Faculty and Professional Research   Plaster Creek Stewards

12-1-2021

Relative Success of Native Plants in Curb Cut Rain Gardens

Ana Singh
Calvin University

Rachel Warners
Calvin University

Jonathan Walt
Calvin University

Patrick Jonker
Calvin University

David P. Warners
Calvin University, david.warnerrs@calvin.edu

Restoration Notes

Restoration Notes have been a distinguishing feature of *Ecological Restoration* for more than 25 years. This section is geared toward introducing innovative research, tools, technologies, programs, and ideas, as well as providing short-term research results and updates on ongoing efforts. Please direct submissions and inquiries to the editorial staff (ERjournal@ sebs.rutgers.edu).

Relative Success of Native Plants in Urban Curb-Cut Rain Gardens Ⓒ

Ana Singh (Department of Biology, Calvin University, Grand Rapids, MI), Rachel Warners (Department of Biology, Calvin University, Grand Rapids, MI), Jonathan Walt (Department of Biology, Calvin University, Grand Rapids, MI), Patrick Jonker (Department of Biology, Calvin University, Grand Rapids, MI) and David Warners (corresponding author: Department of Biology, Calvin University, 3201 Burton Street SE, Grand Rapids, MI, USA, dwarners@ calvin.edu)

Impermeable surfaces such as rooftops, roads, and parking lots contribute high volumes of stormwater runoff to local waterways, exacerbating flood risk and stream bank erosion (Wang et al. 2001, Bierwagen 2007). Additionally, stormwater runoff is typically warmer than natural stream inputs causing thermal pollution and can contain high levels of pathogenic microbes that threaten human and non-human health downstream (Trimble 1997, Almasri and Kaluarachchi 2004, Page et al. 2012, Hathaway et al. 2016). Green infrastructure is an approach that addresses such problems by incorporating native plants and the environmental services they provide into urban spaces (EEA 2011, EPA 2019). One example is to install native gardens to catch and filter stormwater runoff, encourage aquatic and terrestrial biodiversity, and benefit human health (Burghardt et al. 2009, Bouma et al. 2015, Moore et al. 2016, Pennino et al. 2016). Since green infrastructure practices in urban settings are so new, little data exist for identifying which native species perform best in these novel sites. We report on the two-year survival and performance of species installed in 11 urban curb-cut rain gardens. Identifying the relative success of different species in urban locations with chemical and biotic stressors is important for designing effective green infrastructure (Elmqvist et al. 2013).

Ⓒ *Color version of this article is available through online subscription at: http://er.uwpress.org*

Plaster Creek Stewards (PCS) is a community-based watershed group in Grand Rapids, Michigan, USA, that is associated with Calvin University. PCS began a curb-cut rain garden (CCRG) project in the summer of 2015 with the installation of 11 gardens. These gardens are installed between the sidewalk and roadway, with a street-side opening (where the curb has been cut), allowing for interception of stormwater that otherwise would pass through storm drains and into the nearest waterway (Figure 1). Once captured by a CCRG, stormwater can exit the garden in three ways: evaporation from moist surfaces, transpiration through leaf stomata, or percolation past the root zone into the soil. Each CCRG was engineered to handle a 2-year storm event which is the Michigan standard (2.57 inches of rain in 24 hours). The cost of each garden, around $1500, was covered by a grant to PCS from the State of Michigan Department of Environment, Great Lakes, and Energy. PCS instructs each homeowner to water the transplants as needed for the first month only. CCRG maintenance is done collaboratively by a PCS crew and the homeowner for 2 years, after which time homeowners are responsible for ongoing maintenance.

For these CCRGs native species from local genotypes are selected for their stable root systems that process large volumes of stormwater, and for their propensity to attract native insect and avian biodiversity (Smith et al. 2006, van Heezik et al. 2008, Burghardt et al. 2009, Isaacs et al. 2009). Additionally, rain gardens may serve as important sources of genetic diversity for nearby remnant populations of native plants. We allow homeowners to select which species to use in their specific rain garden and provide them with a CCRG maintenance brochure and a visual map of their garden (Figure 2).

