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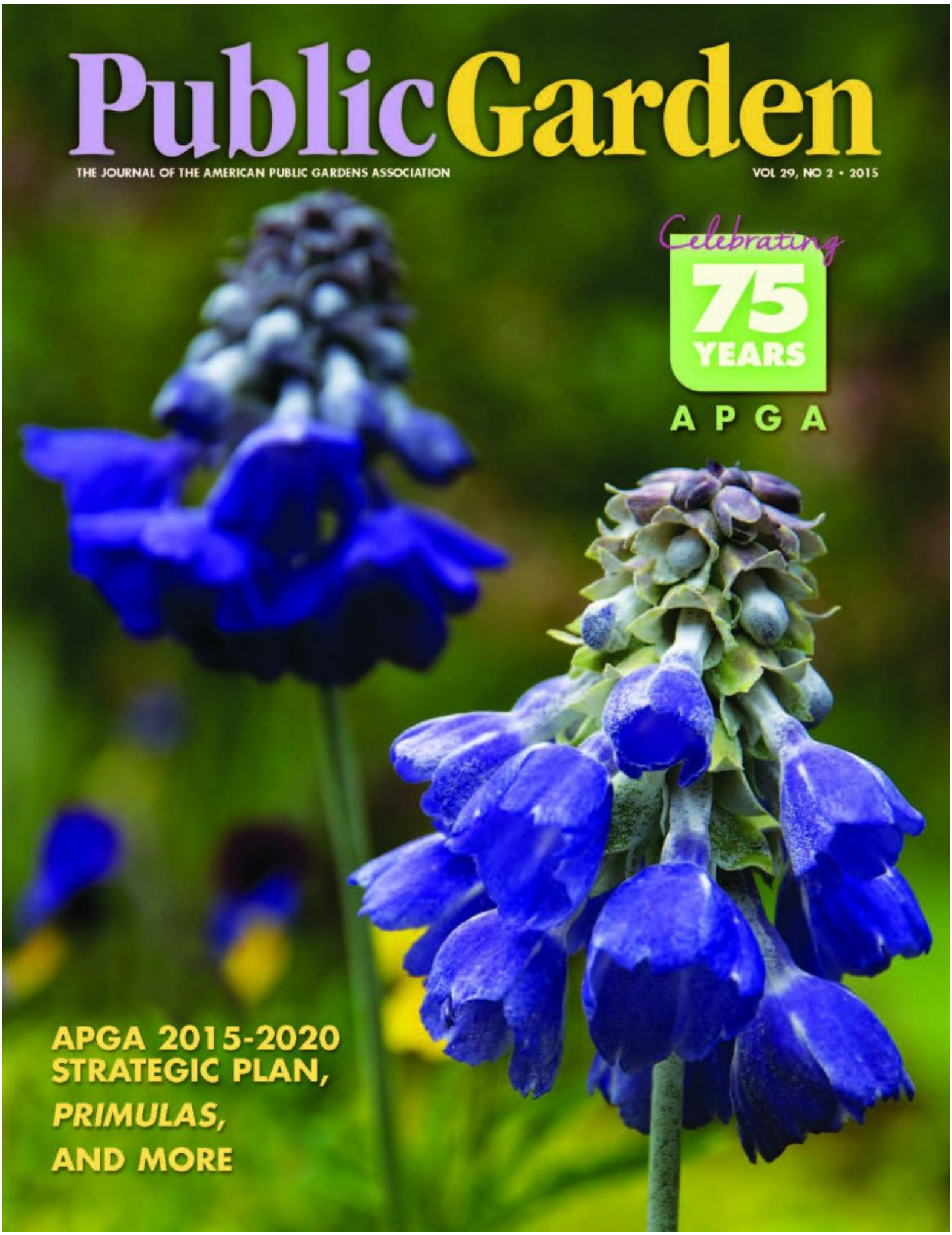


