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URBAN TRAIT CHANGES IN WEEDY PLANT COMMUNITIES, NATIVE SPECIES
EVOLUTION, AND BOTANICAL SCIENCE OUTREACH

By

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ABSTRACT OF THE DISSERTATION

Urban trait changes in weedy plant communities, native species evolution, and botanical
science outreach

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The creation and expansion of cities and suburban developments impact the ability of plant species to survive and reproduce on local, regional, and global scales. With over 50% of the world's growing human population residing in urban areas, the identification and qualification of plants found in such regions is becoming increasingly important to both understand the urban-nature biological interface and counteract the "extinction of experience" of nature for city dwellers. My dissertation project uses field surveys of urban plant communities in disturbed habitats, an international plant trait database, common garden experiments of populations of a native, weedy herb, *Plantago rugelii* (American or blackseed plantain, in the family Plantaginaceae), and a newly developed public science education and outreach activity focused on edible urban weeds. My overarching questions were, (1) How do community and population-level traits differ between vascular plants of urban and exurban environments; (2) How do native plant populations evolve in response to urbanization; and (3) How do these community shifts and evolutionary outcomes for urban flora redefine the scope of urban botanical

education? I used Bayesian statistical inference to answer questions about trait patterns and upheld expectations for higher standards of hypothesis testing in the plant sciences. My main research findings were that (1) the flora of asphalted parking lots have reduced beta diversity, reduced phylogenetic diversity, and larger proportions of short-lived, non-woody, and C₄ plant species compared to the surrounding regional species pool; (2) parking lots filter for plant species with combined abiotic and biotic pollination strategies and generalized dispersal strategies involving animal vectors from across multiple taxonomic orders; and (3) urban *P. rugelii* have fewer reproductive spikes, longer time to maturation of fruit, taller maximum spike height, and reduced leaf thickness compared to rural populations of the same species across the Philadelphia and New York City Metropolitan Areas. My botanical education activity details a successful outreach event and provides public access to learning and teaching materials for utilizing six, locally-abundant, and spontaneous urban plant species in urban environmental education. My results show evidence of community-level functional trait filtering in urban hardscape habitats driven by deterministic, niche-based assembly rules; urban phenotypic divergence and evolution of spontaneous species via natural selection; and the ability of commonly overlooked yet freely available urban weeds to inspire and inform learners of all ages. I have also established parking lots and a common, widespread native species as models for analyzing urbanization at a local scale but in the context of global environmental change. Weedy plant species are ideal models for studies of global urban evolution as well as for use in urban environmental education. Increasing the extent and understanding of spontaneously vegetated areas will ultimately lead to reciprocal benefits for humans and nature.

Dedication

For my family

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Dissertation Summary

Urbanization alters the ecology and diversity of species on global, regional, and local scales. This alteration may change the types of experiences humans have with nature in cities and towns. To improve our understanding of urban eco-evolutionary impacts on plant life and human-nature connections, I explored the following major questions: 1) How do community and population-level traits differ between vascular plants of urban and exurban environments; and 2) how do outcomes for urban flora redefine the scope of urban botanical education? To achieve this, I used field surveys of urban plant communities and their traits in novel habitats (**Chapters 1-2**); a common garden experiment with plants from urban and rural populations of a native, weedy herb (*Plantago rugelii*; **Chapter 3**); and an exposition of an annual, public, science education and outreach event focused on edible urban weeds (**Chapter 4**). Research was conducted in and around the heavily urbanized Mid-Atlantic US corridor which includes Philadelphia, Pennsylvania; New York, New York; and New Brunswick, New Jersey.

Ecosystem services and urban vegetation

Plants provide essential services that make the Earth habitable for human beings and many other living organisms. Yet, urbanization and development threaten plant life through habitat transformation, fragmentation, urban environmental conditions, and societal preferences (Williams et al., 2009). Thus, my dissertation work on urban plants is motivated by the need to understand how plants change and evolve under the pressures of recent global environmental change due to urbanization. Even in areas where humans

have modified the natural environment, plants provide many desirable services to improve the quality of human life. Spontaneous urban plants are native or exotic species that survive in cities, suburbs, and other urbanized areas without being cultivated or maintained by humans (Del Tredici, 2010). Combinations of spontaneous and cultivated urban plants create small and large green spaces in cities where urban residents may enjoy recreational opportunities, cooler temperatures, and personal experiences with nature.

Urban green spaces are a critical aspect of biodiversity conservation and ecosystem services in cities, but political and social factors may make it difficult to conserve and properly manage them (Aronson et al., 2017). Moreover, urban green spaces are important for human health and wellness, and the quality of life for city dwellers may increase if we can better facilitate biodiversity in densely developed areas (Fuller et al., 2007). Maintaining urban plant diversity (**Chapters 1-2**), evolutionary potential (**Chapter 3**), and appreciation (**Chapter 4**) in the future may be critical to our survival, and my dissertation dissects the patterns, potential mechanisms, and solutions that underlie this process.

Urban plant community ecology

Urban plant communities are composed of a subset of regional native flora and exotic species pools (McDonnell & Hahs, 2015). Whether or not these pools include a particular species or evolutionary clade is determined by a hierarchy of filters (e.g., climate and biogeography, urban environmental conditions, urban land use history, human preferences, and species interactions) (Williams et al., 2009; Aronson et al., 2016). This

process is based on the biological and ecological traits of each organism, or group of organisms; traits that allow for dispersal, colonization, growth, and ultimately reproduction in urban areas. Consequently, the plant communities of urban environments may acquire a unique composition of those species-level traits that have allowed for passage through, and fitness beyond, urban environmental filters.

A suite of species traits and descriptions is loosely identified as urban plant characteristics across studies of city floras. Urban floras have been associated with higher heat tolerance, height, alkalinity, drought, average seed mass, nutrient rich soils, woodiness, succulence, competitiveness, and increased stress intolerance (C-strategists; Grime, 1977), and vegetative reproduction, non-native origins, and shorter lifespans (Knapp et al., 2008; Dolan, Moore, & Stephens, 2011; Kowarik, 2011; Aronson et al., 2015; McDonnell & Hahs, 2015; Williams et al., 2015; Palma et al., 2017) compared to non-urban floras. At the same time, meta-analysis shows conflicting trends for many species traits among city-wide floristic studies (Williams et al., 2015). The traits of species in urban floras may depend on sub-habitat conditions found within individual cities and towns. In addition, analyzing traits associated with plant extinctions from remnant native and semi-natural habitats in cities may point to different sets of filters from those that abiotically prevent establishment in other urban environments (Hahs et al., 2009; Duncan et al., 2011; Williams et al., 2015). Moreover, differing definitions of “city-wide,” “anthropogenic,” and “urban” lead to problems when comparing and contrasting data from independent studies. Improving trait-based approaches to understanding urban floral communities can provide the functional insight needed to predict future urban floras, anticipate how they will respond to environmental changes,

and advise management and planning strategies for ecosystem services (Pollock et al., 2012; Williams et al., 2015).

Urban floras and invasive species assemblages have lower phylogenetic diversity than their non-urban or native counterparts, respectively (Ricotta et al., 2009; Dolan, Aronson, & Hipp, 2017). For example, while species richness in Europe has increased over the last three centuries, phylogenetic diversity has decreased (Knapp et al., 2017). Functional and phylogenetic homogenization has been observed at small scales within cities and towns (Wittig & Becker, 2010; Lososová et al., 2012), but not necessarily for native species at the city-scale (La Sorte et al., 2014). Non-native and invasive species have been identified as drivers of homogenization at urban habitat and city-scales, but their impacts may depend on time since invasion by individual species (Lososová et al., 2012; La Sorte et al., 2014).

Urban hardscape habitats: Novel communities?

Mapping urban biotope vegetation in Europe, South Africa, and New Zealand over the past four decades has identified spontaneous plant communities typically found in discrete urban habitat types (e.g. lawns, walls, shrubberies, and parklands; e.g., Brunner et al., 1979; Cilliers & Bredenkamp, 2000). A subset of biotopes identified in cities are novel habitat types that support mostly ruderal vegetation (Cilliers & Bredenkamp, 2000). Habitats associated with developed areas and unintentional greenspaces can be defined as novel ruderal habitats (Del Tredici, 2010). These habitats can be uncultivated or cultivated non-remnant areas and are typically found in non-native soil or water that is adjacent to, surrounded by, within, or atop impervious surfaces or structures. These

habitats may also experience direct or indirect mechanical and/or chemical disturbances caused by humans. Novel ruderal habitats include but are not limited to roads, sidewalks, and unmaintained road or sidewalk verges; urban grasslands or unmaintained lawns; stone walls; facades or edges of buildings or fences; tree boxes; parking lots; abandoned buildings, planting beds, or entire lots; channelized rivers; and many wasteland and brownfield sites. While they can be of various ages (newly paved paths to abandoned railways) and exist in non-urban environments, they likely form a disproportionately large part of urban, and to a lesser extent suburban, land area available for spontaneous plant colonization (Davis et al., 2010; Mathey & Rink, 2010).

Within the category of novel ruderal habitats, I use two groupings: hardscape habitats and novel urban greenspaces. Hardscape habitats are indicated by spontaneous vegetation that grows in designed or un-designed cracks or in interstitial spaces within, atop, or immediately surrounded by an impervious surface. For hardscapes, the impervious surface comprises the majority of the land area or fluvial habitat (Lundholm, 2006). Examples of hardscape habitats include channelized rivers, paved roads and lots, paved sidewalks, wall faces, building facades, and some fences. Contrarily, novel urban greenspaces are indicated by spontaneous vegetation that grows in designed or un-designed spaces within an entirely or mostly permeable matrix, such as a lawn, other vegetation, or bare soil. Examples of novel urban greenspaces include road or sidewalk verges; unmaintained lawns, yards, or planting beds; unpaved wastelands; and brownfields.

Novel, urban hardscape habitats are one of the primary land cover products of urbanization and development. Distinct combinations and intensities of environmental

stressors exist across different urban habitat types. Cities and suburbs include variably anthropogenic habitats such as road sides and medians, sidewalks, and mowed lawns in addition to remnant forests. Biotic and abiotic habitat conditions that are historically unprecedented in the temperate biome as well as unique ecological community composition of anthropogenically disturbed habitats are potential indicators of the formation of a novel ecosystem (Hobbs et al. 2006). Novel urban ecosystems are also thought to be the product of crossing an irreversible ecology threshold into an alternative stable state (Hobbs et al., 2013), but this theory has not been tested empirically in urban or terrestrial habitats (but see Capon et al., 2015).

Highly disturbed areas such as urban hardscape habitats may be hotspots for biotic homogenization in cities. Hardscapes such as roofs and walls are often chosen as targets of urban green infrastructure restoration projects, many of which show promise for increasing ecosystem services provisioning as well as supporting increased plant and animal biodiversity (Francis & Lorimer, 2011; Williams, Lundholm, & MacIvor, 2014; Lundholm, 2015). The impact of urban hardscape communities must also be understood on the basis of how they support or degrade the conservation of a diversity of evolutionary histories as well as individual taxonomic units (i.e., phylogenetic as well as taxonomic diversity). In order to form mechanistic hypotheses about urban ecology, I applied taxonomic, phylogenetic, and functional, trait-based methods to habitat-explicit (i.e., hardscape habitat) urban plant datasets. This was done because urban areas are otherwise too highly heterogeneous and pooled, city-wide analyses may mask habitat-specific filtering signals. Thus, in **Chapter 1** I ask,

1. Which plant species inhabit hardscapes?;
2. Do hardscapes serve as a refuge for rare or specialist species?;
3. How taxonomically similar are hardscape plant communities to one another and the regional species pool?;
4. Is phylogenetic diversity of hardscape communities different than the regional species pool?; and,
5. Which functional traits and life history strategies are filtered for or against in urban hardscape plant communities?

Pollination and dispersal in urban plants

For many plant species, interactions with both vertebrate and invertebrate animals are crucial to the completion of the life cycle via pollination and seed dispersal. Urbanization presents many threats to the health of these biological interactions. Increases in habitat fragmentation, non-native species richness, climate change impacts, and air, soil, and water pollution make it difficult for animal species to persist in urban areas (Harrison & Winfree, 2015). Both vertebrate and invertebrate species richness tends to decrease with an increase in urbanization intensity (McKinney, 2008). A lower diversity of pollinator diversity and abundance has been observed at some urban sites (Bates et al., 2011); at others, urban pollinator communities interact with a higher number but a lower proportion of urban plant species (Baldock et al., 2015).

Similar to other urban plant traits, differences in communities of dispersal and pollination vectors in cities have not been shown to impact urban plant communities in a predictable way at the city-wide scale (Williams et al., 2015). Urbanized areas have been

found to favor wind-pollinated and wind-dispersed plants while animal-pollinated species are less frequent (Knapp et al., 2008; Williams et al., 2015). On the contrary, other studies have found that wind-dispersed species are more likely than others to go extinct due to urbanization, and many more have found no clear pattern for dispersal mechanism in plant communities in urban areas (Williams et al., 2015). Knapp et al. (2008) also found that urban plant communities contained a higher frequency of animal-dispersed species than that of non-urban plant communities. In **Chapter 2** I ask,

1. What are pollination and dispersal strategies of plant communities present in novel hardscape habitats?;
2. Do novel hardscape habitats filter spontaneous plant communities for species with non-animal-mediated pollination and seed dispersal mechanisms?; and,
3. Do plant communities in novel hardscape habitats utilize a higher average number of dispersal and pollination syndrome agent types per species than that of the regional pool?

Plant evolution in anthropogenic settings

Because plant traits can differ between and within species, anthropogenic changes in the environment can impact community-level species filtering as well as the evolution of plant populations. It has been shown that plant populations can rapidly adapt to human-induced disturbances on local scales. For example, Solbrig and Simpson (1974, 1977) analyzed dandelion populations from sites subjected to different levels of disturbance and discovered an r-selected ecotype associated with the higher levels of disturbance and a K-

selected ecotype associated with lower levels of disturbance. In a common garden, the r-selected ecotype had a shorter generation time and produced greater amounts of seed, while the K-selected ecotype grew larger vegetatively (Solbrig & Simpson, 1977).

Similarly, *Plantago lanceolata* populations growing closer to roadsides evolved increased tolerance to lead in soil compared to populations located more distantly from the road (Wu & Antonovics, 1976). These and similar findings are useful for making predictions about how urbanization may influence plant species evolution (**Chapter 3**). Nevertheless, it is currently unclear as to which environmental, biological, and social factors or combinations of factors associated with urbanization might be exerting the strongest selective forces on urban plants (Rivkin et al., 2019).

***Plantago rugelii*: A common native model plant**

A fast-growing plant species that is widespread in both urban and non-urban areas in its native range is an ideal organism with which to analyze urban plant evolution (**Chapter 3**). One such plant is the annual, biennial, or perennial herb *Plantago rugelii*. This species, *P. rugelii* Decne (American, Rugel's, or blackseed plantain) of *Plantago* section *Plantago* (Plantaginaceae) is typically considered a weed as it is found in disturbed habitats throughout northeastern North America, where it is endemic (Rahn, 1996).

Plantago rugelii pollen has been identified in paleobotanical studies of the Erie Basin (Sears, 1930), indicating the species' ancient presence in the north-central United States. The plants have fibrous, adventitious roots; a short caudex (a bulky, basal stem) borne with a basal rosette of leaves (Hawthorn, 1974). It also has a mixed mating system with protogynous, wind-pollinated, self-compatible flowers as well as vegetative reproduction

through ramets. The species has fruits as dehiscent capsules, each bearing an average of 4-5 black seeds (matte at maturity; pers. obs.) that swell and become mucilaginous in water (i.e. rain), potentially enhancing ectozoochory (Hawthorn, 1974).

The cosmopolitan invasive *Plantago major* (broadleaf plantain) and *P. rugelii* are extremely similar in morphological appearance and overlap in range in the eastern U.S. and Canada. The two species share numerous qualitative and quantitative morphological characters including but not limited to basal, ovoid leaves with entire to irregularly toothed margins; erect, spicate, dull brownish to greenish inflorescences up to 6 mm in diameter; flowers with 1.5-2.0 mm long keeled sepals, radially symmetrical, glabrous corollas; and four stamens. Nevertheless, they are purportedly unable to hybridize with one another (Rahn, 1957; Sagar & Harper, 1964; Tessene, 1969; Bassett, 1973). Capsule and seed characteristics may be the only reliable traits for proper field identification of *P. major* and *P. rugelii* in northeastern North America (Gray, 1878; Tessene, 1968; Hawthorn, 1974). Likewise, ITS2 (second internal transcribed spacer) DNA sequences are said to differ between *P. major* and *P. rugelii* by 11 substitutions (A. Shipunov, pers. comm.). Some local floras and field guides suggest that *P. rugelii* is identifiable through the presence of purple coloration on the petioles (e.g., Haines, 2011), but I have found that approximately half (or less in certain populations) of *P. rugelii* exhibit this trait in populations throughout the New York City - New Jersey - Philadelphia Metropolitan Area (pers. obs.). Thus, in order to distinguish between *P. rugelii* and its congener, capsule and seed characteristics were used to gather seed from securely identified *P. rugelii* in the field for later use in a common garden experiment. In **Chapter 3** I ask,

1. Are native plant populations phenotypically convergent within urban areas yet phenotypically divergent from conspecific populations in rural areas in key morphological, physiological, and phenological traits?; and
2. Are the patterns of phenotypic divergence and convergence consistent with predictions for putatively adaptive traits for urban plants?

Bayesian inference: Changing statistical paradigms

P-values, the probability of finding a result equally as extreme or more extreme, given that the null hypothesis is correct, have long been used in statistical hypothesis testing in the natural and social sciences. However, there is recent evidence of the inadequacies of P-values. Recommendations for practitioners and users of quantitative hypothesis testing include modifying the traditionally accepted threshold for the significance of P-values from 0.05 to 0.005 or even 0.001 (Johnson, 2013). Additionally, the American Statistical Society does not advise relying on P-values alone as indicators of meaningful differences in means or other parameters of interest (Wasserstein & Lazar, 2016).

In contrast, Bayesian inference allows for the estimation of parameter values along with the uncertainty around those values, with the latter theoretically included as an inseparable description of the former. Thus, the statistical analyses of my dissertation data (**Chapters 1-3**) rely heavily upon the Bayesian inference of statistical models rather than frequentist statistical tests and P-values for hypothesis testing. This is relatively novel, as the first Bayesian meta-analysis in the field of plant ecology was published in 2008 (Koricheva & Gurevitch, 2014) and Bayesian inference has been slow to take hold in plant physiological and ecosystem ecology (Ogle & Barber, 2008). In contrast, other

sub-disciplines of population and community ecology have embraced Bayesian methods for their appropriateness in use with non-normal, hierarchical, and often partially missing data for decades (Kéry & Schaub, 2011).

Bayesian statistical inference and epistemology is based on Bayes' Theorem, which can be described succinctly as

$$P(A|B) = [P(B|A) * P(A)] / P(B)$$

where $P(A)$ and $P(B)$ are the probabilities of events A and B ; $P(A|B)$ is the probability of A having accounted for $P(B)$; and $P(B|A)$ is the probability of B having accounted for $P(A)$ (Bayes, 1763). Suppose A is a hypothesis of interest and B is the data collected to investigate the hypothesis. $P(A)$ is typically known as the prior in Bayesian inference; in this dissertation and in common practice among Bayesian ecologists, $P(A)$ is set to a statistical distribution that is non-informative or vague so as to not influence the outcome of results. $P(A|B)$ is known as the posterior and represents our complete knowledge regarding A after the data are observed. $P(B|A)$ is known as the likelihood, or a statistical description of the process that generates the data. $P(B)$ is usually of no interest since it doesn't involve the hypothesis A and so this term is often considered a proportionality constant. Modern Bayesian analyses usually involve the use of Markov Chain Monte Carlo (MCMC) sampling algorithms (e.g., Gelman et al., 2013). A byproduct of MCMC sampling is that we can easily find the posterior distribution of any function of statistical parameters involved in hypothesis A (Gelfand et al., 1990). A useful function is often the difference between parameters. The posterior distribution of the difference may reveal that 0 is a reasonable value for the difference, thereby indicating that it is rational to regard the parameters as not meaningfully different.

