What Is Local? An Introduction to Genetics and Plant Selection in the Urban Context

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The urban landscape comprises myriad isolated green spaces inhabited by an assortment of vegetation types. To many city dwellers, these green spaces interrupt the monotony of concrete and steel and foster deep social attachment between city dwellers and nature. To a conservationist, these vegetation islands provide unique opportunities to restore ecological function to degraded areas by revegetating them with native plants. However, the restoration ecologist faces many challenges unique to the urban landscape. A significant investment in site preparation may be needed to offset the impacts of abiotic factors including compacted soil, drought, and air pollution. Seedlings that survive to maturity are not guaranteed immunity from these abiotic stresses, as is evident in the tree dieback and declines that plague many city landscapes. Abiotic factors are rarely the sole causal agent of urban tree declines since the presence of a multitude of other factors, such as insects and disease, are associated with symptoms of this decline. For example, drought in combination with insect defoliation predisposed black oak (*Quercus velutina*) to decline (Pike et al., 2001), while defoliation and several pathogens were causal agents in the decline of English oak (*Quercus robur*) (Marçais and Bréda 2006). The impacts of biotic factors on plant health may be heightened or lessened in urban areas depending on the ecology of the insect or disease. In these examples, black oaks in urban areas were more susceptible to damage from gall wasps than trees surrounded by contiguous forest. In contrast, the pathogens inciting decline in *Quercus robur* are less problematic in urban settings where soil disturbance prevent *Armillaria* fungus from spreading great distances.

Environmental stresses, to a limited extent, can be managed through site preparation. Some insects and diseases can be managed with pesticides or other integrated approaches. However, long-term sustainability of a restoration planting, beyond the generation that is planted, can only be realized if the basic requirements for reproduction of plant species are met. The consequences of reproductive failure may be immediate and obvious—for example, if seed fails to form—or delayed until subsequent generations. Processes causing reproductive failures are exacerbated, for some species, when plants are isolated from potential mates—a common occurrence in the fragmented urban environment.

Plant reproduction commences when a pollen grain unites with its female counterpart. Pollen is disseminated by a number of vectors, both biotic (such as insects) and abiotic (e.g., wind). Pollen grains from wind-pollinated plants, such as conifers, can travel long distances before landing, allowing isolated stands to remain reproductively viable even when the nearest individual is some distance away. Some plant species are self-compatible, and their reproduction does not depend on the nearby presence of an unrelated mate. Many species, however, are obligate "out-crossers," and seeds that are produced from an inbred cross are either aborted or result in plants with reduced fitness. Orchid species are obligate out-crossers and provide an interesting demonstration of the potentially damaging effects of inbreeding depression on fragmented populations (Izawa et al. 2007). If plants are dependent on local pollen sources, then it is essential that a variety of unrelated families be available to minimize the effects of inbreeding depression (see Leimu et al. 2006, for a discussion of population size and fitness for a variety of plant species).

Inbreeding depression is the reduction in fitness that occurs when related individuals mate; and it can have significant consequences for a planting's long-term reproductive success. It is most likely to occur in small or isolated plantings that lack contiguous land masses for gene flow or pollen exchange. The relatedness of seed in a given seed source (or seed lot) used in a restoration planting can vary greatly. One seed lot may contain seed bulked from a single plant, while another may contain seed collected from an assortment of plants. Understanding seed collection protocols is essential to ensure that seed from a variety of unrelated seed sources are used, which in turn may reduce the incidence of inbreeding depression for future generations of plants.

Outbreeding depression can also contribute to reduced fitness, and occurs when a local, established population crosses with introduced material of the same species (Hufford and Mazer 2003). Native plants that have survived local stresses have likely evolved traits that maximize their adaptation. Outbreeding depression occurs after the native and introduced material breed, and the offspring of these "hybrid" crosses contain a combination of adapted and non-adapted traits. Outbreeding depression may be mitigated by planting seedlings grown from seed procured from a nearby source where environmental conditions are similar to that of the planting site. The effects of outbreeding depression can take decades to be realized, since future generations are affected.

