

SCIENCE

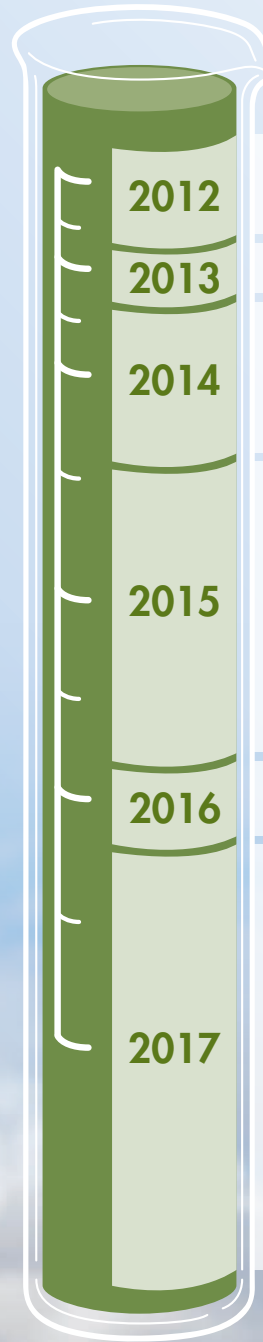
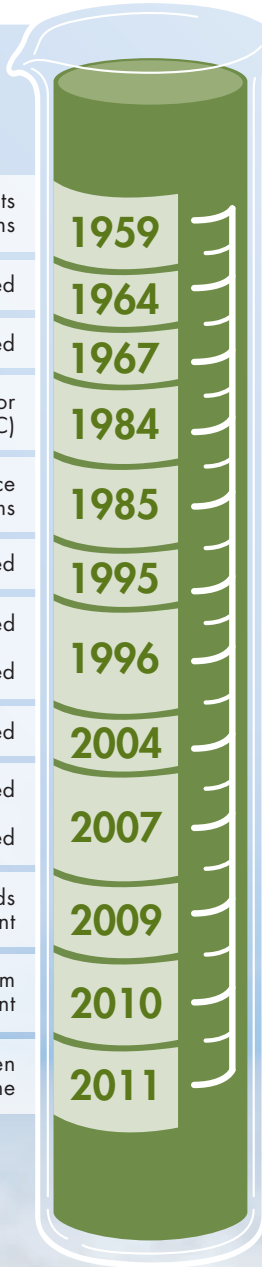
2017 YEAR IN REVIEW

Plants are fundamental to life, from the air that we breathe to the food that we eat. Science is the foundation of botanic gardens, from understanding how to grow plants in gardens to conserving biodiversity outside gardens. Thus, plant science serves as a key programmatic element at Denver Botanic Gardens.



Science at Denver Botanic Gardens

Kathryn Kalmbach Herbarium of Vascular Plants moved to Denver Botanic Gardens
Living Collection first accessioned
Sam Mitchel Herbarium of Fungi established
Founding member of the Center for Plant Conservation (CPC)
Accredited by the American Alliance of Museums
Monitoring of <i>Astragalus microcymbus</i> initiated
Department of Research & Conservation formed
Monitoring of <i>Penstemon harringtonii</i> initiated
Monitoring of <i>Eriogonum brandegeei</i> initiated
Adjunct Researcher program established
Monitoring of <i>Sclerocactus glaucus</i> initiated
Conservation Genetics Lab founded with funds from the Gladys Cheesman Evans Endowment
Tissue Culture program initiated with funds from the Gladys Cheesman Evans Endowment
Sam Mitchel Herbarium of Fungi specimen information available online



ON THE COVER

AV Infrastructure and Media Arts Project Manager Gavin Culbertson won first place in the American Institute of Biological Sciences' 2017 Faces of Biology Photo Contest for his picture of a master's student identifying plants

2012
Kathryn Kalmbach Herbarium of Vascular Plants specimen information available online

2013
Phenology Trail at York Street established

2014
Joined the Global Partnership for Plant Conservation

2014
Phenology Trail at Mount Goliath and Chatfield Farms established

2015
Launched graduate program through the Department of Integrative Biology at the University of Colorado Denver

2015
Denver Botanic Gardens' Collection of Arthropods established

2015
Joined the Global Genome Biodiversity Network (GGBN) and signed onto the Global Genome Initiative – Gardens program

2016
Joined the Ecological Restoration Alliance of Botanic Gardens

2016
Joined North American Mycoflora Project

2017
Celebrated the 50th Anniversary of the Sam Mitchel Herbarium of Fungi



Science at the Gardens

The mission of the Gardens' science program is to investigate and explain biodiversity patterns and processes. We conduct rigorous, scientific research; engage stakeholders across local and global communities to share our knowledge and expertise; and expand and maintain the Gardens' scientific capacity to contribute to our vision of a biodiverse world. Each project and partnership we pursue advances this mission.