Environmental education using urban plants

A practical implication of my research (**Chapters 1-3**) is that learners and environmental educators working in hardscape-bound, urban, and/or urbanizing areas may not have immediate, local access to the same subset of plant biodiversity that may be available to learners and educators in non-urban areas, even within the same region. Furthermore, this restraint may lead to profound social and educational inequities for urban residents, such as reduced ecological sense of place, environmental sensitivity, and an increased risk of health issues associated with nature-deficit disorder (Chawla, 1998; Ming Kuo, 2013; Russ & Krasny, 2017). However, several cosmopolitan plant species are reliably found in city floras globally, such as *Stellaria media* (chickweed) and *Poa annua* (annual meadow grass; Aronson et al., 2014), and many urban weeds are also edible (Wiersema & León, 2013), which makes them fun, interesting, and easy to use in science outreach with the public. Thus, **Chapter 4** details an outreach activity utilizing several common spontaneous urban plants as a free and abundant natural resource for botanical education in cities and suburbs. My teaching goals for this activity were:

1. To inspire enthusiasm in a wide-age range of participants;
2. To enable people to enjoy, risk and cost free, edible weedy plants;
3. To disseminate information regarding the safe identification, procurement, and preparation of weedy plants; and
4. To broaden perspectives and attitudes about weedy plants.

Summary of results

In this dissertation I established that parking lots and a common, widespread native species can be used as research models to analyze urbanization at local scales while considering global environmental change. In **Chapter 1**, I found that parking lots, a common type of hardscape habitat, impose stringent filters on plant communities leading to increased proportions of short-lived, non-woody, and C₄ plant species as well as reduced phylogenetic and beta diversity compared to the regional species pool. Building upon this, I showed in **Chapter 2** that parking lots also filter for plant species with diverse pollination strategies (i.e., both biophily and abiophily) and generalized dispersal strategies involving both non-animal mediated and animal-mediated mechanisms, with the latter from multiple taxonomic orders. Urban plant strategies are further illustrated in **Chapter 3**, where I show that urban and/or New York City *P. rugelii* have fewer reproductive spikes, longer time to mature fruit, and taller maximum spike height when compared to rural populations of the same species. These trends are likely evidence of urban evolution via natural selection. To better inform the public and connect people with nature, **Chapter 4** describes an informal botanical outreach event that was held in New Brunswick, New Jersey, USA, and for which I created and disseminated publicly available teaching materials. These materials highlight the use of six locally abundant, edible, spontaneous urban plants in cooking recipes in the aim of restoring people's sense of place despite urbanization trends. I was successful in encouraging participants across age ranges to express excitement and enthusiasm in trying new culinary dishes featuring weeds; collect resources enabling effective plant identification, collection, and

preparation with the intent to use them in the future; and entertain wider viewpoints regarding the usefulness of spontaneous vegetation.

Conclusion and future research directions

Urbanization brings drastic ecological change to a native landscape, but the subset of species that can establish urban populations may adapt in ways that are specifically beneficial given their biology and life history. In this dissertation I established parking lots and a common, widespread native species as models for analyzing urbanization at a local scale but in the context of global environmental change. Weedy plant species in general are likely ideal models for studies of global urban evolution as well as urban environmental education due to their abundance and availability.

My results will help scientists, planners, land managers, and educators understand how creating dense urban developments may: (i) limit the types of wild species able to colonize and create populations in cities, towns, and suburbs; (ii) create and maintain heritable genetic change between urban populations and rural populations of the same species; and (iii) determine which plants can and will contribute to today's increasingly urban human experience. Future urban plant ecology research in hardscape habitats should analyze the viability of plant populations and evaluate whether or not these habitats are ultimately sources or sinks for urban species. Novel, adaptive traits in hardscape habitats may ultimately become prevalent in select plant species due to the interplay between ecology and evolution on contemporary timescales, and the urban selective pressures driving these changes should be identified. Likewise, future research in urban plant evolution should investigate the adaptive significance of traits for which

genetically-based, urban phenotypic divergence from rural populations is observed.

Analyzing the genetic basis of evolutionary responses in urban plants would connect phenotype to genotype — a major goal of both basic and applied natural sciences research. Lastly, we must determine how to most effectively conduct urban environmental education to raise public support for the preservation and restoration of green spaces in urban as well as non-urban areas. Increasing the extent and understanding of spontaneously vegetated areas will lead to reciprocal benefits for humans and nature.

Chapter 1

Hardscape floristics: Functional and phylogenetic diversity of parking lot plants

Abstract

The study of organisms living in extreme environments has shaped our knowledge of the deterministic and stochastic factors that contribute to community assembly. With hardscape habitats, humans have created a novel land cover type that is physically analogous to extreme terrestrial environments such as deserts, barrens, and rocky outcrops and may harbor rare or specialist species and communities.

Questions: (1) Which plant species inhabit hardscapes?; (2) Do hardscapes serve as a refuge for rare or specialist species?; (3) How taxonomically similar are hardscape plant communities to one another and the regional species pool?; (4) Is phylogenetic diversity of hardscape communities different than the regional species pool?; and (5) Which functional traits and life history strategies are filtered for or against in hardscape plant communities?

Methods and Location: We surveyed the vascular plant communities of 17 asphalt parking lots in New Jersey, US, to use as a focal hardscape habitat for this study.

Results: Parking lot plant communities contained 119 vascular plant taxa out of the 2199 regional species and had a lower beta and phylogenetic diversity. The parking lot flora had significantly higher frequencies of annuals, biennials, C₄ plants, ruderal strategists, non-natives, herbaceous plants, self-compatible species, and species from the Caryophyllales, Asterales, Ulmaceae, and Plantaginaceae clades compared to the regional pool, and contained no New Jersey threatened or endangered species.

Conclusions: Hardscape habitats may be similar to naturally occurring, extreme terrestrial environments in that they impose stringent filters on ecological communities leading to increased proportions of short-lived and C₄ plant species compared to the regional pool. Nevertheless, hardscapes are unlikely to serve as biodiversity refuges in the Northeastern US as they create novel abiotic conditions that may be hostile to many native, rare, and specialist species.

Introduction

Extreme terrestrial environments such as deserts, barrens, rocky outcrops, and volcanic islands are subject to abiotic conditions that act as strong filters on local community composition and structure (Rothschild & Mancinelli, 2001). Such habitats can provide us with valuable information in understanding how plant communities assemble and the importance of deterministic and stochastic processes in driving compositional outcomes (Chase, 2007; Caruso et al. 2011). Furthermore, these extreme environments are often the epicenter of eco-evolutionary dynamics associated with novel adaptations, such as C₄ photosynthesis in plants (Sage, Christin, & Edwards, 2011), and host many endemics, providing refuge to locally and globally rare species (Rundel et al., 1991; Nuzzo, 1996; Danin, 1999; Ware, 2002; Durant et al., 2012). Understanding the processes that shape community composition in these environments has shaped our foundational knowledge of ecological systems.

Humans have created a novel extreme environment associated with urban ecosystems: hardscape habitats (hereafter “HH[s]”). HHs are widespread in cities and suburbs and include sidewalks, roads, buildings, medians, plazas, parking lots, and other

types of impervious surfaces or structures (Lundholm & Richardson, 2010). HHs share physical and ecological characteristics with naturally-occurring environments such as deserts, barrens, and rocky outcrops (Lundholm & Richardson, 2010), and are characterized by a confluence of physiologically stressful environmental factors, such as intense aridity, periods of extreme heat, and mechanical and chemical disturbance via vegetation management practices and foot and vehicle traffic. The maximum surface temperature of pavement is 14 to 27°C higher than maximum air temperature in the summer, and HH surface temperatures can be 20 to 25°C higher than surrounding lawns (Solaimanian & Kennedy, 1993; Kjelgren & Montague, 1998), creating localized heat islands. HHs thus offer an opportunity to study the onset of eco-evolutionary processes that could lead to adaptation and speciation.

Novel HHs may serve as a model for extreme filtering of plants in highly anthropogenically altered environments. Analyzing HH floristic composition will allow us to understand how communities assemble in these novel habitats that must be accounted for in modern ecological theory due to their widespread spatial extent (Davis et al., 2010). Spatially-explicit environmental filters will be reflected through spatially-explicit differences in the taxonomic, phylogenetic, and functional diversity measures of ecological communities (Williams et al., 2009; Aronson et al., 2016). Hardscape-specific functional, phylogenetic, and taxonomic diversity analyses of spontaneous plant communities will also contribute to predictions of the functional traits and evolutionary potential of current and future urban floras (McDonnell & Hahs, 2013; Williams, Hahs, & Vesk, 2015).

In this study, we examine the flora of HHs. As these are new anthropogenic landscapes, we characterize the flora of these habitats for the first time to examine how plant communities assemble in these extreme urban environments and how floras are taxonomically, phylogenetically and functionally filtered from the regional species pool (hereafter “regional pool”). Our research questions are: (1) Which species inhabit HHs?; (2) Do HHs serve as a refuge for rare or specialist species?; (3) How taxonomically similar are hardscape plant communities to one another and the regional species pool?; (4) Is phylogenetic diversity of HH communities different from the regional species pool?; and (5) Which functional traits, niche indicators, and life history strategies associated with growth and reproduction are filtered for or against in a hardscape plant community?

To answer these questions, we performed a case study of the spontaneous flora of parking lots on Rutgers University-New Brunswick campus (New Jersey, US) as representative of novel HHs across the Northeastern United States. We predict that parking lots will filter the regional pool to a subset of species with a suite of pre-adapted characteristics. Specifically, we expect that parking lots would have a low beta diversity among individual parking lot sites and that phylogenetic diversity would be lower in parking lots due to abiotic filtering and phylogenetic clustering around highly stress tolerant lineages. Furthermore, we predict that spontaneous plant communities of parking lots will have a higher proportion of ruderal, stress-tolerant, annual/biennial, non-woody plants that are more likely to survive and reproduce amidst frequent mechanical and chemical disturbances from vehicles and vegetation management. We expect that plants that utilize C₄ or CAM pathways for photosynthesis would be generally better adapted to

these hot, arid environments. We also predict that clonal and/or self-pollinating species would be more likely to succeed and reproduce in parking lots, due to decreases in pollinators and isolation from other patches due to fragmentation (Winfree, Bartomeus, & Cariveau, 2011; Johnson et al., 2015).

Materials and Methods

Parking lot selection

Parking lots are widespread HHs: they are estimated to occupy about 33,000 km² across the continental United States, slightly larger than the US state of Maryland (Davis et al., 2010). We surveyed 17 asphalted parking lots owned and maintained by Rutgers University. They were located in New Brunswick (population ~57,000) and Piscataway (population ~56,000), in Middlesex County, New Jersey, US (US Department of Agriculture plant hardiness zone 7a; USDA, 2012). Parking lots were selected for their availability and accessibility for the study, as well as the lots' range in size, diversity of locations, and maintenance (i.e. re-paving) history (Table S1). Selected lots were not weed-whacked or sprayed with herbicide between 19 May and 1 Sep 2014, and had not been re-paved for at least two years prior (personal communication, G. P. Ambrosy, Feb 2014). During survey months, average daily high, low, and average temperatures were 27.1°C, 14.7°C, and 20.9°C, respectively; there were 13 days with high temperatures above 32°C. Rainfall during this period averaged 126 mm per month, but only 48 mm fell in August (NJ State Climatologist, 2018).

Parking lot surveys and reproduction sampling

To inventory the parking lot flora, we surveyed the presence of spontaneously occurring vascular plant species in two microhabitats in asphalted parking lots: curb edges and asphalt cracks (Figure 1). Unsampled microhabitats included tree or planting islands and spaces around drain grates, but these represented minimal cover or were absent from most parking lots. A curb edge was defined as the linear space between the asphalt perimeter of a parking lot and the base or side of another impervious surface (such as a curb, wall, or sidewalk). Surveyed asphalt cracks measured >2 mm deep, >5 mm wide, and >25 cm long within the asphalted area. All curb edges were surveyed. Curb edges and asphalt cracks may or may not provide plants with physical contact to the non-asphalt substrate below the asphalt or contain visible, developed soil or litter layers. In curb edges and cracks that contained visible soil, median depth was 12 mm (range 1–65 mm).

In 2014, all (17) lots were surveyed once between 27 May and 9 June; 15 were surveyed again between 7 and 18 July; and all lots were surveyed for a final time between 20 and 29 August (Table S1). The asphalt crack and curb edge microhabitats were surveyed for species richness in each lot during survey sessions, except in one instance (Table S1). Species presence in asphalt cracks and curb edges of each lot were recorded separately during data collection but species lists were pooled for analyses unless otherwise stated. To assess sexual reproduction during each survey, we used a random number generator to select approximately 25% of the total curb edge area (i.e., one side of a rectangular lot) and about 10% of the total asphalt area for crack habitats (i.e., the area of 10% of the parking spaces in the lot) to identify individuals bearing flowers or fruits to species. We identified all specimens to the lowest level of taxonomic specificity that could be determined from their morphological and developmental status using

regional floras (Rhoads & Block, 2007; Haines, 2011). We identified all vascular plants growing in parking lots with at least two true leaves to family- or lower-level classifications (i.e. genus or species), except for four specimens that lacked reproductive structures and/or had been significantly damaged *in situ*; these specimens were excluded from the study. We used the USDA Plants Database (USDA, 2016) for taxonomic standardization of family, genus, and species names. Specimens with only genus- or higher-level identifications were excluded from trait and phylogenetic analyses.



Figure 1 (above): Parking lot microhabitats support vascular plant life. Two microhabitat types were surveyed for species richness in 17 parking lots on Rutgers University – New Brunswick campus, New Jersey, US: (a) curb edges, and (b) asphalt cracks.

Regional species pool identification

The main campus of Rutgers University is located in the townships of New Brunswick and Piscataway, both located within Middlesex County, New Jersey (US). We acquired all spontaneous (native and non-native) vascular plant species in the USDA Plants database on 12 April 2016 to generate a complete regional pool (USDA, 2016) with records in Middlesex County and surrounding counties (Mercer, Monmouth, Somerset, and Union). All but five species (*Amaranthus blitum*, *Chenopodium glaucum*, *Cyperus compressus*, *Erechtites hieraciifolius*, and *Zelkova serrata*) found in parking lot communities were also listed in the regional pool (USDA, 2016). The five species new to the county pool were added to the regional pool data set.

Beta diversity analyses

Beta diversity measures differences in species composition among sites within and between communities. Total beta diversity is a measure of dissimilarity that can range from 0 to 1, with higher values indicating higher dissimilarity and lower values indicating higher similarity between communities. As such, high beta diversity measurements can help identify unique species assemblages that may support higher overall species richness (or gamma diversity). Low beta diversity indicates homogeneous species assemblages across sites (McKinney, 2006). The ‘betapart’ R package was used to assess total Sørensen’s beta diversity (β_{SOR}) between the regional pool and pooled parking lot communities as well as among the 17 individual parking lot communities (Baselga & Orme, 2012; Baselga et al., 2018; R Core Team, 2018). To determine whether the individual parking lot communities are more or less homogenous than would be expected by chance, we compared β_{SOR} calculated for the observed species assemblages to a

distribution of β_{SOR} values calculated from 1000 simulations of sets of 17 parking lot communities. Simulations were created with the ‘resamp.2s’ function in the ‘SPACoDiR’ package in R which randomly selected species from the regional pool to form iterations of 17 parking lot communities with the same individual richness values as the observed communities (Hardy, 2010).

Phylogenetic analyses

We assessed the clustering of evolutionary lineages represented by parking lot communities as a subset of the regional pool by: (i) building a phylogeny of the regional pool (or regional megatree), then (ii) calculating phylogenetic diversity metrics based on differences between the observed (pooled, parking lot) community phylogeny and randomly-generated (null) communities. We used Phylomatic v3 to construct our regional megatree topology from the Phylomatic R20120829 plants megatree based on APG III taxonomy (Webb, Ackerly, & Kembel, 2008). The final megatree representing the regional flora contained 2127 seed plant species as terminals (Supplemental Methods).

The mean nearest taxon distance, mean pairwise distance, net relatedness index, and nearest taxon index (MNTD, MPD, NRI, and NTI, hereafter, respectively) measures can be used to test whether or not the observed community contains species that are more or less closely related (or clustered) compared to that of an expected (or null) community (Tucker et al., 2017). MNTD is the average phylogenetic distance between each of the taxa in the observed community and their closest observed relatives in the community; NTI is a standardized, richness independent version (or effect size) of MNTD that

assesses clustering between closely related taxa (Webb et al., 2002; Vamosi et al., 2009). MPD is the average pairwise distance between each of the taxa in the observed community and all other taxa in that community; NRI is a standardized, richness independent version (or effect size) of MPD that assesses overall clustering, including deep level clustering, throughout the phylogeny (Webb et al., 2002; Vamosi et al., 2009). NRI and NTI values >1.96 designate statistically significant patterns of phylogenetic clustering while values < -1.96 show statistically significant patterns of phylogenetic evenness (Santos et al., 2010).

We used Phylocom software for calculating MNTD, MPD, NRI, and NTI and for identifying regional megatree nodes that were significantly over-represented or under-represented in the parking lot species phylogeny (Webb et al., 2008). MNTD and MPD values for the observed parking lot phylogeny were compared to 999 null communities generated by randomly selecting species from the regional phylogeny pool without replacement while maintaining the species richness of each individual parking lot community (Webb et al., 2008); we incorporated measures of frequency into this analysis by using the number of lots in which each species was present as a proxy for abundance. We assessed over- and under-representation of nodes in the regional megatree by comparing the number of taxa in the (observed, pooled) parking lot communities from each node in the regional megatree to the distribution of the number of taxa from each node in 999 null communities generated by randomly selecting species from the regional phylogeny pool without replacement while maintaining the species richness of the pooled parking lot communities (Webb et al., 2008).

Trait data acquisition and standardization

We used the TRY Plant Trait Database to gather both public and private plant species categorical trait data on Grime's C-S-R (competitor, stress tolerator, ruderal) species strategy, clonal/vegetative reproduction capacity, selfing capacity, photosynthetic pathway, lifespan/longevity, and woodiness (Grime, 1977; Kattge et al., 2011; Table S2). We standardized the raw data into categories of qualitative trait states, which are all the observed, standardized conditions of a given trait used in this study (Table S2). We excluded entries that were unable to be interpreted as an indication of one or more than one trait state for the given trait. We used the USDA Plants database to gather threatened and endangered species statuses in New Jersey for each species in the regional pool (USDA, 2016). We defined rare and/or specialist species in this study as those designated threatened or endangered in New Jersey by the USDA (2016).

Trait state analyses

We used binomial models in a Bayesian statistical framework (Gelman et al., 2013) to compare the proportions of species with each trait state and status in the pooled parking lot communities to those proportions in the non-parking lot subset of the regional pool (Supplemental Methods). The same statistical methods were used to compare the frequencies of species with each trait state between the communities of reproductive and non-reproductive parking lot species; and between the communities of those species found in asphalt cracks and all other species in parking lots and the regional pool. Bayesian models were fitted with R package R2jags using Markov chain Monte Carlo (MCMC) methods (Su & Yajima, 2015; R Core Team, 2018). All models were run using

three MCMC chains with three different initial values for 500,000 iterations and burn-in of 50,000 iterations, which achieved convergence. Trait state frequencies were considered significantly different from one another if the posterior distribution of the difference between the 95% credible intervals of the relative frequencies (θ_i ; Supplemental Methods) did not overlap with 0, indicating that 0 was not a credible value for the difference in trait state or status frequency between the communities.

Results

Taxonomic diversity analyses

In parking lots we found a total of 119 vascular plant taxa representing 98 genera and 40 families, all angiosperms except *Juniperus sp.* (Cupressaceae). This included 103 taxa identified to species (or species complex [*Plantago major*/*P. rugelii* and *Oxalis stricta*/*O. corniculata*]), 17 taxa identified to genus, and one only to family (i.e., Poaceae; Table S3). The 18 taxa identified to either genus- or family-level were determined morphologically to be distinct species from other congeneric taxa (or other grasses, in the case of Poaceae) in the parking lots. On average, individual parking lots contained 29 taxa (range 11–70). Forty-six taxa were only found in one parking lot (Table S3). Forty-three species were native to the continental US, 56 were non-native, and four have both native and non-native populations in the continental US (Appendix 1). On average, parking lots contained 13 native (range 3–31) and 15 non-native species (range 6–32).

The regional pool consisted of 2199 vascular plant species (591 genera, 141 families; Appendix 1). Parking lots supported 5.4% of species in the regional pool, with individual parking lots containing between 0.5% and 3.2%. Fifty-three unique taxa

(44.5% of taxa) in parking lots were reproductive, i.e., only 2.4% regional pool species were reproductive in parking lots (Table S3). No threatened or endangered species from the regional pool were found in parking lots (Appendix 1).

