the New York Botanical Garden (NYBG) where he continues his research on Melastomataceae. With about 177 genera and 5,800 species, Melastomataceae is one of the most easily recognized tropical plant families and the Smithsonian and NYBG have some of the world's best collections due to multiple generations of curator research on the family.

Michelangelo has authored or co-authored over 160 publications from book length monographs to large scale phylogenetic studies that have encompassed 70 new species and hundreds of new nomenclature changes. Most recently, he is co-editor with Renato Goldenberg (Universidade Federal do Parana) and Frank Almeda (California Academy of Sciences) of the forthcoming book titled *Systematics, Evolution, and Ecology of Melastomataceae*, which is due out in July and promises to be a definitive synopsis of worldwide melastome research.

Michelangeli has an active program and field work in Latin America, has advised or co-advised 25 graduate students and postdocs, mostly Latin American students working on melastomes, and has even starred in an IMAX documentary, *Lost Worlds: Life in the Balance*, about South American table-top mountains called tepuis.

Ken Wurdack presented the medal to Michelangeli at the 19th Smithsonian Botanical Symposium at the National Museum of Natural History in Washington, DC, on May 13, 2022.

Past recipients of the Cuatrecasas Medal are Rogers McVaugh from the University of North Carolina at Chapel Hill (2001); P. Barry Tomlinson from Harvard University (2002); John Beaman from the Royal Botanic Gardens, Kew (2003); David Mabberley from the University of Leiden, The Netherlands, and the Royal Botanic Gardens, Sydney (2004); Jerzy Rzedowski and Graciela Calderón de Rzedowski from Instituto de Ecología del Bajío, Michoacán, Mexico (2005); Sherwin Carlquist from Rancho Santa Ana Botanic Garden and Pomona College (2006); Mireya D. Correa A. from the University of Panama and Smithsonian Tropical Research Institute (2008); Norris H. Williams from the Florida Museum of Natural History and the University of Florida, Gainesville (2009); Beryl B. Simpson from the University of Texas at Austin (2010); Walter S. Judd from the University of Florida at Gainesville (2012); Ana Maria Giulietti Harley from the Universidade Estadual de Feira de Santana, Brazil (2013); H. Peter Linder from Zurich University (2014); Paulo Günter Windisch from Universidade Federal do Rio Grande do Sul, Brazil (2015); Kamal Bawa from the University of Massachusetts Boston (2016); Robin B. Foster from the Field Museum (2017); Alan K. Graham from the Missouri Botanical Garden (2018); Sandra Knapp from the Natural History Museum in London (2019); and Sebsebe Demissew from the Gullele Botanic Garden and Addis Ababa University, Ethiopia (2021).

Fabián Michelangeli accepts the 19th José Cuatrecasas Medal for Excellence in Tropical Botany during the 19th Smithsonian Botanical Symposium. (photo by Ken Wurdack)

Abstracts from the speakers of the 19th Smithsonian Botanical Symposium

The 19th Smithsonian Botanical Symposium, "Life on the Edge: Exceptional Plants in Exceptional Places," was held on 13 May 2022. The invited speakers specializing in conservation, ecology, systematics, and genetics explored plant survival in extreme parts of the natural world. Below are the abstracts from the papers that were presented by the invited speakers.

Susan Pell (far left), USBG Deputy Executive Director, and Eric Schuettpelz (far right), Chair of the Botany Department, join the speakers of the 2022 Smithsonian Botanical Symposium at the National Museum of Natural History (from left): Fabián Michelangeli, Ben Nyberg, Jenna Ekwealor, Tanisha Williams, and Jessica Allen. (photo by Ken Wurdack)

Jessica Allen
Eastern Washington University

"Urban Lichens: Symbioses in the built environment"

Densely populated urban areas are centers of exceptional human culture, wealth and political power. The biodiversity that occupies major cities alongside their human inhabitants, while typically not exceptional in their rarity, are exceptional in their adaptability and resilience. Of the biodiversity observed in cities, lichens are some of the most colorful and ubiquitous. These quintessential symbioses are the dominant and most diverse organisms in many of the harshest environments on the planet, yet they are incredibly sensitive to anthropogenic change. In this talk I will discuss how lichens have responded to urbanization in the Northeast Megalopolis over the past two centuries and will compare these patterns to those observed in select cities around the world. I will discuss the lichens of New York City, the heart of the Northeast Megalopolis, in depth, where a documented decline occurred throughout much of the 19th and 20th centuries. Since the 1970s there has been a notable rebound in the lichens of New York, and I will introduced you to some of the remarkably resilient city-dwelling species that have managed to grow, and even thrive, in one of the mostly densely urbanized regions on the planet.

