Decisions . . . Decisions . . . How to Source Plant Material for Native Plant Restoration Projects

Brook Herman (corresponding author: U.S. Army Corps of Engineers, Chicago District, Chicago, IL 60604, Brook.d.herman@usace.army.mil), Stephen Packard (Audubon Chicago Region, Evanston, IL), Cathy Pollack (U.S. Fish and Wildlife Service, Chicago Ecological Services Field Office, Barrington, Illinois), Gregory Houseal (Tallgrass Prairie Center, University of Northern Iowa, Cedar Falls, IA), Shawn Sinn (Conservation Land Stewardship, Inc, Elmhurst, IL), Chip O'Leary (Forest Preserves of Cook County, River Forest, IL), Jeremie Fant (Chicago Botanic Garden, Glencoe, IL), Abigail Derby Lewis (The Field Museum, Chicago, IL), Stuart Wagenius (Chicago Botanic Garden, Glencoe, IL), Danny Gustafson (The Citadel, Charleston, SC), Kristina Hufford (University of Wyoming, Department of Ecosystem Science & Management, Laramie, WY), Bob Allison (Cardno JFNew, Walkerton, IN), Kelsay Shaw (Possibility Place Nursery, Monee, Illinois), Steve Haines (Prairie Moon Nursery, Winona, MN) and Corrine Daniels (Applied Ecological Services, Inc., Brodhead, WI).

How far away should the genetic origin of plant material be from the restoration site? This is a primary question for restoration practitioners, but there are no simple answers. Issues involving cost, availability, adaptability, population genetics, and community resilience complicate practitioners' abilities to determine precise locations and distances from the restoration site. The majority of formalized guidelines for sourcing plant material are determined on a project-by-project basis. This important decision can affect the longterm sustainability of the restored community and potentially negatively impact levels of adaptive variation in local populations of native species.

"Local is best" is a commonly held tenet among restoration professionals. Unfortunately, "local" means different things to different people and, depending on the long term goal of your project, local may not be best. Local or local ecotype is an extension of the concept of plant ecotypes that has been used to describe and identify populations that originated and are adapted to local conditions (e.g., climate, soils, pathogens, etc.). Using local seed sources is an effort to identify populations that have experienced similar evolutionary selective forces (abiotic and biotic interactions), which should result in higher fitness of plants introduced at restoration sites. However, our ability to predict the spatial and temporal scale of variation in adaptive traits differs among populations and species (Linhart and Grant 1996). Significant differences in fitness may occur between individuals a meter apart and another set of differences between individuals located 100s of kilometers away (Waser and Price 1985, Galloway and Fenster 2000). Defining and identifying local populations is difficult, typically occurs with imperfect knowledge of underlying genetic differences, and results in an inconsistent set of assumptions among practitioners, such as policies that state anywhere from 40 kilometers to over 320 kilometers from the site of concern (Saari and Glisson 2012).

The reason for intense scrutiny of this issue is the possibility of short-term or longterm failure of introduced plants, potential inbreeding resulting from low genetic diversity and/or increased invasive characteristics within restored populations, and introduction of novel genes into adjacent local populations (Hufford and Mazer 2003). Failure to thrive can result from maladaptation of introduced plants to local conditions that can cause poor germination, establishment, or disruption of plant-animal interactions, such as pollination (Keller et al. 2000). Local native populations experience outbreeding depression (reduced survival, seed set, and seed viability) as a result of the introduction of alien genes (Hufford et al. 2012).

Potential negative impacts to local populations and longterm success of the restored community have motivated the selection of plant material for native plant restoration. However, longterm success also depends on the restored community's ability to adapt to changing environments and adaptation is more likely to occur in genetically diverse populations (Fant et al. 2008). In regions that need restoration, nearby remnant populations may have reduced genetic diversity because of their small size and isolation. If local sources are constrained to these remnant populations, the amount of genetic variation may not be sufficient for population persistence over time.

In order to explore this complex issue, the U.S. Army Corps of Engineers' restoration ecologist, Brook Herman, Chicago District, organized and hosted the *Plant Material Sources for Ecological Restoration Conference*, focused on the restoration of native plant communities using plant material sourced from outside the project site. More than a dozen restoration practitioners, researchers, and nursery professionals gathered in Chicago, IL on July 25, 2012 to present their study results, real world examples, and expert opinions. Approximately 50 people attended. Participants ranged from local forest preserve ecologists to endangered species specialists to biologists working on mine reclamation projects. The workshop consisted of 14 presentations with intermittent open discussion among the presenters and participants. Discussion focused on the pros and cons of options for sourcing seed based on the conservation goals, type of project, and budgetary constraints.