Parking lot communities were more similar to each other than to the regional pool; beta diversity values among individual parking lot communities were lower (i.e., show less dissimilarity) than those between parking lots and the regional pool. Parking lot communities were also more similar to one another than would be expected by chance. The mean total Sørensen's beta diversity (β_{SOR}) among observed individual parking lots was 0.847, while mean β_{SOR} of 1000 simulations of parking lots with randomly selected species from the regional pool was 0.989 (range 0.983–0.994; $P < 0.001$). The β_{SOR} between the pooled parking lot communities and the regional pool was 0.911.

Phylogenetic diversity analysis

The parking lot phylogeny (including 103 plant taxa identified to species) had a significantly lower MPD and MNTD than what would be expected from null models, indicating that phylogenetic distance between randomly selected pairs of taxa and between any given taxon and its nearest relative are reduced in parking lots (263.2 and 52.4, respectively; $P < 0.05$ and $P < 0.01$, respectively; Table S4). The NRI and NTI of the parking lot phylogeny were 2.382 and 2.269, respectively, indicating significant phylogenetic clustering, both between closely related taxa and for deep level clustering (Table S4).

The parking lot pool of 103 species contained 82 eudicots, 40 of which belonged to Caryophyllales or Asterales. Nodes for eudicots, Caryophyllales, Asterales,

Plantaginaceae, Asteraceae, Caryophyllaceae, Ulmaceae, *Veronica* spp., *Plantago* spp., *Oxalis* spp., *Cyperus* spp., *Setaria* spp., and *Spergularia* spp. diversity were significantly overrepresented with numbers of taxa in the parking lot phylogeny than would be expected from null community phylogenies as drawn from the regional pool (all $P < 0.05$; Figure 2; Table S5). Nodes for monocots and *Carex* spp. had fewer representative taxa in the parking lot phylogeny than would be expected from null models ($P = 0.024$ and $P < 0.001$, respectively; Figure 2; Table S5).

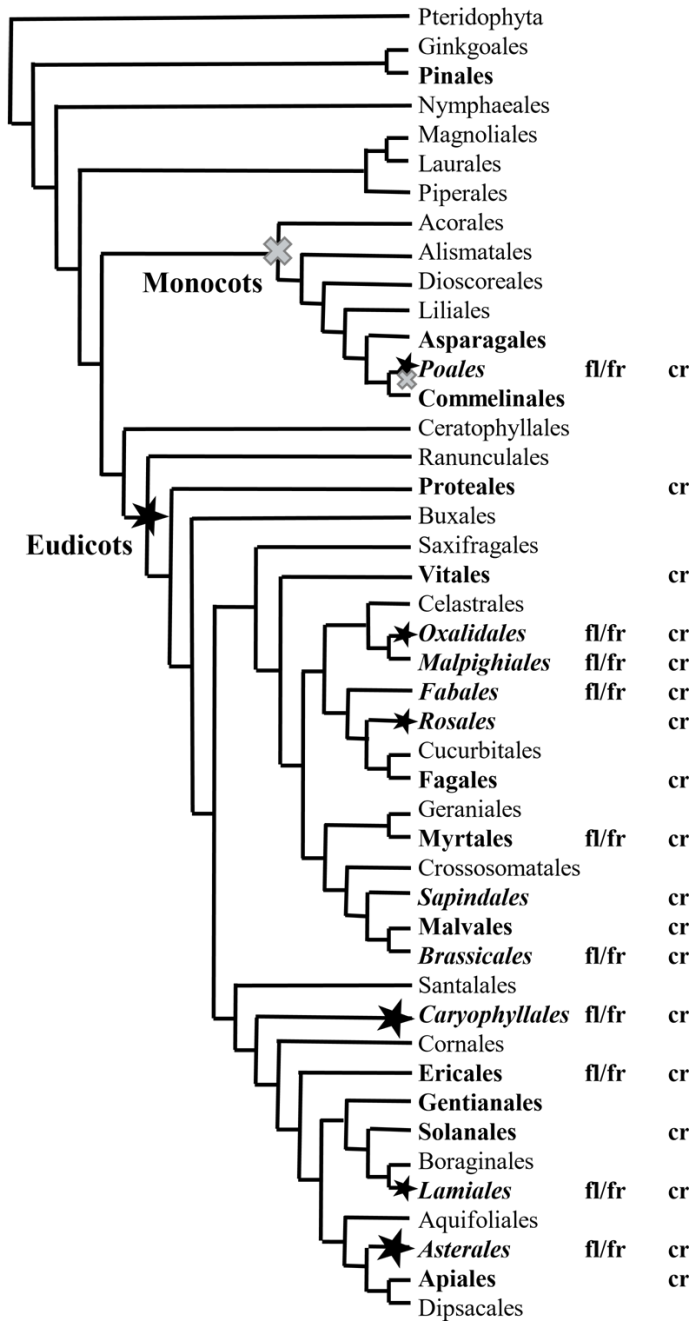


Figure 2 (above): Representation of parking lot taxa within an order-level phylogeny of the regional species pool based on APG III taxonomy. The regional pool was sourced from species occurrence records for Middlesex, Union, Somerset, Mercer, and Monmouth Counties in New Jersey, US (USDA, 2016). Bolded orders: present in

Rutgers parking lot communities. Bolded, italicized orders: present in eight or more (i.e., half of sampled) individual parking lots. Large black stars and large gray X's indicate the locations of orders or larger clades that were significantly overrepresented (black stars) or underrepresented (gray X's) with taxa in parking lot communities as compared to 999 null phylogenies from randomly selected communities from the regional pool; small black stars and small gray X's indicate the locations of families or genera that were significantly overrepresented (black stars) or underrepresented (gray X's) with taxa (overrepresented taxa, all $P < 0.01$; monocots, $P = 0.012$; *Carex*, $P < 0.001$). Poales contains both underrepresented and overrepresented taxa. "fl/fr": taxa that produced flowers and/or fruit in parking lots. "cr": taxa present in asphalt crack microhabitats.

Trait frequency analysis

Compared to the regional pool, trait states with significantly higher frequencies in the parking lot flora were annual lifespan (mean effect size +44%), biennial lifespan (+28%), C₄ photosynthetic pathway (+15%), Grime's R (ruderal) strategy (+31%), non-native origin (+34%), self-pollinating (+8%), and non-woodiness (+9%; Figure 3). There were significantly lower frequencies than would be expected for species being native (mean effect size -32%), perennials (-10%), clonal (-17%), C₃ (-9%), Grime's C (competitive) strategy (-21%), and woody (-8%) in the parking lot flora (Figure 3). Compared to the other (i.e., non-asphalt crack-dwelling) species in the region, trait states with significantly higher frequencies among asphalt crack-dwelling parking lot species were annual and biennial lifespans, C₄ photosynthetic pathway, Grime's R species strategy, non-woodiness, and non-native origin (Figure S1). Compared to the non-reproductive parking

lot species, trait states with significantly higher frequencies among reproductive parking lot species were annual lifespans and non-woodiness (Figure S2).

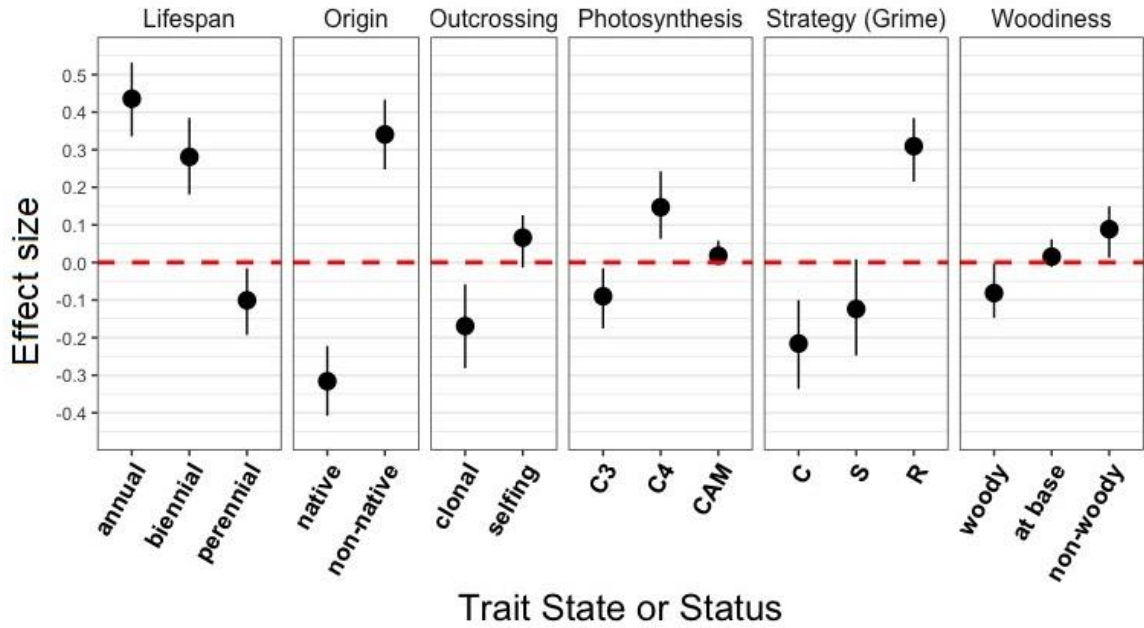


Figure 3 (above): Posterior distributions of effect sizes for trait states associated with regional plant species' presence in parking lot habitats. Circles represent means; vertical lines represent 95% confidence intervals. For Strategy, "C" = competitive; "S" = stress tolerant; and "R" = ruderal. Trait states CAM, S, and woody at base overlap with the 0.0 line (horizontal, dotted), and thus are non-significant. Significantly positive effect size values indicate that a higher frequency of species with that trait state or status were found in parking lots compared to that of the regional pool; significantly negative effect size values indicate that a lower frequency of species with that trait state or status were found in parking lots compared to that of the regional pool.

Discussion

The extreme abiotic conditions that parking lots pose on living organisms result in phylogenetic and functional filtering of the regional pool. Additionally, HHs seem to be hotspots for non-native species assemblages. We found that the HH plant assemblages used in our study are more similar to one another in taxonomic beta diversity than null models of HH plant assemblages would predict. Hardscape species do not represent an evenly distributed or random selection of lineages from the regional phylogeny, but rather a subset of deeply and terminally clustered lineages. The HH species set in these lineages contain a higher proportion of annual or biennial species, non-natives, self-compatible species, C₄ species, ruderal strategists, and/or non-woody species than the regional pool.

We found only 119 taxa in parking lots out of 2199 regional plant species, and taxonomic beta diversity was reduced compared to the regional pool. In contrast, floras at the city-wide scale often exhibit high dissimilarity (Aronson et al., 2014; La Sorte et al., 2014). Although our results suggest that urban species pools could experience filtering in large part due to the presence and extent of HHs, city squares and boulevards in have been found to increase floristic diversity in Central European cities (Lososová, et al., 2012). Nevertheless, parking lots and other HHs may not contribute as greatly to the beta diversity as previous habitats in urban areas, like parks, street medians, and abandoned properties (Tonteri & Haila, 1990; Lososová, et al., 2012).

We also found that the species pool of HHs is significantly more phylogenetically clustered than the regional species pool. This is not a surprising finding but does support the hypothesis that hardscapes are an important filter on species and phylogenetic diversity. Similarly, urban floras have a lower phylogenetic diversity than their non-urban

counterparts (Ricotta et al., 2009; Dolan, Aronson, & Hipp, 2017). For example, in urbanizing regions of Europe over the last three centuries, although species richness has generally increased, phylogenetic diversity has decreased (Knapp, Winter, & Klotz, 2017). Furthermore, phylogenetic clustering has been found in other urban habitats, specifically North American yard floras (Knapp et al., 2012).

Our findings also support most of our predictions related to the traits that are filtered for and against in parking lots, namely: (i) non-woody, ruderal, annual, and/or biennial species are more likely to survive and reproduce in the face of frequent mechanical and chemical disturbances; (ii) self-compatible species are better able to establish populations if specialist insect or vertebrate pollination vectors are lacking; and (iii) C₄ plants are better adapted for life in hot and arid conditions than C₃ plants. Many of these traits have been associated with plant persistence and/or success in city-wide floras (Knapp et al., 2008; Dolan et al., 2011; Kowarik, 2011; Williams et al., 2015; Palma et al., 2017). We also identified four traits negatively associated with parking lots that have shown the opposite trend in city-wide studies, namely woodiness, perennial lifespan, clonal reproduction, and competitive (C) species strategy (Williams et al., 2015; Dolan et al., 2017). These results highlight the need to study multiple urban habitats in order to understand the filters that cities as a whole pose on ecological communities.

Our results demonstrate that HH plant communities may be functionally similar to those of other terrestrial extreme environments. Natural extreme terrestrial habitats such as warm deserts also have floras in part characterized by short-lived herbs and C₄ photosynthetic species (Mulroy & Rundel, 1977; Archibold, 2012). Rocky outcrops can

be similarly dominated by C₄ and annual species (Akhani & Ziegler, 2002; Anderson, Fralish, & Baskin (Eds.), 2007).

With respect to the subset of sexually reproductive species in parking lots, we found that parking lots may prevent perennials, long-lived, or woody plants from reaching reproductive maturity. This is likely because of management practices; both mechanical and chemical strategies are used in these parking lots to reduce vegetation cover. Notably, selfing species were found at a higher frequency in parking lots than non-selfing species, but selfing species were not significantly more likely to reproduce in parking lots. This could indicate that being self-compatible is associated with other HH community traits, however self-compatibility alone may not be a driver for successful reproduction in parking lots. Furthermore, sexual reproduction of hardscape species may need to be assessed at finer temporal or demographic scales to detect the impacts of habitat filtering on reproductive rates.

The overrepresentation of eudicots, Asterales, and Caryophyllales in parking lots supports some of our hypotheses and also highlights additional traits that may confer ecological advantages to HH species. The Caryophyllales are a diverse clade with many plants characterized by C₄ photosynthesis and betalain pigments (Simpson, 2010; Sage et al., 2011). C₄ photosynthesis allows plants to more efficiently fix carbon under drought or heat stress, and betalains may be involved in managing vegetative stress (Des Marais, 2015). Similarly, the Asteraceae (Asterales) and Chenopodiaceae s.s. (Caryophyllales) each contain a notable proportion of species with seed and fruit dimorphism, or heterocarpy, which may benefit species that can divert energy towards one strategy over another in the face of environmental uncertainty (Imbert, 2002; Simons, 2011).

Modern asphalt is a recent human innovation; likewise, parking lots, roads, building facades, and other HHs are ecologically and evolutionarily novel to many organisms (Hobbs, Higgs, & Hall, 2013). HHs likely impose selective pressures that promote contemporary evolution at the population level, but HH abiotic conditions are also filtering species at the community level in urban and urbanizing areas. If our mechanistic hypotheses are correct, many HH species have genetic traits that make them more suited for life in these anthropogenic environments. An alternative but not mutually exclusive strategy may be that species that are generalists or phenotypically plastic for traits of high selective value are those species that are most frequently found in HHs. Our conclusions, however, may be limited to the filtering effect of HHs spatially embedded within an urban to suburban temperate region. HHs situated within non-urban and/or non-temperate environments may filter for similar plant community traits, but the resulting hardscape assemblages may represent non-homogenous and/or non-phylogenetically clustered subsets of the regional species pool.

Abiotic habitat filtering may primarily dictate species composition and assembly in extreme environments such as hardscapes. Nevertheless, novel HHs are unlikely to serve as biodiversity refuges in the Northeastern US, as they create abiotic environmental conditions that may be hostile to a large proportion of native, rare, and/or specialist regional species. Hardscapes are not only novel, extreme environments, but they are also impacted by the deterministic and stochastic processes associated with human activities. Thus, hardscapes may not support floristic communities that are ecologically analogous to those of natural, extreme terrestrial environments but rather floras that reflect filtering mechanisms associated with the anthropogenic preferences and norms. We may be

observing the formation of a new vegetation type—the temperate asphalt flora—due to the selective properties of asphalt in urban and suburban habitats. Future ecological studies of hardscapes or other anthropogenic habitats should investigate linkages between specific anthropogenic practices (e.g. vehicle traffic or herbicide application) and compositional outcomes at multiple habitat scales.

Supporting Information for Hardscape floristics: Functional and phylogenetic diversity of parking lot plants.

Supplemental Methods

Phylogenetic analyses

We used the ‘taxonlookup’ package in R to source and format taxonomic information for each species prior to creating trees (Pennell, FitzJohn, & Cornwell, 2016). Twenty-two species of non-seed plants were excluded from the final megatree due to lack of information in the Phylomatic R20120829 megatree (Webb et al., 2008; The Plant List, 2013). We dated nodes and established branch lengths with the ‘bladj’ function in Phylocom v4.2 and used the ‘phytools’ package in R to collapse over-nested singleton nodes that resulted from pruning (Wikström, Savolainen, & Chase, 2001; Revell, 2012). Fifty additional non-seed plant species were excluded from the final (dated) regional megatree due to missing node ages in data used by the BLADJ algorithm (Wikström et al., 2001). We used Phylocom v4.2 algorithms ‘comstruct’ and ‘nodesigl’ for calculating

phylogenetic diversity metrics and for identifying over-represented or under-represented nodes (Webb et al., 2008).

Trait data acquisition and standardization

Grime (CSR) species strategy trait data entries available for all regional species in TRY were standardized into three non-mutually exclusive trait state categories, namely “C,” “S,” and “R” (Table S2). The same was done for: photosynthetic pathway trait data entries, creating categories “C₃,” “C₄,” and “CAM”; lifespan trait data entries, creating categories “annual,” “biennial,” and “perennial”; and plant woodiness trait data entries, creating categories, “woody,” “woody at base,” and “non-woody” (Table S2). Two mutually exclusive trait state categories (“Y” and “N”) were created for the clonal/vegetative reproduction capacity and selfing capacity traits in this study by interpreting data entries from the following TRY traits: species reproduction type, diaspore type, plant clonal growth form, plant morphological adaptations (seed or dispersal unit metamorphoses), and plant vegetative regeneration capacity; and flower fertilization strategy, pollination syndrome, flower sexual self-incompatibility mechanism, and flower sexual syndrome, respectively (Table S2). We excluded trait data from TRY described as a “species’ mean” or “species’ median”. Measures of central tendency are less variable than individual data points, and species’ means or medians could represent trait states that are not actually observed on individuals of a given species (such as would be the case with a bimodal trait distribution).

For native status, a species was considered native if any of its populations originated in the continental US, and a species was considered non-native if any of its

populations originated outside of the continental US (USDA, 2016). We used the iPlant Collaborative Taxonomic Name Resolution Service version 4.0 (Boyle et al., 2013) to standardize and correctly match all species-trait entries between the TRY database and the USDA Plants database; final species lists published in this study use the taxonomic standards of the USDA Plants database (USDA, 2016; Table S4). TRY trait data were available for between 25.1% and 74.0% of regional species and 61.2% and 87.4% of parking lot species, depending on the trait (Table S2).

Trait state analyses

The null hypothesis tested for all trait states and statuses in statistical models was

$$(1) \quad \theta_{p,i} - \theta_{r,i} = 0$$

where $\theta_{p,i}$ is the frequency of species in community p (i.e., parking lot) with trait state i and $\theta_{r,i}$ is the frequency of species in community r (i.e., regional [non-parking lot]) with trait state i . The binomial distribution is parameterized with θ and n , the relative frequency of success and the total number of Bernoulli trials, respectively. Here, y_i is the number of species with trait state i in a community; y_i is assumed to be drawn from a binomial distribution with parameters θ_i and n_i , the relative frequency of species with trait state i in that community and the total number species from that community with data available for the trait, respectively. The frequencies of binary traits with mutually exclusive trait state categories as well as the frequencies of binary or categorical traits and statuses with non-mutually exclusive trait state categories were modeled thus:

$$(2) \quad y_i \sim \text{Binomial}(\theta_i, n_i)$$

$$(3) \quad \theta_i \sim \text{Beta}(1, 1)$$

where relative frequency parameter θ_i is given a non-informative prior – a uniform distribution bounded between 0 and 1.

Supplemental Tables and Figures

Table S1 (below): Parking lot information for the 17 Rutgers University (New Brunswick, New Jersey, US) parking lots surveyed for spontaneous vascular plants in 2014. Lot IDs are those used by Rutgers University Dept. of Transportation Services (<http://parktran.rutgers.edu/>) circa 2014. Lat./long. coordinates were collected during the first survey session via GPS (accurate within 5 m) from the northern-most point of the parking lot. Lot areas were provided by Rutgers University Center for Remote Sensing and Spatial Analysis (<http://www.crssa.rutgers.edu/>) in 2014. Re-paving history provided by Rutgers University Dept. of Administration and Public Safety (<https://ipo.rutgers.edu/>) in 2014. Adjacent land cover for each lot (within ~3m from perimeter) was recorded during the first survey session and excludes the category “roads” which were found adjacent to all lots. The number of spaces per lot were counted during the first survey session.