Jenna Ekwealor
Smithsonian Institution

"The secret lives of desert moss"

Desert plants experience extreme fluctuations in light, temperature, and water availability. These intense conditions shape the development, life history, and evolutionary trajectory of desert mosses. In this talk, I will present on two such processes: vegetative growth and sexual reproduction. First, I discuss the discovery of Mojave Desert mosses occurring as hypoliths under milky quartz rocks. To characterize this unique moss microhabitat, we deployed microclimate dataloggers and collected samples in a Mojave site containing quartz hypoliths. The results of this study highlight the need to consider microhabitats, especially in extreme environments, where mosses may find refuge from the prevailing macroclimatic conditions. Second, I discuss how natural populations of many desert mosses appear highly female-biased based on the presence of reproductive structures. The dryland moss *Syntrichia caninervis* is notable for its low frequency of sex expression and strong female bias. Using molecular methods, we uncovered the genetic sex of non-expressing shoots and compared the patterns of phenotypic and genotypic sex ratios in Mojave populations. The findings shared in this talk contribute to our understanding of how the environment may modulate habitat filtering, vegetative growth, and sexual reproduction in *S. caninervis*, either through its direct influence on physiology or through selection.

Fabián A. Michelangeli
New York Botanical Garden

"Endemism and adaptations in the flora of the lost world"

The dramatic landscape of the "tepuis", the table-top mountains raising over the forest and savannas of the Guayana Shield, have fostered great interest in the biota of the region. In spite of that, our knowledge of the flora and its relation to other tropical biomes is far from complete. During this talk we will discuss our understanding of high levels of endemism at the species and generic levels of the tepui flora and the remarkable diversity of adaptations to the poor and acidic soils, and high levels of irradiation.

Ben Nyberg
National Tropical Botanical Garden

"A conservation airlift: applications of drone technology in plant conservation"

Cliff habitats are hard to study since their extreme topography can make access difficult and dangerous. New tools are changing that equation. Drones are now being applied to allow botanical survey of vertical surfaces. Over the past few years, this aerial technology has led to a number of important discoveries as well as compre-

Continued on page 8

Abstracts

Continued from page 7

hensive inventories of rare cliff species. A new project is underway to allow remote collection of plant material and assist with identification and conservation in these difficult environments.

Tanisha M. Williams
Bucknell University

"Protecting the Fynbos: climate change insights from South Africa"

The clock is ticking as we try to save the world's biodiversity from climate change. Projections have calculated that by the end of 2100 up to one and every six species will become extinct or will be at a breaking point setting its path towards extinction. Such drastic events will have significant impacts on biodiversity patterns and ecosystem functioning. Scientists are urgently working to understand historical and contemporary responses to increasingly stressful environments, conserve species and their habitats, and make meaningful projections. South Africa is home to several biodiversity hotspots and has the fifth highest number of plant species in the world. The Fynbos, a South African hotspot, has recently seen record breaking droughts and fires devastating this unique ecosystem. Collaborations between a global network of scientists, government offices, nonprofit organizations, and concerned community members are helping to document, monitor, and conserve species in the Fynbos. A multidisciplinary approach, using herbarium records, trait-based ecology, genomics and other methods, is being used to understand the mechanisms that influence species distributions and their responses to climate change. This talk will take you on a tour of how we are trying to save this threatened biodiversity hotspot.

Additional scenes from the 19th Smithsonian Botanical Symposium

Top: Susan Pell, USBG Deputy Executive Director, delivers opening remarks. Middle: Ken Wurdack presents the 19th José Cuatrecasas Medal for Excellence in Tropical Botany. Bottom: Eric Schuettpelz moderates the 19th Smithsonian Botanical Symposium. (top and bottom photos by Ken Wurdack; middle photo captured by Zoom).

Acknowledgments

The success of the Symposium was due to the significant time and efforts of the following people:

Organizing committee: Pedro Acevedo, Amy Bolton, Janelle Burke, Rose Gulledge, Gary Krupnick, Susan Pell, Paul Peterson, Eric Schuettpelz, Kenneth Wurdack, and Elizabeth Zimmer

Administrative support: MaryAnn Apicelli, Marisol Arciniega-Melendez, and Adriana Reynolds

Botanical data for all: The U.S. National Herbarium is digitized!

