Chicago Botanic Garden
Negaunee Foundation Fund for Invasive Species
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The Chicago Botanic Garden is pleased to report on the Negaunee Foundation Fund for Research on Invasive Species. Never before has the need for coordinated invasive species research and land management efforts been more pressing—or more widely recognized as vital to environmental, economic, and human interest. As recently reported in the *New York Times,* invasive species are responsible for a $33 billion annual loss in U.S. crop production due to complex traits such as dormancy, mimicry, and genetic mutations that make them resistant to herbicides. Left unmanaged, invasive species wreak havoc on native plant and animal communities and bear significant safety and health risks. All told, more than 3,300 nonnative plant species occur in self-sustaining populations in natural areas in the U.S. today: sixteen invasive plant species alone infest an estimated 125 million acres.

As an international leader in applied science research and education, the Garden is pioneering research and cost-effective land management strategies to address these urgent concerns. In partnership with public and private land managers, trained volunteers, and federal agencies such as the Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. Department of Agriculture, the Garden's scientists are helping support ecological services that fight the spread of invasives, while restoring the biodiversity of prairie, wetland, and gravel hill plant communities. Cohesive programs of habitat monitoring and species identification, carried out by trained botanists and citizen scientists, are offering early identification of aggressive invasive species and leading to best practice land management models being used by private partners such as ComEd. The generous support from the Negaunee Foundation Fund for Research on Invasive Species is critically important to this work.

Buckthorn, Carbon Sequestration, and the Chemistry of Climate Change

Dr. Dan Larkin and Jim Steffen, conservation scientists at the Garden, study the drivers of ecological degradation—particularly invasive plant species—that necessitate restoration. In the Chicago area, the invasion of common buckthorn (*Rhamnus cathartica*), imported from Europe in the mid-1800s and used locally as windscreen by many homeowners, has crowded out competing plants and caused large areas of woodland to lose their characteristic open-canopied structure. Steffen's more than two decades of work removing buckthorn from the Garden's Mary Mix McDonald Woods and restoring native plant species prompted a long-term experiment to determine whether restoring impacted areas of the woods would improve rates of carbon sequestration.

With support from students Rachel Gentile and Chad Zirbel, who participate in the Garden's ten-week Research Experiences for Undergraduates (REU) program, and College First high school students Alan Lane and Kassandra Altantulkhuur, Steffen and Larkin set out to answer this question. Their thinking was that buckthorn-dominated areas had displaced important understory plants. When these areas of native woodland vegetation rebounded, extending deeply penetrating roots into the soil, it would help trap carbon-based compounds underground. The results of their three-year study, recently published in the journal *Restoration Ecology*, showed that restoration in the

Garden's McDonald Woods did, in fact, enhance carbon sequestration—a very exciting discovery with implications for climate change mitigation and enhanced growth in native trees. "Even though restoration involved cutting down a lot of buckthorn, it actually led to a net increase in wood biomass, an increase that was also positively correlated with restoration age. Buckthorn's thickets may look impressive, but its trunks and branches are puny compared to most trees. We think that taking out buckthorn may have freed native trees that can really get big, like white and red oaks, to better reach growth potential," Larkin said.

Buckthorn-dominated area showing a lack of understory vegetation *Open-canopied woodland with robust growth of native vegetation*

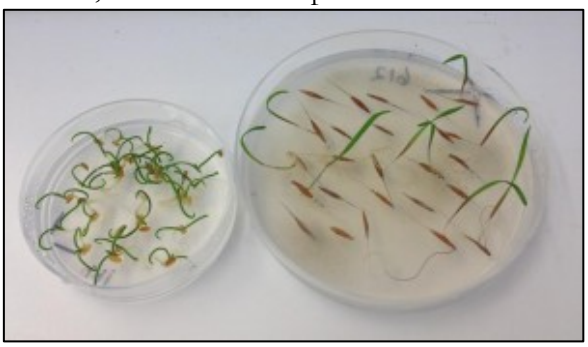
Indeed, invasive plants such as buckthorn are the bullies of the plant world—arch enemies to biodiversity because of their capacity to grow fast, steal nutrients from surrounding plants, and alter the light and soil conditions where they occur. In the case of Dog violet (*Viola conspersa*), a threatened plant that scientist Dr. Pati Vitt, curator of the Dixon National Tallgrass Prairie Seed Bank, has studied for ten-years, the shade created by buckthorn's dense canopy reduces Dog violet's reproduction through open-pollinated flowers and affects seed setting patterns, threatening the plant's local extinction. To combat this problem, the Garden has stepped in with a regional habitat management model based on ten years of volunteer data and integral models that plot "before and after" data. As predicted, removal of buckthorn every few years has led to greater population size and more genetic diversity in the Dog violet. More broadly, the study's results imply that invasive management may help engineer plant populations with greater genetic diversity and, therefore, more resilience to environmental changes.

