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The Importance of Phenological Diversity in Seed Mixes for Pollinator Restoration

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ABSTRACT: Restoration projects that support pollinators are becoming increasingly popular. Pollinating insects require resources, including nectar and pollen, throughout the growing season. However, commercially available seed mixes vary considerably in their phenological diversity, as well as in the diversity of species and plant families included, and in their forb:grass ratio (by seed count). Each of these is important for the support of a diverse pollinator community. We examined several commercial mixes to determine if they met our criteria for optimal pollinator support. Most mixes did not contain many, if any, species that bloom in the spring. Suggestions on additional plant species to include in upper Midwest pollinator restorations seed mixes to extend the season of bloom are provided. Although our recommendations are regionally focused, these principles could be extended to any plant community.

Index terms: phenological diversity, pollinator conservation, restoration seed mixes

BACKGROUND

Pollinator declines are widespread and documented around the world (Potts et al. 2010). Because of the recognition that bees in particular are critical for their pollination services in agricultural systems, many have called for the restoration of natural landscapes to support both honey bees and native bees, including the recently released *National Strategy to Promote the Health of Honey Bees and Other Pollinators* (Pollinator Health Task Force 2015), and the *National Seed Strategy* (Plant Conservation Alliance 2015). Several studies have demonstrated the utility of native plant borders around orchards and agricultural fields in improving crop pollination success (Russo et al. 2013; Woodcock et al. 2014; Orford et al. 2016), and pollinator gardens are increasing in popularity in home and corporate landscapes. Some departments of transportation are reconsidering their mowing schedules in order to minimize damage to road verge plants used by pollinators. They are also considering the use of pollinator friendly seed mixes for roadside plantings.

Also gaining momentum in recent years is concern for the monarch butterfly and its migration across North America. The monarch is a charismatic species that has been declining very rapidly. This is due in part to the loss of the milkweed (*Asclepias*) species required for larval development and to declines in nectar sources needed to fuel its long migration (Brower et al. 2012), coincident with an increase in use of glyphosate herbicide (Pleasants and Oberhauser 2012). Plans to restore milkweed corridors throughout monarch breeding grounds are underway across the United States. Taken together, the groundswell of enthusiasm for pollinator restoration is impressive and it is incumbent on us, the restoration community, to do it well. Whether they are pollinator gardens, highway corridors, supplemental seeding of a prairie remnant, or restoration of an old field, we need to design species mixes that are effective for pollinator support.

Pollinating insects, including bees, butterflies, and moths, rely on a diversity of plant and floral resources (i.e., nectar and pollen) throughout their life cycle. Depending on the bee species, either the overwintering queens (in *Bombus*) or new adults (in solitary bees) emerge in the spring. These emerging bees need early-flowering plants within the flight range of their nesting habitat, which can vary based on bee species (Greenleaf et al. 2007). Floral resources are needed both for adult bees to feed upon, and to provide provisions of pollen and nectar for their offspring. For lepidopterans (butterflies and moths), plant requirements vary across their lifecycle, and include specific egg laying substrates, overwintering sites, and larval food plants. Often, larvae may have specific host species that they need for development, whereas adults are often more generalized in their nectar requirements. Ensuring that both host plants and nectar resources are present within a community is important to maintaining a robust presence of lepidopterans (Scheper et al. 2014; Baude et al. 2016).