Inbreeding and outbreeding depression are not the only genetic factors to consider in optimizing the sustainability of a planting. Lynch (1991) provides a theoretical comparison of inbreeding and outbreeding effects. Rogers and Montalvo (2004) present a comprehensive discussion of the importance of biodiversity and genetics in plants and planting programs. Extrinsic factors, such as matching seed source to the planting location, also play a role in determining reproductive success. In plant species with high levels of biodiversity, such as conifers with continental-wide ranges, matching the correct seed source to a site is critical to ensure survival and reproductive longevity. Seed-transfer zones, delineated from climate, soil, elevation, and occasionally from common-garden data, can be employed to assist in matching seed to a particular geographic area. Ying and Yanchuk (2006) provide an informative summary of the history and methodology behind seed zones established in British Columbia for forestry applications. However, for many species, the distance that seed lots can be safely "moved" without risking maladaptation is not as well established. In the absence of clear seed-transfer designations, local seed sources provide the best insurance against the deployment of plants that are not suitably adapted for environmental conditions in the restoration planting.

Conservationists face a new hurdle in today's world—the emerging threat of climate change. Research on the implications of climate change for the evolution of native plants (see example in

Etterson and Shaw 2001) is a burgeoning field of study. A plant's success in a novel climate will be determined by its ability to disperse, breed, and adapt to its new surroundings (Davis et al. 2005). A plant's ability to tolerate changes in its environment, or its plasticity, is dependent on its genetics. More research is necessary to inform our understanding of plasticity and tolerance in plants, both in urban and rural landscapes. A general strategy to maximize biodiversity both within and among species will improve the chance that genes for adaptation are present in the population facing dramatic environmental changes.

Historically, plants migrated northward as temperatures rose and glaciers retreated (Davis and Shaw 2001). Plants attempting to migrate today face significant impediments that are both of human (urbanization and agriculture) and nonhuman origin (lakes and rivers). These barriers can be quickly overcome through a restoration effort. Should seed sources from southern locales be favored in northern areas over local sources given the forecasts of increasing temperature? This notion of "assisted migration" in which distant seed sources are favored over local sources in anticipation of climate change is controversial (see McLachlan et al. 2007). Restorers are faced with the need to balance risks of introducing a seed source with the potential maladaptation that might result from climate change. Weather is notoriously erratic; global mean temperatures may be rising, but day-to-day fluctuations can create stressful conditions for plants that are far removed from their origin. In addition, plants that are moved great distances also risk being out of sync with the photoperiod to which they have adapted. Finally, seed or seedlings from distant locations may introduce fungi, insects, or other "volunteers" that could be harmful to flora and fauna inhabiting the planting site. A quantitative approach relying on data from common garden trials can assist in determining appropriate seed sources for future climate scenarios. This method is demonstrated for black spruce (*Picea mariana*) in Lesser and Parker (2006). The risks associated with assisted migration may be easier to justify for plant species that face extinction in a specialized or unique population or extinction of the species as a whole.

Restoration of native plants is a costly but valuable investment across a fragmented and often degraded urban landscape. To maximize planting success in the short- and long-term, efforts should be made to incorporate the genetic infrastructure of desired plant species into restoration plans. For example, plants that tolerate inbreeding may only require a small number of individuals to reproduce successfully in the future. Other plants might benefit from the inclusion of numerous unrelated families, or additional plant species that support populations of local bees or other pollen vectors. In the absence of clear seed-transfer guides, local seed sources should be utilized to improve the likelihood that seed will be adapted to its novel environment. Climate change brings a new set of challenges to conservation planning. For plants that face extinction, radical measures may be needed to ensure their preservation. For all other plants, restoration can enhance the diversity of existing plant communities, which in turn may offset the potential for inbreeding and provide the plant community with the genetic tools needed to thrive and evolve to the changing climate. The extra steps needed to ensure the long-term sustainability of a restoration effort will provide the greatest benefit to future generations of plants and the people who treasure them.

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