2018. Proceedings of the Indiana Academy of Science 127(2):115–123

EFFECT OF NATIVE AND NON-NATIVE PLANTINGS IN URBAN PARKING LOT ISLANDS ON DIVERSITY AND ABUNDANCE OF BIRDS, ARTHROPODS, AND FLOWER VISITORS

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ABSTRACT. Redesigning urban landscapes so that they better support biodiversity has the potential to reduce well-documented losses of pollinators and birds. This study tested whether small-scale native and non-native ornamental urban plantings affect either arthropod or bird diversity. Birds, floral visitors, and arthropod diversity were monitored in six parking lot islands landscaped with native plants and six parking lot islands with non-native ornamental plantings on the Indiana University South Bend campus located in South Bend, St. Joseph County, Indiana. Higher bird species richness and four times higher bird abundance was observed in parking lot islands with native plantings compared to non-native plantings. Abundance of flower visitors was significantly higher in native areas compared to non-native areas. There was no significant difference in arthropod order richness between the two types of parking lot islands. However, arthropod abundance was significantly higher in native plantings compared to non-native ornamental plantings. Overall, including native plants in small-scale landscaping increases biodiversity by supporting higher abundances of arthropods, flower visitors, and birds.

Keywords: Native plants, non-native plants, biodiversity, arthropods, birds, urban landscapes

INTRODUCTION

The amount of area covered with non-native turf grasses used in lawns is estimated to be 163,812 km^2 ($\pm$ 35,850 km^2) – an area three times larger than any irrigated crop in the United States (Milesi et al. 2005). In addition to non-native turf grasses, non-native plant species are commonly used in urban landscaping and urban sprawl favors the spread of non-native plant species (Concepción et al. 2016). Habitats with few native plants are associated with a decrease in native herbivore species, lower insect abundance, and reduced diversity and abundance of native bird species (Burghardt et al. 2009; Helden et al. 2012; Concepción et al. 2016). Over large spatial scales, urban landscapes are associated with homogenization and an increase in generalist insect and bird species (Aronson et al. 2014; Thomas 2016; Jokimaki et al. 2018). Although urbanization is generally thought to contribute to loss of biodiversity and increased homogeneity of communities, studies done at different spatial scales show mixed effects on biodiversity (Murthy et al. 2016; Jokimaki et al. 2018). Bird diversity at a local scale (level of trees) and landscape scale has been compared and both were important in determining bird distribution in urban areas (Melles et al. 2003). At intermediate to large spatial scales, species richness can increase with human population density due to heterogeneous landscapes that promote diversity (Murthy et al. 2016). For example, higher biodiversity and better connectivity between patches can occur in areas that mix vegetation present in residential (gardens, yards, street spaces) and non-residential (parks and other green space) areas (Smith et al. 2014). There is also evidence that structural complexity (the vertical distribution of vegetation) in a community is more important towards increasing bird diversity and abundance compared to plant species composition (Atauri & de Lucio 2001; Tews et al. 2004). Determining how biodiversity is affected at different scales (local patches, habitat, landscape, and global levels) is of theoretical interest in identifying factors that have the greatest effects on biodiversity and has practical interest in designing urban landscapes that support biodiversity and ecosystem function.

Specificity of plant-insect interactions is one factor that can contribute to small spatial scale effects on biodiversity. Approximately 90% of all insect herbivores can only reproduce and survive on plant lineages with which the insects have a shared evolutionary history (Southwood et al.

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1982). This specialization can be extreme with over 50% of 64 hemipteran species tested showing preference for wild-propagated plants over cultivars of the same species (Poythress & Affolter 2018). Even generalist insects that should be able to survive on a broad range of plant hosts have poor survival on non-native plant species (Tallamy et al. 2010). Therefore, areas dominated by non-native plant species will likely differ in arthropod abundance and diversity compared to areas with primarily native plants. In addition, indirect factors, such as competition between native and non-native plant species, can reduce the visitation rates of floral visitors to native plants, resulting in lowered reproductive success for native plants (Stubbs et al. 2007).