## APGA 2015-2020 STRATEGIC PLAN,

## *PRIMULAS*,

## AND MORE

# *The Race for* PLANT SURVIVAL

JANET MARINELLI

Trees are the largest, longest-lived, and most charismatic of plants. They also make life difficult for those trying to preserve them. But it's not impossible—every arboretum has a specialist who can make a difference. *(See story online.)*

PHOTO CREDIT: WIKIMEDIA COMMONS

A cage protects a native lady slipper orchid from deer at the small remnant of native pineland being restored at the Sister Mary Grace Burns Arboretum in New Jersey. *(See story online.)*

PHOTO CREDIT: MICHAEL GROSS

## *What do an Ice Age safari, test tube plants, and gene hunts have to do with your garden?*

Imagine we're in a Land Rover, cruising around south central Utah ten thousand to twenty thousand years ago, on the lookout for local wildlife. Bison and bighorn sheep graze among herds of mastodons and mammoths. Giant ground sloths the size of modern-day elephants stand on powerful hind legs looking for something to eat. Prehistoric camels weighing close to two tons are pursued by dire wolves and saber-toothed cats. Muskoxen keep an eye out for the giant short-faced bear, one of the Pleistocene epoch's most formidable predators.

What's wrong with this picture? Ice Age megafauna are certainly impressive, but we're chlorophyll addicts, and what we really want to see are plants. We hop out of the vehicle to admire a meadow full of bright yellow wildflowers about two feet tall.

Fast forward to the twenty-first century, and this plant has been named the autumn buttercup, *Ranunculus aestivalis*. A relict of the wetter Pleistocene, it is the showiest and most graceful buttercup in the West. The critically imperiled species now survives in one distinct habitat in the world, spring-fed meadows on the western slope of Utah's Sevier River outside the town of Panguich—a rare microhabitat in otherwise dry, open country. In this place where mastodons may once have roamed now stand fourteen motels, four restaurants, three fast food joints, five gas stations, three gas and convenience stores, a fabric shop, two grocery stores, two hardware stores, a hospital and clinic, real estate offices, two places to buy Indian crafts, and a Daughters of Utah Pioneers Museum all surrounded by a sea of ranches.

Once considered as dead as the mastodon, the autumn buttercup was

rediscovered in a pasture in 1982. Yet like so many species, it is threatened by the loss and degradation of its habitat. And, like so many plants at risk as climate change intensifies, it may not be able to adapt to the prolonged arid conditions to come. What follows is the story of the autumn buttercup, and how its fate, like that of countless other plants, is increasingly in the capable hands of horticulturists and scientists at public gardens.

## Horticulture to the Rescue

In hopes of saving the buttercup, in 1991 The Nature Conservancy purchased the pasture land, calling it the Sevier Valley Preserve. But six years later, the population had still plummeted from over four hundred plants to fewer than twenty. The species was put on the federal List of Endangered and Threatened species, and two public gardens, the Center for Conservation and Research of Endangered Wildlife (CREW) at the Cincinnati Zoo & Botanical Garden and The Arboretum at Flagstaff; the US Fish & Wildlife Service; and Weber State University teamed up with The Nature Conservancy to restore the buttercup in its native habitat.

A small number of seeds from the few remaining plants were collected and sent to CREW where state-of-the-art micro-propagation techniques were used to germinate them in test tubes. In the words of Valerie Pence, CREW's director of plant research and the maestro of micro-propagation, "Each seed produced a genetically unique clone that was multiplied by tissue culture—a technique in which the tissues are grown on an artificial sterile medium." The resulting shoot-producing cultures can be propagated indefinitely, she says, and when plants are needed, they're transferred to another medium and encouraged to form roots.

Once the tissues developed leaves and a simple root system, they were moved to The Arboretum at Flagstaff. There they were potted and grown in a greenhouse until each filled a six-inch pot. After hardening off in a lathe house, the buttercups were finally returned to the Sevier River valley in 2007, ready to take on the dry winds and heat of their ancestral home.