Indeed, insect diversity is correlated with plant species diversity in a variety of ecosystems, and declines in plant and insect diversity often occur in parallel (Biesmeijer et al. 2006; Ghazoul 2006; Carvalheiro et al. 2010). Fragment size and proximity to a range of floral or nesting resources in an urban matrix may also play a role in overall insect diversity. This is particularly true of specialist species when resources become limiting in small, isolated fragments (Cane et al. 2006). Because graminoids and wind pollinated woody taxa provide few resources for pollinators, a high forb:grass ratio can be indicative of a plant community providing good pollinator support. But the incidence of high plant diversity, or even the "right" plant diversity (i.e., a high diversity of forbs), may or may not be sufficient to support a varied pollinator community. It is very important to have floral resources available throughout the growing season. In other words, phenological diversity may be as important, or more important, than species diversity. For example, a study of floral resource availability and pollinator diversity in restored landfill sites versus reference grassland sites in the UK showed that the seasonal abundance of floral resources varied between restored and naturally occurring sites. Reference sites contained greater plant species richness in the spring while restored sites had greater plant species richness in the autumn (Tarrant et al. 2013). Correlated with this pattern, Tarrant et al. (2013) found that restored sites supported fewer spring floral visitors, but greater autumn floral visitors. Similarly, in a recent paper, Salisbury et al. (2015) found that gardens in the UK that contained both native and nonnative species supported more pollinators, and cited greater phenological diversity as one reason for the increase. However, greater phenological diversity can be accomplished using solely native species if planned judiciously.

Plant communities may have times in the growing season when many species are in bloom, and other times when few species are in bloom. For instance, in midwestern prairies there is a "green lull" in early summer when few species bloom (Anderson 1995) as the early spring taxa have completed flowering, and the late summer taxa have yet to bloom. This pattern may be exacerbated by climate change, which tends to cause greater phenological shifts in early flowering species (Hegland et al. 2009). Plant species that bloom during the green lull may be a critical resource for the support of pollinators and, therefore, have a higher importance value than might otherwise be suggested. For instance, two of the rare species that we study, *Cirsium pitcheri* (Torr. ex Eaton) Torr. & A. Gray and *Platanthera praeclara* Sheviak & Bowles, begin blooming in mid-June. There are few other forbs in flower when they are at peak bloom. For *C. pitcheri*, a species found on the sand dunes of the western Great Lakes, there are often no other forbs flowering on the dunes during the 2–3 weeks of its peak bloom (Havens and Vitt, unpub. data). Both plant species are visited by scores of insect species, likely because they provide nectar and pollen at a time of year when there are few other options (Havens and Vitt, unpub. data).

This observation motivated us to consider whether or not pollinator restoration seed mixes include species that span the growing season. In some locations, restored sites may provide nearly twice the floral resources overall because of their greater area relative to naturally occurring or remnant sites (Tarrant et al. 2013), thus increasing the importance of phenological diversity in restored sites. Although others have also stressed the importance of phenological diversity for pollinators (e.g., Tilley et al. 2013), here we specifically ask if those recommendations have been implemented by the seed industry. Because the richness of insect diversity is closely linked to the diversity of the floral resources on which they depend (Potts et al. 2003; Steffan-Dewenter 2003; Hegland and Boeke 2006; Cusser and Goodell 2013), ensuring the phenological diversity of seed mixes is critically important to supporting robust populations of pollinating insects.

COMPOSITION OF POLLINATOR SEED MIXES: A CASE STUDY

Habitat or landscape scale phenological diversity of managed habitats may be constrained or altered by our choices of seed mixes. We conducted an internet search for seed mixes recommended for use in Illinois for pollinator conservation, either specifically labeled as CP42 compliant (meeting the USDA standards for Pollinator Habitat under the Conservation Reserve Program) or recommended by the Xerces Society. Several mixes were offered by multiple vendors so we restricted the sample to unique mixes. We identified 11 seed mixes that met our criteria and determined their species and family diversity, forb:grass ratio, and the flowering phenology of forb species included in each mix. We also indicated what resources each plant species provided and what insects utilized each plant. Our results are shown in Table 1 and Appendix (refer to BioOne to view online).

General seed mixes for prairie restoration often contain more grasses than forbs, in part because many grasses are easier to produce, making grass-dominated mixes less expensive. Recommendations on the forb:grass ratio for pollinator support are varied, but in the sources we examined they were typically 2:1 or 3:1 forbs to grasses, respectively (e.g., Natural Resources Conservation Service recommends no more than 25% grasses; National Park Service, 40% grasses). As expected, most of the pollinator seed mixes provided a greater number of forbs and a higher forb:grass ratio than those available for general prairie/grassland restoration. However, a few seed mixes provided a forb:grass ratio lower than that typically recommended for pollinator support (Table 1). Additionally, very few pollinator seed mixes included forbs that bloom throughout the growing season, and most were dominated by late-season bloomers. We found that spring flowering species were either few, or missing altogether.