Lot Name	Location	Area (sq. m.)	No. Spaces	Re-paving History	Adjacent Land Cover	Surveyed 27 May - 9 June? (Y/N)	Surveyed 7-18 July? (Y/N)	Surveyed 20-29 August? (Y/N/curbs only)
4	New Brunswick, NJ (40.498 6° N,	716	6	N/A	buildings, ruder al area,	Y	Y	Y

	74.4478 ° W)				sidew alk			
5	New Brunsw ick, NJ (40.498 8° N, 74.4479 ° W)	756	12	N/A	lawn, ruder al area, sidew alk	Y	Y	Y
78	New Brunsw ick, NJ (40.482 7° N, 74.4357 ° W)	1467	20	N/A	lawn, planti ng beds, sidew alk	Y	Y	Y
75	New Brunsw ick, NJ (40.481 9° N, 74.4321 ° W)	1907	31	N/A	lawn, buildi ngs, planti ng beds, sidew alk	Y	Y	Y
71A	New Brunsw ick, NJ (40.481 6° N, 74.4292 ° W)	3090	27	N/A	forest , lawn, ruder al area	Y	Y	Y
Ag	New Brunsw ick, NJ (40.474 1° N,	3158	69	N/A	lawn, sidew alk	Y	Y	Y

	74.4348 ° W)							
95	New Brunswick, NJ (40.479 9° N, 74.4443 ° W)	4396	73	N/A	lawn, garden plots, sidewalk	Y	Y	Y
58C	Piscataway, NJ (40.527 7° N, 74.4690 ° W)	5829	68	N/A	lawn, sidewalk	Y	Y	curbs only
63A	Piscataway, NJ (40.523 2° N, 74.4560 ° W)	6473	75	Fully re-paved in 2012	lawn, sidewalk	Y	N	Y
97	New Brunswick, NJ (40.479 0° N, 74.4365 ° W)	7099	151	N/A	lawn, sidewalk	Y	Y	Y
70	New Brunswick, NJ (40.484 5° N, 74.4369 ° W)	7772	116	N/A	sidewalk, lawn, buildings	Y	Y	Y

74A	New Brunswick, NJ (40.4863° N, 74.4322° W)	8249	124	Partially re-paved in 2010	lawn	Y	Y	Y
82	New Brunswick, NJ (40.4836° N, 74.4315° W)	8283	70	N/A	lawn, buildi ngs, sidewalk	Y	Y	Y
20	New Brunswick, NJ (40.5056° N, 74.4509° W)	8402	78	N/A	buildi ngs, lawn, planti ng beds	Y	Y	Y
109	Piscataway, NJ (40.5176° N, 74.4294° W)	9281	122	Partially re-paved in 2010	lawn, buildi ngs, sidewalk	Y	Y	Y
62	Piscataway, NJ (40.5274° N, 74.4579° W)	9633	126	N/A	lawn, sidew alk	Y	N	Y
99C	New Brunswick, NJ (40.478	11218	195	N/A	lawn, sidew alk	Y	Y	Y

4° N,
74.4288
° W)

Table S2 (below): Data on eight plant traits and statuses were collected for all regional and parking lot species as available from the TRY Plant Trait database (Kattge et al., 2011; and references therein: Fitter & Peat, 1994; Cornelissen, 1996; Meir et al., 2002; Quested et al., 2003; Cornelissen et al., 2004; Díaz et al., 2004; Hill, Preston, & Roy, 2004; Kühn, Durka, & Klotz, 2004; Wright et al., 2004; Craine et al., 2005; Gachet, Véla, & Tatoni, 2005; Kerkhoff et al., 2006; Preston, Cornwell, & DeNoyer, 2006; Muller et al., 2007; Kleyer et al., 2008; Reich et al., 2008; Ciocorlan, 2009; Green, 2009; Kattge et al., 2009; Klimešová & De Bello, 2009; Moretti & Legg, 2009; Paula et al., 2009; Reich, Oleksyn, & Wright, 2009; Wirth & Lichstein, 2009; Flowers, Galal, & Bromham, 2010; Laughlin et al., 2010; Laughlin et al., 2011; Prentice et al., 2011; Blonder et al., 2012; Dainese & Bragazza, 2012; Han et al., 2012; Kapralov, Smith, & Filatov, 2012; Koele et al., 2012; Chen et al., 2013; Manzoni et al., 2013; Zanne et al., 2014), and the USDA Plants database (USDA, 2016) to assess functional and phylogenetic diversity of a hardscape habitat floral community. Merging existing trait records for clonal and selfing capacities was done in R v3.3.3 (R Core Team, 2017). For trait analyses, the regional pool consisted only of those species not found in parking lots (i.e., 2199 less 103).

Trait or status name	Data source	Data availability: regional species (2096 max)	Data availability: parking lot species (103 max)	Keywords used for standardization	Trait state or assigned (*not mutually exclusive)	No. of regional species with trait state or status	No. of parking lot species with trait state or status
Native status	USDA Plants data	2096	103	native	native (to	1621	47

	of same name				continen tal US)*		
				non-native	non- native (to continen tal US)*	502	60
Species	TRY	541	63	competitive	C*	441	38
strategy type	database trait			or C			
(Grime)	of same name			stress- tolerant or S	S*	275	24
				ruderal or R	R*	316	57
Clonal/vegeta tive	Merging of multiple	910	80	vegetative	Y	655	44
reproduction	TRY			(from Species			
capacity	database			reproduction			
	traits:			type data);			
	Species			vegetative			
	reproduction			(from			
	type,			Diaspore			
	Diaspore			type data);			
	type, Plant			buds, bulbils,			
	clonal			tubers,			
	growth form,			rhizomes,			
	Plant			above-			
	morphologic			ground			
	al			stems, plant			
	adaptations:			fragmentatio			
	seed or			n, plantlets,			
	dispersal			or turions			
	unit			(from Plant			
	metamorpho			clonal			
	ses, and			growth			
	Plant			form); bulbs,			
	vegetative			bulbils, plant			
	regeneration			fragmentatio			
	capacity			ns, buds,			

phylogenous
shoots,
rhizomes,
pleicorms,
root shoots,
runners,
tubers, or
turions (from
Plant
morphologic
al
adaptations:
seed or
dispersal unit
metamorphos
es data);
stolons,
branching
root stocks,
buds, bulbils,
bulbs,
suckering,
corms,
creeping
stocks,
ramets,
rooting at
nodes, plant
fragmentatio
n, plantlets,
moderate,
rapid,
rhizomes,
rooting
shoots, slow,
tubers, or
tussock-

				forming (from Plant vegetative regeneration capacity data)			
				only seed/spore or generative (from Species reproduction type data); only seed, fruit, or generative (from Diaspore type data)	N	255	36
Selfing capacity	Merging of multiple TRY database traits: Flower insemination strategy, Pollination syndrome, Flower sexual self- incompatibili- ty mechanism,	526	63	autogamy, automixis, facultative allogamy, facultative autogamy, or mixed mating (from Flower insemination strategy data); autogamy, cleistogamy, or selfing	Y	453	60

and Flower	(from			
sexual	Pollination			
syndrome	syndrome			
	data); self-			
	compatibility			
	(from Flower			
	sexual self-			
	incompatibili			
	ty			
	mechanism);			
	apomixis,			
	selfing,			
	cleistogamy,			
	or autogamy			
	(from Flower			
	sexual			
	syndrome			
	data)			
	only	N	73	3
	allogamy			
	(from Flower			
	insemination			
	strategy			
	data);			
	“selfing			
	never” (from			
	Pollination			
	syndrome			
	data); self-			
	incompatibili			
	ty or			
	unknown			
	mechanism			
	(from Flower			
	sexual self-			
	incompatibili			
	ty			

				mechanism data); and dioecy or obligatory out-crossing (from Flower sexual syndrome data)			
Photosynthetic pathway	TRY	851	82	C3	C3*	787	69
	database trait			C4	C4*	77	19
	of same name			CAM or crassulacean acid metabolism	CAM*	4	1
Plant lifespan	TRY	1139	88	annual	annual*	287	61
	database trait			biennial or “bi-annual”	biennial *	160	37
	of same name			pluriennial, perennial, shrub, tree, or poly- annual	perennia l*	986	68
Plant woodiness	TRY	1552	90	woody	woody*	346	12
	database trait			suffrutescent or woody at base	woody at base*	26	2
	of same name			grass, non- woody, or herbaceous	non- woody*	1229	80

Table S3 (below): 119 spontaneous vascular plant taxa identified in asphalt cracks or curb edges of 17 parking lots on Rutgers University campus in New Brunswick and Piscataway, New Jersey, US in 2014. Four taxa belong to species complexes (*Plantago* major/*P. rugelii* and *Oxalis stricta*/*O. corniculata*) within which the identification of imperfect and immature specimens is difficult, yet post-survey knowledge about the flora of Rutgers University suggested that both species in each complex were likely to have been observed in parking lots (unpublished data, L. Struwe). We identified all plants with at least 2 true leaves to family- or lower-level classifications (i.e. genus or species). Four damaged and/or immature specimens were unable to be identified to family and excluded from the study.

Genus	Asphalt crack	Reproductive	No. lots
<i>Acalypha rhomboidea</i>	Y	Y	6
<i>Acer rubrum</i>	Y	N	4
<i>Ageratina altissima</i>	N	N	2
<i>Ailanthus altissima</i>	Y	N	9
<i>Alliaria petiolata</i>	Y	N	1
<i>Allium</i> sp.	N	N	1
<i>Amaranthus blitum</i>	N	Y	4
<i>Amaranthus</i> sp.	Y	N	2
<i>Amaranthus spinosus</i>	N	N	1
<i>Ambrosia artemisiifolia</i>	Y	N	2
<i>Anagallis arvensis</i>	Y	Y	5
<i>Apocynum cannabinum</i>	N	N	1
<i>Arctium minus</i>	N	N	1
<i>Arenaria serpyllifolia</i>	N	Y	4
<i>Artemisia vulgaris</i>	Y	N	5
<i>Baccharis halimifolia</i>	N	N	1

<i>Bidens sp.</i>	N	N	1
<i>Bromus arvensis</i>	N	Y	1
<i>Buddleja davidii</i>	N	N	1
<i>Celtis occidentalis</i>	Y	N	1
<i>Cerastium fontanum</i>	Y	Y	9
<i>Chamaesyce maculata</i>	Y	Y	12
<i>Chenopodium album</i>	Y	Y	4
<i>Chenopodium glaucum</i>	Y	Y	1
<i>Cirsium vulgare</i>	N	Y	1
<i>Commelina sp.</i>	N	N	1
<i>Convolvulus arvensis</i>	N	N	2
<i>Conyza canadensis</i>	Y	Y	9
<i>Coronopus didymus</i>	Y	Y	3
<i>Crataegus sp.</i>	Y	N	2
<i>Cyperus amuricus</i>	Y	N	1
<i>Cyperus compressus</i>	N	Y	1
<i>Cyperus dentatus</i>	Y	Y	3
<i>Cyperus squarrosus</i>	Y	Y	5
<i>Cyperus strigosus</i>	Y	N	2
<i>Daucus carota</i>	Y	N	1
<i>Dianthus armeria</i>	Y	N	1
<i>Digitaria sanguinalis</i>	Y	Y	16
<i>Duchesnea indica</i>	N	N	1
<i>Dysphania pumilio</i>	Y	N	12
<i>Echinochloa crusgalli</i>	Y	Y	1
<i>Eclipta prostrata</i>	N	Y	1
<i>Eleusine indica</i>	Y	Y	15
<i>Elymus repens</i>	N	Y	3
<i>Epilobium coloratum</i>	Y	Y	4
<i>Eragrostis sp.</i>	Y	N	15

<i>Erechtites hieraciifolius</i>	Y	Y	9
<i>Erodium cicutarium</i>	N	Y	1
<i>Eupatorium serotinum</i>	Y	Y	8
<i>Festuca sp.</i>	Y	N	1
<i>Galinsoga quadriradiata</i>	Y	N	2
<i>Gleditsia triacanthos</i>	N	N	1
<i>Hieracium caespitosum</i>	N	N	1
<i>Ipomoea sp.</i>	Y	N	1
<i>Juncus bufonius</i>	Y	Y	6
<i>Juniperus sp.</i>	N	N	6
<i>Kummerowia stipulacea</i>	Y	Y	3
<i>Lactuca canadensis</i>	N	N	3
<i>Lactuca serriola</i>	N	N	2
<i>Lamium amplexicaule</i>	N	Y	3
<i>Lepidium virginicum</i>	Y	Y	8
<i>Lindernia dubia</i>	Y	Y	3
<i>Lolium perenne</i>	N	N	1
<i>Malva sp.</i>	Y	N	1
<i>Matricaria discoidea</i>	N	N	1
<i>Medicago lupulina</i>	Y	Y	5
<i>Melilotus officinalis</i>	N	N	1
<i>Mollugo verticillata</i>	Y	Y	16
<i>Muhlenbergia schreberi</i>	N	N	1
<i>Oenothera biennis</i>	Y	N	2
<i>Oxalis</i>	Y	Y	13
<i>stricta/corniculata</i>			
<i>Panicum sp.</i>	Y	N	10
<i>Parthenocissus</i>	N	N	2
<i>quinquefolia</i>			
<i>Phragmites australis</i>	Y	N	3
<i>Phytolacca americana</i>	N	N	1

<i>Plantago lanceolata</i>	Y	Y	6
<i>Plantago major/rugelii</i>	Y	Y	14
<i>Platanus sp.</i>	Y	N	1
<i>Poa annua</i>	N	N	1
<i>Poa compressa</i>	N	N	1
<i>Polygonum aviculare</i>	Y	Y	16
<i>Polygonum convolvulus</i>	N	N	1
<i>Polygonum pennsylvanicum</i>	Y	Y	7
<i>Polygonum persicaria</i>	Y	Y	5
<i>Populus sp.</i>	N	N	1
<i>Portulaca oleracea</i>	Y	Y	15
<i>Prunella vulgaris</i>	Y	Y	1
<i>Quercus imbricaria</i>	N	N	1
<i>Quercus sp.</i>	N	N	2
<i>Robinia pseudoacacia</i>	Y	N	5
<i>Rubus phoenicolasius</i>	N	N	4
<i>Rumex crispus</i>	N	Y	2
<i>Scleranthus annuus</i>	Y	Y	2
<i>Senecio vulgaris</i>	Y	Y	8
<i>Setaria faberi</i>	N	N	1
<i>Setaria pumila</i>	Y	N	1
<i>Setaria pumila</i>	Y	Y	8
<i>Solanum ptycanthum</i>	Y	N	2
<i>Solidago canadensis</i>	Y	N	3
<i>Sonchus sp.</i>	N	N	3
<i>Spergula arvensis</i>	Y	N	1
<i>Spergularia rubra</i>	Y	Y	3
<i>Spergularia salina</i>	Y	Y	3
<i>Stellaria media</i>	N	Y	5

<i>Symphyotrichum racemosum</i>	Y	Y	7
<i>Taraxacum officinale</i>	Y	Y	10
<i>Toxicodendron radicans</i>	N	N	2
<i>Tridens flavus</i>	N	N	1
<i>Trifolium dubium</i>	Y	Y	1
<i>Trifolium repens</i>	Y	Y	15
<i>Triplasis purpurea</i>	Y	Y	4
<i>Ulmus pumila</i>	N	N	1
Poaceae sp.	Y	N	17
<i>Veronica arvensis</i>	N	Y	5
<i>Veronica peregrina</i>	N	Y	4
<i>Veronica polita</i>	N	N	1
<i>Vicia sp.</i>	N	N	1
<i>Vitis sp.</i>	Y	N	4
<i>Zelkova serrata</i>	Y	N	8

Table S4 (below): Spontaneous parking lot flora is significantly phylogenetically clustered. Assessed via Phylocom v4.2 for calculating mean nearest taxon distance (MNTD), mean pairwise distance (MPD), net relatedness index (NRI), and nearest taxon index (NTI) for the observed parking lot communities ($N_{\text{parkinglotspecies}} = 103$; Webb et al., 2008). MNTD and MPD values for the observed community phylogeny were compared to 999 null communities' MNTD and MPD values, respectively, as generated by randomly selecting species pools of the same richness from the regional pool without replacement. 'Rank low/high' indicates the number of null community values that fell above/below the observed value, respectively. Statistical significances for the differences between observed and null means were determined from the ranks (* = $P_{\text{two-tailed}} < 0.05$; ** = $P_{\text{two-tailed}} < 0.01$). NRI and NTI values > 1.96 tend to designate statistically significant phylogenetic clustering while values < -1.96 tend to show statistically significant phylogenetic evenness (Santos et al., 2010).

	Observed	Null mean \pm SD	Rank low/high	Effect size
MPD	263.2	293.9 \pm 12.9	990/9 *	NRI = 2.382
MNTD	52.4	74.3 \pm 9.7	996/3 **	NTI = 2.269

Table S5 (below): Phylogenetic nodal over- and under-representation in New Jersey, US parking lot plant communities. Counts of taxa per node (column “taxa”) for the observed parking lot species phylogeny were compared to counts of taxa per node in each of 999 null communities generated by randomly selecting species from the regional pool without replacement. Only nodes with “node names” fully provided by the Phylocom v4.2 “nodesigl” output are shown here (Webb et al., 2008). Positive and negative signals indicate clades that were significantly overrepresented or underrepresented at $\alpha = 0.05$, respectively, with taxa in the parking lots. Sabiales, Asterales, and Trochodendrales are eudicot orders. Ceratophyllales is a sister group to the eudicot clade but was not represented in the parking lots. Analysis conducted with “nodesigl” algorithm in Phylocom v4.2 (Webb et al., 2008). ‘Rank, low’ and ‘rank, high’ indicate the number of null community values that fell above/below the observed value, respectively. Statistical significances for the differences between observed and null numbers of taxa per node were determined from the ranks.

Node name	Observed no. taxa	rank, high	rank, low	signal	<i>P</i> (two-tailed)
Sabiales to Asterales	82	998	0	+	<0.001
Trochodendrales to Asterales	82	998	0	+	<0.001
Ceratophyllales & eudicots	82	991	6	+	0.012
Eudicots	82	991	6	+	0.012
Caryophyllales	21	999	0	+	<0.001
Monocots	21	12	975	-	0.024
Asteraceae	19	989	6	+	0.012
Asterales	19	977	8	+	0.016

Caryophyllaceae	8	999	0	+	<0.001
Plantaginaceae	6	982	4	+	0.008
<i>Cyperus</i>	5	996	0	+	<0.001
<i>Plantago</i>	3	988	0	+	<0.001
<i>Setaria</i>	3	997	0	+	<0.001
<i>Veronica</i>	3	980	1	+	0.002
<i>Spergularia</i>	2	997	0	+	<0.001
<i>Oxalis</i>	2	988	2	+	0.004
Ulmaceae	2	981	2	+	0.004
<i>Carex</i>	0	0	998	-	<0.001

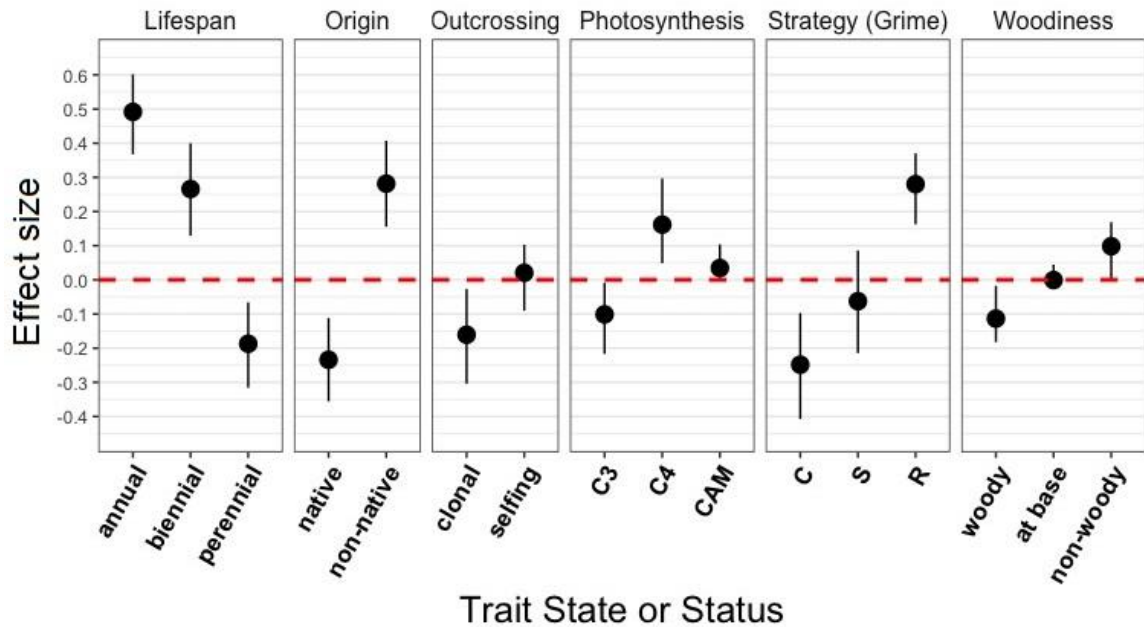


Figure S1 (above): Posterior distributions of effect sizes for trait states associated with regional plant species' presence in the asphalt cracks of a parking lot habitat. Circles represent means; vertical lines represent 95% confidence intervals. For strategy (Grime), "C" = competitive; "S" = stress tolerant; and "R" = ruderal. Trait states' confidence intervals for selfing, CAM, S, and woody at base overlap with zero, and thus are not different from 0 and non-significant. Significantly positive effect size values indicate that a higher frequency of species with that trait state or status were found in the asphalt crack community compared to that of the remaining parking lot and regional pool; significantly negative effect size values indicate that a lower frequency of species with that trait state or status were found in the asphalt crack community compared to that of the remaining parking lot and regional pool.