Reintroduction can be a nail-biter, and there is no easy ending to this story. So far, buttercups reared *in vitro* have been planted out three times, and continued reintroductions will be necessary until there is a self-sustaining population at the Sevier Valley site. A few years ago, another population was discovered on a nearby ranch, providing new seeds for additional *in vitro* lines and greater genetic diversity, giving the species more of a fighting chance.

*(Editor's note: Expanded coverage—including conservation efforts by gardens large and small, as well as governmental agencies here and abroad, and a basic conservation toolkit pdf for download—can be found at www.publicgardens.org/content/current-public-garden.)*

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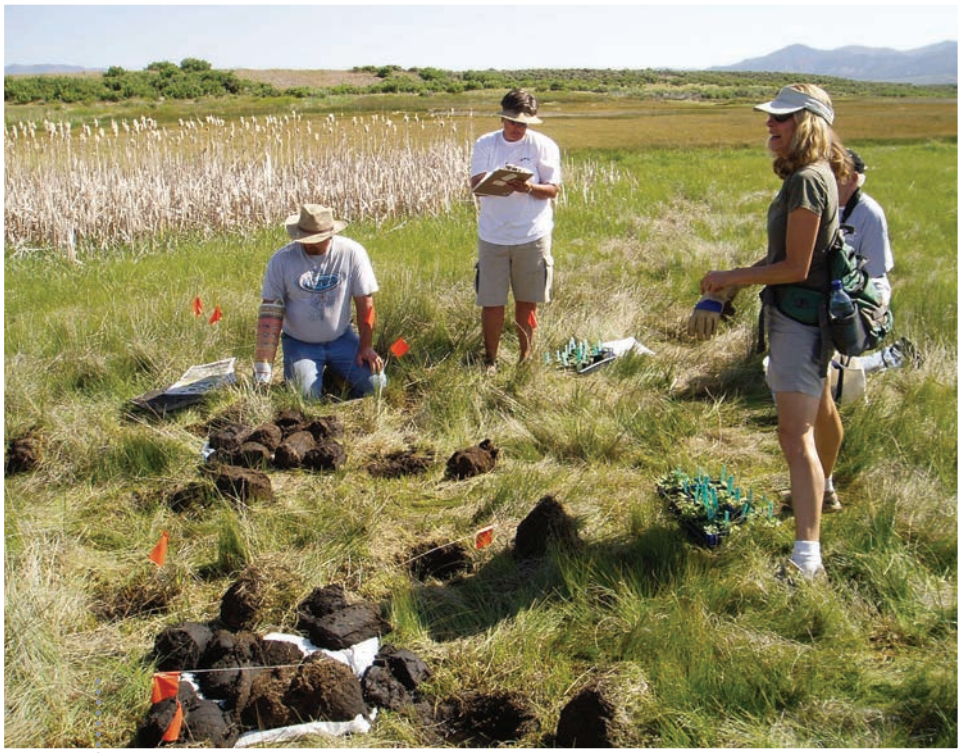

Autumn buttercups are ready to take on the heat and dry winds of their ancestral home along Utah's Sevier River.

PHOTO CREDIT: SHEILA MURRAY

A relict of the Pleistocene epoch, the autumn buttercup is one of a growing number of plants whose fate is in the capable hands of horticulturists and scientists at public gardens. A plant propagated *in vitro* is ready to be potted in soil.

PHOTO CREDIT: SHEILA MURRAY

*continued from the APGA website*

### *Technological Leaps*

The autumn buttercup is just one example of how the science of saving plants has progressed in leaps and bounds. It's also a textbook case of "integrated conservation," considered the gold standard of plant preservation, in which public gardens partner with government agencies and other groups to protect and restore threatened species in their habitats (*in situ*) and back up these natural populations in seed and tissue banks as well as living plant collections (*ex situ*).

Continuing propagation breakthroughs by Valerie Pence and Christina Walters, the micropropagation wizard at the federal seed bank in Fort Collins, Colorado, make sci-fi seem tame. Of particular conservation concern are the 20-25 percent of plant species called "exceptional," those producing seeds that are not easily preserved in seed banks because they can't survive drying and are killed in the freezer when ice crystals form. A small but increasing number of these species can now be safely stored with new cryogenic technologies—coaxed into a state of suspended animation at -321° F in liquid nitrogen. The feat that made this possible was figuring out how to surgically remove the growing portion of the seed (called the embryonic axis) and germinate it *in vitro*.

