Chicago Botanic Garden
Report on Research Activities
Searle Research Endowment Fund
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The Plant Science and Conservation Department had a remarkable year. From helping ComEd restore native prairie communities beneath Illinois utility corridors to understanding the impacts of climate change on rare plants in the western United States, Garden scientists and students are positively impacting plants and plant communities around the world. Their work in the past year was supported in part by more than 48 active research and training grants, including more than $4 million in new or pledged grants. Garden scientists taught classes at Northwestern University as part of the joint program in Plant Biology and Conservation and mentored undergraduates and high school students in the Science Career Continuum. Together Garden scientists and graduate students published 58 papers in scientific journals and 30 reports and bulletin articles—providing the scientific basis for large-scale land management and conservation practices. The Chicago Botanic Garden is deeply grateful for the support of the Searle Research Endowment Fund, which provides a firm foundation for sustaining and advancing this critical work.

Understanding and Mitigating Threats to Plants, Fungi and Native Habitats

Much of the Garden's research this year centered on climate change. A popular theory among scientists is that as the planet warms, plant populations will migrate north and to higher elevations in pursuit of cooler temperatures. Yet in their investigation of the dry gypsum habitat of the Arizona strip, just north of the Grand Canyon, Garden conservation scientists Patti Vitt, Ph.D., Kay Havens, Ph.D., and post-doctoral research associate Shannon Still, are finding a more bewildering pattern of ecologic drift.

With support from a three-year grant from the U.S. Department of the Interior Bureau of Land Management the scientists are using the Garden's GIS (Geographic Information System) Laboratory, to create species distribution models for more than 400 rare sensitive species, including cacti, penstemon, yellow-flowered desert poppy (*Arctomecon californica*) and nakedstem sunray (*Enceliopsis nudicaulis*). The models predict where these plants will migrate in 2020, 2050, and 2080. Many of the cacti Still studies, vulnerable to illegal harvest and threatened by regional development, face a grim outlook and could lose up to 95 to 100 percent of suitable habitat by 2080. "We're not seeing a consistent migration direction, and the majority of distributions are getting smaller," Still said.

In response to such dispiriting projections, the Garden is using *ex situ* conservation strategies, such as seed banking, to establish a repository of genetic material that can be studied and, ultimately, used for rehabilitation of public lands. In collaboration with the Bureau of Land Management and six U.S. botanic gardens, the Garden continued their participation in the national Seeds of Success (SOS) program, which has gathered more than 15,000 seed collections stored at the National Center for Genetic Resources Preservation in Fort Collins, Colorado. In fifteen to twenty years, this project aims to collect and preserve seed samples for the majority of plant species in the United States, particularly those used in restoration. The Garden's GIS modeling data is helping to guide collection efforts and develop seed transfer zones for

restoration and assisted migration programs. “As the climate changes, many plant communities are becoming degraded by wildfires, invasives, pests, and other threats,” said Havens. “Seeds provide the material to restore these degraded sites. The question is, if a particular plant can no longer survive, should we move them? That is called assisted migration.”

The worldwide loss of pollinators poses another serious threat to plants and native habitats. With honeybee deaths on the rise across the world—up to 40 or 50 percent of commercial U.S. bee hives have been lost to colony collapse disorder, according to the *New York Times* —expanding the knowledge of plant-pollinator interactions has never been more important. Krissa Skogen, Ph.D., a conservation scientist at the Garden, believes that floral scent, in addition to floral color and size, influences the pollination selection process critical to plants survival and genetic adaptation. Since 2008, Skogen has investigated the role of floral scent in the pollination of *Oenothera harringtonii*, an evening primrose endemic to the shortgrass prairie of southeastern Colorado. This past year, using a combination of field, greenhouse, and molecular tools, she and her colleagues assessed long-distance pollination events via hawkmoths, a busy, hummingbird-like insect which uses its antennae to detect floral scents such as green apple, coconut, and jasmine. “Floral scent is this fascinating black box of data that a lot of reproductive biologists haven’t yet collected,” Skogen said.