The Secrets Underground

Prairie and woodland restorations are typically assessed solely by their above ground visible characteristics, such as plant diversity and productivity. However, in neglecting to assess belowground ecosystem health, scientists may be missing half of the picture. To fill this knowledge gap, Garden conservation scientist Dr. Louise Egerton-Warburton and Lauren Umek, a Ph.D. student in the joint Chicago Botanic Garden/Northwestern University graduate program, are conducting several experiments exploring restoration from a soils-focused ecological perspective. Assisted by REU interns Breonna Slum, Mariah Allen, and Ben Girgenti, one of the major focuses has been to investigate the effects of soil manipulation and seeding rates on ecosystem recovery and buckthorn suppression. Initial results of this research were recently published in *Ecological Restoration* and have been presented at several national and international scientific meetings.

Egerton-Warburton is also working with Corey Palmer, a graduate student in the Garden's Plant Biology and Conservation program, and Jenifer Yost, an Honors student at Lake Forest College, to examine the effects of restoration following invasive plant removal on indicators of soil quality. Using 15 sites of varying restoration ages located within the Chicago Wilderness Land Management

Program, analyses showed that early restoration efforts enhanced soil quality through increases in soil carbon storage, structure, and microbial community function. As restored communities age, however, sites require more intensive management, such as aggressive invasive plant removal and planting native grasses, to maintain these benefits. In 2013, the results were presented at the Ecological Society of America in Minneapolis, the Natural Areas Meeting in Chicago, and the International Union of Soils Scientists Global Soil Carbon Symposium in Madison, and will be published in *Progress in Soil Science*.



At the same time, Egerton-Warburton and Rob Hevey, a graduate student in the Garden's Plant Biology and Conservation program, are working on the recovery of symbiotic root fungi in oak woodlands following the removal of buckthorn. Notably, the removal of buckthorn resulted in a significant increase in the diversity of symbiotic root fungi and thus access to soil resources. This finding is particularly encouraging because it suggests that some of the effects of buckthorn may be reversed. These results were presented at the Ecological Society of America in Minneapolis, and World Conference on Ecological Restoration in Madison.

Together, these studies have highlighted the importance of considering the belowground ecosystem in invasive species management, most notably the unseen consequences of current restoration and land management practices, as well as providing insights into how management practices can be more effective, especially with regard to traits associated with soil quality and diversity.

Regional Impacts of Invasion and Restoration

The Chicago Wilderness Land Management Research Program (CWLMRP), commonly called "100 Sites for 100 Years," is a cross-disciplinary research program linking regional land management with ecological research. A network of more than 122 protected natural areas represent the region's dominant woodlands, prairie remnants, and former agricultural prairie restorations. With this project, Umek and her collaborators are evaluating the effectiveness of current management practices for restoring and conserving biodiversity and restoring key processes necessary for the long-term stability of threatened ecosystems. Poised to make significant impacts in our understanding of invasion and restoration ecology, this is the first long-term research program of this scope to investigate restoration activities in a metropolitan region.

In collaboration with researchers at Purdue University, Umek is also exploring the possibility of using satellite images to map buckthorn distribution. Historically, this has been a difficult task because invasive shrubs such as buckthorn typically grow beneath taller canopy trees and are not visible from satellite images. However, a remote sensing technology, LiDAR, can be used to describe these plant communities in three dimensions and may be useful to determine their regional cover.

Native "Winners" Vs. Invasive Bullies

When it comes to invasive species, competition is the watchword. But in an age of rapid land development, species fragmentation, and climate change, competition is not always fair. Out on the Colorado Plateau, Dr. Andrea Kramer, a conservation scientist at the Chicago Botanic Garden, is working with a research team to give native plants a competitive advantage. Since invasive species such as cheatgrass arrived on the Plateau more than a century ago, they have fueled destructive fires and led to numerous other problems, including the decline of native species. Rising concentrations

of atmospheric carbon dioxide are likely to blame, as they have decreased the digestibility and potential decomposition of the cheatgrass and led to its proliferation. As cheatgrass has become more abundant, it has primed the land for more intense and frequent fires. Thus, the cycle advances like compound interest, steadily building momentum. Finding a solution to the problem is not only important for native plants, but also for threatened animals, such as the sage grouse bird, that rely on a healthy plant habitat for survival.