Unfortunately, no one knows how many plants are exceptional. Longwood graduate student Sara Heim Wallace is surveying public gardens to get a better idea of the number of threatened exceptional species in Canada and the United States. What's more, cryopreserving each species presents a unique challenge. To date, CREW has developed protocols for the *in vitro* propagation of several dozen rare species that can be stored in liquid nitrogen in its CryoBioBank along with rhino sperm and assorted gametes and embryos of other animals on the brink of oblivion.

In another technological leap, plant conservation has entered the era of molecular genetics. Just sixty-two years since James Watson and Francis Crick revolutionized science by describing the three-dimensional structure of DNA, it is possible to pinpoint a species' genetic diversity so it can be safeguarded in seed banks and in the wild. Not long ago, finding a single gene among vast stretches of DNA was a seemingly impossible task. But new and better molecular tools have made gene hunts faster, cheaper, and more practical. "Now," says John Clark, the new director of the Center for Plant Conservation, "instead of three or five genes, we can look at whole genomes." He hopes to put the new technology in the service of imperiled plants.

Beyond the technological bling, a number of new programs have been mobilized in support of plant survival. Among those in which public gardens play a leading role is the Global Strategy for Plant Conservation. Adopted by the parties to the Convention on Biological Diversity, it provides gardens with sixteen targets to shoot for by 2020, from ensuring that at least 15 percent of each of the world's ecological regions or vegetation types is effectively managed or restored (Target 4) to preserving 75 percent of plant species *ex situ* in living collections and seed banks (Target 8).

Plants like the autumn buttercup can only be reintroduced if appropriate habitat exists in the wild, and yet plant communities continue to be degraded, fragmented, and overrun by invasive species. The Ecological Restoration Alliance of Botanic Gardens, led by Botanic

Gardens Conservation International (BGCI), was launched in 2012 to encourage restoration at large and small gardens alike. The Sister Mary Grace Burns Arboretum at Georgian Court University, for example, is restoring a small remnant of New Jersey pinelands forest found on the campus. Invasive species are being removed and species found in surrounding similar habitat are being reintroduced. Fairchild Tropical Botanic Garden launched the Connect to Protect Network to help restore South Florida's pine rockland ecosystem, one of the most endangered in the world. The goal is to create corridors and stepping stone gardens to connect surviving isolated fragments to promote gene flow and improve the health of native pine rockland plants.

It's difficult to restore ecosystems when millions of their keystone plants are being killed by lethal pests and diseases. Organisms from the Emerald Ash Borer to Sudden Oak Death put not only threatened but once common species at risk. The American Public Gardens Association formed the Sentinel Plant Network to contribute to plant conservation by engaging public garden professionals, volunteers, and visitors in early detection and diagnosis and raising public awareness about the problem.

The thirty-nine leading public gardens under the Center for Plant Conservation umbrella have successfully safeguarded 788 of the country's most imperiled species in living collections and seed and tissue banks. As part of its Seeds of Success program, the federal Bureau of Land Management has partnered with six botanic gardens, zoos, and municipalities in support of its mission to "collect, conserve and develop native plant materials for rehabilitating and restoring lands in the U.S." A portion of each collection goes into long-term storage and the rest is used as needed for research and grown to provide seeds for restoration efforts. As for living collections, the North American Plant Collections Consortium was established by APGA to coordinate a continent-wide approach to preserve plant germplasm and promote high standards of plant collections management.

Genetically diverse living collections at public gardens, seed banks, and cryopreserved germplasm have the power to prevent plant extinction, but much work remains. In a report on how close the botanical community is to achieving the Global Strategy for Plant Conservation's target of having 75 percent of threatened plant species in *ex situ* collections by 2020, BGCI found that only 9 percent of threatened US plants were safeguarded in collections, mostly seed banks, that capture the species' genetic diversity. The conservation value of the 17 percent growing in living plant collections is sketchy at best: 41 percent of these are known only from one living collection. What's more, according to BGCI, "while some living collections are wild-collected and curated in sufficient numbers to support high genetic diversity, this is not likely the case for many living plant collections."