Long-distance pollination, because of its role in gene transfer, has widespread implications for how plants evolve and where they live. Because they are adept at moving pollen over long distances—up to 20 miles in a night, compared to bees that typically forage within one to five miles—hawkmoths may be important in maintaining species cohesion among *Oenotheras* plant communities. Through a three-year $864, 928 grant from the National Science Foundation, beginning January 14, 2014, Skogen, along with Garden conservation scientists Jeremie Fant and Norman Wickett and collaborators at Amherst College and Cornell University, will be involved in the world’s first study of scent-driven, geographic diversification in groups of interacting organisms. This project, titled "Dimensions: Collaborative Research: Scent-mediated diversification of flowers and moths across western North America," will be supported by the largest NSF grant in the Garden’s history. The research integrates three dimensions of biodiversity through studies of (1) *functional* trait variation and selective forces in the field and experimental arrays, (2) the *genetic* basis of the variation from the population to phylogenetic level using comparative genomics, and (3) patterns of *phylogenetic* diversity in *Onagreae* and *Mompha*. With this groundbreaking project, the Garden moves another step closer to having a positive impact on the future of the evening primrose.

Citizen Science

The field of citizen science, given its name in the 1990s by researchers at the Cornell Laboratory of Ornithology, empowers people from all walks of life to participate in the scientific process and help advance knowledge in a wide range of scientific disciplines. Thanks in part to the ease of collaborating with partners and reporting results via the Internet, such projects have proliferated at the Garden over the past decade, collecting tens of thousands of “crowd-sourced” observations and working at continental and even global scales. Following are a few outstanding achievements.

- In collaboration with the National Ecological Observatory Network (NEON), the Garden's Project BudBurst engages the public to collect important ecological data about the timing of leafing, flowering, and fruiting of plants (*plant phenophases*)—all of which are related to climate. Since 2007, this project has led to the collection of some 16,000 submitted observations for 250 target plants across a range of hardiness zones. The program, which has significant implications for determining seed set and pollination patterns, was recently featured in an article co-authored by Havens and Sandra Henderson for a 2013 edition of *American Scientist*.
- Safeguarding the legacy of one of North America's most endangered ecosystems, the Dixon National Tallgrass Seed Bank houses 2,510 accessions of 1,256 species. Contributions from land managers and independent seed collectors across the Midwest added 181 accessions of 145 species to the Dixon National Tallgrass Prairie Seed Bank in 2012. Portions of the seeds are reserved for use in restoration projects.
- The Plants of Concern (POC) program, now in its thirteenth year, engages citizen scientists in the monitoring of 237 endangered, threatened and rare species at 318 sites managed by 116 landowners throughout the Chicago Wilderness region, which includes Illinois, Wisconsin, and Indiana. Since its inception, POC has trained and engaged 733 citizen scientists, who have contributed 17,750 hours to monitoring imperiled plants.

Documenting and Understanding Diversity

Investigations of plant diversity have taken Garden scientists across the globe, from the lush tropics of Thailand to the grassland steppes of Mongolia. With support from several multi-year National Science Foundation (NSF) grants, this work is expanding knowledge on the diversity and evolutionary relationships of plants, fungi, and diatoms. Notable projects in 2012 focused on edible fungi, the origin and early evolution of flowers, the radiation of the first mosses, and genetic studies of two culturally important species of *Artocarpus,* breadfruit and jackfruit, native to Southeast Asia. Following are research highlights.

A team of paleobotanists from Chicago Botanic Garden, Yale University, and Niigata University, in Japan, joined colleagues in Mongolia for field work to search for early fossil flowers (angiosperms) and remains of other fossil plants. Mongolia has an abundance of fossil deposits that date to the early Cretaceous period, about 100 to 130 million years ago, when flowering plants first appear in the fossil record and then rapidly diversity. Although much work has been done in Mongolia searching for dinosaurs, very little paleobotanical field work and research has been undertaken. On their fourth and most recent trip since work began in 2011, Garden conservation scientist Pat Herendeen, Ph.D., and his colleagues explored natural bedrock exposures and dormant and active coal mines to gather clay, siltstone, and lignite samples for disaggregation and closer study using light microscopy.