The 11 gardens in this study were installed in a southeast Grand Rapids neighborhood that has indigenous sandy soils. This neighborhood was chosen because its substrate provides higher infiltration rates and improved likelihood of plant success when compared to clay soils (Haan et al. 2011). In Michigan these spaces between the sidewalk and street are seasonally exposed to road salt and infiltrated by automobile grit and toxins brought in by stormwater runoff. During the growing season the CCRGs experience extreme moisture variations ranging from inundation to almost xeric conditions. In addition, they are threatened by urban weeds that have been under intense selection

Figure 1. Example of a curb-cut rain garden one full growing season after initial planting. Water moving along the curb destined for a storm drain becomes diverted into the garden, where the curb has been cut. Debris and sediment are captured within the concrete pavers. The water continues to flow into the basin where it slows down, percolates into the soil, evaporates, or is transpired by native plants in the garden.

pressure for decades. All these influences create extremely challenging conditions for native plants propagated from local remnant populations that were never exposed to such stressors, offering small examples of ecological restoration in novel ecosystems (Kowarik 2011, Ahern 2016). We collected data one year after the gardens were planted to assess 1) which species showed the highest survivorship, and 2) which species showed greatest performance (e.g., grew the best). We evaluated our data against two null hypotheses—that there would be no difference in survival or performance among the species tested.

From mid-June to mid-August 2015, we planted approximately 15 different native perennial species in each of the 11 gardens, although not every garden received the same combination of species. All the plants used had been germinated earlier that spring in PCS greenhouses and were of similar age (4–6 months) and height (10–15cm), and all the gardens were of similar size (approximately 50m²). At the time of planting three of the gardens were found to have such sandy soil that a compost amendment (20% screened topsoil and 80% compost) was added. The amendment was spread two inches thick over the surface of each of these three gardens before planting was done.

We collected data from June 7–13, 2016, in all 11 of the 1-year-old curb-cut rain gardens. Survivorship was recorded by species as the percent of plants that were present in 2016 compared to the original number that had been planted in 2015. We developed an index of performance by randomly selecting five plants from each species cluster within the garden. Three researchers independently

evaluated each of the five plants by assigning a performance rating of 1–10, with 1 indicating a small, stunted plant and 10 a robust, thriving plant. The average performance score per plant was calculated from the three student estimates, and scores from the five plants per garden were averaged for a species performance score in each garden. An overall performance score was calculated for each species by averaging these values across gardens. Survivorship and performance were combined to graphically represent the overall success of each species.

For data analysis, we only used species that had been planted in at least three of the gardens, resulting in a list of 21 native species. To evaluate the compost amendment, we constructed linear mixed effect models for survivorship and performance as a function of species, presence/absence of compost, and their interaction, with a random intercept for garden. This approach was used to determine which species would have the highest predicted survivorship and highest predicted performance in an average CCRG, with and without compost. Models were fitted in R (R Core Team 2020) using the lmer function within the lme4 package (Bates et al. 2015). We used analysis of variance to test the interaction between species and compost. This statistical approach accommodates the unbalanced design of this study.