There are many bee species that are active early in the year, particularly *Bombus* queens, *Osmia* spp., and Adrenids (Appendix – refer to BioOne to view online). The mixes we looked at would do little to support these bee species. We need to make a greater effort to include more spring flowering species into seed mixes. This might entail adding, if appropriate for the site, native woody taxa such as *Amelanchier*, *Acer, Cercis, Salix,* and *Cornus* spp. that are known to provide early season pollinator resources. We provide some suggestions for forb taxa suitable for Illinois and the upper Midwest in Table 2.

Table 1. An overview of the species diversity, forb:grass ratio, family diversity, and bloom season coverage of 11 seed mixes recommended for pollinator conservation use in Illinois (x-axis is month, y-axis is # taxa blooming). Several of the mixes are offered by multiple vendors. Taxonomy follows USDA Plants database. Family abbreviations: Acan = Acanthaceae, Api = Apiaceae, Asc = Asclepiadaceae, Aster = Asteraceae, Camp = Campanulaceae, Clus = Clusiaceae, Comm = Commelinaceae, Fab = Fabaceae, Lam = Lamiaceae, Lil = Liliaceae, Lyth = Lythraceae, Onag = Onagraceae, Ranunc = Ranunculaceae, Ros = Rosaceae, Scroph = Scrophulariaceae, Verb = Verbenaceae.