The majority of plants found so far are gymnosperms, mostly members of the pine family and related conifers. These discoveries have yielded some answers as to how plants evolved over the past hundred million or so years—such as how major events like volcanic eruptions, disease, or climate

change may have impacted changes in their structure and in plant communities. Other sediment samples, revealing no seeds or pollen grains *in situ*, show no connection to any group of plants known today. An article the researchers submitted to the *American Journal of Botany* details a possible representative of stem pinaceae from *Schizolepidopsis canicularis*, an extinct group of conifer that belongs to the pine family.

Greg Mueller, Ph.D., Negaunee Foundation Vice President of Science at the Garden, continued his research on the vital role fungi play in ecosystems around the world. One of his interests this year was the chanterelle (*Cantharellus cibarius*), an edible mushroom with an estimated global commerce of $1.25 to 1.4 billion. Activities in 2012 focused on completing species study in a unique forest in Guyana. Until fairly recently, scientists assumed that chanterelles growing around the world belonged to a single species. Subtle differences in color and size were attributed to normal variations within a species. However, recent DNA analysis suggests the chanterelle genus contains myriad distinct species. This summer, Mueller and his research team found three different chanterelles growing in the Chicago area. The findings have important implications for understanding the threats to individual species and the ecosystems they inhabit.

The National Science Foundation's Assembling the Tree of Life project aims to construct a genealogical map for all 1.7 million living and extinct species on earth. As part of this endeavor, Norman Wickett, Ph.D., a conservation scientist at the Garden, and his collaborators Bernard Goffinet, Ph.D., at the University of Connecticut and Jon Shaw, Ph.D., at Duke University, received a three-year, $428,000 award from the National Science Foundation to investigate the genetic lineage of pleurocarpous mosses that date to the Cretaceous period, when flowering plants began to dominate land. Mosses play critical ecological roles throughout the world, and studying this "branch" of the tree of life is helping to build upon the current understanding of life's evolutionary history. "We're trying to use information from today to go back in time and look at what cellular mechanisms were important in determining what was critical for these plants to survive," Wickett explained.

Building Capacity

At a time when many university biology and botany departments are downsizing, training the next generation of plant scientists, conservation biologists, and environmental stewards remains a departmental priority. The continued success and rising reputation of the joint graduate programs with Northwestern University has led to a 37 percent increase in applications in the Ph.D. program for 2013 over 2012. This year, the program welcomed six new M.S. and two new Ph.D. students for a total of 11 Ph.D. and 24 M.S. students. In total, 43 percent of graduates from the master's program are currently working in plant biology and/or conservation fields, 40 percent are pursuing Ph.D. degrees, and 17 percent are working in other fields. Recent student fieldwork has taken place in the Chicago region, Wisconsin, Minnesota, the Great Basin, California, Guyana, and Mexico.

The Garden's science-learning programs target students in their formative years, when their educational interests and neurologic capacities are malleable. Chicago Public School students are uniquely served through the Garden's Science Career Continuum (SCC), which brings African American and Hispanic students to the Garden for engaging, hands-on science learning. The

Continuum welcomed 66 students for its summer sessions in 2012 and 65 in 2013. The program starts with Science First for Chicago public middle school students, continues with College First for high school students, and extends to undergraduate internship opportunities in conservation research. SCC students come primarily from low-income homes and are the first in their families to consider college. Eighty-nine percent of 2012 College First graduates have gone on to four-year colleges, with seven majoring in STEM—science, technology, engineering, or math—fields. Three 2013 graduates received full scholarships to prestigious universities, including Cornell University, Davidson College, Carleton College.

