A Rose Is a Rose Is a Rose... Or Is It? Ecotypes versus Locally Sourced Plants for Aquatic Habitat Restoration and Enhancement Projects

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Abstract. Horticulturists and agronomists have a long history of using selective breeding to take advantage of intraspecific (within-species) variation with the goal of developing novel varieties of plant species. These efforts are responsible for the availability of countless improved food, forage, and ornamental varieties that are valued by farmers, landscapers, and home gardeners. In contrast, little attention has been paid to the idea of evaluating intraspecific variation to identify plants derived from a specific ecosystem (ecotypes) of native species that could improve the success rate of habitat restoration and enhancement projects, especially in aquatic systems. These projects often specify that plant material used for restoration be collected from local donor sites to preserve the area's gene pool, but nearby source populations may be nonexistent or may not be well-adapted to conditions at the recipient (transplant) site. This paper, which summarizes information presented at the American Society for Horticultural Science Invasive Plants Research Professional Interest Group workshop in 2022, provides evidence that unimproved, wild-type species can be useful in aquatic habitat restoration and enhancement projects, particularly when conditions at sites targeted for restoration differ from those in nearby systems, or when sites are expected to undergo shifts in conditions because of factors such as climate change.

We typically think of naturally occurring, wild-type species (i.e., plants that are unimproved by humans) as being mostly homogeneous, with populations comprising individuals that are extremely similar to one another. However, significant intraspecific variation often exists within a species' gene pool (Hufford and Mazer 2003). For example, Osuna-Mascaró et al. (2023) evaluated geographically discrete populations of bunchgrass (*Achnatherum thurberianum*) and found that environmental variables drove local adaptation in groups of plants derived from a specific ecosystem (ecotypes). Humans have long used selective breeding to exploit this intraspecific variation to develop novel varieties of improved food, forage, dyes, and ornamental plants. For example, fruit and nut crops that are native to North America and have been improved through selective breeding include American elderberry (*Sambucus canadensis*), black raspberry (*Rubus occidentalis*), highbush blueberry (*Vaccinium corymbosum*), cranberry (*Vaccinium macrocarpon*), pecan (*Carya illinoinensis*), and others. Varieties are available for native trees and shrubs such as eastern redbud (*Cercis canadensis*), flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), and southern magnolia (*Magnolia grandiflora*), and for ornamental herbaceous plants including common sunflower (*Helianthus annuus*), purple coneflower (*Echinacea purpurea*), Stokes aster (*Stokesia laevis*), and many others.

It is clear that intraspecific variation provides the building blocks needed to develop superior plant varieties that make our world more productive and beautiful. In contrast, little attention has been paid to the idea of screening discrete, geographically separated populations of native species to identify ecotypes with desirable traits that occur as a result of intraspecific variation. Although this strategy can be useful in a number of circumstances, it is especially important in situations in which there is little direct financial reward for developing or identifying plants with "superior" characteristics. For example, a goal of many variety development programs is to produce plant material that will be sold on the open market, where a premium is often associated with new types of a particular species that offer specific traits (e.g., more attractive flowers or foliage, higher yield, or improved disease resistance). However, plant selection is nearly an afterthought in many aquatic habitat restoration and enhancement projects, which often rely on field-collected donor plant material that is constrained only by species (Hayes E, personal communication).

Aquatic habitat restoration and enhancement projects typically specify that plant material used for restoration should be collected from local donor sites to preserve the area's gene pool (Furse B, personal communication). In addition to "genetic purity," many project managers believe that provenance is the primary driver that influences plant establishment; that is, that locally sourced donor plant material will be well-adapted to conditions at nearby recipient transplant sites. This premise is supported by Smart and Dick (1999) and Dick et al. (2005), who reported that locally grown (or collected) native species should be used in revegetation projects because these "local" ecotypes are often adapted to specific geographic regions. This may be true in some donor-recipient situations, but in many cases, nearby source populations may be nonexistent or not well-adapted to the recipient site. There are a number of explanations for the dearth of appropriate plant material available for use in aquatic habitat restoration and enhancement projects. For

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
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example, local populations of a particular species may not be available because of proximity (in other words, the recipient site may be geographically isolated and thus located a significant distance from potential donor sites that host the same species). Perhaps there are nearby sites that historically hosted populations of the desired species, but those former populations have been destroyed due to anthropogenic events (e.g., development, pesticide and/or heavy metal contamination, herbicide usage, or nutrient loading from fertilizer runoff or septic tanks) or nonanthropogenic events (e.g., saltwater intrusion, substrate scouring, or predation by herbivores). In another scenario, nearby donor sites may currently host populations of the desired species, but despite geographic proximity, conditions such as substrate composition, salinity level, and trophic state (nutrient load) differ greatly between donor and recipient sites, resulting in poor establishment of transplanted material (Bakker et al. 2013; Reynolds et al. 2021).