The survivorship model with associated ANOVA test identified species as a significant factor ($p = 0.0002$), leading us to reject the null hypothesis that all species will have equal survivorship across gardens. There was no significant overall effect between compost treatment and
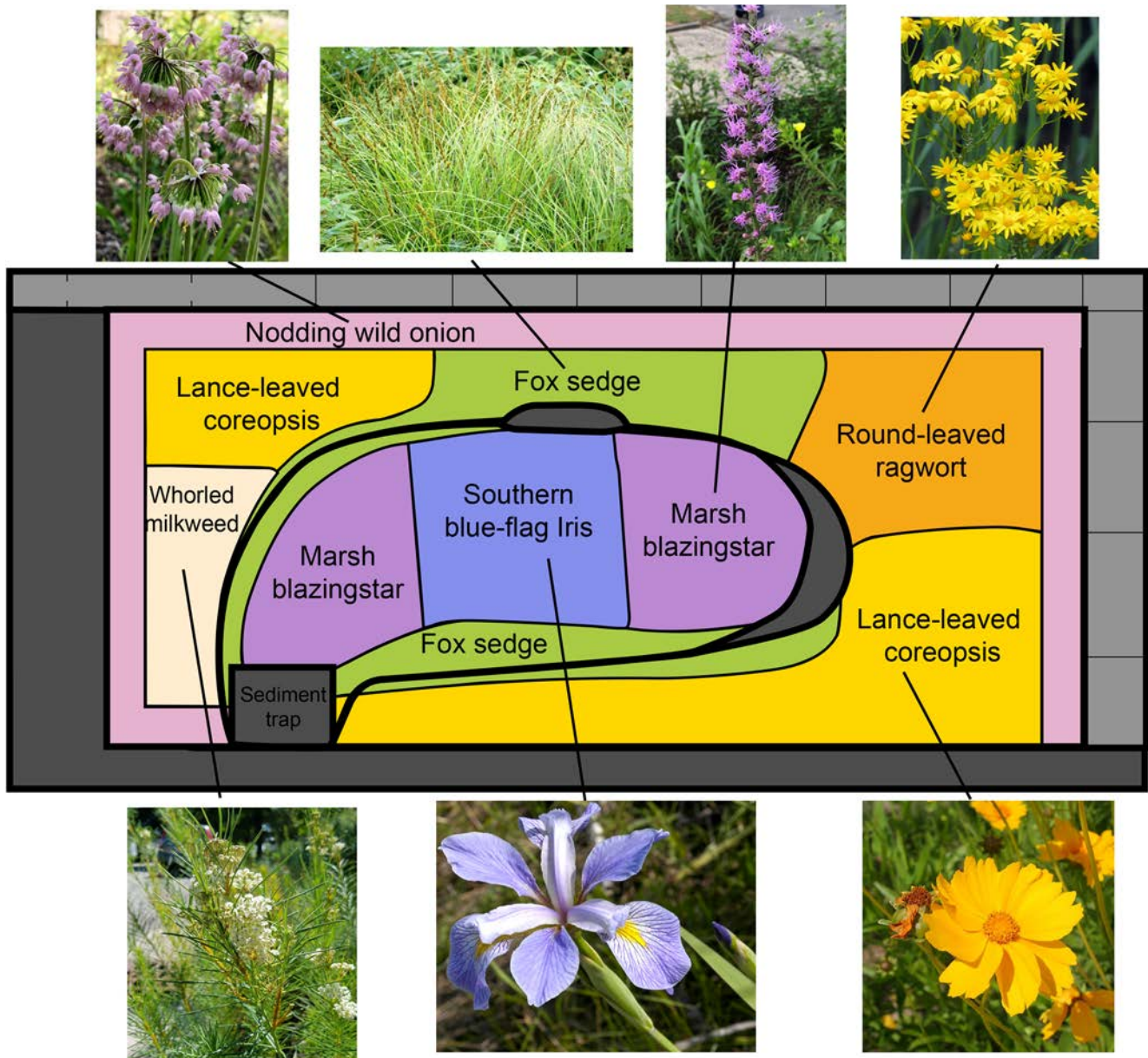
Figure 2. Example of a design map given to homeowners for their specific curb-cut rain garden. Map illustrates that species were planted in distinct clusters, facilitating maintenance as well as monitoring. Residential homeowners were invited to assist in species selection.

survivorship ($p = 0.3383$). However, the interactive effect between compost and species was significant, suggesting that in terms of survivorship, individual species respond differently in composted and non-composted gardens ($p = 0.0134$). Given that PCS now uses compost in all curb-cut rain gardens, species were ordered in Figure 3 according to their survivorship in composted gardens (values slightly over 1.0 are an artifact of the model and can be translated as 100% survivorship).

Two of the species with greater expected survivorship in non-composted gardens (*Amorpha canescens* and *Lupinus perennis*) typically grow in well drained nutrient poor soils. The enhanced water holding capacity or enhanced nutrient status from compost may discourage these species (Isbell

et al. 2013, Spargo and Doley 2016). The other four species with higher survivorship in non-composted gardens (*Carex gracillima, Eurybia macrophylla, Aquilegia canadensis,* and *Allium cernuum*) tend to grow in shady habitats in West Michigan and may be responding more to another environmental variable such as light.