In her work near Utah's Zion National Park, Kramer collaborates with other botanists to identify native plants that have naturally begun adapting to the new environmental conditions. Unlike their counterparts in unaltered areas, these species have learned how to grow their roots deeper, absorb more water, or found other ways to gain an advantage. Not only are these plants capable of surviving in an unnaturally harsh environment, but they could prove to be genetically "smart" and "fast" enough to keep invasive species in check. In the Garden's labs, Kramer is working with Alicia Foxx, a graduate student in the Garden's Plant Biology and Conservation program, to stage trials between cheatgrass and native winners in conditions nearly identical to those in the Plateau. Once the strongest native winners are identified, she will work with local partners in the West to test whether post-fire revegetation work carried out by the Bureau of Land Management can be improved with the use of 'native winners' in seed mixes. Then, Kramer and her partners will make sure the seed is available for restoration work—positioning the native winners for success.

Pitcher's Thistle: A Centuries-long Adaptation

Invasive species research takes time, experimental creativity, and geographic breadth—and occasionally can lead to unintended results. In 1997, Dr. Kay Havens, director of plant science and conservation at the Garden, joined a team of researchers to reintroduce Pitcher's thistle (*Cirsium pitcher*) to Illinois Beach State Park. Thistles are typically resilient, even weedy, according to Havens, and the presence of a rare, at-risk thistle was baffling. A subsequent five-year grant to study the demography and genetics of the pink-and-cream blooming plant, completed in 2011, revealed that the threatened species was in decline due to invasive species, predation by goldfinches, and most curious of all, predation by a biocontrol weevil (*Larinus planus*) introduced to control weedy thistles.

This summer, seeking an explanation for these surprising results, Havens and her colleague Pati Vitt traveled to Door County, Wisconsin, to observe the interactions of the weevil with Pitcher's thistle. Together with their research team, they recorded detailed notes about the frequency and time of visits by the troublesome weevils, as well as visits by friendly pollinators, like bees. In total, they monitored 27 visiting insect species. Their results showed that Pitcher's thistle is especially susceptible to the biocontrol weevil, whose larvae feast on emerging seeds. Unfortunately, if a blooming thistle loses its seeds before they are dispersed, new plants cannot be started. "The weevils have become very widespread in Pitcher's thistle and they cut the seed output by about half," said Havens. While the decline of the fragile shoreline plant—which lives four to eight years and only blooms once—is troubling, it is also a case study in each plant's remarkable capacity for genetic resiliency and survival. "Every species represents a unique solution to an entire set of environmental problems," said Vitt. These solutions, she explained, may solve large-scale problems for people or other species in ways yet to be determined. "The species has intrinsic value because it has these unique solutions that evolved over hundreds of thousands of years."

Wetland Plant Communities, Secretive Marshbirds, and Marine Life

Invasive species not only threaten the biodiversity of the plant community, they also affect the health and abundance of the animals living there. Marshbirds such as rails, bitterns, grebes, coots are among the most under-studied bird groups in North America. Well-camouflaged in dull-colored

grays and browns, these birds commonly hide among reeds and bulrushes at the water's edge or skim the water's searching for aquatic plants. As wetlands are degraded by watershed disturbances and invasive plant species, scientists are concerned that these birds may be at risk of losing their homes. Using data from 60 natural and restored wetlands in southern Wisconsin, along with four years of marshbird monitoring data from collaborators, Larkin and master's student Wes Glisson are evaluating the capacity of habitats restored under the U.S. Department of Agriculture's Wetland Reserve Program to support these birds of high concern. A paper submission is expected by Jan 1, 2014, and a follow-up grant proposal to support expanded research with the Wisconsin Department of Natural Resources and Michigan Natural Features Inventory is forthcoming. "Preliminary analysis suggests that reed canary grass has a fairly significant impact on these birds. It's creating real losses in supporting that group of wildlife," Larkin said.

Also dependent on healthy plant communities are fish and other marine animals, increasingly threatened in Lake Erie, the Gulf of Mexico, the Long Island Sound, and many Wisconsin lakes by algal blooms, which deprive the animals of oxygen. Scientists such as Larkin, and his Ph.D. student Paul Hartzog, believe wetland vegetation may help control algal blooms by removing high levels of nitrogen from agricultural fertilizer run-off before it leaks into waterways. Hartzog is conducting denitrification studies of wetland systems dominated by native *Carex stricta* (tussock sedge), a so-called "native ecosystem engineer," to determine if these plants are better equipped to absorb nitrogen than those dominated by invasives such as *Phalaris arundinacea* (reed canary grass). As part of this work, Hartzog is collaborating with plant geneticist John Kelly at Loyola University, to analyze DNA microbial samples. The results of this and related experiments conducted by Garden conservation scientists at the University of Michigan Biological Station, published in *Aquatic Botany*, have led to insights into how aggressive invasive plants uptake nutrients, alter soil conditions, displace native species, and may be more effectively managed in the future.