By Sylvia Orli and Julia Beros

The breadth of collections held at the U.S. National Herbarium (USNH) document the incredible biodiversity and botanical heritage on our planet and serve as the backbone of our work. In service to the public and as the foundation for research, these collections, as they exist now and grow, are at the core of our mission and purpose as an institution. Making these assets available, in physical and digital form, is a fundamental part of fulfilling our responsibility. The USNH is one of the world's largest and most diverse botanical collections, accounting for nearly 5 million specimens, the digitization of which fulfills our goal to make specimen data and images discoverable and accessible to all.

Since 2015, the Department of Botany and the Smithsonian Digitization Program Office (DPO) have embarked on a joint project to digitize all pressed and packeted plant specimens, which comprise the great majority of our collections. Collaborating with the contracted digitization company *Picturae*, based in the Netherlands, we have employed a conveyor belt system and a high-throughput approach to realize this ambition. This approach to digitization provides high resolution images and transcriptions of label data for each specimen. These assets are ported to our data catalog and subsequently aggregated with global collections data from other herbaria. By these means, the digitization of the USNH has a huge impact on botanical research throughout the world—collecting and codifying data that can unexpectedly inform the work of researchers near and far.

On May 13, the digitization conveyor scanned its last botanical specimen, the end of a 7-year run which digitized more than 3.8 million sheets, transcribed more than 2.8 million specimen labels, and added more than 80,000 new taxa to our collection catalog. We can now look in our herbarium cases and find a barcode on every sheet within every cubby, and inversely we can search a barcode or name (or any other possible line of data query) and look into our herbarium cases from our computer screens. This fantastic achievement can be credited to the hard work of staff and contractors throughout the Smithsonian, a collaboration that spans across units and job titles.

Ride the digitization conveyor belt like a Smithsonian herbarium sheet. A high-speed point-of-view video has been posted on Smithsonian's social media channels that shows a botanical specimen sheet being digitized. The sheet is removed from a herbarium cabinet, rides on a cart down a hallway, is placed on the conveyor belt by gloved hands, is photographed from above, and then returns to the herbarium cabinet. Using this conveyor belt system, the U.S. National Herbarium has digitized more than 3.8 million herbarium sheets. The video is available for viewing at https://twitter.com/smithsonian/status/1535257893888458753 and https://www.facebook.com/Smithsonian/videos/590438809005159.

The foundational steps in the conveyor process begin in the specimen cases where collections were curated to their proper taxa and each folder barcoded with a unique ID number. Between 3-4 cases of material were prepped and brought to the conveyor per day to keep the conveyor at full speed. The conveyor is a long rolling belt where a technician places specimens at one end, and as these specimens transit to the other end, they are imaged and the photos are simultaneously reviewed by another technician to ensure the systems are operating correctly. The bulky objects and fruits were cataloged individually by hand. As the project went through the herbarium, sheet by sheet, this gave the team the opportunity to perform repairs on specimens that were damaged.

Implementation of the conveyor belt at the NMNH required several updates to our infrastructure and file transfer protocols. High-throughput internet connections were installed that could transfer 3,000–4,000 high resolution images to an image server each day. These images were also ported to our Digital Asset Management System (DAMS) using a copy utility designed specifically for mass digitization projects. Images from the DAMS were then transferred to our data catalog. On the data side, a workflow utilizing several scripts and macros was created to import 30,000–40,000 data records to the data catalog at one time. Transfers of data occurred daily, weekly, and monthly; small batches amassed into larger batches that eventually made their way to the data catalog at a rate of 60,000 records per month.

At any part of the process of digitization there was opportunity for moments of discovery and inquiry (as in the case where unique photographs and illustration plates were happened upon, or personal letters attached to specimens, as well as intimate notes and drawings made by a collector) but none more so than in the depths of collection data that was reviewed day in and day out in shared access sheets. Those working on the project developed a keen eye to repeat collectors, their handwriting and habits of note taking, and even their relationships to places, subjects, and other researchers. Through each record there was a small story being told—an un-

Continued on page 10

Digitization

Continued from page 9

likely collector on crew with Captain Cook, or a moss plucked from a historic first voyage into uncharted waters, collections from Theodore Roosevelt's many hunting and collecting expeditions throughout east and central Africa, the prolific collections of Agnes Chase's grasses, the varied expeditions of J.N. Rose, the conglomeration of other botanical institution's collections, and so on. One could spend days immersed in collections from only Mexico or only Sweden and develop an aptitude for the geography and historic names of these places.

The remarkable change in workflow is best appreciated by looking at the past. Prior to the installation of the conveyor belt, our only available approach to large-scale digitization involved crowdsourcing. Botany uploaded 98 projects to the crowdsourcing venues in a two-year period (2014-2015) and 50,000 records were transcribed using this process, requiring countless hours of imaging, creating new projects and downloading the data. In its first two years of operation (2016-2017), the conveyor belt project yielded over 1.1 million records and images. Notably, cost and time savings with the conveyor have been significant, relative to traditional (one person/lightbox/camera) means. Although expensive upfront, the conveyor provided a 45% cost reduction and 80% processing time reduction over traditional means of digitization.