Since birds rear about 96% of their young on insect protein or use insect protein as food sources during different seasons, changes in insect abundance and diversity may also affect bird abundance and diversity (Dickinson 1999). For instance, insectivore bird species have been shown to decline with increasing urbanization while omnivore bird species increase in abundance (Burghardt et al. 2009; Helden et al. 2012; Strohbach et al. 2013). These studies compared insect and bird diversity in areas with mostly native plants or mostly non-native plants separated by more than 1.5 km or compared insects and birds associated with native and non-native trees. The objective of our study was to test whether there were differences in arthropod and bird diversity and abundance in small-scale urban plantings using either native plants or non-native ornamental plants that are located in parking lot islands.

We hypothesized that due to the evolutionary history of plant-insect interactions, native plants would support more arthropods and attract more birds due to greater food resources. An alternative hypothesis is that areas with similar vegetation structure would attract and support similar bird diversity and abundance. To test these hypotheses, richness and abundance of arthropods, floral visitors, and birds were compared in parking lot islands that were similar in number of trees (thus similar vertical vegetation structure), but were planted with either non-native ornamental plants or plants native to the midwestern United States over three months.

METHODS

Site description.—Indiana University South Bend is an urban campus located along the St. Joseph River in South Bend, Indiana, population approximately 100,000. New parking lot islands were constructed as rain gardens and landscaped with plants native to Midwestern prairies and savannas in 2012 when the Education and Arts building was renovated. Older parking lot islands have traditional landscaping dominated by non-native ornamental plants and small native trees (cultivars of *Amelanchier* sp. and *Crataegus* sp.). In 2015, we selected six parking lot islands with non-native ornamental plants (defined as plant species not present in the area before European settlers) and six parking lot islands with mostly native plantings (defined as plant species that have historically occurred in the region; Fig. 1). Parking islands with traditional landscaping (referred to as non-native areas) were dominated by non-native plants and native plant parking lot islands (referred to as native areas) were dominated by native plant species (Table 1). To make the area sampled in native and non-native plots more similar, five of the non-native plots were two adjacent islands (Figure 1). None of the sites contained bird feeders, water sources, or other structures that could affect arthropod and bird abundance.

Traffic was low due to summer hours, and was the same across the parking lot. Number of trees per site was counted, and the amount of herbaceous plant cover, plant species present, and average plant height was estimated using 1 m^2 quadrats. A transect tape was laid through the parking lot island and a stratified random design was used so that quadrats were sampled randomly within each 5 m section. The average distance between the native and non-native parking lot islands was 12.5 $\pm$ 8.08 meters, and the average ($\pm$ standard deviation) size of native areas at 157 $\pm$ 81.1 m^2 compared to 28 $\pm$ 11.6 m^2 in non-native areas (see Fig. 1). Percent plant cover was estimated using the Daubenmire scale ($<$ 5%, 5–25%, 25–50%, 50–75%, 75–95%, and $>$ 95%), and the midpoint values were used for calculations (Elzinga et al. 1998). Percent cover was calculated per plant species and due to overlapping of individuals, plant cover could exceed 100%.

Arthropods.—Arthropods were collected from each site using 355 mL (12 oz) yellow solo bowls as pan traps. Pan traps were filled with water and a drop of dawn dish soap. Three bowls were placed randomly within each site once per week, weather permitting, from