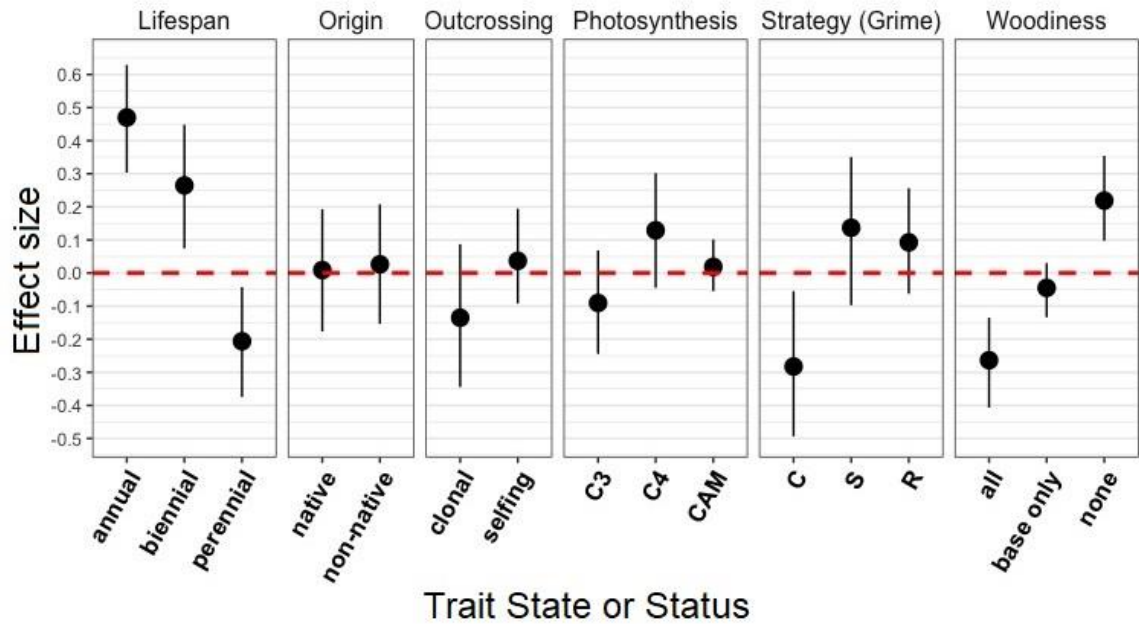


Figure S2 (above): Posterior distributions of effect sizes for trait states associated with plant sexual reproductivity in a parking lot habitat. Circles represent means; vertical lines represent 95% confidence intervals. For strategy (Grime), “C” = competitive; “S” = stress tolerant; and “R” = ruderal. Confidence intervals for all trait states except annual, biennial, and perennial lifespans, C, woody (all), and non-woody overlap with zero, and thus are not different from 0 and non-significant. Significantly positive effect size values indicate that a higher frequency of species with that trait state or status were found in the sexually reproductive parking lot species compared to that of the non-sexually reproductive species; significantly negative effect size values indicate that a lower frequency of species with that trait state or status were found in the sexually reproductive parking lot species compared to that of the non-sexually reproductive species.

Chapter 2

The seed dispersal and pollination strategies of hardscape habitat plants

Abstract

Understanding community assembly for wild species in anthropogenic settings has never been more important, as biodiversity and ecosystem services are threatened by continual habitat destruction. Pollination and seed dispersal strategies of plant species in ecological communities can serve as indicators of how biotic and abiotic factors interact to influence ecosystem function, structure, and composition over space and time. In this study I ask, do hardscape habitats select for certain pollination and seed dispersal mechanisms in plants? Using species lists and methods generated in Chapter 1, I determined which classes of seed dispersers and pollinators were associated with parking lot plant communities. These communities contained a higher proportion of species that utilize six or more types of dispersal vectors and a lower proportion of species that have only one type of dispersal vector than the regional species pool. Parking lot communities also contained a higher proportion of species that utilize both animal-mediated and non-animal-mediated pollination mechanisms than the regional species pool. Novel hardscape habitats may filter for plant species with highly generalized dispersal syndromes because deterministic processes dominate plant community assembly in the hardscape flora. This study highlights multimodal pollination and generalist dispersal processes as important potential drivers of community assembly in extreme, novel environments.

Introduction

Pollination and seed dispersal strategies of plant species in ecological communities can serve as indicators of how biotic and abiotic environmental factors interact to maintain ecosystem function, structure, and composition over space and time. Understanding community assembly for wild species in anthropogenic settings has never been more important, as biodiversity and ecosystem services are changing rapidly due to human-mediated disturbances and habitat loss (McKinney, 2006; Aronson et al., 2016). Novel hardscape habitats, including sidewalks, roads, buildings, medians, plazas, parking lots, and other types of impervious surfaces or structures have drastically influenced local ecological conditions (Lundholm & Richardson, 2010), impacting species conservation and ecological function.

In 2004, hardscape habitats in the United States covered over 110,000 km², an area approximately the size of the state of Virginia (Frazer, 2005). Human-made hardscape habitats are a type of extreme environment and analogous in some ways to natural extreme terrestrial environments such as deserts, rocky outcrops, and barrens. These environments as well as novel hardscape habitats tend to exhibit high surface temperatures, low average soil moisture, and limited soil or soil organic matter (Rothschild & Mancinelli, 2001). Similarly, plant communities in warm deserts, rocky outcrops, and parking lots (the latter being a novel hardscape habitat) are characterized by annual herbs, C₄ photosynthesis, and the ability to withstand both drought and mesic conditions (Mulroy & Rundel, 1977; Akhani & Ziegler, 2002; Anderson, Fralish, & Baskin (Eds.), 2007; Archibold, 2012; Chapter 1). Although the extreme abiotic conditions found in novel hardscape habitats as well as naturally occurring extreme

terrestrial habitats may be significant deterministic drivers of community assembly processes in those habitats (Rundel et al., 1991; Nuzzo, 1996; Danin, 1999; Ware, 2002; Durant et al., 2012; Chapter 1), plant species may also be selected for or against by filters in novel hardscape habitats based on their ability to successfully (i) reach these habitats in space through seed dispersal, and (ii) reproduce there, usually through sexual reproduction via pollination (Ozinga et al., 2005).

Seed dispersal can be a key driver of plant community assembly. Major seed dispersal syndromes include adaptations for dispersal by wind, water, self (e.g., explosive fruits), and animals, where the latter category can include mammals, birds, and ants, among other groupings (Howe & Smallwood, 1982). Animal dispersal of seeds is much less frequent for plants in deserts and semi-arid regions globally than in wet or mesic regions (Howe & Smallwood, 1982). This pattern may be similar in novel hardscape habitats where vegetation structure to provide food resources and protect non-bird vertebrates from predators is lacking. Wind dispersal is most common across dry habitats globally and increases in frequency along environmental gradients as vegetation structure becomes more open, while the frequency of water dispersal in plant communities increases with soil moisture (Howe & Smallwood, 1982; Ozinga et al., 2004).

Variable pollination success among plants due to limited pollinating vectors may also create an environmental filter for species establishment in plant communities (Sargent & Ackerly, 2008). For example, two ornamental *Ficus* spp. only began to invade native plant communities in Florida after the introduction of their specialist pollinator to the region so they could set seed (Nadel, Frank, & Knight, 1992). Hardscape habitats host an abundance of herbaceous plant species but very few shrubs and trees (Chapter 1),

creating an open vegetation structure and allowing for occasional windiness: habitat qualities both typically associated with wind pollination over biotic pollination (Culley, Weller, & Sakai, 2002). Additionally, the potential for urban warming to create mismatches between plant flowering times and pollinator activity may be locally intensified in hardscape habitats (Harrison & Winfree, 2015), where temperatures are extremely high (e.g. Davis et al., 2010). Moreover, hardscape habitats such as parking lots are likely to be hotspots for environmental contaminants like diesel exhaust and heavy metal contamination that may reduce the abundance and diversity of specialist insect pollinators in these habitats (Harrison & Winfree, 2015). Thus, plant species in hardscape habitats with wind-dispersed diaspores, and wind-pollinated or self-pollinated flowers may be more resistant to local extinction than species with biotic dispersal and/or zoophilic pollination needs (Bond, 1994; Waser et al., 1996).

In this study, we analyzed the spontaneous vascular flora of parking lots, a common hardscape habitat across the United States (Davis et al., 2010). We predict that plant communities of parking lots will contain a lower proportion of species that have animal-mediated pollination and seed dispersal syndromes than that of the regional pool because animal pollinators and dispersers may be reduced in both abundance and diversity due to urban-associated warming and environmental pollution (Harrison & Winfree, 2015). Second, do hardscape habitats filter spontaneous plant communities for species with generalized pollination and seed dispersal syndromes, and against pollination and dispersal specialists? We predict that plant communities of parking lots will have a higher average number of dispersal and pollination syndrome vector types than that of the regional pool.

Materials and Methods

The regional pool and parking lot community species list used in this study was developed during a previous study of hardscape habitats (Chapter 1). Thus, methods for parking lot selection, parking lot surveys for spontaneous vascular plant species richness, and regional species list acquisition were described in detail in Chapter 1. The regional pool was defined as the vascular plant species found in Middlesex County, New Jersey, USA (USDA, 2016).

Pollination and dispersal vector data acquisition and standardization

We used the TRY Plant Trait Database to gather both public and private raw categorical trait data for regional (including parking lot community) plant species to assess pollination syndrome, animal- and non-animal-mediated pollination capacity, dispersal syndrome, and animal- and non-animal-mediated dispersal capacity (Fitter & Peat, 1994; Kühn, Durka, & Klotz, 2004; Gachet, Vêla, & Tatoni, 2005; KEW, 2008; Kleyer et al., 2008; Moretti & Legg, 2009; Paula et al., 2009; Kattge et al., 2011). Dispersal and pollination syndrome observations in the TRY database include both theoretical determinations as well as empirical (i.e., field or lab based) observations of these mechanisms (Kattge et al., 2011). We standardized the raw data values into categories of trait states, which are the possible conditions of a given trait (Table S1). For TRY trait data, we excluded entries that were unable to be interpreted as an indication of one or more than one trait state.

Dispersal syndrome TRY data entries available for all regional species were standardized into seven non-mutually exclusive trait state categories, namely “wind dispersed,” “self-dispersed,” “water dispersed,” “non-human mammal dispersed,” “ant dispersed,” “bird dispersed,” and “other non-human zoochory” (Table S1). Pollination syndrome TRY trait data entries were standardized into nine non-mutually exclusive categories: “wind pollinated,” “self-pollinated,” “beetle pollinated,” “fly pollinated,” “bee or wasp pollinated,” “water pollinated,” “general insect pollinated,” “butterfly or moth pollinated,” and “other non-human biophily”. We also used dispersal syndrome and pollination syndrome TRY trait data entries to create a second trait for each syndrome (i.e., “Dispersal syndrome: zoochory” and “Pollination syndrome: biophily”) by standardizing the data differently. Dispersal syndrome and pollination syndrome TRY trait data entries were standardized into two non-mutually exclusive categories, “animal-mediated” and “non-animal-mediated”; a third trait state, “animal- and non-animal-mediated,” was added for each trait and assigned to species that were also assigned both “animal-mediated” and “non-animal-mediated” status (Table S1). Species with trait data entries were thus assigned to one or more trait states for each trait as described above. Any single datum as well as multiple observations assigning individual species to one or more trait states were interpreted equally (i.e., non-weighted trait state assignment); the number of unique observations contributing to each trait state assignment were only parsed out for analysis in order to answer questions of species bias in the TRY database. All data manipulations were done in R v3.3.3 (Wickham, 2007; Wickham & Francois, 2015; R Core Team, 2018). To determine if hardscape habitat plant communities have a lower proportion of species that have animal-mediated pollination and seed dispersal

mechanisms than that of the regional pool, we conducted a trait state frequency Bayesian analysis using beta-binomial models as detailed in Chapter 1.

Specialists versus generalists and vector counts

To determine if plant communities growing in parking lots have a higher average number of dispersal and pollination syndrome vector types than that of the regional pool, we quantified the total number of trait state categories (corresponding to total number of vectors used) for both pollination and dispersal for each species in the regional pool and the parking lot community. For example, each species could have dispersal syndrome observations consisting of any, none, or all of the following trait states: wind, self or un-assisted, water, non-human mammal, bird, ant, or another non-mammal animal. In other words, each species had either 0, 1, 2, 3, 4, 5, 6, or 7 dispersal vector types observed. We considered species specialized for dispersal if they had exactly one dispersal vector type observed; species were considered generalized for dispersal if they had five or more dispersal vector types observed. The same process of vector type counting was done for pollination syndrome, where each species could have observations consisting of any, none, or all of the following trait states: wind, self or un-assisted, beetle, fly, bee or wasp, butterfly or moth, or another animal. In other words, each species had either 0, 1, 2, 3, 4, 5, 6, or 7 possible pollination vector types observed. We considered species specialized for pollination if they had exactly one pollination vector type observed; species were considered generalized for pollination if they had four or more pollination vector types observed. We also quantified the total number of observations used from the TRY database (in assigning vector count) for each species in the regional pool and parking lot

community. The total number of observations only included unique observations; for example, two dispersal syndrome data points for one species from within one reference that were both standardized to “wind dispersal” would be counted as one unique observation, not two.

Database bias analyses

Testing such hypotheses becomes more complex when major plant trait databases are known to have a species bias (Kattge et al., 2011; Sandel et al., 2015). For five quantitative plant traits (i.e., specific leaf area, seed mass, leaf nitrogen, height, and photosynthetic capacity) in the TRY plant trait database, Sandel et al. (2015) found that the number of observations per species was either positively or negatively biased for the trait value estimate, depending on the trait and how frequently species’ measurements were reported (Kattge et al., 2011). Our results may be relics of database bias due to high reporting rates of findings on ruderal or cosmopolitan species, such as those found in high frequencies in parking lots (Chapter 1). Thus, investigating the intensity of the bias itself and introducing corrective procedures to the analyses are necessary to avoid misinterpretation of the data (Violle, Borghy, & Choler, 2015).

We applied database bias corrective measures to control for the number of observations per species for those species for which at least one observation for the trait was available in the database. We used two unknown mean, unknown variance, linear models in a Bayesian framework and used the deviance information criterion (DIC) to determine whether the relationship between the total number of dispersal vector types of each species (y_i) and the number of dispersal syndrome observations contributing to that

species' vector count (x_i) were better fit with one overall slope (β_1) and intercept (β_0) or with distinct slopes ($\beta_{1,parking}, \beta_{1,region}$) and intercepts ($\beta_{0,parking}, \beta_{0,region}$) for each community. DIC is an appropriate tool for model selection in this case (Spiegelhalter et al., 2002; Hooten & Hobbs, 2015). DIC values are interpreted relative to one another, where the lower DIC value tends to indicate the better model fit if the difference between values is at least 3 to 7 (Spiegelhalter et al., 2002). We used the one slope, one intercept model as follows

$$y_i \sim N(\theta_i, \sigma^2); \quad \theta_i = \beta_0 + \beta_1(x_i)$$

with

$$\tau = 1/\sigma^2; \quad \tau \sim \text{Gamma}(0.001, 0.001)$$

and

$$\beta_0 \sim N(0.0, 0.000001); \quad \beta_1 \sim N(0.0, 0.000001)$$

as non-informative, flat priors. For the two slope, two intercept model, the non-informative priors for variance (σ^2) as well as the distinct slopes ($\beta_{1,parking}, \beta_{1,region}$) and intercepts ($\beta_{0,parking}, \beta_{0,region}$) were maintained as above, but we modeled the data as

$$y_i \sim N(\theta_i, \sigma^2); \quad \theta_i = (k_i)[\beta_{0,parking} + \beta_{1,parking}(x_i)] + (1 - k_i)[\beta_{0,regional} + \beta_{1,regional}(x_i)]$$

where the dummy variable (k_i) is equal to 1 for the parking lot community or 0 for the regional pool.

We repeated this analysis to test whether the relationship between the total number of pollination vector types of each species (y_i) and the number of pollination syndrome observations contributing to that species' vector count (x_i) were better fit with one overall slope (β_1) and intercept (β_0) or with distinct slopes ($\beta_{1,parking}, \beta_{1,region}$) and intercepts ($\beta_{0,parking}, \beta_{0,region}$) for each community. Bayesian models were fitted and DIC

for each model was calculated with package R2jags v0.5-7 in R v3.3.3 using Markov chain Monte Carlo (MCMC) methods (Su & Yajima, 2015; R Core Team, 2018). All models were run using three MCMC chains with three different initial values for 100,000 iterations and burn-in of 10,000 iterations, which achieved convergence.

Results

The parking lot community contained a significantly higher frequency of species with non-animal-mediated pollination (+14%) and non-animal-mediated dispersal (+11%) mechanisms than the regional pool (Figures 1-2). The parking lot community also contained a significantly higher frequency of species with a combination of both non-animal-mediated and animal-mediated pollination (+18%) and dispersal (+20%) mechanisms than that of the regional pool (Figures 1-2). In addition, the parking lot community contained a significantly higher frequency of species with wind dispersal capacity (+19%), self or un-assisted dispersal capacity (+22%), water dispersal capacity (+19%), non-human mammal dispersal (+23%), bird dispersal capacity (+17%), dispersal capacity via other non-human animals (+12%), self or un-assisted pollination capacity (+20%), and hymenopteran (bee) pollination capacity (+12%; Figures 1-2).

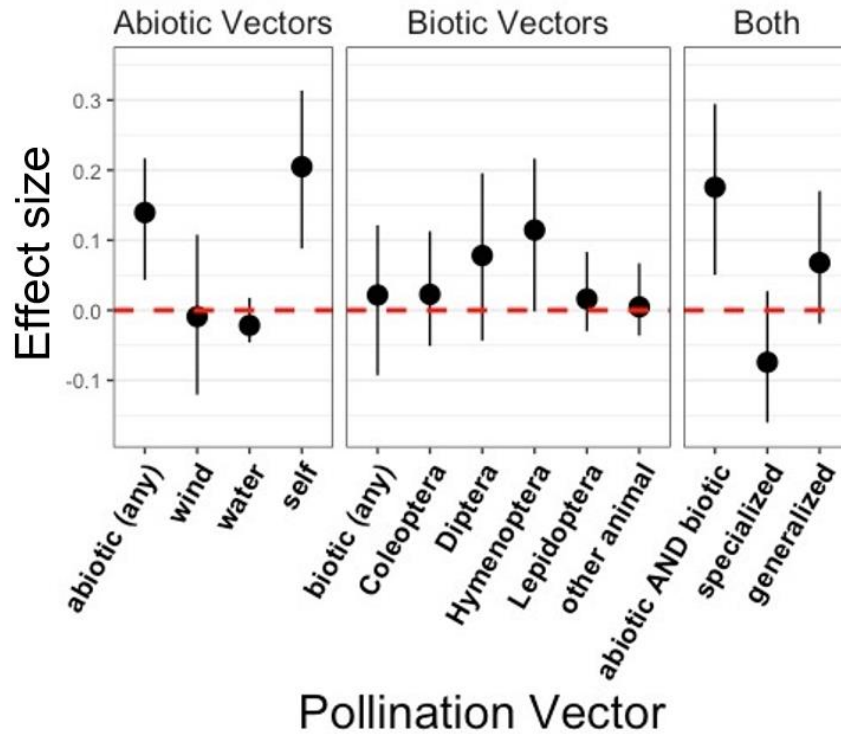


Figure 1 (above): Posterior distributions of effect sizes for pollination strategies

associated with regional plant species' presence in parking lot habitats. Points represent means; vertical lines represent 95% credible intervals. Pollination vectors wind, water, all biotic vectors and combinations, specialized, and generalized overlap with the 0.0 line (horizontal, dotted), and thus are non-significant. Significantly positive effect size values indicate that a higher frequency of species with that pollination strategy were found in parking lots compared to that of the regional pool; significantly negative effect size values indicate that a lower frequency of species with that pollination strategy were found in parking lots compared to that of the regional pool.