With this process, by 2020, we had completed the dicotyledons in our collections and most of the monocotyledons excluding the Poaceae. The pandemic put a hard stop to the imaging component of the project in March 2020, but within a few months it was given allowance to restart. Welcoming two contractors back into the dark and nearly empty halls of the Botany Department the project began imaging again and kept the data rolling, both making up for lost time and inspiring hope in our collective work. Between this time and March 2022, the team finished the Poaceae and most of the lichens and bryophytes, both of which were collections requiring special attention to their organization as they were still in the midst of curation projects. Given the skeletal team to prepare, move and scan the collection, coupled with new scheduling challenges and covid protocols, this timeline is quite astonishing. The last few weeks of the conveyor run were dedicated to retrieving the hidden specimens, tucked away in offices and back rooms, or loaned to other institutions, ensuring that every US botanical specimen was indeed digitized.

With the herbarium finished, our goal is to keep the herbarium at 100% digitized by imaging and cataloging every new specimen that comes to the herbarium. The Digitization Program Office (DPO) has helped Botany develop a plan to maintain its "fully digitized" status for the foreseeable future. The benefits and accomplishments of this project are already resonating with other research units and the museum is now implementing this digitizing technology to image the dragonfly collections of the Department of Entomology. The vision of the Botany Department is to make the herbarium collections accessible and visible to everyone who has an internet connection and to support research and general botanical curiosity. Moreover, there is an immense feeling of gratitude among all who touched the project. Not only does it fulfill part of our mission as a research institution, but it also fulfills our shared belief in the importance of openly accessible data both in the preservation of our natural history and in support of the growth and pursuit of knowledge and understanding.

Lost South American wildflower named "extinctus" rediscovered (but still endangered)

-Adapted from the Field Museum

Scientific names get chosen for lots of reasons— they can honor an important person, or hint at what an organism looks like or where it's from. For a tropical wildflower first described by Smithsonian Botanist **Laurence Skog** and his colleague Lars Kvist in 2000, the scientific name "*extinctus*" was a warning. The orange wildflower had been found 15 years earlier in an Ecuadorian forest that had since been largely destroyed; Skog and Kvist suspected that by the time they named the species, it was already extinct (*Syst. Bot. Monogr.* 59: 1-118; 2000; https://doi.org/10.2307/25027883). But in a new paper in *PhytoKeys* (https://doi.org/10.3897/phytokeys.194.79638), researchers report the first confirmed sightings of *Gasteranthus extinctus* in 40 years.

"*Extinctus* was given its striking name in light of the extensive deforestation in western Ecuador," says Dawson White, a postdoctoral researcher at Chicago's Field Museum and co-lead author of the paper. "But if you claim something's gone, then no one is really going to go out and look for it anymore. There are still a lot of important species that are still out there, even though overall, we're in this age of extinction."

The rediscovered plant is a small forest floor-dweller with flamboyant neon-orange flowers. While the pollinator for *G. extinctus* is unknown, other species in the genus are pollinated by insects and hummingbirds.

Gasteranthus extinctus is found in the foothills of the Andes mountains where the land flattens to a plane that was once covered in cloud forest. The region, called the Centinela Ridge, is notorious among biologists for being home to a unique set of plants that vanished when its forests

The bright orange flowers of the Ecuadorian cloud forest herb *Gasteranthus extinctus*. (photo by Riley Fortier)

were almost completely destroyed in the 1980s. The late biologist E.O. Wilson even named the phenomenon of organisms instantly going extinct when their small habitat is destroyed "Centinelan extinction."

The story of Centinela was also an alarm to draw attention to the fact that over 97% of the forests in the western half of Ecuador have been felled and converted to farmland. What remains is a fine mosaic of tiny islands of forest within a sea of bananas and a handful of other crops.

"Centinela is a mythical place for tropical botanists," says Nigel Pitman, a conservation ecologist at the Field Museum and co-lead author of the paper. "But because it was described by the top people in the field, no one really double-checked the science. No one went back to confirm that the forest was gone and those things were extinct."

But around the time that *Gasteranthus extinctus* was first described in 2000, scientists were already showing that some victims of Centinelan extinction weren't really extinct. Since 2009, a few scientists have mounted expeditions looking for *G. extinctus*, but they weren't successful. But when White and Pitman received funding from the Field Museum's Women's Board to visit the Centinela Ridge, the team had a chance to check for themselves.