It is possible that species that did not respond positively to the addition of compost were indirectly influenced by competition, which may have been exerted by the rapid response of adjacent species that did respond positively. Species with slow growth after germination and transplanting (such as *Allium cernuum* in our experience), are likely more susceptible to competitive influences. It might be better to cultivate such species in a greenhouse or nursery
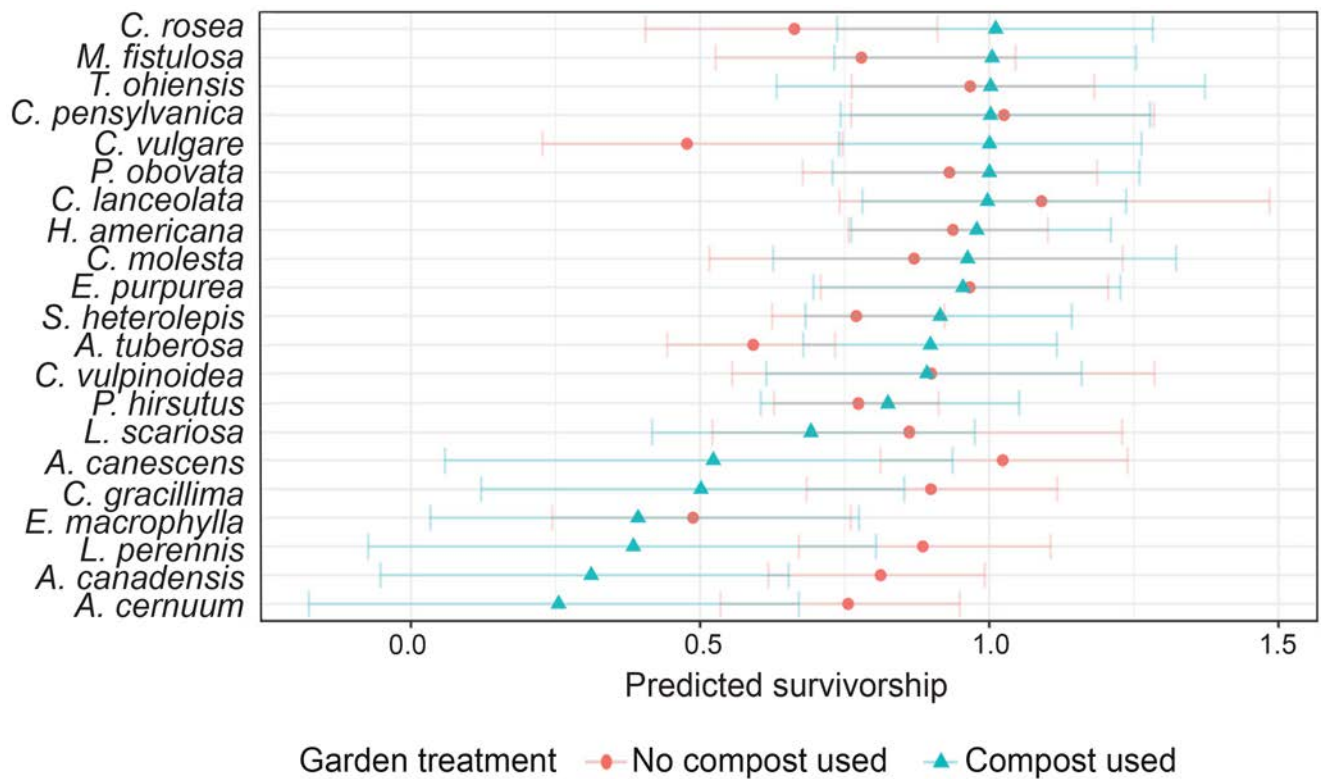
Figure 3. Predicted survivorship values by species for non-composted gardens (diamond-shaped dots) and composted gardens (triangle-shaped dots). Error bars represent 95% confidence intervals.