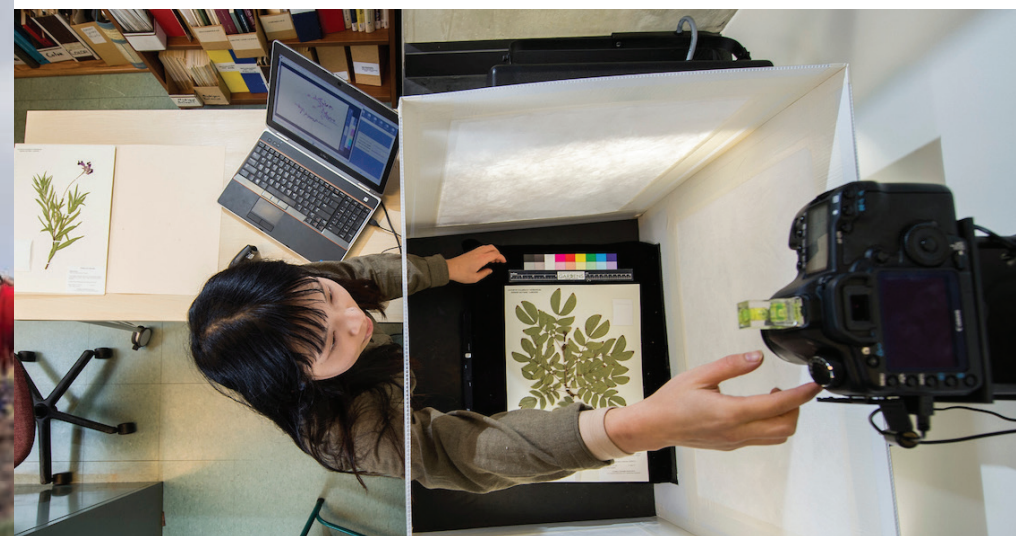
2017 saw expansions in programs and partnerships. New staff and graduate students contributed to increased documentation of vascular plants and fungi, initiated investigations on fungal evolution and taxonomy, delved deeper into tissue culture propagation techniques and enhanced our seed ecology and conservation program. New partnerships with the Global Genome Initiative – Gardens and Global Genome Biodiversity Network drove us to collect plant tissue samples expanding the list of species available to a global network of genomic researchers.

In recognition of our roots, we celebrated 50 years of fungi at the Gardens with a year-long appreciation of the importance of fungi in our ecosystems and the role the Sam Mitchel Herbarium of Fungi plays in the documentation and understanding of fungal diversity in the Southern Rocky Mountain Region.

As we prepare to break ground on the new Freyer – Newman Center for Science, Art and Education in 2018, we look forward to the next chapter of science at the Gardens.

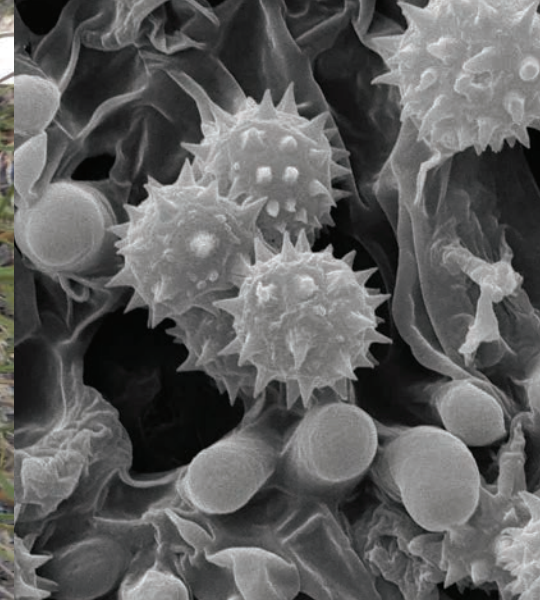
Gardens photographer Scott Dressel-Martin won third place in the American Institute of Biological Sciences' 2017 Faces of Biology Photo Contest for his picture of imaging herbarium specimens