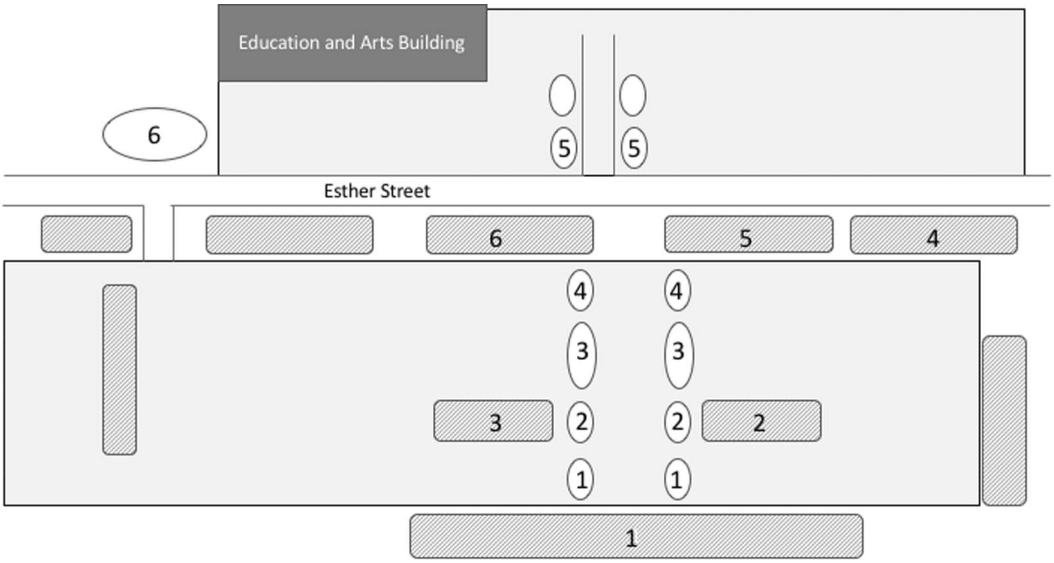

Figure 1.—Parking lot islands landscaped with either native or non-native plant species on the Indiana University South Bend Campus (EA = Education and Arts Building). Parking lot islands with native plants are shown in shaded rectangles (numbered 1–6) and parking lot islands with non-native ornamental plants shown in solid circles (numbered 1–6). Drawing shows location of plots, but is not drawn to scale.

June–August 2015 for a total of 11 days of sampling. All sites were sampled on the same days and bowls were left out for the same amount of time on each sampling date (16–18 hr). Arthropods were identified to order (Milne & Milne 1995) and abundance was recorded.

Floral visitors.—Floral visitors were collected from each site using 104 mL (3.5 oz) solo cups following protocols from Ksiazek et al. (2014). These cups were painted with Krylon Fluorescent Lemon Yellow paint to attract floral visitors, and each cup was filled with water and a drop of dawn dish soap to trap visitors (Ksiazek et al. 2014). Cups were left out for 24 hr and were placed on the ground 5 m apart from one another. Only Hymenoptera (bee and wasp) abundance was counted. Due to the difference in area among parking lot islands, there were more cups in the native areas; therefore, results are reported as average number of individuals per cup. Floral visitors were sampled only once per month, on days with no rain, for July and August to reduce risk of depleting their populations. As with arthro-

Table 1.—Vegetation characteristics for parking lot islands landscaped with native plants or non-native plants (sd = standard deviation, ns = not significantly different). Asterisk (*) indicates significant difference between parking lot island types.

Vegetative characteristics	Native plant areas (mean ± sd) n = 6 sites	Non-native plant areas (mean ± sd) n = 6 sites	Statistics
Total plant cover per m^2 (%)	148.1 ± 0.1*	107.5 ± 0.1	T = 4.5, df = 10, $P < 0.001$
Native cover (%)	106.7 ± 0.1*	18.9 ± 0.1	T = 7.5, df = 10, $P < 0.001$
Non-native cover (%)	41.3 ± 0.2	88.5 ± 0.1	
Number of plant species			
Native	20.8 ± 3.7*	2.0 ± 0. 9	T = 6.6, df = 10, $P < 0.001$
Non-native	6.6 ± 2.7	3.8 ± 1.8	T = 1.7, df = 10, $P = 0.06$
Average plant height (cm)	77.7 ± 6.9*	52.0 ± 6.7	T = 6.0, df = 10, $P < 0.001$
Average number trees per site	2.2 ± 3.0	2.2 ± 1.6	ns

Table 2.—Arthropod abundance, floral visitor abundance, and arthropod diversity and community similarity indices for parking lot islands with native and non-native plants. sd = standard deviation. Asterisk (*) indicates significant difference between parking lot island types.