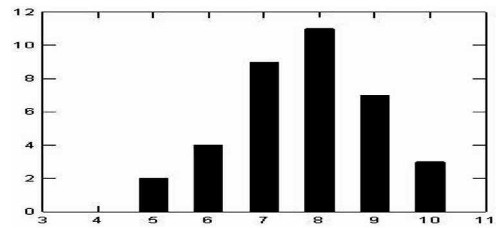
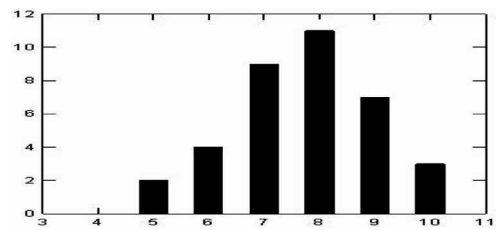
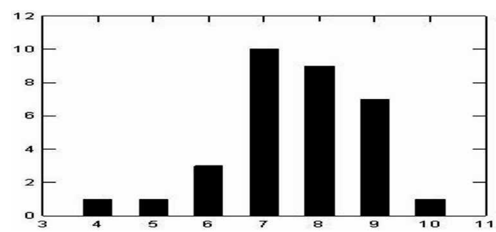
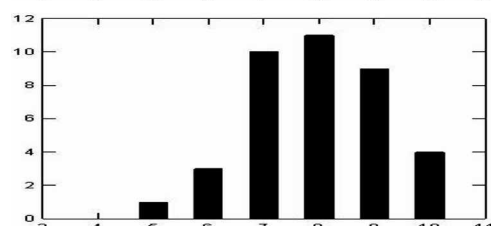
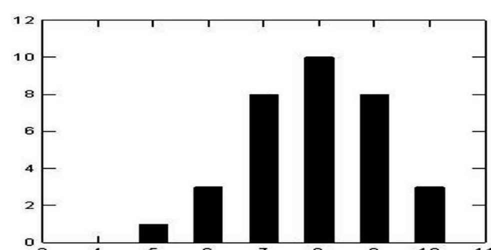
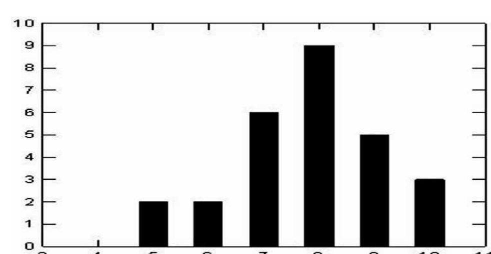
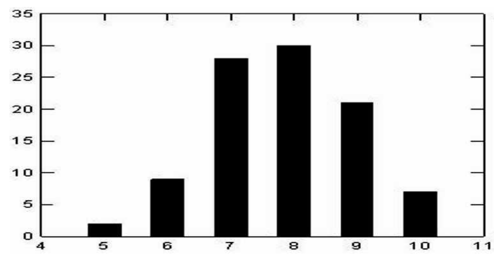
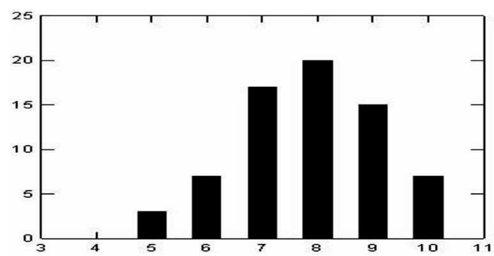
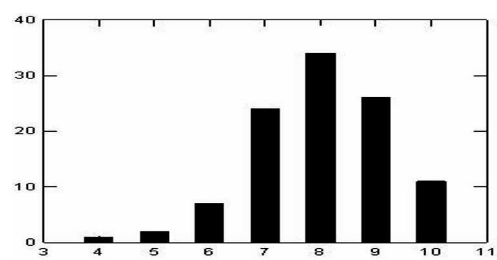
Seed Mix	Number of Species	Forb:Grass Ratio (percentages by seed count)	# Species in Each Form Family in Mix	
IL CP42 Mesic Pollinator Mix	13 forbs/5 grasses	60:40:00	Api. – 1 Asc. – 1 Aster. – 5 Comm. – 1 Fab. – 2 Lam. – 2 Scroph. – 2	
IL CP42 Dry-Mesic Pollinator Mix	13 forbs/5 grasses	60:40:00	Api. – 1 Asc. – 1 Aster. – 4 Comm. – 1 Fab. – 3 Lam. – 1 Scroph. – 2	
IL CP42 Wet-Mesic Pollinator Mix	12 forbs/5 grasses	50:50:00	Aster. – 5 Fab. –3 Lam. – 1 Lyth. – 1 Ranunc. – 1 Scroph. – 1	
IL Pollinator Mesic Mix	13 forbs/3 grasses	80:20:00	Asc. – 1 Aster. – 4 Comm. – 1 Fab. – 3 Lam. – 2 Scroph. – 2	
IL Pollinator Dry Mix	12 forbs/3 grasses	75:25:00	Asc. – 1 Aster. – 2 Comm. – 1 Fab. – 3 Lam. – 2 Scroph. – 2 Verb. – 1	
IL Pollinator Wet Mix	11 forbs/3 grasses	45:55:00	Api. – 1 Asc. – 1 Aster. – 4 Comm. – 1 Camp. – 1 Scroph. – 2 Verb. – 1	

Table 1 (*Continued*). An overview of the species diversity, forb:grass ratio, family diversity, and bloom season coverage of 11 seed mixes recommended for pollinator conservation use in Illinois (x-axis is month, y-axis is # taxa blooming). Several of the mixes are offered by multiple vendors. Taxonomy follows USDA Plants database. Family abbreviations: Acan = Acanthaceae, Api = Apiaceae, Asc = Asclepiadaceae, Aster = Asteraceae, Camp = Campanulaceae, Clus = Clusiaceae, Comm = Commelinaceae, Fab = Fabaceae, Lam = Lamiaceae, Lil = Liliaceae, Lyth = Lythraceae, Onag = Onagraceae, Ranunc = Ranunculaceae, Ros = Rosaceae, Scroph = Scrophulariaceae, Verb = Verbenaceae.