Cleaning seeds to be deposited in a seed bank as part of our partnership with CPC





| Rescuing *Physaria bellii*



| Scanning electron microscopy (SEM) of *Laccaria* spores



| Collecting a tissue sample for the Global Genome Initiative – Gardens program



| *Juniperus horizontalis*

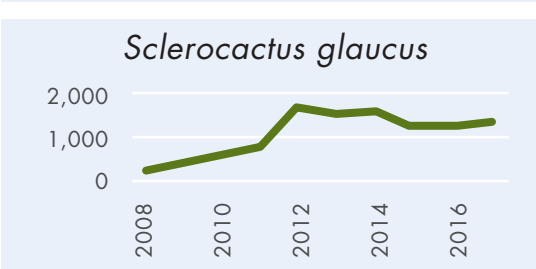
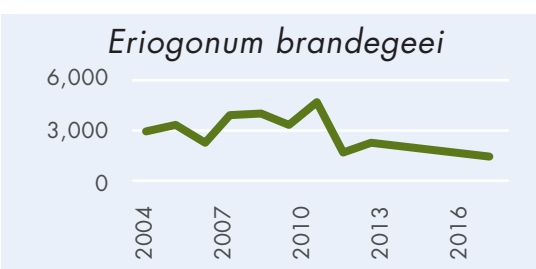
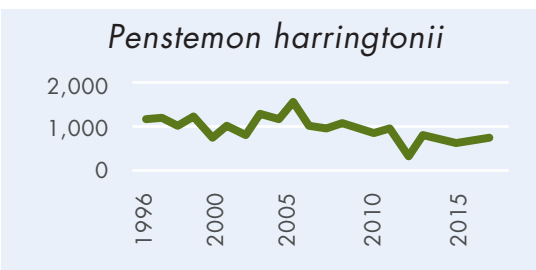
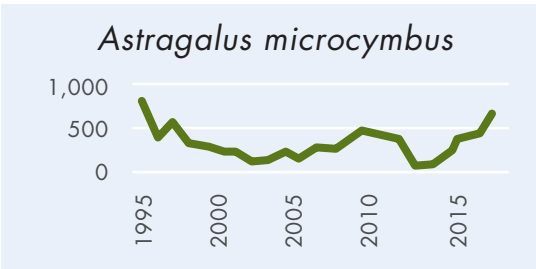
Scientific Highlights

Population Biology

For many rare species, we lack vital information about their life histories or **long-term responses to environmental variation**. To support their conservation, we provide critical data to land and natural resource managers on the status and biology of these rare species. Long-term demographic monitoring has long been a foundation of our conservation programs. We monitor demographic rates, herbivory, land use and plant responses to climate variables, which enables land and natural resource managers to best manage for the survival of these species. Currently we monitor *Astragalus microcymbus* (since 1995), *Penstemon harringtonii* (1996), *Eriogonum brandegeei* (2004) and *Sclerocactus glaucus* (2007).

Ex Situ Collections | Bell's Twinpod (*Physaria bellii*)

We utilize both *in situ* and *ex situ* methods to conserve the more than 500 rare plants in Colorado. One such species, Bell's twinpod (*Physaria bellii*), is restricted to shale and limestone soils of the Niobrara and Pierre formations in Boulder and Larimer counties. This species is primarily threatened by urbanization. Last fall, a Colorado Department of Transportation (CDOT) project in Boulder County planned to widen a road-cut inhabited by *Physaria bellii*. A CDOT employee reached out for help. **We rescued 45 plants**, which Gardens horticulturists transplanted to over-winter. Serendipitously, we already collected seed from nearby populations earlier in the summer. The seed along with the transplants will be used for future revegetation on adjacent properties.



| Number of individuals, totaled over all monitored populations, by year

Fungal Biodiversity

Exploring the depths of fungal diversity is a daunting task, but we are digging deeper to explore and expose the unique fungal flora of the Southern Rockies. Towards this goal, **we joined the North American Mycoflora Project** (mycoflora.org) as a regional leader and contributor. Broadly, this project seeks to collect, describe and document fungal diversity across North America using DNA sequence data tied to vouchered specimens. At the Gardens, three undergraduate students, from three universities, are contributing by sequencing DNA from representative samples of Colorado fungi and establishing the genetic identities of *Amanita pantherina* and *Laccaria nobilis*, which have questionable distributions and species determinations. These projects will bring us closer to understanding the fungi of the Southern Rockies.