Metric	Native plant areas	Non-native plant areas	Statistics
Arthropod abundance (individuals per bowl) mean ± sd	12.7 ± 7.2*	7.0 ± 3.8	Mann Whitney U $_{8,8}$ = 54, P = 0.02
Floral visitor abundance (number floral visitors per cup) mean ± sd	2.6 ± 1.2*	1. 5 ± 0.8	T = 4.29, df = 22, P < 0.001
Arthropod order richness	15	16	T = 0.60, df = 20, P = 0.59
Shannon's Diversity Index (H) (Arthropod orders)	1.77	1.89	
Bray-Curtis Index for arthropod community similarity			70%

pod collection, each site was sampled on the same day.

Birds.—Birds were monitored three days per week from June to August for a total of 28 days of observations. Preliminary observations showed that there was more bird activity in the morning than at other times during the day, thus birds were monitored for 1.5 hr between 7:00–9:00 am. The sites were observed using 10-minute rotations, and the order of observations was randomly rotated each day. Bird species were identified (Sibley 2003; Cornell Lab of Ornithology 2015) and abundance of each species was recorded. To minimize double counting individual birds, during rotations between sites the observer noted birds traveling between sites and only recorded these birds once for the area where they were first observed.

Statistical analysis.—Species richness and Shannon's Diversity Index was calculated for arthropod orders and birds present in native and non-native plantings. A two-tailed t-test assuming unequal variances was used to test whether there were significant differences in vegetative characteristics, flower visitor, or in bird abundance. The % plant cover data was arcsine square root transformed to meet distribution assumptions. Variances did not meet the assumption of homogeneity of variances in the arthropod abundance data set, so a Mann-Whitney U-test was used to test for differences in arthropod abundance between native and non-native plantings.

Community similarity for arthropod orders and bird species in native and non-native plantings was calculated using the Bray-Curtis Index. The Bray-Curtis index includes both richness and evenness and varies from 0% (meaning no species are similar between two areas) to 100% (all species present in similar abundance in each area).

RESULTS

Vegetative characteristics.—Mean percent plant cover was 1.3 times higher in parking lot islands with native plants compared to parking lot islands with non-native (Table 1). Plant species richness was 3.1 times higher in areas with native plantings compared to non-native plantings (Table 1, Appendix 1). Average herbaceous plant height was approximately 25 cm higher in native areas than non-native areas (Table 1). However, the number of trees per site was similar, thus vertical vegetation structure was similar between native and non-native sites (Table 1).

Arthropod abundance and richness.—There were on average 5.7 more arthropods per bowl in native areas (Mann-Whitney U $_{8,8}$ = 54, P < 0.05) compared with the number of individuals per bowl in non-native areas (Fig. 2, Table 2). A total of 15 arthropod orders were identified (Fig. 2), and there was no significant difference between sites in arthropod richness at the taxonomic level of order (Table 2). Shannon's diversity index (H) was slightly higher in non-native areas compared to native areas (Table 2).

The Bray-Curtis Index for arthropod orders showed 70% community similarity between the parking lot islands with native vs. non-native landscaping (Table 2). Floral visitor abundance was significantly higher in native plant areas with on average 57% more floral visitors per cup in native areas compared to non-native areas (Table 2).