Seed Mix	**Number of Species**	**Forb:Grass Ratio (percentages by seed count)**	**# Species in Each Form Family in Mix**
IL Pollinator Plus Mix	35 forbs/3 grasses	83:17:00	Api. – 2 Asc. – 2 Aster. – 14 Comm. – 1 Fab. – 9 Lam. – 2 Lil. – 1 Ros. – 1 Scroph. – 2 Verb. – 1
Midwest Mesic Pollinator Mix	24 forbs/3 grasses	66:44:00	Api. – 1 Asc. – 2 Aster. – 10 Comm. – 1 Fab. – 5 Lam. – 3 Scroph. – 1 Verb. – 1
Pollinator-Palooza Mix	40 forbs (incl. 1 shrub)/6 grasses	45:55:00	Api. – 2 Asc. – 3 Aster. – 18 Camp. – 1 Clus. – 1 Comm. – 1 Fab. – 4 Lam. – 4 Lil. – 1 Onag. – 1 Scroph. – 3 Verb. – 1
Western Great Lakes Mesic Mix	31 forbs/4 grasses	Not given	Api. – 2 Asc. – 2 Aster. – 17 Comm. – 1 Fab. – 3 Lam. – 2 Lil. – 1 Scroph. – 2 Verb. – 1







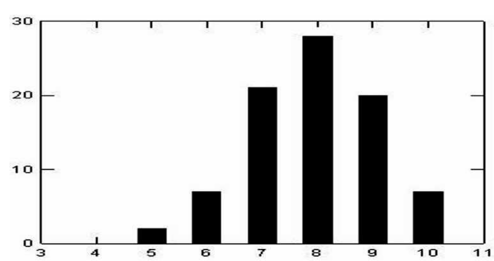
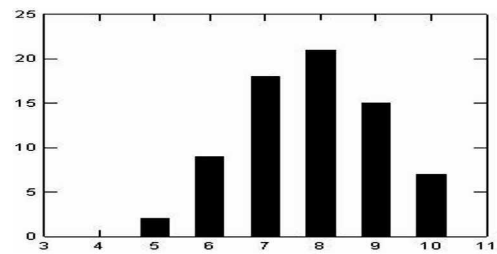


Table 1 (*Continued*). An overview of the species diversity, forb:grass ratio, family diversity, and bloom season coverage of 11 seed mixes recommended for pollinator conservation use in Illinois (x-axis is month, y-axis is # taxa blooming). Several of the mixes are offered by multiple vendors. Taxonomy follows USDA Plants database. Family abbreviations: Acan = Acanthaceae, Api = Apiaceae, Asc = Asclepiadaceae, Aster = Asteraceae, Camp = Campanulaceae, Clus = Clusiaceae, Comm = Commelinaceae, Fab = Fabaceae, Lam = Lamiaceae, Lil = Liliaceae, Lyth = Lythraceae, Onag = Onagraceae, Ranunc = Ranunculaceae, Ros = Rosaceae, Scroph = Scrophulariaceae, Verb = Verbenaceae.

Seed Mix	Number of Species	Forb:Grass Ratio (percentages by seed count)	# Species in Each Form Family in Mix
Western Great Lakes Dry Mix	24 forbs/5 grasses	Not given	Acan. – 1 Asc. – 2 Aster. – 10 Comm. – 1 Fab. – 5 Lam. – 3 Scroph. – 1 Verb. – 1



CONCLUSIONS

Local and regional efforts to reverse pollinator decline by garden groups, federal and state agencies, farmers of insect-pollinated crops, and other stakeholders are heartening and we applaud these efforts. However, these efforts largely support common species of insect pollinators, and those that are able to adapt to the intensive agricultural landscape. Species that are rare, or don't fare well in an agricultural matrix, may become increasingly imperiled if conservation efforts are focused solely on crop pollination services (Kleijn et al. 2014). Restoration of natural habitats focused on native pollinators may bridge this gap.