As presenters conveyed their experiences, several key questions arose: Can the type of pollen/seed dispersal mechanisms of different functional groups (e.g., grasses vs forbs) inform how to source species? Should project type (e.g., urban park vs. high quality remnant) dictate the distance to a source population? Should the project site conditions (e.g., soils, microclimate, etc.) constrain which sources (and by extension nursery microclimate) are considered for sourcing material? Given predictions for climate change, should sources come from further South (or North if located in southern hemisphere) of the project site? Is the cost of sourcing multiple populations, increasing genetic diversity and resilience, justifiable for long term sustainability in light of future climate change? What is the relative importance of inbreeding or outbreeding depression for local and introduced restored plant populations?

There are three distinct groups of professionals that play a role in the design and construction of native plant restoration projects. They represent restoration practitioners, academic researchers, and nursery professionals. The first presenters (Stephen Packard, Cathy Pollack, Gregory Houseal, Shawn Sinn and Chip O'Leary) represented restoration practitioners. An overarching theme from this group was that each project site presents unique challenges that should be met with a flexible set of restoration goals and objectives. Clear precise restoration goals will inform decisions about where to locate seed sources. For example, the goals of the North Branch restoration (Stephen Packard) supported source collection protocols within a 24-kilometer radius of the restoration site. Shawn Sinn pointed out that many contract specifications call for a radius of 240–400 kilometers from the restoration site. While distance from the restoration site was considered, matching the characteristics (e.g., soils) of donor with recipient sites also played a role. Chip O'Leary described the history of the Kankakee Sands restoration project in terms of first delineating general seed source areas (80-km radius) to fine-tuning areas based on geomorphology and soil type. And finally, when sources for specific species are not available within predefined areas, working with other agencies, private landowners, and commercial suppliers should be considered. Consideration should also be given to the time it will take to cultivate these relationships and efficiently propagate and prepare enough plant material for current (e.g., phase in species as they become available) and future restoration projects. Consistent demand for desired species and specific sources will incentivize nursery professionals to supply them in quantities needed.

The second group (Jeremie Fant, Abigail Derby Lewis, Stuart Wagenius, Danny Gustafson, and Kristina Hufford) presented their academic research, ranging from evaluating gene flow between populations, genetic diversity of rare species, effects of climate change on species distributions, cases of outbreeding depression, and failure of non-local ecotypes. Jeremie Fant provided an overview of genetic issues that should be considered in locating sources. For instance, practitioners should consider amount of genetic diversity of donor populations, how to identify distinct local populations and why they are distinct, and potential for adaptation of introduced material to local microclimatic variables. Genetic diversity and resilience of a plant community to climate change should be carefully considered during project plan formulation. Abigail Derby Lewis advocated a flexible range of distances for source material based on climate change model projections and long term functional success of restored plant communities. Also, species at the southern extent of their range (in the northern hemisphere) within the area may not be suitable targets for restoration. Local adaptation can be difficult to detect with molecular genetic tests, and there may be differences in adaption to microclimates of populations within species that are assumed to be similar. Danny Gustafson's research on dominant grasses of the tallgrass prairie, southeastern coastal salt marsh, and sweetgrass (*Muhlenbergia filipes*) plant communities showed genetic and ecological differences between local and non-local plant material. These differences in morphology, plant-insect interactions, and genetic signature persisted more than 20 years after planting adjacent to a remnant prairie, despite evidence of gene flow between local and non-local genotypes. Stuart Wagenius's research indicates that prairie remnants adjacent to restoration sites may be in danger of becoming less fit because of inadvertent introduction of non-local genes into their gene pool and disruption of pollination of rare species from closely related non-local species. Kristina Hufford ended with a review of possible strategies for sourcing material based on each species' pollen and seed dispersal mechanisms. For example, genetic similarity between two sites is assumed to be greater in wind-dispersed compared to animal-dispersed populations. Life history traits can be used to predict the distance over which species are likely to adapt to local environmental conditions.

The final group of presenters represented professional nurseries specializing in propagating native plants (Bob Allison, Kelsay Shaw, Steve Haines, and Corrine Daniels). Growers expressed a commitment to work within any distance or microclimate constraints and with any list of species given enough time to locate and propagate quantities required for a contract. Frequently, contracts require uncommon or rare species with insufficient time to locate and propagate them, requiring substitutions with less desirable species. Kelsey Shaw emphasized the economic realities of growers needing a consistent demand for uncommon species or specific sources to result in a readily available supply from growers. Also, Bob Allison said that many growers do not keep track of specific microclimate characteristics of source populations that are used for propagation, although this can be retroactively added and tracked if there is a demand for this type of information.