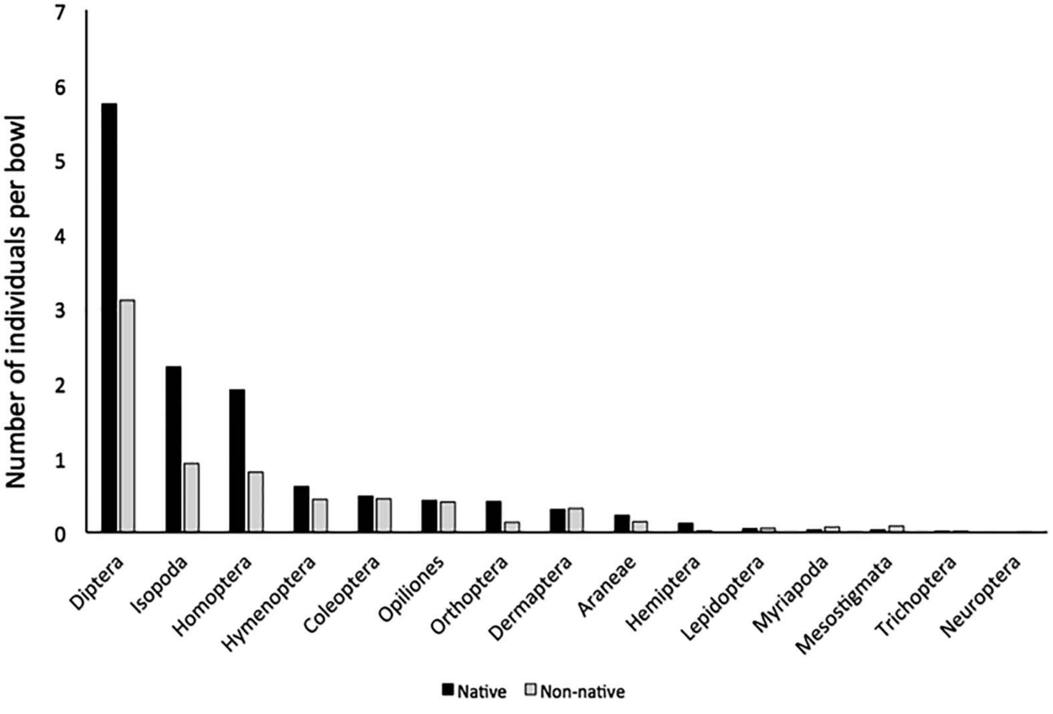

Figure 2.—Mean number of arthropods per bowl in native and non-native areas for June-August categorized by order (n = 11 sampling days).

Bird abundance and richness.—Bird abundance was four times greater in native areas than in non-native areas (Table 3). Significantly more bird species were observed in the parking lot islands with native plants compared to areas with non-native plants (Table 3; native sites = 12 species of birds, non-native sites = 8 species of birds). The bird species were mostly omnivores and herbivores (Table 4), and the European starling and house sparrow were the only two species that were non-native to this region. More European starlings were observed in non-native areas (3 in native vs. 18 in non-native), whereas more house sparrows were observed in native areas (68 in native vs. 17 in non-native). In addition, two insectivore bird species were only seen in native areas. Shannon's diversity index was slightly higher in non-native areas than native areas (Table 3). Unlike the arthropod data, the bird community only showed a 31.4% Bray-Curtis similarity between native and non-native areas (Table 3). Overall, parking lot islands with native plant species had a greater abundance and diversity of bird species.

DISCUSSION

In this study, we compared two hypotheses that may affect arthropod and bird diversity in urban landscapes. The first hypothesis states that due to

Table 3.—Comparison of bird abundance and diversity indices and community similarity in native and non-native parking lot areas. Asterisk (*) indicates significant difference between parking lot island types.

Bird abundance and diversity	Native areas	Non-native areas	Statistics
Bird abundance (individuals/area)	441 *	100	T = 5.03, df = 54, $P < 0.0001$
Bird richness	12 *	8	T = 5.42, df = 54, $P < 0.0001$
Shannon's Diversity Index (H)	1.75	1.89	
Bray-Curtis Index for community similarity			31.4%

Table 4.—Bird species observed in native and non-native areas for June–August 2015 and their diet (n = 28 days of observations for 1.5 hours in the morning). **Bold** indicates bird species only observed in areas with native plantings. All other bird species were seen in both native and non-native areas.

Bird species (common/scientific name)	Diet	Native/Non-native
Goldfinch (*Spinus tristis*)	Herbivore	Native
House Finch (*Haemorhous mexicanus*)	Herbivore	Native
Cedar Waxwing (*Bombycilla cedrorum*)	Omnivore	Native
Chipping Sparrow (*Spizella passerina*)	Omnivore	Native
Mourning Dove (*Zenaida macroura*)	Omnivore	Native
Robin (*Turdus migratorius*)	Omnivore	Native
European Starling (*Sturnus vulgaris*)	Omnivore	Non-Native
House Sparrow (*Passer domesticus*)	Omnivore	Non-Native
Brewer's Blackbird (*Euphagus cyanocephalus*)	**Omnivore**	**Native**
Cardinal (*Cardinalis cardinalis*)	**Omnivore**	**Native**
House Wren (*Troglodytes aedon*)	**Insectivore**	**Native**
Black Capped Chickadee (*Poecile atricapillus*)	**Insectivore**	**Native**