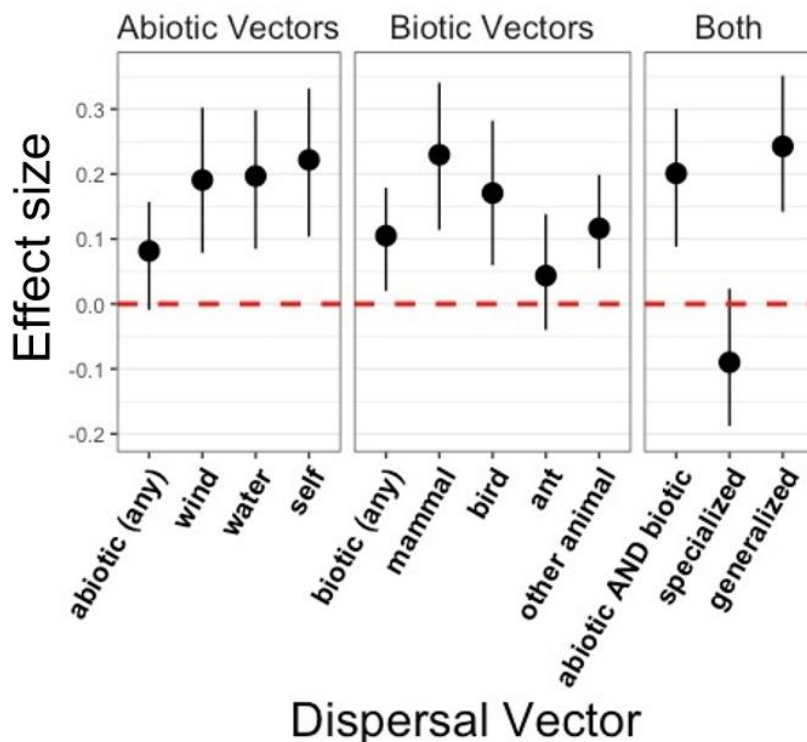


Figure 2 (above): Posterior distributions of effect sizes for seed dispersal strategies associated with regional plant species' presence in parking lot habitats. Points represent means; vertical lines represent 95% credible intervals. Dispersal vectors abiotic (any), ant, and specialized overlap with the 0.0 line (horizontal, dotted), and thus are non-significant. Significantly positive effect size values indicate that a higher frequency of species with that dispersal strategy were found in parking lots compared to that of the regional pool; significantly negative effect size values indicate that a lower frequency of species with that dispersal strategy were found in parking lots compared to that of the regional pool.

Species in the parking lots have more dispersal vectors and pollination vectors on average than those in the regional pool (Figures 3-4). For dispersal, the regional species had a mean of 2.06 dispersal vectors per species (range 0 to 7), while the parking lot

species had a mean of 3.22 dispersal vectors per species (range 0 to 7; Figure 3). For pollination, the regional species had a mean of 2.25 pollination vectors per species (range 0 to 5), while the parking lot species had a mean of 2.62 dispersal vectors per species (range 1 to 5; Figure 4).

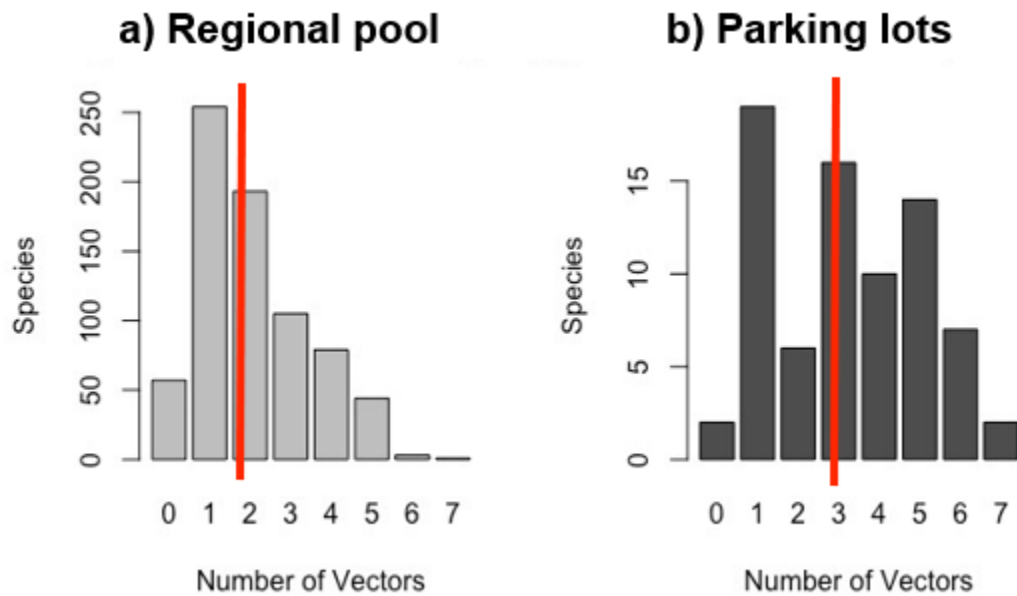


Figure 3 (above): The number of dispersal vector types for (a) regional pool species was 2.06 vectors on average per species (range 0-7), while (b) parking lot species had an average of 3.22 vectors per species (range 0-7; Table S1). Red vertical lines indicate the mean number of vectors per species for each community. Dispersal data is from the TRY Plant Trait Database (Kattge et al., 2011).

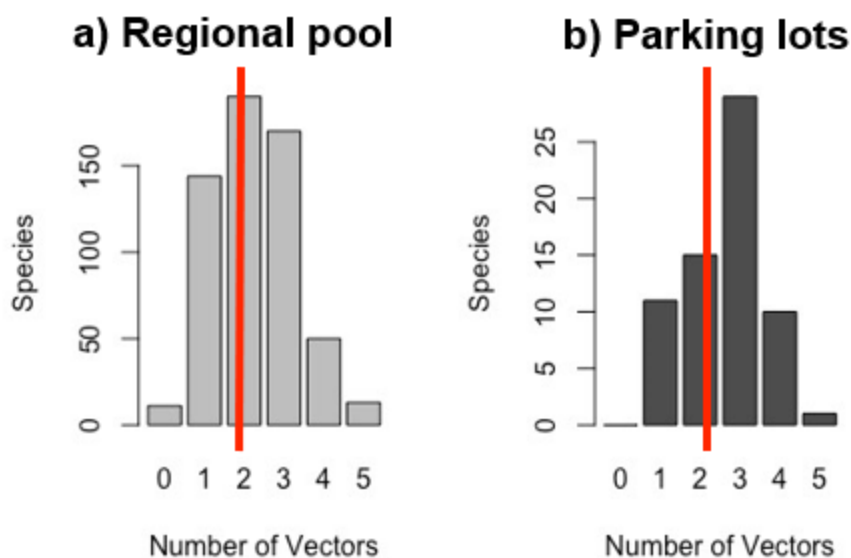


Figure 4 (above): The number of pollination vector types for (a) regional pool species was 2.25 vectors on average per species (range 0-5), while (b) parking lot species had an average of 2.62 vectors per species (range 1-5; Table S1). Red vertical lines indicate the mean number of vectors per species for each community. Pollination data is from the TRY Plant Trait Database (Kattge et al., 2011).

There are more observations in the TRY Plant Traits database on dispersal syndrome and pollination syndrome per species on average for the parking lot community than for those in the regional pool (Figures 5-6). For dispersal syndrome, the database has 2734 unique observations on 736 regional species, or 3.72 unique observations on average per regional species, whereas there are 421 unique observations on 76 parking lot species, or 5.54 unique observations on average per parking lot species (Figure 5). For pollination syndrome, the database has 1860 unique observations on 578 regional species, or 3.22 unique observations on average per regional species, whereas there are 248

unique observations on 66 parking lot species, or 3.76 unique observations on average per parking lot species (Figure 6).

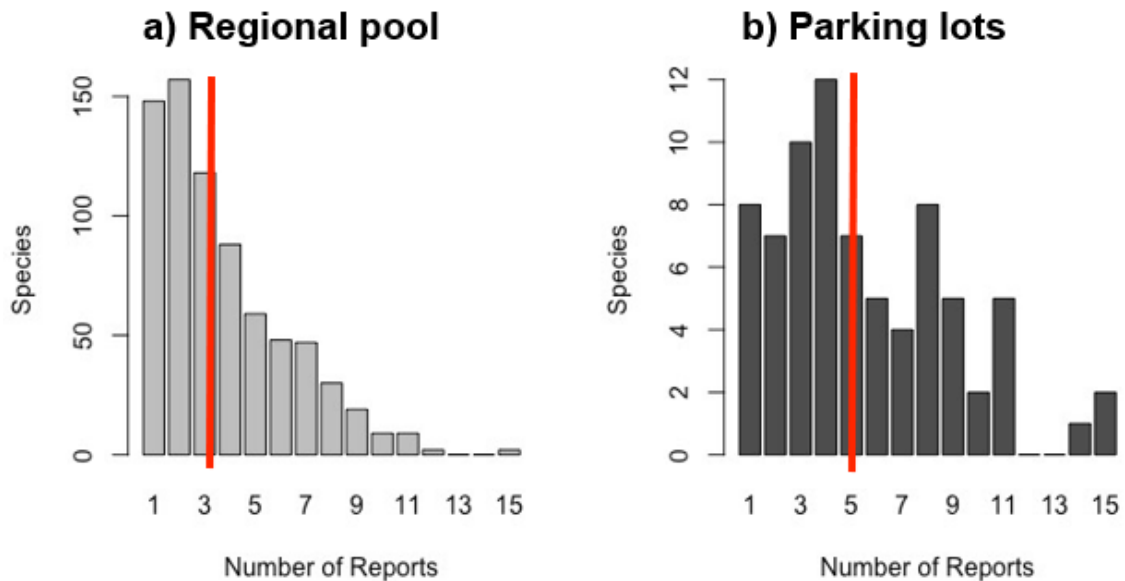


Figure 5 (above): Reports per species in the TRY Plant Traits database on dispersal mechanisms (Kattge et al., 2011). There were 3.7 reported observations on average per (a) regional species (range 1-15), whereas there were 5.5 reported observations on average per (b) parking lot species (range 1-15). Red vertical lines indicate the mean number of reports per species for each community. Identical dispersal mechanism observations for a given species from a single data source within the TRY database were counted as one report.

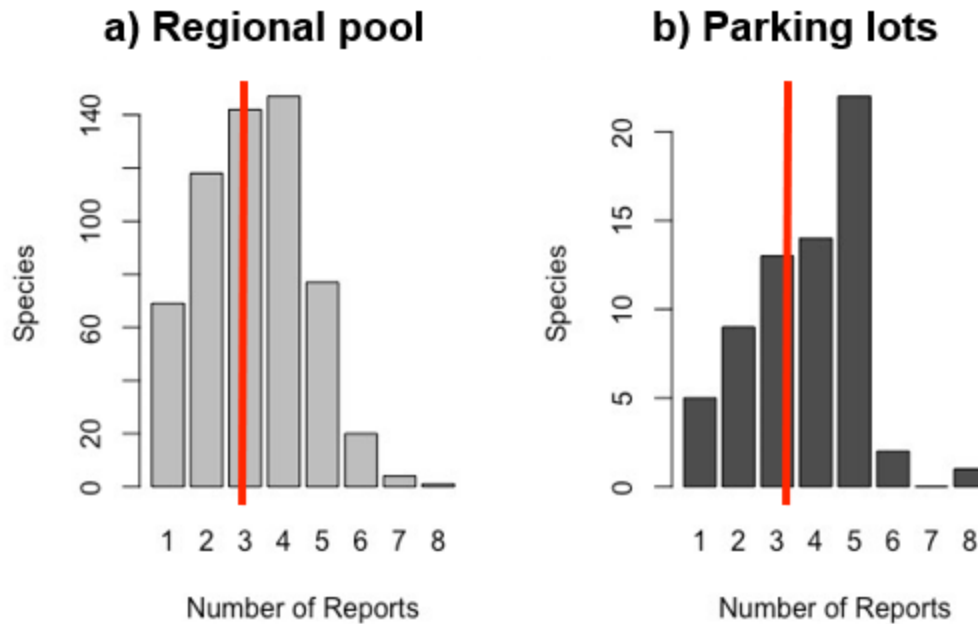


Figure 6 (above): Reports per species in the TRY Plant Traits database on pollination mechanisms (Kattge et al., 2011). There were 3.2 reported observations on average per (a) regional species (range 1-8), whereas there were 3.8 reported observations on average per (b) parking lot species (range 1-8). Red vertical lines indicate the mean number of reports per species for each community. Identical pollination mechanism observations for a given species from a single data source within the TRY database were counted as one report.

After controlling for the higher number of observations available for parking lot species over regional pool species, the parking lot species still have a higher average number of dispersal vector types than that of the regional species. The number of dispersal vectors per report count for the regional pool had a mean of 0.587 (range 0 to 1), while the parking lot species had a mean of 0.620 (range 0 to 2). In contrast, the number of pollination vectors per report count for the regional pool and parking lot

species each had equal means of 0.757 (range 0 to 2 for regional species; range 0.25 to 1.5 for parking lot species).

For species-specific dispersal vector counts as predicted linearly by number of dispersal vector observations, the two-slope, two-intercept model for dispersal vectors returned a DIC that was 16.4 lower than that of the one-slope, one-intercept model, indicating that the observed dispersal vector data for parking lot species and regional species are significantly better fit by two separate linear models (i.e., one for each community) as opposed to a single linear model (Figure 7). As interpreted from the two-slope, two-intercept model, the means of the posterior distributions of the parking lot community slope ($\beta_{1,parking}$) and intercept ($\beta_{0,parking}$) were both higher than those of the regional pool ($\beta_{1,regional}$ and $\beta_{0,regional}$, respectively). The two-slope, two-intercept model was calculated to have a DIC of 2669.0 with means of the posterior distributions for the regional slope ($\beta_{1,regional}$) of 0.461 (95% CI = 0.441-0.481), the regional intercept ($\beta_{0,regional}$) of 0.347 (95% CI = 0.256-0.436), the parking lot community slope ($\beta_{1,parking}$) of 0.480 (95% CI = 0.432-0.526), and the parking lot community intercept ($\beta_{0,parking}$) of 0.566 (95% CI = 0.269-0.872). The one-slope, one-intercept model was calculated to have a DIC of 2685.4 with means of the posterior distributions for the slope (β_1) of 0.471 (95% CI = 0.453-0.490) and the intercept (β_0) of 0.339 (95% CI = 0.253-0.422).

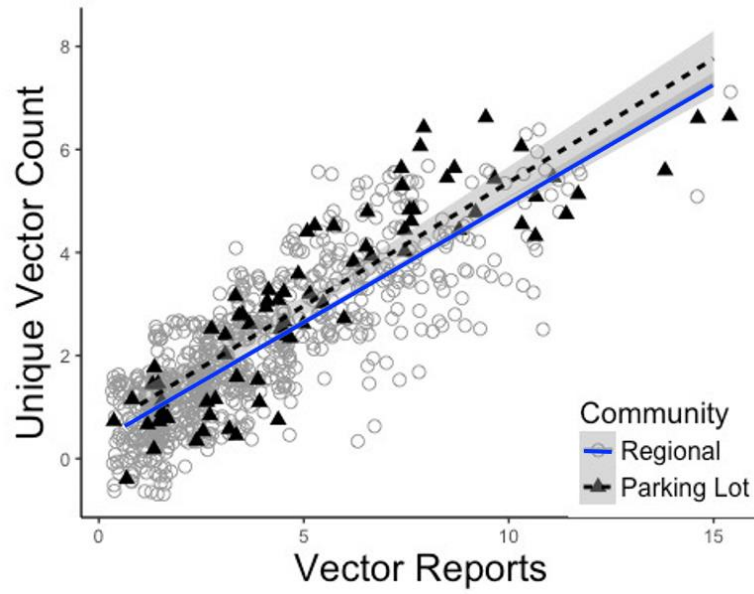


Figure 7 (above): Number of dispersal vector types plotted against number of dispersal mechanism reports per species. Each point represents a single species either from the regional pool (gray circles) or the parking lots (black triangles). The best fit linear trend line for the regional pool species is solid blue; the best fit line for the parking lot species is dashed and black.

For species-specific pollination vector counts as predicted linearly by number of pollination vector observations, the one-slope, one-intercept model and the two-slope, two-intercept model returned DICs of 1967.6 and 1975.3, respectively, indicating that the observed pollination vector data are better fit by a single linear model than two separate linear models (Figure 8).

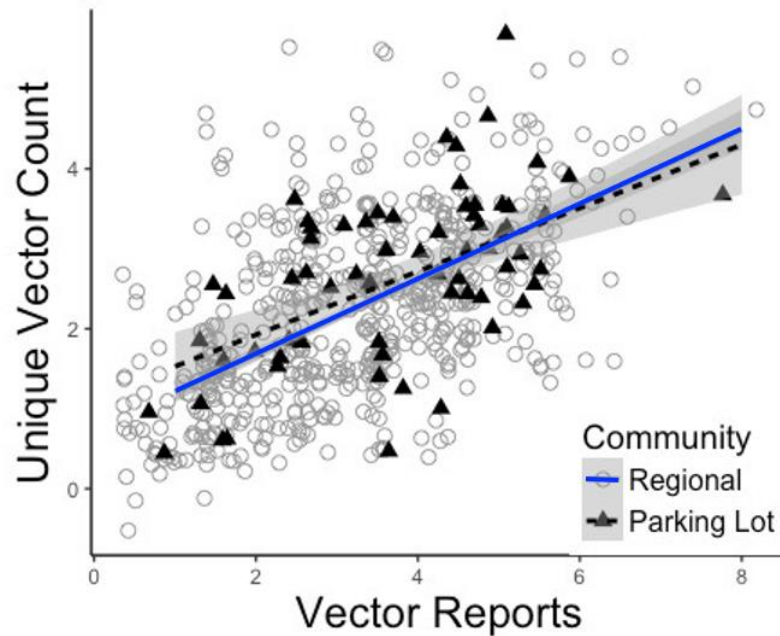


Figure 8 (above): Number of pollination vector types plotted against pollination mechanism reports per species. Each point represents a single species either from the regional pool (gray circles) or the parking lots (black triangles). The best fit linear trend line for the regional pool species is solid blue; the best fit line for the parking lot species is dashed and black.

Discussion

This study of the pollination and dispersal syndromes associated with hardscape habitat plants highlights multimodal pollination and generalist dispersal syndromes as important potential drivers of community assembly in these extreme, novel environments. Species with both animal vectors as well as non-animal vectors for dispersal and pollination were significantly more frequent in parking lot communities than in the regional pool. In other words, hardscape habitats likely create an environmental filter that selects for plant species with a higher probability of immigration via seed dispersal through diverse

vectors. Additionally, hardscapes may provide a selective advantage to species that are pollinated by both animal and non-animal vectors.

Although specialists are not uncommon, many plant species have floral and/or fruiting phenotypes that may promote pollination and/or seed dispersal interactions from more than one vector (Ozinga et al., 2014; Gómez et al., 2015). Plant species with these generalized pollination and seed dispersal syndromes, in which multiple animal groups, water, wind, and/or the plant itself can confer pollination and seed dispersal services, may be less likely to experience local extinction due to failed mutualisms or novel environmental conditions than specialist plant species (Bond, 1994; Waser et al., 1996). Generalist pollination syndromes in plants also tend to be found in habitats where pollinator movement through the habitat may be detrimental to pollinator survival (Waser et al., 1996); this may be the case in novel urban hardscape habitats (Chapter 1).