We are expanding genetic resources through collections.

Global Genome Biodiversity Network

We are expanding genetic resources through collections. The Global Genome Initiative – Gardens program, supported by the Smithsonian, aims to make tissue samples of all living plant species available to researchers to preserve and understand the earth's genomic diversity. This year, the Gardens kick-started our collaboration with this program. **Every new herbarium specimen we collected was accompanied by a tissue sample**, which is available to researchers through the Global Genome Biodiversity Network. The network hosts an easy to search database of genomic material that researchers can request. The Gardens' own biorepository swelled this summer by about 2,000 new tissue samples as our field crews mobilized to collect samples across Colorado, from plants in the alpine tundra to the eastern plains and even from our own gardens.

Plant Exploration

For three decades, the Gardens has been involved in plant exploration. Globally and regionally we explore ecosystems similar to Colorado's to find plants with ornamental potential. **These plants are assessed for cultivation and introduction to Colorado as landscape plants based on their ecological needs.** In September, we travelled to Wyoming, Montana and Idaho to find **unique genotypes of creeping juniper (*Juniperus horizontalis*)**. During the trip, cuttings were made of plants with different physical traits among populations. These plants will be displayed in our gardens and will showcase the wide array of morphological diversity of this species. While on the trip, seeds of associated species were collected which will add authenticity to the display and enhance our native plant collections.



Ecological Stewardship

More than 2,000 plants from 85 native riparian species have been planted or are currently in propagation.



In 2014, Denver Botanic Gardens launched a project to restore the riparian ecosystem along the section of Deer Creek that flows through Chatfield Farms. Deer Creek, part of the Chatfield Basin that includes over 550 plant species and 70 mammalian species, is a degraded riparian habitat, the result of intensive land management since the 1800s. In 2016, three in-stream structures were installed to improve the flow and bank structure of the creek. With a combination of in-stream structures, busy beavers building dams downstream, weed management and planting native species, we are restoring this ecosystem.

As part of the restoration project we established **ecological monitoring plots**. Each year we survey 12 different areas along the creek to document and measure the type and abundance of understory and canopy plants, as well as the diversity of macroinvertebrates (like caddisflies and crayfish) inhabiting the waters. **Two years' worth of ground vegetation data are published online via the Global Biodiversity Information Facility (GBIF)**. Making these data globally available and free for use, alongside hundreds of millions of other biodiversity data points, increases the potential for our study to have a wider impact and to be incorporated into other ecological research. Every year, we will add data to GBIF, helping current and future scientists paint a bigger picture of how ecological restoration impacts biodiversity.

This year, we began a **soil seed bank study** to assess the feasibility of passive restoration at Chatfield Farms. A graduate student led the effort to collect soil cores across the site. Germinated seed are currently being



(TOP TO BOTTOM) Deer Creek; Ecological monitoring; Soil seed bank study

grown out for identification with the hope that the seed bank holds a good collection of native species compared to non-native species allowing for passive restoration.

We developed a **demonstration riparian garden** to highlight the diversity of native riparian plants in this region. We prepped the garden site in 2016 and conducted the first plantings for this garden in June 2017. Additional plants are growing in the greenhouse that will be planted in the next year. Overall, more than 2,000 plants from 85 native riparian species have been planted or are currently in propagation. Twenty-six of these species were also seeded in the garden.

To highlight the creek, riparian areas, native species, beaver activity and our restoration efforts, an **interpretive trail** for self-guided tours has been installed. We also conducted 17 tours with 163 people this year to engage local communities with this vibrant landscape and demonstrate how our work impacts these plant and animal communities. The footage from two trap cameras allows us to demonstrate the importance of riparian habitats to communities unable to visit the site.

Next year we will be using funds recently awarded from the Colorado Water Conservation Board to work with Jefferson County Open Space and Metropolitan State University of Denver to conduct a **feasibility study** to restore Deer Creek upstream of our property on the Hildebrand Ranch Open Space to extend our South Platte River Basin Restoration work.



(TOP TO BOTTOM) Sign along the interpretive trail; Volunteers at the demonstration garden; Heron caught on the trap camera



Natural History & Living Collections

These collections express humanity's connection to the natural world through documentation and research. The natural history collections capture species diversity and distribution; thereby holding precious evidence for how landscapes and populations change over time. As a museum, the Gardens' collections support scientists, horticulturists, artists, consultants, land managers and educators.