### *The Ultimate Game-changer*

As if conservationists didn't already have their hands full, they are finding that climate change is complicating matters even more. In its 2006 *Declaration on Climate Change and Plant Conservation*, the Gran Canaria Group, comprised of botanic gardens and other conservation groups around the world, calculated that, during the course of the twenty-first century, climate change may doom as many as half of the estimated four hundred thousand plant species in existence today.

During past climate upheavals, most plants were able to keep pace with the changing conditions. As glaciers waxed during the Pleistocene, for example, most plants of the eastern

forests survived by migrating to so-called refugia in the South. But studies suggest that the migration of species back then was an order of magnitude slower than those required for the current rate of climate change. Without human help, countless species may not be able to migrate fast enough, and others will be stopped dead in their tracks by housing subdivisions, shopping malls, and sprawling industrial complexes.

In the topsy-turvy world to come, plants and the animals that depend on them, all migrating at their own rate, will find themselves with implausible companions in novel ecosystems. In a hundred years, for example, California's Central Valley could become the preferred habitat for many cacti and succulents now found in Arizona—if they can manage to get there. Along the coast, California's iconic redwoods could still be hanging on because adult trees are so long-lived, but the climate will have become so dry and inhospitable to young trees that the adults will be a forest of the living dead, unable to reproduce.

Until recently, conservationists were pursuing a strategy devised before the implications of climate change became apparent. They established a network of preserves and other protected areas. They did what they could to halt the spread of invasive, nonnative species that are making these habitats less hospitable for native plants and animals. They brought rare plants like the autumn buttercup into cultivation and bolstered remaining populations by returning propagated plants to their native range in the wild.

This strategy was based on a view of nature in which plant communities are perceived as unchanging and what constitutes "native" is considered absolute and enduring. However, conservationists are now scrambling to plan for future conditions, despite the fact that they don't fully understand how plants will behave when forced into areas where they currently do not exist, under conditions that are not yet precisely known. New conservation approaches are required to move us from the world we have known to one we have never seen.

A few short years ago most scientists considered one approach, assisted migration, all but inconceivable. While current conservation protocols include reintroducing a plant to its current or historic range, assisted migration is reintroduction on steroids, in which a species is moved to a new environment, potentially far from where it is right now, to keep pace with climate change. Critics howl that intentionally moving species to a new environment risks transforming struggling organisms into destructive invaders, or inadvertently spreading disease. With this in mind, scientists at Missouri Botanical Garden have floated a proposal for a heavily chaperoned form of assisted migration—using a network of public gardens to supervise and keep an eye on relocated plants. As Peter Raven, the Garden's director emeritus, has written, the science and practice of plant conservation "will need to be refined and developed greatly if we are to make sound decisions in these areas over the decades to come."

Public gardens are increasingly seen as bridges to this uncertain future. One thing is clear—many plants will have no future unless botanical gardens and arboreta play a key role in safekeeping them in seed and tissue banks and cultivating them in living collections. "I do believe that every public garden has an important role to play in plant conservation," says Casey Sclar, executive director of APGA. Even if it is not defined in their mission, he says, gardens can employ education and displays to reduce plant blindness and help the public appreciate the beauty and the plight of plants. Living collections "offer a real-time look at how plants are adapting to climate change," he adds. "And God forbid a species should go extinct in the wild, we have a back-up with live plants growing at public gardens under the watchful eyes of professionals."