With a projected increase in the availability of science-related careers from 2010 to 2020, the need to provide a pipeline from the school setting to paid opportunities in the field has become a national priority. The Conservation and Land Management internship program is the Garden's broadest effort to recruit, train, and engage recent graduates in the fields of conservation biology, ecology, botany, wildlife biology, and natural resource management. In 2013, 700 applications were received for 92 internships. These internships provide college graduates stewardship opportunities on public lands across the western United States. Twenty-six interns that had been hired in 2012 were extended into 2013, bringing the total number of interns working in 2013 to 118. The majority of internships were with the Bureau of Land Management (103), followed by US Fish and Wildlife Service (4), US Geological Survey (4), National Park Service (3), and other organizations (3).

The Garden's expertise in plant science and conservation also has attracted the interest of private partners. The Corporate Roundtable on Sustainability, established in 2010, provides an informal, collaborative forum for companies seeking to broaden their environmental leadership and corporate social responsibility. This bridge to the private sector has helped forge new research partnerships with broad implications for energy conservation, land management, and restoration. In a pilot program now underway, the Garden is reviewing research design options and best practice models for converting ComEd utility right-of-ways threatened by invasive species into sustainable native prairie habitats. When research is finalized in 2016, the Garden, ComEd, and the Illinois Department of Natural Resources aim to implement the most effective approaches in ComEd's ongoing maintenance of 3,000 corridor right-of-way miles and 5,300 miles of power lines throughout northern Illinois. "We are hopeful the lessons learned from this collaboration can one day serve as a road map on how a groundbreaking public-private partnership can protect natural habitats beyond northern Illinois," Mueller said.

Using Plants and Fungi for Human Benefit

Chicagoland Grows is an innovative plant introduction program developed to promote the use of new plant cultivars that are well-adapted to the growing conditions of the Upper Midwest. A corporate partnership among the Chicago Botanic Garden; The Morton Arboretum; and the Ornamental Grower's Association of Northern Illinois (OGA), the program distributes selected hybrids from plant breeding programs to licensed growers at over 125 nurseries across North America and in Europe. Sales of the plants generate royalties that support the breeding and research efforts of the Garden and The Morton Arboretum to develop future introductions. This

year, three new plants were introduced: *Phlox* 'Forever Pink', which was developed at the Garden, *Acer saccharum* 'Morton' or Crescendo sugar maple from The Morton Arboretum's collections, and *Syringa pekinensis* 'Zhang Zhiming' or Beijing Gold Tree Lilac from the Beijing Botanic Garden in China. These new introductions have been promoted to the horticulture industry and gardening public through exhibition at three trade shows, bulletins, and numerous printed and electronic media promotions. Significantly, agreements have been signed with two plant introduction consortia in Europe which will legally protect and control the propagation and sales of the program's plants across the European Union. Legally protecting the program's plants in the United States, two patent applications have been filed with the U.S. plant patent and data is being collected for nine more applications. Royalty income for 2012 was $141,000, an increase of $11,000 over the previous year's income.

Conclusion

In its research, training, and practice, the Chicago Botanic Garden recognizes the growing need for leadership in plant science research and education. This year, Garden scientists helped predict future ecological shifts resulting from climate change and long-distance pollination, unearthed clues about the earliest conifers and mosses, and explored the genetic diversity of delicious chanterelles. Through the joint graduate program with Northwestern University, the Science Career Continuum, and the Conservation and Land Management program, scientists are sharing their knowledge with youth and adults to educate the next generation of plant scientists and environmental stewards. The Corporate Roundtable on Sustainability is extending this work to private partners and, thereby, increasing their commitment to environmental sustainability.

The Chicago Botanic Garden deeply appreciates the Searle Research Endowment Fund, which undergirds the Garden's vision of a conservation science program that continues to advance our understanding of how resilient plant communities develop and thrive, while building capacity for conserving and restoring them. Please accept our genuine gratitude.