Living Collection

For the first time, **we successfully propagated, grew and displayed *Echium candicans* and *Echium wildpretii*** from the Canary Islands. These species have very specific growing conditions with their first year spent in the vegetative stage and flowering the second year. Through rigorous cultivation, we successfully produced numerous plants to display both indoors and on the grounds.

Enhanced access to our living collections through Botanic Gardens Conservation International's PlantSearch database has led to an increase in the use of our collections for research. In 2017, researchers from Uppsala University in Sweden spent a week **collecting floral scent from 12 *Penstemon* taxa in the Gardens.** Individual flowers of select species were bagged and hooked up to vacuum pumps to capture floral scent. They are hoping to gain insight into the role of floral scent and color in *Penstemon* speciation. The breadth and depth of our collections made Denver the ideal location for this project further demonstrating their value.



| The flowers of *Echium wildpretii*

Arthropod Collection

The arthropod collection documents the diversity of insects, spiders and myriapods that creep, crawl and fly around the Gardens. As an exceptional center of plant diversity, the Gardens may attract species not typically part of the eastern plains flora. We continue to document this unique diversity.



| Pinning insects for the Arthropod Collection |

Sam Mitchel Herbarium of Fungi

Fifty years ago, Dr. D.H. "Sam" Mitchel founded Denver Botanic Gardens' Herbarium of Fungi, which was renamed in his honor in 2009. A physician, Sam was fascinated with the mushrooms he found hiking with his kids, which sparked a lifelong passion to understand Colorado fungi. His passion spread to the community and pulled in volunteers who helped grow the collection. In celebration of the 50th anniversary, the Gardens' mycologists visited Sam's former ranch. **Of the many species documented, they collected, again, for only the second time in the state, *Tubaria confragosa*** replicating the first collection of this species by Sam in 1969. To cap off the year of celebration, we were joined by current and former volunteers, Gardens staff and Colorado Mycological Society members to rejoice in 50 years of preserving and documenting Colorado's fungal diversity and Sam's 100th birthday.



| Identifying a specimen in the herbarium

Kathryn Kalmbach Herbarium of Vascular Plants

For 200 years, botanists and plant enthusiasts have documented Colorado's flora with carefully collected and preserved herbarium specimens. The stunning prairies of Colorado's eastern plains remain woefully under collected. **With over a half million plant specimens representing Colorado's flora, only 5% are from the plains.** Many reasons attest to this deficit, but a simple one is that the plains experience long drought cycles making plant collecting unproductive most years. In 2017, Kiowa County was blessed with rains and subsequently ablaze with flowers. Our small expeditions were rewarded with a vibrant flora, which culminated in **nearly 50 county records** and many specimens representing only the second or third time a species was documented. We also intensely sampled a montane forest to document unusual species and plant communities, hiked to the peaks of mountains to sample alpine species and explored a fen near a rural, mountain library documenting species critical to supporting wildlife.



| Collecting in Gilpin County |



Engagement

Training the Next Generation

Our **graduate program** expanded in 2017 with the addition of two new students. These students are integrated into both the University of Colorado Denver and the Gardens and were primarily advised by Gardens staff. We also mentored other graduate students on their research projects and grant applications and supported **undergraduate internships** that contributed to Gardens' research and horticulture programs. All students are trained in a setting where scientific inquiry is used to address on-the-ground management problems and participated in outreach events to communicate science to visitors and the public.

SPNHC

For the first time, the annual meeting of the **Society for the Preservation of Natural History Collections** was held in Denver. We co-hosted the international conference with the Denver Museum of Nature and Science. The meeting was a flurry of animated discussions aimed at improving best practices for preserving, sharing and managing collections, which is essential to caring for the Gardens' Natural History Collections. Some participants wrapped up the conference by visiting several of Colorado's best places to connect with our natural world from Florissant Fossils Beds to Mount Goliath.

Scientific Communication

A tour can be a simple walk highlighting landmarks or explain a vision, current findings and future plans. In 2017, we gave 69 in-depth tours of the **Natural History Collections** and restoration efforts along **Deer Creek** to share our projects with our peers, students and the public. Tour attendees see our challenges and opportunities, visualize the scope of work and learn about the importance of our projects. To help meet public interest in the Natural History Collections, we established **regularly scheduled drop-in tours** for Gardens visitors.

| Master's student identifying specimens

Two seasonals, one undergraduate and one recent graduate, assisting in monitoring *Penstemon harringtonii*



Publications

Bramel, P., **S. Krishnan**, D. Horna, B. Lainoff, and C. Montagnon. 2017. Global conservation strategy for coffee genetic resources. CropTrust.Org and World Coffee Research.