## Plant Conservation by the Numbers

- Percent of global plants requiring conservation action: 33%
- Percentage of US plants requiring conservation action: 33%
- Number of US native plants: 17,000
- Number of US species now extinct or extinct in the wild: 217
- Number in the Center for Plant Conservation's National Collection of Endangered Plants: 788
- Percentage in germplasm collections, mostly seed banks, with high genetic diversity: 9%*
- Percentage known only from living plant collections: 17%*
- Percentage in living plant collections known from only from one collection: 41%*
- Percentage of species on the federal Endangered Species List that are plants: 57%
- Percentage of federal endangered species expenditures received by plants: 3.86%
- Number of plant species recovered and removed from the Endangered Species List: 5
- Percentage of advanced degree programs in botany lost since 1988 at the highest-funded US universities: 50%
- Number of nonnative species that have escaped into the wild, many of them weedy or invasive: 4,000
- Amount spent by the US every year to control invasive plants: $25 billion

**According to collections data uploaded to Botanic Garden Conservation International's PlantSearch database as of November 19, 2013*

## Pushing Boundaries at the Center for Plant Conservation

For more than thirty years the Center for Plant Conservation (CPC) has been at the forefront of efforts to save America's most imperiled plants from being lost forever. At the heart of this network of thirty-nine member gardens is the National Collection of Endangered Plants, a genetically diverse sample of seeds, tissues and cultivated specimens for 788 of the rarest US native species stored at CPC's member gardens and at the US Department of Agriculture's National Center for Genetic Resources Preservation seed bank in Fort Collins, Colorado. "Nothing like this exists anywhere else," says John Clark, the CPC's new executive director.

Clark points out that the scientists under the CPC umbrella include many of the leaders of plant conservation research, pioneering cutting-edge propagation techniques and

employing advanced genetic tools, as well as studying the horticulture and ecology of these rarest of the rare of this country's native flora. They are involved in on-the-ground fieldwork and data collection. They have also been key to the advancement of the young science of reintroduction, using plants propagated from the National Collection to bolster declining wild populations.

John Clark joins the CPC at a time when the science and practice of plant conservation need to make giant strides to keep pace with the changing reality for plants on the ground. The CPC that emerges from this tumultuous period, he says, "will be remarkably different than the CPC of the past."

Although 788 imperiled plants have been safeguarded in *ex situ* collections, that is a small fraction of the more than five thousand species considered at risk. Clark hopes to build on the National Collection, incorporating more threatened plants. He also aims to "broaden the concept of participating institutions." Even private, for profit companies could contribute, Clark says, such as Christmas tree farms raising the imperiled Fraser fir, or landscape architects restoring urban wastelands. In fact, Clark believes it is worth exploring the reintroduction of plants beyond wilderness areas, the current practice. "Pristine wilderness is just an idea at this point. It doesn't really exist anymore."

One of the most important responses to the challenge of climate change, he says, will involve using new molecular technologies to more precisely identify the genetic diversity of species that are banked and reintroduced to the wild to increase the chances that they can adapt to changing conditions. He advocates going even further, not just preserving but manipulating genetic diversity when necessary. As an example, he points to the American chestnut, which was virtually wiped out by an introduced fungal pathogen. A century ago one out of every four hardwood trees in the eastern forests was an American chestnut, and in spring the species' white blossoms seemed to blanket the hills with snow. Genes from the Asian chestnut and other plants inserted into the American chestnut have created transgenic trees that are close to identical to wild American chestnuts yet immune to the blight. "If we can restore the American chestnut to the eastern forests using a Chinese chestnut gene," says Clark, "I'm all for it."

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**The Tree Conservation Challenge**

Trees may be the largest, longest-lived and most charismatic of plants, but they sure make life difficult for those struggling to protect them from extinction. Globally, over eight thousand tree species are at risk, according to the Global Trees Campaign, and eleven hundred species are considered critically endangered.

Trees pose obvious conservation challenges. Little is known about their basic biology, which species are threatened, or what level of genetic diversity needs to be preserved for different tree groups. Because trees take up a lot of space when mature, it's difficult to safeguard their genetic diversity in plant collections. They don't reach reproductive maturity for

decades, so it can take a long time to see that a species is having trouble producing seedlings in the wild. This also means that trees are less likely than any other type of organism to keep pace with climate change, as was illustrated in a little-noticed chart in the 2014 report of the Intergovernmental Panel on Climate Change. To make matters even worse, compared to other plant groups, trees have a high number of "exceptional" species that are not easily seed banked.