Specific sites are targeted for restoration for a variety of reasons, but most aquatic projects are designed to mitigate a damaged or disturbed water body and restore it to its former condition, which typically included hosting a variety of native plants that provided habitat and food for aquatic fauna such as turtles and fish (Hayes E, personal communication). A number of systems that are targeted for restoration have conditions that are less than ideal—or even "hostile"—to some native plant species (Dick et al. 2005; Kupsky and Dornbush 2019; Smart and Dick 1999). For example, many recipient sites have substrates that are rich in nutrients and organic material, but most native aquatic plants prefer nutrient-poor, sandy substrates. Some recipient sites are experiencing saltwater intrusion because of rising sea levels, but most freshwater aquatic plants are intolerant of salinity. As reported by Johnson et al. (2023), propagule sources such as seed zones that are based on adaptative traits are not available for most species used in restoration projects. However, van Andel (1998) stated that including nonlocal plant material in restoration projects could be useful if nearby populations of desirable species are lacking. Therefore, a lack of locally sourced plant material from a donor site with conditions similar to the recipient site should not stand in the way of aquatic habitat restoration and enhancement. As mentioned previously, plant selection for these projects is usually limited to stating which species is to be used, so there is little market for varieties and therefore little incentive to engage in breeding efforts to develop improved varieties of aquatic plants. However, unimproved ecotypes of native species can be useful in aquatic habitat restoration and enhancement projects, particularly when conditions at sites targeted for restoration differ from those in nearby systems, or when sites are expected to undergo shifts in conditions because of factors such as climate change (Reynolds et al. 2021; van Andel 1998).

Leger et al. (2020) reported that screening seeds from multiple local ecotypes of native plants was useful for rapidly identifying and selecting source populations with desirable or adaptive traits that could be beneficial in restoration projects. One way to identify unimproved ecotypes that have desirable characteristics is to collect plants from discrete ecosystems and evaluate them under common nursery conditions. Common nursery trials typically involve growing plants under a variety of conditions based on what challenges are present at transplant sites. Johnson et al. (2023) used common nursery studies to evaluate 17 different traits in 69 populations of sulfur-flower buckwheat (*Eriogonum umbellatum*) and reported that climate-driven adaptive evolution appeared to occur among the populations. For example, locations with warmer temperatures and greater rainfall hosted ecotypes with larger leaves and flowers, greater seed production, and higher shoot dry weights.

Similar studies have been undertaken for eelgrass (*Vallisneria americana*), a native submersed aquatic plant that is used extensively in habitat restoration and enhancement projects in Florida, USA. This species accumulates the greatest amount of biomass when grown in sandy substrates (McFarland and Shafer 2008) and low-fertility conditions (Anderson and Kalff 1986), but areas targeted for restoration often have substrates that are rich in organic matter and nutrients. Gettys and Haller (2013) grew eight ecotypes of eelgrass in five substrates that ranged from pure sand (no organic matter) to pure peat (100% organic matter) and were amended with one of four fertilizer rates, with the goal of identifying ecotypes that would be likely to perform well in transplant sites with less than ideal conditions for eelgrass establishment. They reported that ecotypes responded differently to the treatments and identified ecotypes that were broadly adapted, which could be useful in restoration projects.

Another method to identify unimproved ecotypes with desirable characteristics is by subjecting ecotypes to a range of concentrations of a particular stressor. For example, saltwater intrusion and increased salinity are becoming more problematic for freshwater aquatic systems, particularly in coastal Florida (Xiao and Tang 2019). In addition to affecting human uses of water (e.g., irrigation, drinking), saltwater intrusion can disrupt aquatic plant community compositions and could cause a shift from predominantly native flora to mostly invasive species (Tootoonchi et al. 2022). Native freshwater ecotypes that are tolerant of high salinity would be valuable inclusions in restoration of aquatic systems that are likely to experience saltwater intrusion and would provide built-in resiliency against salt stress. To address this issue, Tootoonchi et al. (2020) grew 24 ecotypes of eelgrass in water with salinity that ranged from 2 parts per thousand (ppt) to 20 ppt for 5 weeks. They identified several ecotypes that tolerated moderate (10 ppt) to high (15 ppt) salinity, which could be useful in aquatic restoration projects that are located in areas where saltwater intrusion occurred.

Based on the examples outlined previously, it is clear that screening unimproved ecotypes of native species could provide solutions for aquatic restoration projects. Traditional breeding programs are designed to develop new plant varieties with desirable traits and have markets that are ready and willing to buy them, thus providing a financial incentive to undertake such activities. In contrast, most aquatic habitat restoration and enhancement projects only list a particular species that should be included in the project. Although there is little or no direct financial benefit to identifying ecotypes of native species that grow under conditions that are less than ideal, using ecotypes that perform well under suboptimal conditions will ultimately result in greater plant establishment and increased success of aquatic habitat restoration and enhancement projects. These factors reduce costs in the long run (because re-planting is less likely to be needed) and result in viable, resilient ecosystems with native plants that are well-adapted to current and future conditions.

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