Jabeen, S., M. Kiran, S. Ulluah, **A. W. Wilson**, G. M. Mueller, M. Fiaz, and A. N. Khalid. 2017. *Amanita glarea*, a new species in section *Vaginatae* from Pakistan. *Phytotaxa* 306 (2): 135-145.

Krishnan, S. 2017. Sustainable coffee production. Oxford Research Encyclopedia of Environmental Science. DOI: 10.1093/acrefore/9780199389414.013.224.

Koch, R. A., **A. W. Wilson**, O. Séné, T. W. Henkel, and M. C. Aime. 2017. Resolved phylogeny and biogeography of the root pathogen *Armillaria* and its gasteroid relative, *Guyanagaster*. *BMC Evolutionary Biology*: 17-33.

Riser II, J. P., A. L. Schwabe, and **J. R. Neale**. 2017. Novel microsatellite development and characterization for *Phacelia formosula* (Hydrophyllaceae). *Applications in Plant Sciences* 5 (7): 1700030.

Wilson, A. W., T. W. May, and G. M. Mueller. Biogeography of the Ectomycorrhizal Mushroom Genus *Laccaria*. *Biogeography of Mycorrhizal Symbiosis*, Ecological Studies 230. Ed. Leho Tedersoo. 273-297.

Wingate, J. L. 2017. *Sedges of Colorado*. Wingate Consulting.

Crane, B. S., J. M. Cruse-Sanders, J. Downing, J. L. Hamrick, K. Havens, A. Highland, S. Jacobi, T. N. Kaye, A. T. Kramer, E. V. Lonsdorf, A. Novy, **J. M. R. Neale**, P. Smouse, D. Tallamy, and A. White. 2017. When does local matter? A new tool to assess risks and benefits when selecting native plant materials for planting. 6th Global Botanic Gardens Congress. Geneva, Switzerland.

DePrenger-Levin, M. E., J. M. Neale, and **R. A. Hufft**. 2017. Conservation planning for Colorado's alpine plant communities based on herbarium records: Better predictions of plant response to a changing climate. Natural Areas Conference. Fort Collins, CO.

Hufft, R. 2017. Ecological Stewardship: Restoration at Denver Botanic Gardens Chatfield Farms. Invited presentation. Department of Integrative Biology, University of Colorado Denver. Denver, CO.

Hufft, R. A., M. E. DePrenger-Levin, R. A. Levy, and **M. Islam**. 2017. Using herbarium records to assess shifts in phenology in alpine plants and select indicator species for climate change. Botany. Fort Worth, TX.

Hufft, R. Ecological stewardship: Restoration at Denver Botanic Gardens Chatfield Farms. Invited presentation. Front Range Open Space Research Symposium. Boulder, CO.

Hufft, R. and **A. Seglias**. 2017. Ecological stewardship: Restoration at Denver Botanic Gardens Chatfield Farms. Natural Areas Conference. Fort Collins, CO.

Hufft, R. 2017. Chatfield riparian restoration. Invited presentation. University of Colorado Denver, Department of Integrative Biology. Denver, CO.

Krishnan, S. 2017. Botanic gardens and crop wild relatives – harnessing institutional and staff capabilities in developing specialized programs. 6th Global Botanic Gardens Congress. Geneva, Switzerland.

Krishnan, S. 2017. Global conservation strategy for coffee genetic resources. Invited presentation. Regis University, Department of Biology. Denver, CO.

Krishnan, S. 2017. The global conservation strategy for coffee genetic resources. American Society for Horticultural Science Conference. Waikoloa, HI.

Krishnan, S. 2017. What is the global coffee conservation strategy? Invited presentation. 2017 Re:Co Symposium. Seattle, WA.

Levy, R. 2017. An economical method for creating custom QR code labels. Society for the Preservation of Natural History Collections Annual Meeting. Denver, CO.

Neale, J. R. 2017. Applied Conservation at Denver Botanic Gardens. Invited presentation. University of Colorado, Colorado Springs, Conservation Biology Course, Spring Semester. Colorado Springs, CO.

Neale, J. R. 2017. Applied Conservation at Denver Botanic Gardens. Invited presentation. Colorado Native Plant Society, Denver Chapter. Denver, CO.