Starting in the summer of 2021, they began combing through satellite images trying to identify primary rainforest that was still intact (which was difficult, White recalls, because most of the images of the region were obscured by clouds). They found a few contenders and assembled a team of ten botanists from six different institutions in Ecuador, the US, and France, including Juan Guevara, Thomas Couvreur, Nicolás Zapata, Xavier Cornejo, and Gonzalo Rivas. In November of 2021, they arrived at Centinela.

"It was my first time planning an expedition where we weren't sure we'd even enter a forest," says Pitman. "But as soon as we got on the ground we found remnants of intact cloud forest, and we spotted *G. extinctus* on the first day within the first couple hours of searching. We didn't have a photo to compare it to, we only had images of dried herbarium specimens, a line drawing, and a written description, but we were pretty sure that we'd found it based on its poky little hairs and showy "pot-bellied" flowers."

Pitman recalls mixed emotions upon the team finding the flower. "We were really excited, but really tentative in our excitement— we thought, 'Was it really that easy?'" he says. "We knew we needed to check with a specialist."

The researchers took photos and collected some fallen flowers, not wanting to harm the plants if they were the only ones remaining on Earth. They sent the photos to taxonomic expert **John Clark**, a former Smithsonian post-doctoral fellow and current research associate, who confirmed that, yes, the flowers were the not-so-extinct *G. extinctus*. Thankfully, the team found many more individuals as they visited other forest fragments, and they collected museum specimens to voucher the discovery and leaves for DNA analysis. The team was also able to validate some unidentified photos posted on the community science app iNaturalist as also being *G. extinctus*.

The plant will keep its name, says Pitman, because biology's code of nomenclature has very specific rules around renaming an organism, and *G. extinctus*'s resurrection doesn't make the cut.

While the flower remains highly endangered, the expedition found plenty of reasons for hope, the researchers say.

"We walked into Centinela thinking it was going to break our heart, and instead we ended up falling in love," says Pitman. "Finding *G. extinctus* was great, but what we're even more excited about is finding some spectacular forest in a place where scientists had feared everything was gone."

The team is now working with Ecuadorian conservationists to protect some of the remaining fragments where *G. extinctus* and the rest of the spectacular Centinelan flora lives on. "Rediscovering this flower shows that it's not too late to turn around even the worst-case biodiversity scenarios, and it shows that there's value in conserving even the smallest, most degraded areas," says White. "It's an important piece of evidence that it's not too late to be exploring and inventorying plants and animals in the heavily degraded forests of western Ecuador. New species are still being found, and we can still save many things that are on the brink of extinction."

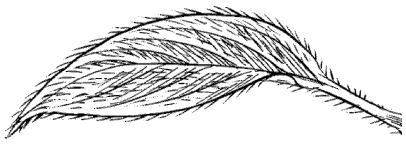
"Our Places" explores connections to nature

The National Museum of Natural History (NMNH) opened its latest exhibition, "Our Places: Connecting People & Nature," on July 1, 2022. "Our Places" explores how people form connections to the natural world through the places we live, work, study, and visit. Everyone is shaped by and are shaping their connections to the natural world. Through the exhibit and its accompanying programming, the museum hopes to inspire visitors to identify their special places in nature, reflect on their connections with them, and become more caring about them. Personal stories from Smithsonian scientists, including **Jun Wen** and **Gary Krupnick** from the Department of Botany, highlight how their connections with places inspire and enrich their own work.

"Our Places" is an experimental venue for exploring questions to help NMNH better understand museum visitors (how they conceptualize nature, connect with nature and others, and reflect upon these connections), and how different interpretive approaches engage museum visitors and enhance their experience. As such, "Our Places" will be successful if the museum learns something about its visitors and the interpretive approaches that can be used in developing future projects. Museum staff and interns populate the exhibit to interact with visitors, ask for their reactions to what they see, and encourage them to leave behind messages about their own special places. The exhibit intentionally has a "work in progress" look and feel because it will change over time in response to what is learned and as new stories are featured.

Where is your special place? The exhibit features an online StoryMap which invites participants to share your special places. You can explore and share stories of connection and inspiration from the comfort of your home, classroom, or cellphone at https://storymaps.arcgis.com/stories/8237f22e8e52462b83514f21c436928d.

The exhibition will be on view through July 2024.



Corpse flower creates a stench in the research greenhouse

Titan arum (*Amorphophallus titanium*) flowering in the Botany Research Greenhouses on the morning of July 7, 2022. (photo by Ken Wurdack)

A Titan arum (*Amorphophallus titanium*) flowered in the Botany Department Research Greenhouses on the afternoon of July 6, 2022, and lasted only 24 hours before the spathe began to shrivel. The flowering was unexpected as the corm was small – no bigger than a basketball – and produced a small inflorescence, only 82 cm tall (not including its stalk).