Coordinated Action

Through its leadership in the creation of PhragNet, a cooperative learning network for Phragmites management, the Garden has developed a standardized protocol for impacted areas slated for control and restoration. This work includes partnerships with the U.S. Fish and Wildlife Service and wetland managers across the United States and into Canada on the adaptive management of wetlands impacted by *Phragmites*. The goal of this effort is to "learn by doing," harnessing leaf and soil samples from wetland managers distributed over a broad geographic area to identify best practices for controlling *Phragmites* and reestablishing diverse native vegetation. Other internet-based decision-support tools are currently being used by the National Wildlife Refuge managers throughout the Great Plains to more effectively control Kentucky Blue Grass and Smooth Brome Grass that have invaded prairies. These monitoring tools, which unite scientific research and conservation practice, are also being used by land managers at Minnesota Department of Natural Resources and The Nature Conservancy.

The Garden's 225 acres of natural areas—including McDonald Woods, Dixon Prairie, Skokie River Corridor, and the Garden Lakes—are managed to enhance habitat quality and increase native flora and fauna diversity. During 2013, all flowering garlic mustard plants were removed from the entirety of the Garden's woodlands (over 110 acres), and from nearly

all of the Skokie River Corridor and the Dixon Prairie. This follows an award-winning removal of garlic mustard (over 36,000 pounds) from the Garden campus in 2012, which earned the Garden first place in the USDA Forest Services Garlic Mustard Challenge. Along the Garden's 5.7 miles of lake shoreline, reed canary grass (*Phalaris arundinaceae*) and common reed (*Phragmites australis*) were particularly problematic during the 2013 growing season, likely due to April floodwaters that carried seeds of these plants into the Garden Lakes from upstream areas; nonetheless, aggressive eradication efforts by Garden staff appear to be keeping these plants in check. Efforts continue to control purple loosestrife (*Lythrum salicaria*) in the Skokie River Corridor and the Garden Lakes, and each successive year's management yields reduced populations of this notoriously invasive wetland plant.

The private sector has also taken notice. In 2010, ComEd invited the Garden to take part in a pilot program to review research design options and determine the best practices for converting utility right-of-ways whose power lines are threatened by buckthorn, narrow leaf cattail, Japanese honeysuckle and other invasives into sustainable native prairie landscapes. While ComEd has maintained utility corridors in the past with routine brush mowing and manual labor, such upkeep has proved costly—an initial six-day tree and brush removal at the ten-acre Illinois Beach State Park site, for instance, cost $34,787—and not always effective, particularly for invasive plants that may rebound vigorously year after year. "We're interested, because ComEd is the second-largest land owner in the state, and improving the habitat could have a major impact on the whole region," said Dr. Greg Mueller, vice president of Science and Academic Programs at the Chicago Botanic Garden. "It fits the type of public-private partnership that allows companies like ComEd to be better stewards of their land and allows the Chicago Botanic Garden access to land for use as a research opportunity."

Now, in the program's third year, plant life abundant nearly 200 years ago has reemerged with surprising vigor. Altogether nearly 300 different plant species, including 225 native species and 40 newly identified species, have been recorded on the six 1.5- to 1.8-acre research plots. Ground nuts whose meaty roots were boiled and served by early Midwestern settlers during the winter months have reappeared alongside the scouring rush stalks once used by prairie homesteaders to scrub pots and pans. When research is finalized in 2016, ComEd aims to implement the most effective approaches in their 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.

Conclusion

The management of invasive species represents one of the most pressing environmental challenges of the twenty-first century. From loss of plant diversity, to changes in ecosystem function and character, to the threats posed to birds, fish, and food webs, the untold consequences of invasive species have far-reaching implications for the sustained health and beauty the planet. Through research collaborations with universities and state and national agencies, coordinated land management efforts that span the country, and public and private partnerships to synthesize a multi-disciplinary knowledge base and build a coalition against the spread of invasive species, the Chicago Botanic Garden is answering the call for timely, cost-effective prevention and corrective solutions to this global threat. We are deeply grateful for the support of the Negaunee Foundation Fund for Research on Invasive Species in assisting this valuable work.