Neale, J. R. 2017. Denver Botanic Gardens: GGI-Gardens roundtable. Sixth Global Botanic Gardens Congress. Geneva, Switzerland.

Neale, J. R. and **M. E. DePrenger-Levin**. 2017. Rare plants and precipitation in Colorado. Invited presentation. National Center for Atmospheric Research Advanced Study Program. Boulder, CO.

Neale, J. R., M. E. DePrenger-Levin, R. A. Hufft, R. A. Levy, and **M. Islam**. 2017. Correlations between precipitation and phenology in Colorado's alpine with an eye towards predicting plant response to changing climates. Center for Plant Conservation Annual Meeting. San Diego, CA.

Seglias, A. E., E. Williams, and **A. T. Kramer**. 2017. Seed ecology of restoration-relevant forb species native to the Southwest United States: Phylogeny and climate influence inter- and intraspecific variation in germination. Native Seed Science, Technology and Conservation Initial Training Network Conference. Richmond, England.

Wilson, A. W. and **Mueller, G. M.** 2017. Exploring the South American origins of *Laccaria*. 9th Latin American Mycological Congress. Lima, Peru.

Wilson, A. W. 2017. Finding fungi with phylogenetics. Invited presentation. University of Colorado Denver, Department of Integrative Biology. Denver, CO.

Wilson, A. W. 2017. *Laccaria* in southeast Asia: taxonomic and systematic diversity from a biogeographically important region. Mycological Society of America. Athens, GA.

Wilson, A. W. 2017. The mysterious and magical movement of mushrooms on mountains. Invited presentation. Colorado Mycological Society. Denver, CO.

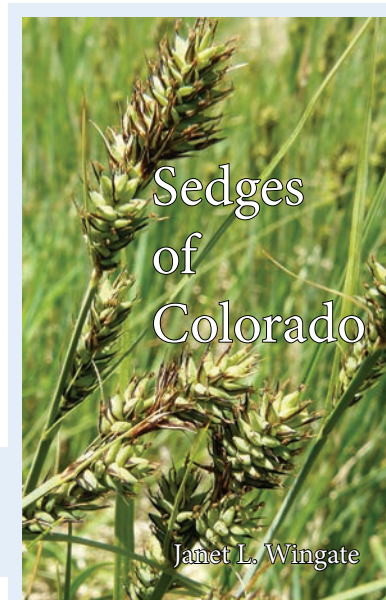
Wilson, A. W. 2017. The mysterious and magical movement of mushrooms on mountains. Invited presentation. San Francisco State University, Spring Fungi Course. Sierra Nevada Field Campus, CA.

Wilson, A. W. 2017. Using DNA sequence data to delimit fungal species. North American Mycological Association. Cable, WI.

Select Presentations

Alba, C. M. 2017. Science, partnerships and outreach at Denver Botanic Gardens. Invited presentation. Denver Zoo Advanced Inquiry Program. Denver, CO.

Bone, M. 2017. Plant Select® Celebrating 20 years. Colorado State University, Eleventh Biennial Short Course. Fort Collins, CO.





Breaking Ground in 2018

Courtesy of Davis Partnership Architects |

The fusion of science and art is the heart of Denver Botanic Gardens. In 2018, the Freyer – Newman Center will break ground and marks the final step in the Gardens' four-phase Master Development Plan. **The Center will house the new herbaria and laboratories** in addition to six classrooms, four galleries and an expanded library.

Thank You to Our Funders

Borgen Family Foundation
Center for Plant Conservation
Colorado Department of Agriculture
Denver Debutante Ball
The Garden Club of Denver

National Fish and Wildlife Foundation Five Star &
Urban Waters Program
Plant Select™
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We gratefully acknowledge the many other individuals who provide financial support for our work throughout the year as well as our dedicated volunteers who share their time and expertise. Science at Denver Botanic Gardens is also supported with distributed income from Denver Botanic Gardens Endowment Funds. Denver Botanic Gardens is supported by the Scientific & Cultural Facilities District funded by the tax payers of the Denver metro area.

To keep up-to-date with science at Denver Botanic Gardens, you can sign up for the quarterly Science e-newsletter by clicking "Subscribe" at the bottom of botanicgardens.org and selecting "Science."

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Photos taken by Scott Dressel-Martin and Gardens staff.

DENVER BOTANIC
GARDENS

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