The Department of Botany has multiple Titan arum corms of varying sizes and had flowerings in 2003, 2005, 2006, 2007, 2013, and 2021, the last of which during the Covid-19 pandemic prematurely collapsed and never fully opened. Some of these flowerings have been put on public display at the U.S. Botanic Garden.

The floral scent of rotten meat can be detected far away and has evolved to entice carrion beetles and flies in Indonesia where the species is native. The inflorescence initially has a female phase when it first opens, followed by a male phase with the anthers releasing copious pollen. Eventually, the plant will then die back and enter a resting phase as an underground corm, after which it will send up a large umbrella-like leaf.

Wings of Life: Pollinator Week 2022

The week of 20-26 June 2022 was designated as Pollinator Week to mark a necessary step toward addressing the urgent issue of declining pollinator and plant populations. Pollinator Week events included plantings, seminars, and celebrations aimed at lifting up pollinators and the important conservation work being done on their behalf across the world. As a member of the North American Pollinator Protection Campaign (NAPPC), the National Museum of Natural History (NMNH) hosted a series of events to mark Pollinator Week.

On June 21, NMNH hosted a virtual discussion, "Reimagining Greenspace for Pollinators," featuring NMNH conservation biologist **Gary Krupnick**, Thorne Rankin and Sally Shea (DC Natives), and Sara Via (University of Maryland Extension). During the program, participants learned how to reimagine backyards and urban spaces as working pollinator gardens that support biodiversity. The webinar has been archived and is available for viewing at https://naturalhistory.si.edu/education/after-hours/webinar-reimagining-greenspace-pollinators.

On June 23, NMNH partnered with the U.S. Forest Service and the U.S. Department of Agriculture to host a Pollinator Celebration. During the morning event, museum visitors celebrated pollinators and learned about how we are all connected to pollinators and plants. The celebration included interactive activities and a concert with Latin Grammy Award-winning musician MISTER G. Several learning stations at the event, including one hosted by Gary Krupnick, had giveaways for the visitors, such as flyers, booklets, bookmarks, and posters. The event was held in Q?rius, The Coralyn W. Whitney Science Education Center of NMNH.

As in year's past, an educational pollinator poster was designed and distributed by the Pollinator Partnership and their partners (including federal agencies, nonprofits, and for-profits), to promote Pollinator Week. The 2022 poster, "Wings of Life: Pollinating Butterflies and Moths," is a celebration of fanciful, jewel-winged pollinators and the essential role they play in

pollination, culture, and ecosystem services throughout North America. Butterflies and moths are found in almost every terrestrial ecosystem from deserts to tropical rainforests, and thousands of flowering plants have evolved to rely specifically on their pollination services. The beautiful artwork was drawn by Natalya Zahn, a Vermont-based illustrator and designer deeply inspired by science and nature. Krupnick served as a scientific advisor in the development of the poster.

Posters are available to order on the Pollinator Partnership website <http://pollinator.org/posters.htm>. The website also has a downloadable PDF of the poster. Posters are for educational purposes only and are not intended for resale.

The Pollinator Partnership is the largest non-profit organization in the world dedicated to the protection and promotion of pollinators and their ecosystems. It manages NAPPC, a growing, collaborative body of more than 170 diverse partners, working to implement, promote, and support a clear, continent-wide coordinated action plan in the areas of pollinator research, education, awareness, conservation, and restoration. NMNH has been a partner of NAPPC since its inception in 1999, and Krupnick serves on the NAPPC Steering Committee as U.S. Vice Chair.

NEW FACES

Kasia Ahern (above left) has joined the Botany Department at the National Museum of Natural History (NMNH) on detail as a Collections Program Technician (CPT). She graduated from the George Washington University with a Master of Arts in Museum Studies, specializing in collections management. While in graduate school, she worked as a collections management intern for the Summer Institute in Museum Anthropology (SIMA) within the Department of Anthropology at NMNH. After graduating in 2015, she worked as a contractor in the Division of Fishes at NMNH. Her primary duties as a contractor were cataloging, rehousing, inventorying, and digitizing film and prints using flatbed scanners as well as importing the images and associated metadata into the musuem's electronic database system, EMu. She remained a contractor within the Divisions of Fishes and Amphibians & Reptiles until she became a CPT in 2019. While most of her time as a CPT has been spent cataloging and inventorying specimens in the Division of Birds, she briefly worked on rehousing the bryophyte collection within Botany. She began her detail in February 2022.