Consider oaks, which have achieved their highest diversity here in North America. A few years ago, when the Global Trees Specialist Group, a worldwide network of experts working to conserve threatened trees, attempted to assess the conservation status of all known species, they found that there was enough data to fully evaluate only 175 of the five hundred oak taxa; of these, fifty-six, or 32 percent, were found to be at risk of extinction. When Botanic Gardens Conservation International used its PlantSearch database to survey public garden collections (see "A Basic Conservation Toolkit"), they found that twenty-six, or fewer than half of the imperiled species were in living collections; the provenance of 82 percent of these was either unknown or of horticultural origin and, therefore, of little use for conservation; and many of the twenty-six species were found only at one institution, sometimes as a single plant or only a few.

Like many trees, oaks, even common species, are increasingly at risk from pathogens like Sudden Oak Death. Conserving oaks as mature specimens is complicated by the fact that they readily hybridize. What's more, even high-tech conservation tools such as *in vitro* propagation are exceptionally challenging because their tissues contain tannins. In a 2012 paper, Andrea Kramer, then executive director of BGCI, and Valerie Pence, director of plant research at the Center for Conservation and Research of Endangered Wildlife at the Cincinnati Zoo & Botanical Garden, describe a recent project in which micropropagation was successful for three of four imperiled US oak species tested. However, they point out that for other oaks and other exceptional species, procedures for converting embryos to plantlets *in vitro*, rooting *in vitro*-propagated shoots and acclimating the plants to soil will need to be developed.

To tackle the challenges that lie ahead, the Morton Arboretum recently formed the Center for Tree Science to build collaborations for research on basic tree biology, urban tree care, and conservation of rare tree species. Morton also established ArbNet, a community for tree-focused public gardens, to facilitate the sharing of resources and knowledge and improve professional practices through an accreditation program. "We are faced with huge biodiversity challenges," says Nicole Cavender, Morton's vice president for science and conservation. "Arboreta are in the business of planting and caring for trees. We know how to conserve them through cultivation, and we can certainly make a difference."

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**A Basic Conservation Toolkit**

You don't have to be a mega garden to contribute to plant conservation. Following are five resources that a garden of any size can use to get involved.

• As a first step, upload the current list of the taxa in your collections to Botanic Gardens Conservation International's PlantSearch database. This will expand the collective knowledge of plant diversity in cultivation, and PlantSearch will identify any threatened species in your collection. See http://www.bgci.org/worldwide/1933/.

• Because it can be difficult to know where to start and how to maximize conservation potential while minimizing costs, Montgomery Botanical Center has produced a handy four-page guide, *Building Living Plant Collections to Support Conservation*. It recommends identifying a single imperiled species with the greatest need where your efforts can make a big difference—a long-lived "exceptional species," for example, because living collections may be the last line of defense against extinction for such species that cannot be seed banked. It also offers guidance on how to create and curate the collection for maximum genetic diversity and conservation value. See http://www.montgomerybotanical.org/media/Plant.Conservation.Collection.Guide.pdf.

• APGA's Sentinel Plant Network provides training so public garden professionals can better monitor their collections while contributing to the detection and diagnosis of serious pests and pathogens. If you're not already a member, see http://www.publicgardens.org/content/sentinel-plant-network.

• Care for the Rare provides free interpretation templates that any garden can use to tell the stories of the threatened plants in its collections. The Care for the Rare sign library currently includes forty species at risk, from the Venus fly trap and the golden barrel cactus to the Canary Islands dragon tree. See http://www.bgci.org/usa/carefortherare.

• Climate change is one of the most critical threats to species and ecosystems. APGA's Climate Change & Sustainability Program supports member garden actions as civic and conservation leaders on climate impact reduction measures. For more information contact Program Manager, Sarah Beck, at sbeck@publicgardens.org.

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