Figure 4. Predicted performance values by species for non-composted gardens (diaond-shaped dots) and composted gardens (triangle-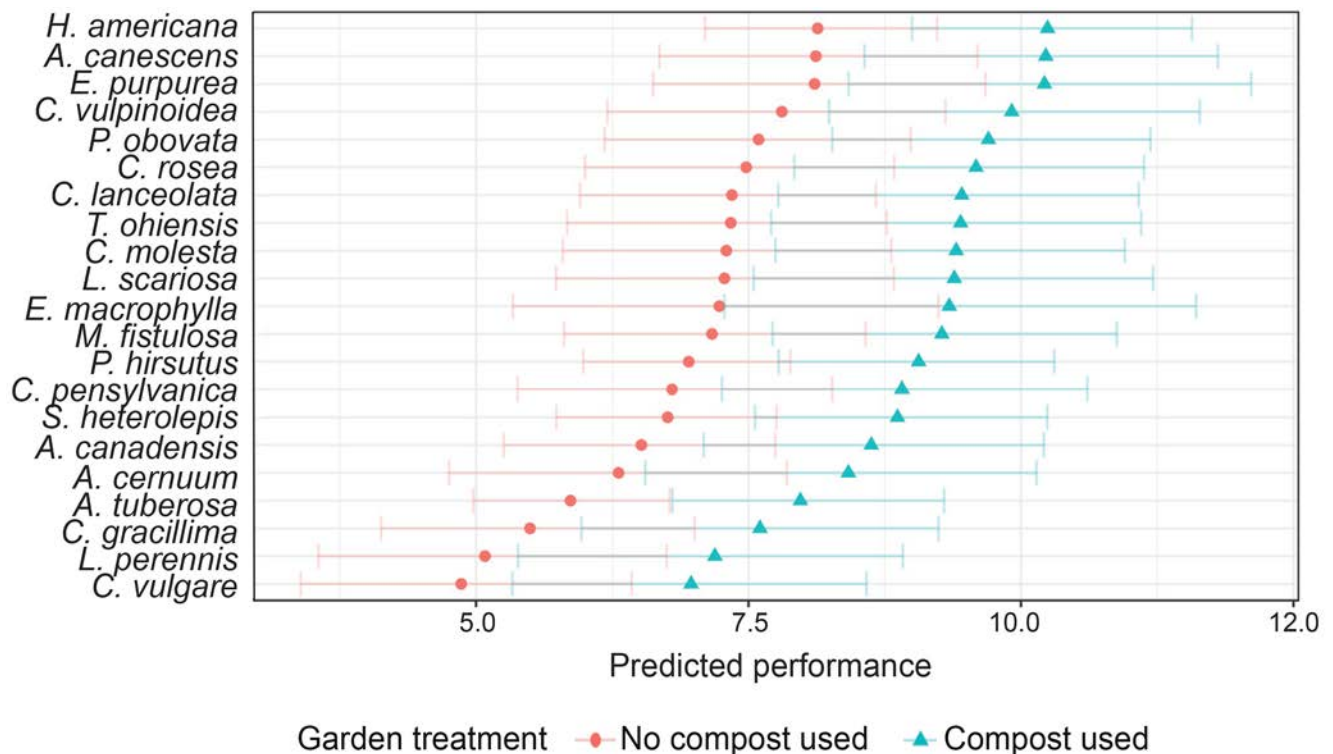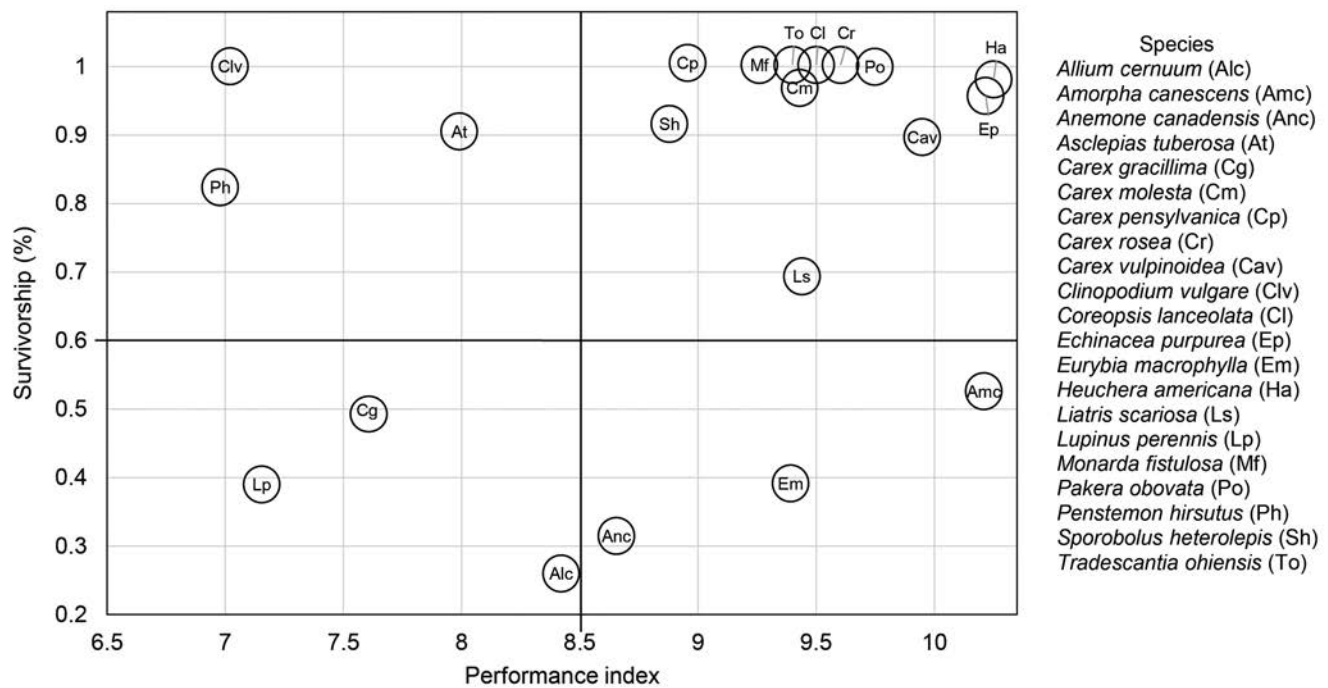shaped dots). Error bars represent 95% confidence intervals. The two sets of dots align because there was no significant interaction effect of species x compost (all species benefitted similarly from the addition of compost).