the evolutionary history of plant-insect interactions, native plants would support more arthropods and attract more birds due to greater food resources. The second hypothesis was that areas with similar vegetation structure would attract and support similar bird diversity and abundance. The parking lot islands had similar vegetation structure in terms of number of trees, but differed in diversity and abundance of native plant species. Our results provide greater support for the first hypothesis that use of native plants in landscaping can increase the abundance of arthropods, abundance of floral visitors, and abundance and diversity of birds.

Non-native plant species negatively affect the biodiversity and abundance of native herbivore species in urban areas (Southwood et al. 1982; Burghardt et al. 2009; Tallamy et al. 2010; Helden et al. 2012; Aronson et al. 2014; Concepción et al. 2016). Larger landscape scale studies have shown that the abundance of moths and butterflies was five times greater and bird diversity was higher in residential areas with predominantly native plants compared to areas with non-native ornamental plants separated by 1.5 or more km (Burghardt et al. 2009). A similar result was observed in our small-scale study where native and non-native areas were located only a few meters away from each other. Arthropod abundance was two times greater in native sites and there was a 57% increase in floral visitors per bowl in native sites compared to non-native sites. In contrast to arthropod and floral visitor abundance, overall richness and Shannon Diversity's index at the level of arthropod order was similar between native and non-native areas for arthropods. The dominance of Diptera in our study increased species evenness (Fig. 2). As a result, the insect diversity index differed little between native and non-native areas.

Four more bird species were observed in the parking lots with native vegetation compared to parking lots with ornamental non-native vegetation. Two of these bird species were insectivores, which may reflect more abundant food sources in the areas with native plants. Studies of urbanization often show that omnivore bird species tend to increase in abundance while insectivore bird abundance decreases (Burghardt et al. 2009; Helden et al. 2012; Strohbach et al. 2013). The greater number of insectivorous birds in our study and in the Burghardt et al. (2009) study suggests that increasing the use of native plants in landscaping would help reverse this homogenization of bird species and loss of insectivorous birds. Perhaps most surprising in our study was that bird abundance was four times greater in the parking lot islands with native plants compared to parking lot islands with traditional landscaping. Little difference was observed in the Shannon diversity index between the two areas, but this could have been due to the dominance of goldfinch and house sparrows skewing the diversity index. Interestingly, for parking lot islands that were only meters apart, the Bray Curtis index for bird community composition showed only 31% similarity between site types. Thus, small-scale differences in landscaping may have large effects on the abundance and diversity of birds.

Plant diversity and plant height were significantly greater in the parking lot islands with native vegetation. This may have biased our results in providing more plant material for arthropods to feed on (bias towards hypothesis 1). This also could have increased the structural heterogeneity of the native habitats, which according to Tews et al. (2004) allows for more diverse niches and increased resources, thus increasing species diversity. To better test the degree to which native plants versus use of non-native plants in landscaping affect arthropod and bird abundance, one would need to plant areas controlling for plant diversity and plant height. We were not able to control this aspect of our study.

Another limitation of this study was that we did not identify all of the arthropods to species, which may mask differences in arthropod diversity between sites (bias towards hypothesis 2). For example, specialist insects were observed on *Asclepias tuberosa* and *Asclepias syriaca*, i.e., *Lygaeus kalmii* (small milkweed bug), *Oncopeltus fasciatus* (large milkweed bug), *Tetraopes tetrophthalmus* (red milkweed beetle), and *Danaus plexippus* (monarch caterpillars and adult butterflies). All of these species are restricted to feeding on species of *Asclepias*, and were not present in areas with non-native ornamental plant species. This is just one example of how native plants can support a more diverse insect community and provide more food resources for higher trophic levels.