On the other hand, our findings suggest that urban hardscape plant communities may not be filtered intensively for true pollinator generalist plants but rather for certain types of pollination syndromes in plant species, whether they be part of a more generalized set of floral traits or not. Stated differently, highly generalist pollinator plants may not be any more likely to become members of novel hardscape plant communities than a plant that has just one syndrome each of non-animal and animal pollination vectors. Plant-animal interactions for pollination and seed dispersal may become crucial to novel hardscape plants in damp periods, such as during flooding, but wind and self-imposed methods may be more beneficial in dry times and drought. Furthermore, the process of pollination itself may be under novel selective pressures in hardscape habitats (Sargent & Ackerly, 2008).

Novel hardscape habitats may be embedded in anthropogenically disturbed landscapes where novel faunal communities can provide unpredictable opportunities as well as ecological mismatches. Interactions with both vertebrate and invertebrate animals are crucial to the completion of the life cycles of many plant species through the processes of pollination as well as seed and fruit dispersal. Empirical evidence for the influence of urbanization on pollination services and pollinator diversity is mounting but lacks universal consensus. Differences in plant community traits related to dispersal and pollination have not been impacted by urbanization in a globally predictable way at the scale of entire cities (Williams et al., 2015). Nevertheless, increased natural habitat fragmentation, non-native species, climate change impacts, and air, soil, and water pollution can make it difficult for some animal species to persist in urban areas (Harrison & Winfree, 2015). For example, fewer specialist species of insects were found in Swiss cities as compared to their associated rural areas (Knop, 2016).

Ecological communities may be shaped by complementary degrees of both niche-based and stochastic exclusion of species (Gravel et al., 2006). Novel hardscape habitats may filter for plant species with highly generalized dispersal syndromes because deterministic, “niche assembly” processes dominate plant community assembly in the hardscape flora (Weiher et al., 2011; Chapter 1). Impervious surfaces (i.e., concrete curbs and asphalt) spatially and environmentally separate the parking lot microhabitats that host plant life (i.e., curb edges and asphalt cracks) from one another and from other suitable habitats for growth outside of parking lots, making mid- to long-distance plant diaspore dispersal critical for colonization. In addition, early colonizers of frequently disturbed areas such as hardscapes may incur fitness benefits due to priority effects and mass

effects across these local communities (Auerbach & Shmida, 1987; von Gillhaussen et al., 2014). Although our results suggest that novel hardscapes may limit the establishment (Chapter 1) of plants in the regional flora due to the inhospitable nature of impervious surfaces, explicitly assessing dispersal ability in hardscapes as a driver over niche-based factors would require further analysis of hardscape metacommunity structure and the use of variance partitioning approaches (e.g., Brunbjerg, Ejrnæs, & Svenning, 2012; Meynard et al., 2013). Alternatively, a combination of both priority effects for species with generalist dispersal capacities as well as local adaptation on an ecological time scale may be at play (e.g. Cheptou et al., 2008; Urban & De Meester, 2009).

Lastly, trait databases such as TRY (Kattge et al., 2011) have been critical to advances in modern ecological and plant sciences (e.g., Falster et al., 2015; Rice et al., 2015), but these databases have the potential to be heavily biased in comparisons across species, functional groups, habitats, or geographic regions with different levels of sampling or reporting efforts. This problem may be exaggerated when estimating and comparing “count” data (i.e., number of pollinators, species richness) which are derived from raw data entries with a categorical structure (i.e., pollination syndrome, species presence) in the database. The biases inherent in data collection must be explicitly tested for each variable of interest during data analysis by correcting for some measure of sampling effort or observation depth. Emphasis on this process will allow us to make more accurate, globally-informed inferences about novel ecological communities.

**Supporting Information for The seed dispersal and pollination strategies of
hardscape habitat plants.**

Supplemental Table

Table S1 (below): Data on pollination and dispersal mechanisms were collected for all regional and parking lot species as available from the TRY Plant Trait database (Kattge et al., 2011; and references therein: Fitter & Peat, 1994; Kühn, Durka, & Klotz, 2004; Gachet, Véla, & Tatoni, 2005; KEW, 2008; Kleyer et al., 2008; Moretti & Legg, 2009; Paula et al., 2009) to assess patterns of species filtering in a hardscape habitat floral community. Merging existing trait records for animal-mediated dispersal (“zoochory”) and pollination (“biophily”) capacities was done in R v3.4.1 (R Core Team, 2018). For trait analyses, the regional pool consisted only of those species not found in parking lots (i.e., 2199 less 103).

Trait name	TRY database trait data used	Data availability:		Keywords used for standardization	Trait state assigned (*not mutually exclusive)	Regional species with trait state	Parking lot species with trait state
		Regional species (2096 max)	Parking lot species (103 max)				
Dispersal syndrome	Trait of same name	736	76	anemochory, chamaechory, wind, air, pappus, or meteorochory	wind-dispersed*	293	45
				unassisted dispersal, autochory, ballochory, barochory, blastochory, herpochory, parent plant, below-ground seed production, vegetative dispersal, boleochory, or ombrochory	self-dispersed*	271	45
				water, ombrochory, bythisochoy, rain, currents, hydrochory, or nautochory	water-dispersed*	366	53
				non-human mammals	mammal-dispersed*	246	43
				ants	ant-dispersed*	100	13
Dispersal syndrome: zoochory	Dispersal syndrome, but standardized into trait states differently than above	733	75	birds	bird-dispersed*	233	37
				insects, worms, fish, reptiles, amphibians, or mollusks	zoochory, other*	7	9
				non-human mammals, ants, birds, animals, zoochory, vertebrates, insects, worms, fish, reptiles, or mollusks	animal-dispersed*	559	64
				anemochory, chamaechory, wind, meteorochory, water, ombrochory, bythisochoy, rain, currents, hydrochory, nautochory, unassisted dispersal, autochory, ballochory, barochory, blastochory, herpochory, parent plant, below-ground seed production, vegetative dispersal, or ombrochory	non-animal-dispersed*	561	66
				[presence of keywords for both animal-mediated and non-animal-mediated dispersal syndromes]	animal- and non-animal-dispersed	387	55
Pollination syndrome	Trait of same name	578	66	anemogamy or wind	wind-pollinated*	184	20
				autogamy, cleistogamy, or selfing	self-pollinated*	281	46
				beetles	beetle-pollinated*	64	8
				flies	fly-pollinated*	329	43
				bees or wasps	bee-pollinated*	376	51
Pollination syndrome: biophily	Pollination syndrome, but standardized into trait states differently than above	578	66	hydrogamy or water	water-pollinated*	20	0
				entomogamy or "insects"	insect-pollinated, general*	383	44
				butterflies or moths	butterfly-pollinated*	23	3
				slugs or "animals"	biophily, other*	22	2
				beetles, flies, bees, wasps, entomogamy, insects, butterflies, moths, slugs, or animals	animal-pollinated*	429	51
Pollination syndrome: biophily	Pollination syndrome, but standardized into trait states differently than above	578	66	anemogamy, wind, autogamy, cleistogamy, selfing, hydrogamy, or water	non-animal-pollinated*	422	58
				[presence of keywords for both animal-mediated and non-animal-mediated pollination syndromes]	animal- and non-animal-pollinated	273	43

Chapter 3

Urban phenotypic evolution in the American plantain (*Plantago rugelii*), a native weed

Abstract

Urbanization and human activity are major contributors to trait evolution in spontaneous species. Urban areas impose habitat fragmentation, abiotic stress, and increased disturbance regimes upon plant populations. Here I ask, are native plant populations phenotypically convergent within urban areas yet phenotypically divergent from conspecific populations in rural areas in key morphological, physiological, and phenological traits? In addition, are the patterns of phenotypic divergence and convergence consistent with predictions for putatively adaptive traits for urban evolution? Utilizing the native weedy plant *Plantago rugelii* (Plantaginaceae), I conducted a common garden experiment with seeds sourced from seven urban and seven rural populations in parks in Philadelphia, New York City, and their respective Metropolitan Areas. Compared to rural plants, in urban plants leaf thickness was lower, number of reproductive spikes was lower, and time to mature fruit was longer overall, but these differences between urban and rural plants were not statistically significant in both metropolitan regions when analyzed independently. The average height of urban plants was taller compared to rural plants in the New York region. It is hypothesized that there may be a trade-off in resources between growing taller versus more numerous reproductive spikes in *P. rugelii* urban plant populations in large, heavily trafficked cities. Patterns of urban trait divergence in *P. rugelii* populations are distinct from those

found in previous urban evolution studies. Species-specific differences in reproductive biology and phenotypic plasticity may ultimately determine how urban environmental pressures influence plant evolution.

Introduction

Urban environmental and geophysical conditions can drive the evolution of spontaneous biological populations of plants and animals (Aronson et al., 2016; Johnson & Munshi-South, 2017). Urbanization causes habitat fragmentation, increased average temperatures and levels of carbon dioxide, altered precipitation patterns, salt stress, increased frequency and intensity of disturbances, shifts in the abundance and diversity of native species, and introductions of new, non-native species (Grimm et al., 2008; Johnson & Munshi-South, 2017). Cities are thus potential epicenters for rapid evolution in response to biotic and abiotic stress (Briggs, 2009). Similarities in environmental pressures among city habitats may lead to convergent, adaptive, microevolutionary changes across patchy populations in single cities or in metapopulations spanning metropolises. These phenotypic signatures of urban evolution may involve divergence between urban and rural populations in observable morphological, physiological, or phenological traits that are key to urban plant success and reproduction.

Plant functional traits can guide the assembly of their associated ecological communities. The three-dimensional organization and architecture of plants are critical in defining how other organisms interact with a habitat and how resources flow through an ecosystem (Westoby & Wright, 2006). The environmental conditions of disturbed, physiologically stressful habitats have been shown to drive plant trait microevolution by

selecting for certain adaptations even at small geographic and time scales (Gadgil & Solbrig, 1972; van Groenendael, 1985). However, we currently have an extremely limited understanding of how plant species may adapt to urban conditions. Few studies have examined intraspecific variation in phenotypic traits in response to urbanization, yet each of these studies do suggest that there may be rapid divergence between urban and non-urban populations within plant species. For example, Cheptou et al. (2008) found that the seed structures affecting dispersal distance had diverged for holy hawksbeard (*Crepis sancta*) due to urban habitat fragmentation in Montpellier, France. In US cities, Gorton et al. (2018) found that urban populations of common ragweed (*Ambrosia artemisiifolia*) flower earlier than rural ones (2018); and Yakub & Tiffin (2017) found that urban Virginia pepperweed (*Lepidium virginicum*) plants bolt earlier and produce fewer leaves than rural ones. Lastly, Thompson et al. (2016) found differences in herbivore defense traits in white clover (*Trifolium repens*) in urban centers that remove fallen snow, because of trade-offs associated with tolerance to colder winter ground temperatures (Thompson, Renaudin, & Johnson, 2016).

Across studies of urban plant communities at the city-wide scale, urban floras have been associated with a higher average seed mass, height, and tolerance for heat, alkalinity, drought, and high-nutrient soils; increased stress intolerance; woodiness; succulence, competitiveness, vegetative reproduction, non-native origin, and short lifespans (e.g., Williams, Hahs, & Vesk, 2015; Palma et al., 2017) compared to non-urban floras. Some of these traits are contradictory to one another (e.g., woodiness and height versus short lifespans) and the evidence needed to clarify urban plant community trends is lacking. In addition, plant traits at the community level will include traits from

many long-lived species potentially destined for local extinction due to recent environmental changes (Hahs et al., 2009; Duncan et al., 2011). Thus, urban community trait associations may fail to highlight the evolutionary selective forces that could drive short-lived urban species populations to evolve rapidly to new environments over several generations.

Species most commonly found in urban floras may also be highly plastic, allowing them to rapidly respond to and tolerate stressful urban conditions during the lifetime of an individual (Crispo, 2008; Slabbekoorn, 2013). Populations of species with highly plastic phenotypes may be either more or less likely to evolve in response to urban environmental pressures depending on both the strength of selection and the extent of plasticity. Phenotypic plasticity can be an adaptive trait in itself as it may allow for populations to initially become established in novel environments that would filter out less tolerant or plastic species; then established populations may evolve due to natural selection (Ghalambor et al, 2007). On the other hand, highly plastic species, once established in urban areas, may not respond to selection through differential reproductive success among individuals in a population, but rather by rapid, non-heritable changes made in phenotypes of individual plants during their lifetimes.

Additional physiological and morphological plant traits related to overall plant strategies and resource allocation may be critical to plant success in urban areas where stressors such as urban warming, drought, salt stress, and disturbance may be intensified compared to rural areas (Harper, 1977; Adler et al., 2014; Johnson, Thompson, & Saini, 2015). Increased water use efficiency by plants during photosynthesis could increase drought resistance (e.g., Wright, Hubick, & Farquhar, 1988) such as for C₄ and CAM

plants (Pate, 2001). An indicator for water use efficiency is the ratio of the amount of carbon-13 to carbon-12 stable isotopes present in leaf tissue; as water use efficiency increases, the ratio of carbon-13 to carbon-12 increases (i.e., becomes less negative; O'Leary, 1988). In addition, the unpredictable nature of many urban environmental conditions and disturbances in time, space, and intensity indicates that plant populations in urban ecosystems may experience high density-independent mortality, potentially leading to selection for life history traits associated with being an r-strategist (Gadgil & Solbrig, 1972). When mortality is unpredictable, selection favors organisms that prioritize reproductive tasks early in life over vegetative establishment and growth, thus deprioritizing survival and extending the lifespan (Harper, 1977). Trade-offs such as these may underpin the connections between plant fitness, plant functional traits, and life history evolution in a given climate and environment (but see Wright et al., 2004). Plants that are selected to grow fast and reproduce quickly tend to invest little in leaf strength and longevity expressed as lower leaf thickness and higher specific leaf area, but higher leaf thickness is also associated with higher photosynthetic and growth rates (Niinemets, 2001; Osnas et al., 2013).

The potential for phenotypic divergence between urban and non-urban populations begs the question of whether convergence on phenotypic traits occurs among urban populations across cities. Both divergent selection pressures reducing gene flow as well as the action of genetic drift in small or isolated urban populations should lead to greater divergence between urban and non-urban. Urbanization can also lead to genetic differentiation between populations within cities through reduced gene flow and increased genetic drift (Blaquart et al., 2013; Wang et al. 2013). However, non-adaptive, genetically-

based trait changes in populations may create impacts for population, community, and ecosystem dynamics in and around urban areas (Palcovacs et al., 2012; Alberti, 2015). Comparisons of urban and non-urban populations within species can determine whether there are signals of convergent evolution both within and between species across urban populations in multiple cities. Evidence of convergent urban evolution would indicate that urban environments have predictable, parallel impacts on plant species across cities, which would allow for the forecasting estimation of changes in urban community dynamics or ecosystem function due to plant functional differences (Alberti, 2015; Rivkin et al., 2019)

Here, I aim to answer the question, are native plant populations phenotypically convergent within urban areas yet phenotypically divergent from conspecific populations in rural areas in key morphological, physiological, and phenological traits? In addition, are the patterns of phenotypic divergence and convergence consistent with predictions for putatively adaptive traits for urban plants, or genetic drift? In the case of the former, I predict that urban habitat fragmentation, frequent ecological disturbances, and unpredictable shifts in the abundance and diversity of native species may lead to urban selection for higher rates of vegetative reproduction; less vegetative (leaf) growth; increased seed production; longer flowering periods; reduced leaf thickness; and increased specific leaf area. I also predict that urban warming, altered precipitation patterns, and salt stress may lead to the evolved tolerance of water stress and heat through physiological means, stomatal density reductions, or through avoidance, by reducing vegetative growth and time to reproductive maturity in urban plant populations (Morgan, 1984).

Methods

Study species

The annual, biennial, or perennial herb *Plantago rugelii* Decne. (American, Rugel's, or blackseed plantain) of *Plantago* section *Plantago* (Plantaginaceae) is typically considered a weed as it is found in disturbed habitats throughout northeastern North America, where it is endemic (Rahn, 1996). It has fibrous, adventitious roots and a short caudex (a bulky, basal stem) borne with a basal rosette of leaves (Hawthorn, 1974). *Plantago rugelii* has a mixed mating system, with reproductive spikes bearing protogynous, wind-pollinated, and self-compatible flowers as well as vegetative reproduction through ramets (from the caudex); it is also highly selfing. The fruits are dehiscent capsules; each contain an average of 4-5 black seeds that can disperse slowly over the course of the late fall and winter, with some persisting on remaining spikes until spring (Hawthorn, 1974).

Wild plant collection

I collected *Plantago rugelii* mother plant specimens and their seed from 14 wild populations throughout the Philadelphia and New York City Metropolitan Areas (Table 1; Figure 1) in October and November 2015. All populations were located in managed, mowed lawns in parks. Lawns make up 70-75% of urban green spaces globally and are commonly cultivated in urban as well as rural parklands (Ignatieva et al., 2015). Seven of these parks were located adjacent to and/or embedded within highly urbanized areas (defined here as census tracts with $>4,000$ people mi^{-2}); seven were in rural or exurban areas ($<2,000$ people mi^{-2}). Rural parks were randomly selected among county or state parks and measured $4,627 \text{ km}^2$ on average (range $1,372\text{--}8,883 \text{ km}^2$; Table 1). Urban

parks in Philadelphia and New York were the largest city, county, or state parks in each city that did not have extensive coastal habitats and measured 3.689 km² on average (range 2,129–6,475 km²; Table 1). Urban and rural park sizes were not significantly different from one another ($P = 0.462$, two-tailed Student's T-test; Table 1). No two rural parks were located within the same county. All parks were open to the public at the time of collection and located within the Northeastern Coastal Forest terrestrial ecoregion (Olson et al., 2001).

Table 1 (below): List of 14 parks containing *Plantago rugelii* source populations for the samples used in this study.

Collection date	Metro region	Environment	Park name	US State	Park size (km ²)	Site Latitude °N	Site Longitude °W
12-Oct-2015	New York City	rural	Duke Island Park	New Jersey	1.372	40.550815	-74.668343
12-Nov-2015	New York City	rural	Thompson Park	New Jersey	2.699	40.331128	-74.141539
1-Nov-2015	New York City	rural	Kakiat Park	New York	1.522	41.146352	-74.114758
6-Nov-2015	New York City	rural	Lewis Morris Park	New Jersey	8.883	40.78862	-74.54382
31-Oct-2015	New York City	urban	Van Cortlandt Park	New York	4.638	40.890358	-73.897365
11-Oct-2015	New York City	urban	Central Park	New York	3.411	40.77554	-73.97523
31-Oct-2015	New York City	urban	Flushing Meadows Park	New York	3.634	40.742641	-73.84941
11-Oct-2015	New York City	urban	Bronx Park	New York	2.906	40.85131	-73.868829
20-Oct-2015	New York City	urban	Prospect Park	New York	2.129	40.668909	-73.970416
28-Oct-2015	Philadelphia	rural	Core Creek Park	Pennsylvania	4.856	40.20001	-74.92218
24-Oct-2015	Philadelphia	rural	Peace Valley Park	Pennsylvania	6.070	40.3194	-75.19385
6-Oct-2015	Philadelphia	rural	Marsh Creek State Park	Pennsylvania	6.989	40.065997	-75.716864
14-Oct-2015	Philadelphia	urban	Fairmount Park East	Pennsylvania	2.630	39.97292	-75.18742
25-Oct-2015	Philadelphia	urban	Pennypack Park	Pennsylvania	6.475	40.026584	-75.015791

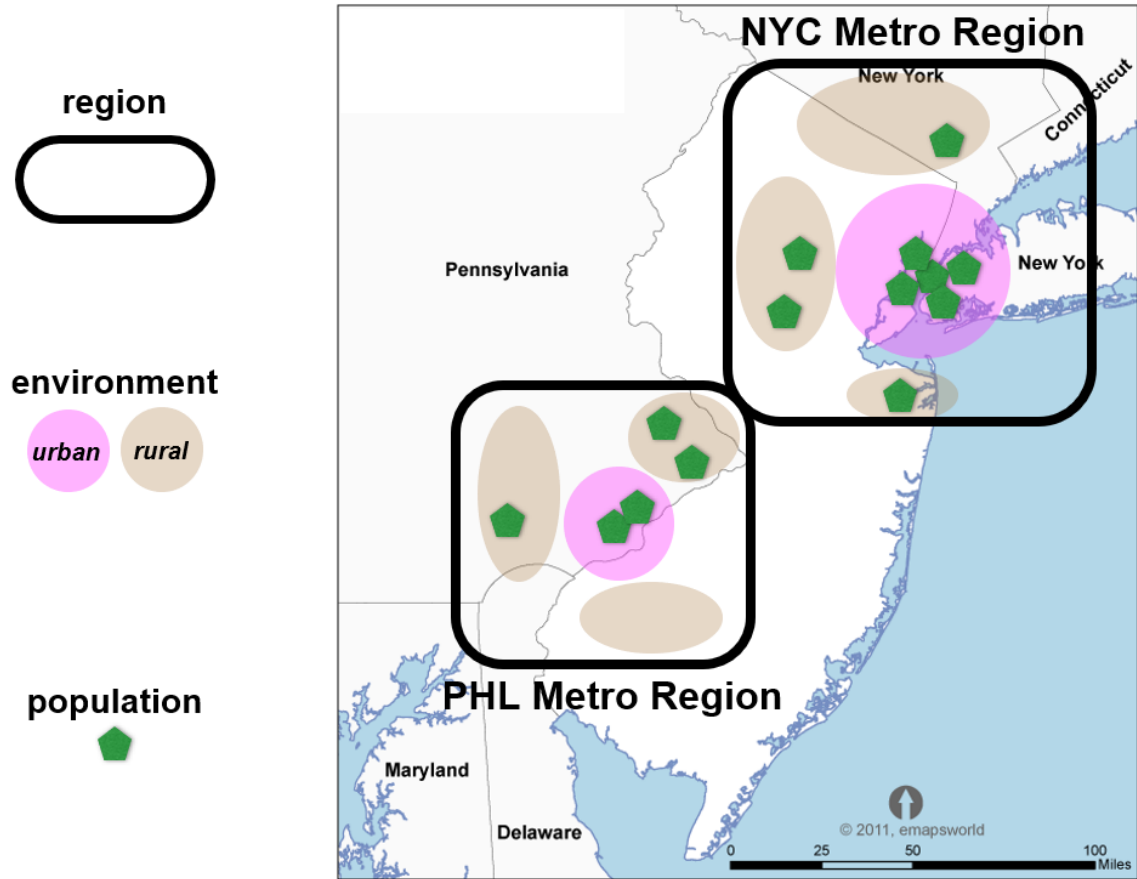


Figure 1 (above): Spatial-ecological hierarchy of seven urban and seven rural plant populations sampled in the New York City and Philadelphia Metropolitan Areas. Seed from seven mother plants per population were collected in fall 2015 and grown in a common garden in central New Jersey beginning in spring 2016.