Figure 5. Overall survivorship vs. performance for 21 native Michigan plant species in composted CCRGs. High survivorship and high performance were exhibited by species in the upper right quadrant. Those in the lower right quadrant had high performance but lower survivorship and species in the upper left quadrant had lower performance but high survivorship. Lower performance and survivorship were exhibited by species in the lower left quadrant.

setting for two years before out-planting. Also, species with low predicted survivorship may have been disproportionately preferred by insects or urban herbivores (rabbits or deer) (Denyer et al. 2007, Thiel et al. 2020).

Plant performance index varied widely among species (p = 0.0009), leading us to reject the null hypothesis that all species will perform similarly in an average CCRG. Unlike the survivorship data, performance was positively affected by compost amendment (p = 0.0006), but there was no significant interaction term, suggesting the compost treatment affected species similarly (p = 0.6236). Therefore, when species are plotted according to their expected performance in composted gardens, these data points track their expected performance in non-composted gardens (Figure 4).

Given that these gardens were all planted in a neighborhood with sandy, nutrient poor soils, the improved nutrient status or water retention capacity from added compost likely enhanced performance (Barzegar et al. 2002, Arthur et al. 2012, al-Bataina et al. 2016). The highest performers can be thought of as species that give a good "first impression" after one year of growth (*Heuchera americana, Echinacea purpurea,* and *Amorpha canescens*). Contrastingly, the low performers (*Asclepias tuberosa, Carex gracillima, Lupinus perennis,* and *Clinopodium vulgare*) might be species to avoid or they could simply be slow growers who require multiple years before achieving maturity (which is what we have found to be true for *Asclepias tuberosa* and *Lupinus perennis*).

Figure 5 illustrates the relative success of species to survivorship and performance together in composted gardens, suggesting management strategies. Most species (12 of 21, upper right quadrant) had expected survivorship over 60%, and performance rankings typically above 8.5. These native plants can be successfully used in urban CCRGs. Species with lower survivorship but high performance (lower right quadrant) might be planted at higher densities and species with lower performance but high survivorship (upper left quadrant) might benefit from more focused care. Those with low survivorship and low performance (bottom left quadrant) may need vigilant management if they are planned to be included in CCRGs.

The approach we developed to evaluate survival and performance worked well and can be replicated in green infrastructure projects elsewhere. Yet, our study included only 21 native Michigan species, and there are many others worthy of consideration for urban restoration projects. We also recognize that when choosing plants for CCRGs transpiration rates and biodiversity benefits of native species should be assessed. Finally, species used in residential neighborhood gardens should also be evaluated for visual desirability ("curb appeal") given that their long-term perpetuation will be dependent on homeowner acceptance.

References

Ahern, J. 2016. Novel urban ecosystems: Concepts, definitions, and strategy to support urban sustainability and resilience. *Landscape Architecture Frontiers* 4:10–21.

Al-Bataina, B.B., T.M. Young and E. Ranieri. 2016. Effects of compost age on the release of nutrients. *International Soil and Water Conservation Research* 4:230–236.

Almasri, M.N. and J.J. Kaluarachchi. 2004. Assessment and management of long-term nitrate pollution of ground water in agriculture-dominated watersheds. *Journal of Hydrology* 295: 225–45.

Arthur, E., W. Cornelis and F. Razzaghi. 2012. Compost amendment to sandy soil affects soil properties and greenhouse tomato productivity. *Compost Science and Utilization* 20:215–21.