Additionally, the presence of small native trees in the parking lot islands with non-native ornamental plants reduced differences in bird abundance between the two site types. For instance, the presence of ripe berries on Serviceberry trees (*Amelanchier* sp.) during the month of June attracted Cedar Waxwings and other omnivore birds to non-native areas during this study. Although four times more birds were observed in parking lot islands with native vegetation, the difference in bird abundance may have been even greater if native trees had been absent from the areas landscaped with non-native ornamentals.

In summary, our results clearly show that landscaping choices, even on a small scale, have large effects on the arthropod and bird community. Although vegetation structure (small understory trees and herbaceous plants) was similar between the parking lot islands in our study, future studies that control plant species richness and height between native and non-native plantings would provide more information on the degree to which native plants drive differences in biodiversity in small-scale urban plantings.

ACKNOWLEGDMENTS

We thank the Indiana University South Bend Student-Mentor Academic Research Teams (SMART) Committee for their support of this project. We also thank two anonymous reviewers for their helpful comments that improved the manuscript.

Appendix 1.—Plant species present in native and non-native parking lot areas. Species with a "+" were found at the site type and species with a "–" were not found at the site type.

Plant species	Native sites	Non-native sites
Acer saccharum Marshall	+	+
Achillea millefolium L.	+	+
Agrimonia gryposepala Wallr.	+	–
Ambrosia artemisiifolia L.	+	–
Amelanchier sp. Medik.	–	+
Andropogon gerardii Vitman	+	+
Anemone virginiana L.	+	–
Aquilegia canadensis L.	+	–
Arnoglossum plantagineum Raf.	+	–
Arrhenatherum elatius (L.) P. Beauv. ex J. Presl & C. Presl	+	–
Asclepias syriaca L.	+	–
Asclepias tuberosa L.	+	–
Bouteloua curtipendula (Michx.) Torr.	+	–
Cirsium arvense (L.) Scop.	+	–
Cirsium vulgare (Savi) Tenn.	+	–
Conyza canadensis (L.) Cronquist	+	+
Coreopsis grandiflora Sweet	+	–
Coreopsis tripteris L.	+	–
Crataegus sp. Tourn. ex L.	–	+
Cyperus esculentus L. var. *leptostachyus* Boeckeler	–	+
Dianthus barbatus L.	–	+
Echinacea purpurea (L.) Moench	+	–
Equisetum hyemale L.	+	+
Eryngium yuccifolium Michx.	+	–
Eutrochium purpureum (L.) E.E. Lamont	+	–
Festuca sp. L.	+	–
Festuca glauca Vill.	–	+
Geranium maculatum L.	+	–
Helianthus annuus L.	+	–
Helianthus occidentalis Riddell	+	–
Hemerocallis fulva (L.) L.	–	+
Heuchera americana L.	+	–
Lactuca serriola L.	+	–
Lathyrus odoratus L.	+	–
Lavandula angustifolia Mill.	–	+
Lespedeza capitata Michx.	+	–
Liatris aspera Michx.	+	–
Medicago lupulina L.	+	+
Monarda fistulosa L.	+	–
Myrica pensylvanica Mirbel	–	+
Nepeta × *faassenii* Bergmans ex Stearn	–	+
Oenothera biennis L.	+	–
Physalis virginiana Mill.	–	+
Poa pratensis L.	–	+
Prunus serotina Ehrh.	+	–
Pycnanthemum virginianum (L.) T. Dur. & B.D. Jacks. ex B.L. Rob. & Fernald	+	–
Rudbeckia hirta L.	+	–
Schizachyrium scoparium (Michx.) Nash	+	–
Securigera varia (L.) Lassen	–	+
Silphium laciniatum L.	+	–
Silphium terebinthinaceum Jacq.	+	–
Solidago canadensis L.	+	–
Sorghastrum nutans (L.) Nash	+	–
Spiraea japonica L.f.	–	+
Symphyotrichum novae-angliae (L.) G.L. Nesom	+	–
Taraxacum officinale (L.) Weber ex F.H. Wigg.	+	+
Taxus baccata L.	+	–
Toxicodendron radicans (L.) Kuntze	+	–
Tradescantia ohiensis Raf.	+	–
Tragopogon pratensis L.	+	+
Trifolium repens L.	+	+

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Manuscript received 29 September 2016, revised 21 December 2017.