From the workshop it became clear that decisions involving where and how to source native plant material should consider species characteristics (e.g., wind-pollinated), the material (seeds vs. live plugs) being sourced, longterm goals of the restoration project, budget, site condition and location of restoration site in relation to local native populations. Participants concluded the workshop with a critical discussion of the issues. We attempted to summarize general guidelines that could be applied during the planning process for projects that involve restoration of native plant communities. Foremost in the decision-making process is consideration of the goals and objectives of the restoration project. If the goals are to enhance a degraded plant community adjacent to a high quality remnant, the best course of action would to be source material from the remnant. In contrast, if the goal is to reestablish a functional wetland within a residential neighborhood, sources may be sought from farther away. Once goals and objectives of a project are clear, protocols for plant material selection can be defined to include the type of microclimate conditions within the site (e.g., loamy vs. sandy soils) and type of species (e.g., wind/animal pollination). If allowable, projects should use a larger region to locate sources, and then plan on sourcing the same species from two or more populations. This increases genetic variation; however, it also includes a risk of outbreeding depression. Be aware that multiple years may be required for many uncommon or rare species and budget accordingly. Finally, we should plan with future environmental conditions in mind. If results from climate models are not readily available for your region, at least consider an increase in average temperature. Although changing climate was one of many issues to consider, there are other local characteristics not projected to change, such as day length. This will fine tune decisions regarding specific species and how far north and south appropriate sources are from your restoration site.

How and where to source plant material for ecological restoration continues to be important for current and future projects. Even though this conference improved our understanding of the complex issues involved with native plant restoration, many questions still remain. For example, how important is finding multiple sources of locally or regionally adapted plant material for the persistence of the restored plant community under changing environmental conditions (Broadhurst et al. 2008, Pickup et al. 2012)? Continued research efforts, using greenhouse studies, common garden plots, and monitoring restoration sites, should be encouraged (Golay et al. 2013). Data gathered from restoration sites are particularly scarce (Gibson et al. 2013). The use of climate change distribution modeling (Potter and Hargrove 2012, Breed et al. 2013) should also be explored. These tools can help to delineate material transfer zones that will encourage more efficient and effective seed sourcing policies and coordination with private industry.

References

Breed, M.F., M.G. Stead, K.M. Ottewell, M.G. Gardner and A.J. Lowe. 2013. Which provenance and where? Seed sourcing strategies for revegetation in a changing environment. *Conservation Genetics* 14:1–10.

Broadhurst, L.M., A. Lowe, D.J. Coates, S.A. Cunningham, M. McDonald, P.A. Vesk and C. Yates. 2008. Seed supply for broadscale restoration: maximizing evolutionary potential. *Evolutionary Applications* 1:587–597.

Fant, J.B., R.M. Holmstrom, E. Sirkin, J.R. Etterson and S. Masi. 2008. Genetic structure of threatened native populations and propagules used for restoration in a clonal species, American beachgrass (*Ammophila breviligulata* fern.). *Restoration Ecology* 16:594–603.

Galloway, L.F. and C.B. Fenster. 2000. Population differentiation in an annual legume: Local adaptation. *Evolution* 54:1173–1181.

Gibson, D.J., S.G. Baer, R.P. Klopf, L.K. Reed, B.R. Wodika and J.E. Wiland. 2013. Limited effects of dominant species population source on community composition during community assembly. *Journal of Vegetation Science* 24:429–440.

Golay, M.G., R. Manatt, C. Mabry, J. Thompson and R. Kolka. 2013. Restoration of herbaceous woodland plants: Persistence, growth, and reproductive success of local and non-local propagules. *Ecological Restoration* 31:378–387.

Hufford, K.M. and S.J. Mazer. 2003. Plant ecotypes: Genetic differentiation in the age of ecological restoration. *Trends in Ecology and Evolution* 18:147–155

Hufford, K.M., S.L. Krauss and E.J. Veneklaas. 2012. Inbreeding and outbreeding depression in *Stylidium hispidum*: Implications for mixing seed sources for ecological restoration. *Ecology and Evolution* 2:2262–2273.

Keller, M., J. Kollman and P.J. Edwards. 2000. Genetic introgression from distant provenances reduces fitness in local weed populations. *Journal of Applied Ecology* 37:647–659.

Linhart, Y.B. and M.C. Grant. 1996. Evolutionary significance of local genetic differentiation in plants. *Annual Review of Ecology and Systematics* 27:237–277.

Pickup, M., D.L. Field, D.M. Rowell and A.G. Young. 2012. Source population characteristics affect heterosis following genetic rescue of fragmented plant populations. *Proceedings of the Royal Society* 280:1–9.

Potter, K.M. and W.W. Hargrove. 2012. Determining suitable locations for seed transfer under climate change: A global quantitative method. *New Forests* 43:581–599.

Saari, C. and W. Glisson. 2012. Survey of Chicago Region restoration seed source policies. *Ecological Restoration* 30:162–165.

Waser, N.M. and M.V. Price. 1985. Reciprocal transplant experiments with *Delphinium nelsonii* (Ranunculaceae): Evidence for local adaptation. *American Journal of Botany* 72:1726–1732.