Savannah Mapes (above right), a graduate student in dinoflagellate research, visited the Botany Department on 21-23 June 2022, to work on Dr. Maria Faust's legacy material. Mapes is a fourth year PhD student at the Virginia Institute of Marine Science. She is studying the dynamics of harmful algal blooming (HAB) species in the lower Chesapeake Bay collecting data for the development of enhanced monitoring and mitigation strategies. She is also working on characterizing a local toxin-producing and bioluminescent HAB species, *Alexandrium monilatum*, describing its life cycle and using molecular techniques to investigate differences between strains. Mapes originally contacted **Rose Gulledge** for mentorship on a fellowship grant in December 2020. She then planned a visit to Botany and MSC to peruse Faust's research material and other work-related documents, reprints, and library. Once finally here (she had to wait 1.5 years due to Covid restrictions), she found a treasure trove of HAB and dinoflagellate material from identification guides, teaching notes (complete with sketches), posters, photographs, SEM images, slides, and field notes. Faust's taxonomic reviews, monographs and learning guides are essential reading for the HAB student; they are heavily used in the classroom as well as in the lab. Mapes' future plans include continuing her career in scientific research on phytoplankton and creating a summer program for early career marine biology students to learn about the importance of phytoplankton and the marine environment through hands-on, field- and lab-based learning experiences.

VISITORS

Michael Windham, Duke University; Fern cytogenetics workshop (3/8-3/10).

Nicolas Medina, University of Maryland; South American Scrophulariaceae and Gesneriaceae (3/23; 4/19; 5/5).

Andrew Henderson, New York Botanical Garden; Arecaceae (4/18-04/29).

Lawrence Zettler, Illinois College; Palauan Orchidaceae (4/29-5/1).

Craig Barrett, West Virginia University; *Microstegium vimineum* (Poaceae) (5/3).

Alexander Damián, University of Wisconsin–Madison; *Vanilla* (Orchidaceae) (5/23-5/28).

Nathália Susin Streher, University of Pittsburgh; Pollination ecology, Brassicaceae (5/23-5/28).

Bertrand Black, University of Vermont; Fern evolution and biogeography (5/24-5/25).

Manuela Dal Forno, Botanical Research Institute of Texas; Lichens (5/25-6/3).

Amanda Grusz, University of Minnesota Duluth; Ferns (5/31-6/15).

Francesco Riga, University of California, Davis; Poaceae (6/1-7/3).

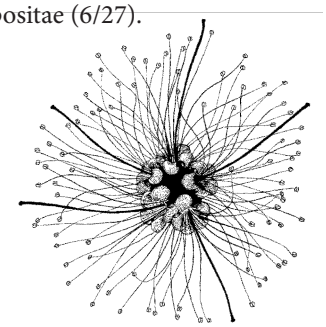
Cody Howard, University of Florida; Collections research (6/13-6/15).

Savannah Mapes, Virginia Institute of Marine Science; Toxic dinoflagellates (6/21-6/23).

Abigail Paradis, Savannah College of Art and Design; Botanical Art Collection archives and illustrations (6/21-8/12).

Daniel Koenemann, Howard University; Polygonaceae (6/23).

Susan Grose, Independent researcher; Compositae (6/27).



HONORS & AWARDS

Jun Wen is a recipient of the 2022 Research Grants Program of the Associate Director for Science and Chief Scientist (ADCS) at the National Museum of Natural History. A total of 16 highly competitive proposals representing the seven science departments at the museum were received and ranked by a peer review committee representative of NMNH science. Of the seven scientists to receive grants, Wen was awarded for her proposal, "Investigating the evolutionary history of temperate disjunctions across North America: a case study on grapes and hickories in the Mexican highlands."

Wen and Research Associate **Greg Stull** will investigate a geographic connection involving plant populations disjunct between the southeast United States and the highlands of Mexico and Central America. Many plant species include populations disjunct between these geographic regions, suggesting a dynamic history of migration across North and Central America during the past ~5 million years. Many of these understudied disjunct populations might also represent distinct species. Using two angiosperm groups (grapes and hickories) as a case study, Wen and Stull will reconstruct the history of plant migrations between these regions and search for cryptic diversity in the Mexican highlands, setting the stage for a broader study of this potentially fundamental biogeographic pattern.