Barzegar, A.R., A. Yousefi, A. Daryshenas and B.E. Clothier. 2002. The effect of addition of different amounts and types of organic materials on soil physical properties and yield of wheat. *Plant & Soil* 247:295–301.

Bates D., M. Maechler, B. Bolker and S. Walker. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67:1–48.

Bierwagen, B.G. 2007. Connectivity in urbanizing landscapes: the importance of habitat configuration, urban area size, and dispersal. *Urban Ecosystems* 10:29–42.

Bouma, C., E. Huizenga and D. Warners. 2015. Assessing a reconciliation ecology approach to suburban landscaping: Biodiversity on a college campus. *The Great Lakes Botanist* 52:93–104.

Burghardt, K.T., D.W. Tallamy and W.G. Schriver. 2009. Impact of native plants on bird and butterfly biodiversity in suburban landscapes. *Conservation Biology* 23:219–24.

Denyer, J.L., S.E. Hartley and E.A. John. 2007. Small mammalian herbivore determines vegetation response to patchy nutrient inputs. *Oikos* 116:1186–1192.

Elmqvist, T., M. Fragkias, J. Goodness, B. Güneralp, P.J. Marcotullio, R.I. McDonald, et al. 2013. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities.* New York, NY: Springer Publishing.

Environmental Protection Agency (EPA). 2019. What is Green Infrastructure?. www.epa.gov/green-infrastructure/what-green-infrastructure.

European Environmental Agency (EEA). 2011. Green Infrastructure and Territorial Cohesion. www.eea.europa.eu/publications/green-infrastructure-and-territorial-cohesion.

Haan, N.L., M.R. Hunter, and M.D. Hunter. 2011. Investigating predictors of plant establishment during roadside restoration. *Restoration Ecology* 20:315–321.

Hathaway, J.M., R.J. Winston, R.A. Brown, W.F. Hunt and D.T. McCarthy. 2016. Temperature dynamics of stormwater runoff in Australia and the USA. *Science of the Total Environment* 559:141–50.

Isaacs, R., J. Tuell, A. Fiedler, M. Gardiner and D. Landis. 2009. Maximizing arthropod-mediated ecosystem services in agricultural landscapes: The role of native plants. *Frontiers in Ecology and the Environment* 7:196–203.

Isbell, F., P.B. Reich, D. Tilman, S.E. Hobbie, S. Polasky and S. Binder. 2013. Nutrient enrichment, biodiversity loss, and consequent declines in ecosystem productivity. *PNAS* 110:11911–11916.

Kowarik, I. 2011. Novel urban ecosystems, biodiversity, and conservation. *Environmental Pollution* 159:1974–1983.

Moore, T.L., J.S. Gulliver, L. Stack and M.H. Simpson. 2016. Stormwater management and climate change: vulnerability and capacity for adaptation in urban and suburban contexts. *Climate Change* 138:491–504.

Page, R.M., S. Scheidler, E. Polat, P. Svoboda and P. Huggenberger. 2012. Faecal indicator bacteria: groundwater dynamics and transport following precipitation and river water infiltration. *Water, Air, & Soil Pollution* 223:2771–82.

Pennino, M.J., R.I. McDonald and P.R. Jaffe. 2016. Watershed-scale impacts of stormwater green infrastructure on hydrology, nutrient fluxes, and combined sewer overflows in the mid-Atlantic region. *Science of the Total Environment* 565:1044–53.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org/.

Smith, R.M., P.H. Warren, K. Thompson and K.J. Gatson. 2006. Urban domestic gardens (VI): environmental correlates of invertebrate species richness. *Biodiversity and Conservation* 15:2415–38.

Spargo, A. and D. Doley. 2016. Selective coal mine overburden treatment with topsoil and compost to optimise pasture or native vegetation establishment. *Journal of Environmental Management* 182:242–50.

Thiel, T., S. Gaschler, K. Mody, N. Bluthjen and B. Drossel. 2020. Impact of plant defense level variability on specialist and generalist herbivores. *Theoretical Ecology* 13:409–424.

Trimble, S.W. 1997. Contribution of stream channel erosion to sediment yield from an Urbanizing watershed. *Science* 278:1442–4.

van Heezik, Y., A. Smith and R. Mathieu. 2008. Diversity of native and exotic birds across an urban gradient in a New Zealand city. *Landscape and Urban Planning* 87:223–32.

Wang, L., J. Lyons, P. Kanehl and R. Bannerman. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. *Environmental Management* 28:255–66.