In general, if native pollinator conservation is a goal, restorationists should strive for using a native seed mix with both high species and phenological diversity, and a large percentage of forbs. Unfortunately, several of the seed mixes marketed as "good for pollinators" that are available for purchase online (which did not include those marketed as CP42 compliant or are recommended by the Xerces Society) contain a high percentage of nonnative species, including some that can be invasive (e.g.,

Table 2. Early spring and spring flowering forbs that could extend the phenological diversity of grassland seed mixes for pollinator conservation in Illinois and adjacent states. "Availability in trade" categories: good (multiple vendors in upper Midwest); fair (at least one regional vendor); or poor (no regional vendors found).

Species	Bloom Time in Illinois	Availability in Trade
Antennaria neglecta Greene	April	Good
Camassia scilloides (Raf.) Cory	May-June	Good
Castilleja coccinea (L.) Spreng.	April-August	Good
Comandra umbellata (L.) Nutt.	April-June	Fair
Dodecatheon meadia L.	April-June	Good
Geum triflorum Pursh.	May	Good
Hypoxis hirsuta (L.) Coville	May-June	Fair
Lithospermum canescens (Michx.) Lehm.	April-June	Fair
Packera aurea (L.) Á. Löve & D. Löve *P. plattensis* (Nutt.) W.A. Weber & Á. Löve *(Senecio)*	May	*P. aurea* – Good *P. plattensis* - Fair
Phlox bifida Beck, *P. pilosa* L.	April - June	Good for both
Pulsatilla patens (L.) Mill. *(Anemone)*	April-May	Good
Sisyrinchium albidum Raf., *S. campestre* E.P. Bicknell	April-June	Good for both
Viola pedata L., *V. pedatifida* G. Don	April-July	Good for both

Melilotus alba (L.) Lam., *Lotus corniculatus* L.), meaning that consumers need to be cautious. We maintain that phenologically diverse communities should be restored using only native species to preclude the risk of introducing taxa that could potentially become invasive. Purchasing or creating mixes with high forb diversity costs more initially, but the payoff will be in restorations that not only support insect diversity, but also other animals and ecosystem services (Wratten et al. 2012).

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Appendix. (Overview below - refer to BioOne online for complete appendix)

Phenology of bee groups and plant species represented in seed mixes in Illinois. For the bee groups, x's indicate bees are active and P's indicate month of peak activity (data extracted from Roberston, 1895 from Carlinville, IL). For plants, x's indicate bloom period in Illinois (phenology data from Swink and Wilhelm, 1994). For the five species not found in Swink and Wilhelm, phenology information was obtained from other resources. The next column indicates the number of seed mixes that contained the species, out of 11 mixes total. All mixes were recommended for pollinator conservation use in Illinois (either CP42 compliant or recommended by the Xerces Society). Taxonomy follows USDA Plants database. Synonyms are indicated in parentheses if alternate names were used in seed catalogs.

The information on flower color, resources provided (N = nectar; P = pollen), and pollinators supported was extracted from Illinois Wildflowers (http://www.illinoiswildflowers.info/index.htm), a compendium of the flora of the state of Illinois, with descriptions of each taxon, its habitat and cultivation, faunal associations and conservation value. Visitor categories assigned by us based upon the spectrum of floral visitors associated with each species. G = Generalist pollinator, usually indicating that visitors are primarily bee species, possibly only short-tongued species (a tongue shorter than ~5.5 mm) or long-tongued (a tongue longer than 5.5 mm is a long-tongued bee), but not frequented by a broad suite of visitors. BG = Broad Generalist, which is generally visited by both long- and short-tongued bees of several genera, syrphid and other flies, wasps, butterflies, and skippers and includes species that may occasionally be visited by hummingbirds. One species was designated at a Narrow Generalist (NG) because it is known to support only a few species of *Bombus*. S = Specialists, which is used to indicate when a plant taxon has a specialist visitor or pollinator (oligolege), which is solely dependent upon the resources of this or closely related taxa in the same genus.