***Carya ovata*, as seen in the John Fairey Garden, Texas. (photo by Jun Wen)**

TRAVEL

Stuart Davies traveled to Singapore and Malaysia (5/10 – 5/29) to conduct meetings with field teams and institutional partners of ForestGEO's Bukit Timah, Lambir, and Pasoh Forest Dynamics Plots, to provide training for upcoming censusing work and data curation, and to give the keynote address at the Forest Research Institute Malaysia's Pasoh Seminar; and to Wintergreen, Virginia (6/17) to meet with professors from Virginia Commonwealth University to discuss the possibility of adding a new plot to the ForestGEO network.

Jenna Ekwealor traveled to Knoxville, Tennessee (4/19 – 4/23) to present a seminar and an associated undergraduate course at the University of Tennessee.

Gabriel Johnson traveled to Woods Hole, Massachusetts (5/27 – 6/6) to attend a workshop on molecular evolution at the Marine Biological Laboratory.

Carol L. Kelloff traveled to Edinburgh, Scotland (6/3 – 6/12) to attend the Society for the Preservation of Natural History Collections (SPNHC) conference as the Archivist attending various committee meetings.

David Kenfack traveled to Zambia (6/24 – 7/4) to participate and present a talk at the 22nd AETFAT (Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale) Congress.

Eric Schuettpelz traveled to Arizona (5/14 – 5/19) to carry out fieldwork and collect fern specimens.

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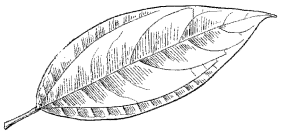
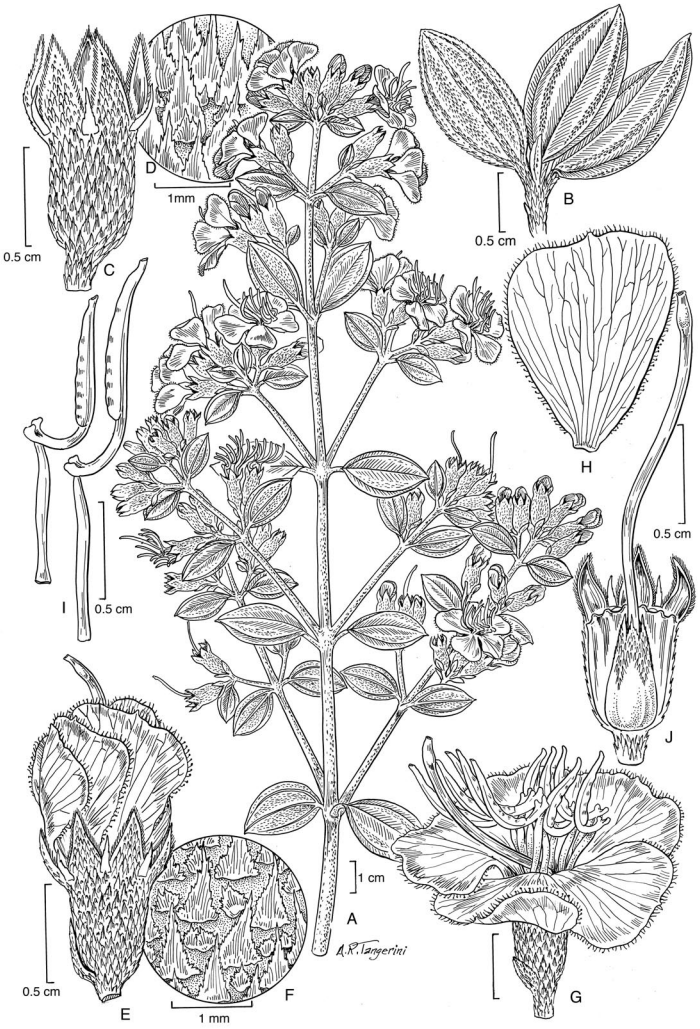


ART BY ALICE TANGERINI

Tibouchina fraterna N.E. Br.

Found on tepuis, the table form mountains of the Guayana Shield, *Tibouchina fraterna* (Melastomataceae) is an exceptional plant from an exceptional place—the theme of the 19th Smithsonian Botanical Symposium, which was held at the National Museum of Natural History on May 13, 2022. Native to Guyana and south Venezuela, *T. fraterna* has been found on Mount Auyán, Mount Duida, and Mount Roraima. *Tibouchina fraternal* was one of a series of melastome drawings Alice Tangerini drew for John Wurdack in 1987, published in the Flora of the Guianas treatment of the Melastomataceae. The narrow page format encouraged Tangerini to illustrate many of the floral characters overlapping parts of the habit with leaf surface details placed underneath the habit. This format style continued until software allowed for scanning and layout digitally. A remark by a reviewer on one of the melastome drawing copies was, "A beautiful illustration! It would be nice to have additional species illustrated like this".



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