One 5,000-m² site (i.e. mowed lawn) within each of the 14 parks was chosen based on *P. rugelii* presence and maturity. To be included in the study, parks had to have at least 20 mature individuals. At each site, seven plants bearing mature seeds and capsules were randomly selected from all available plants using a random number generator, for a total of 98 mother plants across all sites (hereafter referred to as

populations). All collected plants were immediately pressed and dried as vouchers and are permanently deposited at the Chrysler Herbarium (CHRB) of Rutgers University.

Wild seed harvest and germination

In April 2016, I selected the seeds from 2-4 mature capsules per mother plant, with capsules and seeds drawn from the upper and lower parts of one or two spikes per plant, as available. I scarified the surfaces of each seed with a sterile scalpel in April 2016. Up to 10 scarified seeds per mother plant were kept on damp paper towels in petri dishes between 62⁰F and 75⁰F in a Rutgers University greenhouse until cotyledons were each >0.5 cm long and ascending or spreading.

Common garden: planting and maintenance

In May 2016, I planted up to nine seedlings from each mother plant into circular plastic pots measuring 20.3 cm in diameter and kept in open air on an old field plot at Rutgers University's Horticultural Farm 3 in Middlesex County, New Jersey, USA. The soil used in each pot was dug from the old field plot itself just prior to planting. The plot was first tilled and weeded, then soil was added to the pots, and large stones were removed from the soil in pots. Depending on seedling survival, up to three seedlings were initially planted per pot, then thinned down to one seedling per pot. Thus, up to three offspring were propagated per mother plant (depending on survival), for a total of 165 surviving plants in this first-generation (as of 1 July 2016) from 97 mother plants representing all 14 wild, source populations. Pot placement in the field plot was fully randomized along 6 rows of equal length.

During the 2016 growing season, I randomly selected one developing spike per first-generation plant to be the seed source for the second generation. To prevent outcrossing (through wind or animal dispersal of pollen) with other first-generation plants in the plot, I enveloped the selected developing spikes with long, rectangular pockets made out of Tyvek HomeWrap and Tyvek HomeWrap Tape (to create air-tight seals along edges) and fastened with a twist tie at the base of the spike, below any immature flower buds. The self-pollinated spikes were collected in the fall after their capsules had matured, then kept in dry storage at room temperature until April 2017 when their seeds were harvested and germinated as described above. Depending on seedling survival, I planted up to three seedlings of second-generation plants per first-generation mother plant. The second-generation seedlings were planted and thinned in new pots as described above and arranged randomly in the field plot, intermixed with the first-generation pots.

After removal of the self-pollinated spikes from each first-generation plant in 2016, the first-generation cohort remained in the field to grow and reproduce until the end of the 2017 growing season. During the 2016 and 2017 growing seasons, I weeded all pots after one month of growth in the spring and every 2 months thereafter, fertilized once in May (Miracle-Gro Liquid All Purpose Plant Food 12-4-8), and watered every 2-3 days during periods of drought and heat throughout the growing season. Each pot was covered with lightweight, white cloth row cover from the date of planting or sprouting through September to maintain consistent soil moisture and light levels; a hole in the center of each pot's garden cover allowed reproductive spikes to grow upwards (erect or ascending) without impediment.

Data collection

Between 147 and 153 days after planting in 2016, I measured leaf thickness, took samples for specific leaf area (hereafter SLA), took photographs for total leaf area calculations, counted the number of spikes, and measured maximum spike height for all first-generation plants after their first year of growth in the field. Using a random number generator, I randomly selected one healthy, undamaged leaf per plant and used a paper thickness gauge (accuracy to 0.05 mm) to measure leaf thickness at 3 points (central, left, and right sides) along the central, horizontal axis of the leaf laminar surface, avoiding veins; the mode (or mean, in its absence) was recorded. To measure SLA, I randomly selected another healthy, undamaged leaf on each plant and removed 3 circular sections, ca. 6 mm in diameter, from the interior of the lamina, avoiding veins, with a hole puncher. The leaf sections were dried in an oven for >72 hrs at 51°C before weighing their mass. To measure total leaf area per plant, I took photographs of the basal rosette of each plant with a 10 cm ruler on the soil in the pot directly adjacent to and on the same horizontal plane as the leaves. Total leaf area was assessed from the photos with Easy Leaf Area software (Easlon & Bloom, 2014). The count of number of spikes per plant included spikes at any stage of development at the time of sampling.

After 150 days of growth in 2017, I took samples for carbon isotope ratio and stomatal density analyses, counted vegetative ramets, counted the number of spikes, measured maximum spike height, and collected all of the second year's reproductive spikes for estimates of seed set (as a contributor to fitness) from all first-generation plants (after their second year of growth). I sampled one leaf per plant for carbon isotopic ratio analysis by repeating the same methodology (as described above) for SLA; after drying,

leaf samples were processed and sent to the UC Davis Stable Isotope Facility (Davis, California, USA) following their protocol for solid sample analysis by GC-combustion isotope ratio mass spectrometry. For stomatal density, I used the same random leaf selection process to select two leaves per plant then removed a 1 cm² area of each leaf on either side of the mid-vein, intersecting the central, horizontal axis of the lamina. Leaf samples were dried for storage after sampling then rehydrated for 48-72 hrs in a glycerin solution prior to processing. To calculate adaxial and abaxial stomatal densities per unit leaf area, I applied clear nail polish to the upper side of one leaf sample and the underside of the other; once dry, the nail polish and epidermal layers were peeled off each leaf sample with adhesive tape. The peels were affixed to microscope slides for observation of two randomly selected 0.2 mm² areas of the epidermis per sample under a compound light microscope at 20x magnification. I estimated annual seed production (an important contributor to fitness) for each plant with a measurement of the sum of lengths of all spikes from its lowermost capsule to its upper tip.

Between 147 and 153 days after planting in 2017, I took samples for stomatal density analyses, counted vegetative ramets, counted the number of spikes, and collected all spikes for fitness measurements from for all second-generation plants (after their first year of growth). In addition, reproductive status was recorded weekly for each plant in either generation during both the 2016 and 2017 growing seasons. Plants were identified as juvenile, flowering (i.e., with at least one flower with mature styles/stigmas extended beyond tepals), or fruiting (i.e., with at least one fully dehiscent capsule with black, matte seeds).

Data analysis

The probability distributions of trait measurements were determined using the ‘fitdistrplus’ package in R v3.4.1 via the workflow as described in Delignette-Muller & Dutang (2015; R Core Team, 2018), which also included comparing Akaike’s Information Criterion (AIC) values among candidate distributions for each trait dataset (Table 2). I then used Bayesian inference and model choice methods to determine if differences in plant trait distributions are best described by differences in trait means and variances:

- (1) between the two plant source population regions (i.e. New York City versus Philadelphia Metropolitan Areas);
- (2) between the two source population environments (i.e. urban versus rural);
- (3) among 4 source population groups created by the interaction of both factors (Figure 1); and/or
- (4) by one large population (of all sampled plants) defined by a single trait mean and variance.

For normally-distributed trait data, these models (1–4) were described as found in Appendix 2, where Y_{ijk} is the trait value for the i^{th} plant in environment j in region k . For non-normally distributed trait data, the above models were altered to reflect the appropriate probability distribution as described in Appendix 3; non-normal data models were also reparameterized to accurately estimate the means and variances of each trait distribution in a Bayesian framework (Table 2; Appendix 3). Each model’s fit was evaluated relative to the others with the deviance information criterion (DIC) for each trait or trait-cohort combination. I used a minimum threshold of 5 for significant

differences in DIC between models; the lower DIC value tends to indicate the better model fit if the difference between values is at least 3 to 7 (Spiegelhalter et al., 2002).

Table 2 (below): Probability distributions of trait measurements for each trait-cohort dataset were found using the ‘fitdistrplus’ R package and workflow suggested by Delignette-Muller & Dutang (2015; R Core Team, 2018), which included comparing Akaike’s Information Criterion (AIC) values among candidate distributions. X’s indicate probability distributions that would best fit the trait-cohort dataset; bolded X’s indicate probability distributions that were used in modeling the data (Appendices 1-2).

Trait	Cohort(s)	Normal	Gamma	Lognormal	Negative binomial	Weibull	Poisson	Logistic
Vegetative reproduction (clonal ramets)	2017: 1st & 2nd generations, pooled				X			
	2017: 1st generation				X			
	2017: 2nd generation				X			
Carbon isotope ratio	2017: 1st generation	X	X					
Time between first flower and first mature fruit (days)	2018: 1st generation				X			
	2017: 1st & 2nd generations, pooled				X			
	2016-17: 1st generation, averaged	X	X		X			
	2017: 1st generation				X		X	
	2017: 2nd generation	X			X		X	
Time before first flower (days)	2018: 1st generation				X		X	
	2017: 1st & 2nd generations, pooled				X		X	
	2017: 2nd generation	X			X			
Time to first mature fruit (days)	2018: 1st generation				X			
	2017: 1st & 2nd generations, pooled				X			
	2017: 2nd generation	X			X		X	
Fitness (as total fruiting spike length; cm)	2017: 1st & 2nd generations, pooled		X			X		
	2017: 1st generation		X					
	2017: 2nd generation		X			X		
Height (cm)	2018: 1st generation	X				X		
	2017: 1st generation	X				X		
	2016-17: 1st generation, averaged	X				X		
Total leaf area (cm ²)	2018: 1st generation	X				X		
Leaf width (cm)	2018: 1st generation		X	X		X		
Leaf thickness (mm x 10 ⁻³)	2018: 1st generation		X	X				X
Number of reproductive spikes	2018: 1st generation	X			X			
	2017: 1st & 2nd generations, pooled				X			
	2017: 1st generation				X			
	2017: 2nd generation				X			
	2018-2017: 1st generation, summed				X			
Number of reproductive spikes per unit leaf area	2018: 1st generation			X				
Specific leaf area (SLA; m ² /g)	2018: 1st generation		X	X				
Stomatal density (leaf underside)	2017: 1st & 2nd generations, pooled	X	X					
	2017: 1st generation	X	X	X		X		
	2017: 2nd generation	X	X	X		X		X
Stomatal density (leaf upper side)	2017: 1st & 2nd generations, pooled		X	X				
	2017: 1st generation		X	X				
	2017: 2nd generation	X	X	X		X		
Stomatal density (both sides of leaf)	2017: 1st & 2nd generations, pooled		X	X				X
	2017: 1st generation	X	X	X				X
	2017: 2nd generation	X	X	X		X		X

Differences between the means and variances of regional and/or urban-rural traits were derived for the best fit model(s) for each trait if the best fit model(s) was not or did not include model 4 (above). Trait mean and variance values were considered significantly different from one another if the posterior distribution of the difference of the values did not include 0, indicating that 0 was not a credible value for the difference in trait means or variances between the communities. Bayesian models were fitted and

DIC for each model was calculated with package R2jags v0.5-7 in R v3.4.1 using Markov chain Monte Carlo (MCMC) methods (Su & Yajima, 2015; R Core Team, 2018).

Results

Normally-distributed trait data included plant height, total leaf area, and carbon isotope ratio; gamma-distributed data included fitness (as total fruiting spike length) and stomatal densities; lognormally-distributed data included leaf width, leaf thickness, number of reproductive spikes per unit leaf area, and SLA; and negative binomially-distributed data included vegetative reproduction, phenological data, and number of reproductive spikes (Table 2). Models 2 and 3 were the only models identified as best fit to trait data (Table 3; Figure 1). Model 2 was the best or one of the best fit to data on time to first mature fruit, leaf thickness, number of reproductive spikes, and number of reproductive spikes per unit leaf area for one or more cohorts in the common garden experiment; Model 3 was the best or one of the best fit to data on time to mature fruit, height, number of reproductive spikes, and number of reproductive spikes per unit leaf area, for one or more cohorts (Table 3). The remaining traits (total leaf area, carbon isotope ratio, fitness (as total fruiting spike length), stomatal densities, leaf width, SLA, vegetative reproduction, time to first flower, and time between flowering and fruiting) were equally as compatible with Models 1, 2, 3, and 4.

Table 3 (below): Deviance information criterion (DIC) values for 4 models fit to each trait or trait-cohort combination. Model 1: Means and variances diverge between the two plant source population regions. Model 2: Means and variances diverge between the two

source population environments. Model 3: Means and variances diverge among 4 source population groups created by crossing region and environment factors. Model 4: Means and variances are defined by a single mean and variance (Appendix 2). Best fit model(s) and associated significant inferences, if any, for each dataset is (are) bolded. I used a minimum threshold of 5 for significant differences in DIC between models (Spiegelhalter et al., 2002).

Trait	Cohort(s)	Model 1	2	3	4	Significance
Vegetative reproduction (clonal ramets)	2017: 1st & 2nd generations, pooled	465.4	463.5	464.3	464.3	
	2017: 1st generation	270.9	269.4	271.5	270.2	
	2017: 2nd generation	194.2	195	194.6	194.6	
Carbon isotope ratio	2017: 1st generation	341.5	340.2	343.6	339.1	
Time between first flower and first mature fruit (days)	2018: 1st generation	1224.6	1216.5**	1220.1*	1223.4	*URB mean higher in New York only; **URB higher mean overall
	2017: 1st & 2nd generations, pooled	1111.3	1110.4	1112.6	1110.9	
	2018-17: 1st generation, averaged	1784	1785.4	1785.5	1784.2	
	2017: 1st generation	1030.3	1032	1032.6	1029.9	
	2017: 2nd generation	599.1	599.9	600.3	597.8	
Time before first flower (days)	2018: 1st generation	1154.4	1147.0**	1150.3*	1153.4	*URB mean higher in New York only; **URB higher mean overall
	2017: 1st & 2nd generations, pooled	1154.4	1146.9**	1151.3*	1153.6	*URB mean higher in New York only; **URB mean higher overall
	2017: 2nd generation	716.5	716.8	717.9	715	
Time to first mature fruit (generation time; days)	2018: 1st generation	1314.5	1298.4**	1302.4*	1313.8	*URB mean higher in New York only; **URB higher mean overall
	2017: 1st & 2nd generations, pooled	1313.5	1298.5**	1302.9*	1313.5	*URB mean higher in New York only; **URB mean and variance higher overall
	2017: 2nd generation	657.2	656.8	657.8	656.4	
Fitness (as total fruiting spike length; cm)	2017: 1st & 2nd generations, pooled	3004	3004	3004.9	3007.4	
	2017: 1st generation	1843.4	1841.3**	1843.3*	1845.1	*URB variance higher in New York only; **URB variance higher overall
	2017: 2nd generation	959	959.3	960.8	956.4	
Height (cm)	2018: 1st generation	967.2***	962.8**	957.5*	978.6	*URB higher mean in New York only; **URB higher mean overall; ***NYC higher mean and variance overall
	2017: 1st generation	1063.6***	1050.5**	1033.7*	1071.7	*URB mean higher in New York only; **URB higher mean overall; ***New York higher mean overall
	2016-17: 1st generation, averaged	1054.5***	1037.7**	1029.0*	1061.3	*URB mean higher in New York only; **URB mean higher overall; ***New York higher mean overall
Total leaf area (cm ²)	2018: 1st generation	1554.5	1553.5	1557.1	1553.4	
Leaf width (cm)	2018: 1st generation	550.9	548.8**	547.8*	552.7	*URB higher variance in Philadelphia only; **URB higher mean overall
Leaf thickness (mm x 10 ⁻³)	2018: 1st generation	667.9	658.3**	663.4*	665.4	*URB lower mean in New York only; **URB lower mean overall
Number of reproductive spikes	2018: 1st generation	930.8***	923.4**	924.6*	933	*URB lower mean in New York only; **URB lower mean and variances overall; ***Philadelphia mean higher overall
	2017: 1st & 2nd generations, pooled	1860.9	1861	1861.4	1858.9	
	2017: 1st generation	989.6	990.5	991.5	989.3	
	2017: 2nd generation	609.7	611.1	609.8	608.8	
	2016-2017: 1st generation, summed	1145.3	1140.1**	1140.7*	1145.2	*URB mean lower in New York only; **URB mean lower overall
Number of reproductive spikes per unit leaf area	2018: 1st generation	neg457.7***	neg463.7**	neg463.8*	neg463.0	*URB mean lower in New York only; **URB mean lower overall; ***Philadelphia higher mean overall
Specific leaf area (SLA; m ² /g)	2018: 1st generation	826.4	826.5	828.2	826.5	
Stomatal density (leaf underside)	2017: 1st & 2nd generations, pooled	700.1	705	704.3	703.9	
	2017: 1st generation	368	366.7	368.3	367.2	
	2017: 2nd generation	337.3	342	340	338.6	
Stomatal density (leaf upper side)	2017: 1st & 2nd generations, pooled	654.6*	661.2	659.1	659.7	*Philadelphia higher mean overall
	2017: 1st generation	359.6*	365	361.9	364.3	*Philadelphia higher mean overall
	2017: 2nd generation	297.3	298.8	299.9	295.2	
Stomatal density (both sides of leaf)	2017: 1st & 2nd generations, pooled	669.3**	671.4*	669.1	675.2	*RUR higher variance overall; **Philadelphia higher mean overall
	2017: 1st generation	378.1**	377.3*	377.5	380.4	*RUR higher variance overall; **Philadelphia higher mean overall
	2017: 2nd generation	291.8	295.7	294.8	292	

In 2016's common garden, the average height of the tallest reproductive spike was 4.1 (95% CI 2.0–6.1) cm taller and the average number of spikes was 1.7 (95% CI 0.1–3.7) lower for urban plants than rural plants from the New York City region (Figures 2–3). The average number of spikes was 2.2 (95% CI 0.9–3.5) lower (Figure 4) and the variance around the mean number of spikes was 5.1 (95% CI 0.1–10.4) higher for urban than rural plants overall. Trends for the number of reproductive spikes per unit leaf area were the same in magnitude and direction as for number of spikes (Figures 5–6). The average time to mature fruit was 10.7 (95% CI 5.1–16.4) days longer for urban plants than rural plants from the New York City region and 10.2 (95% CI 5.4–15.0) days longer for urban plants overall (Figures 7–8). Leaf thickness was 0.7 (95% CI 0.1–1.3) μm lower for urban plants overall (Figure 9). In 2017's common garden, the average height of the tallest spike was 7.4 (95% CI 4.7–9.9) cm taller for urban plants than rural plants from the New York City region.

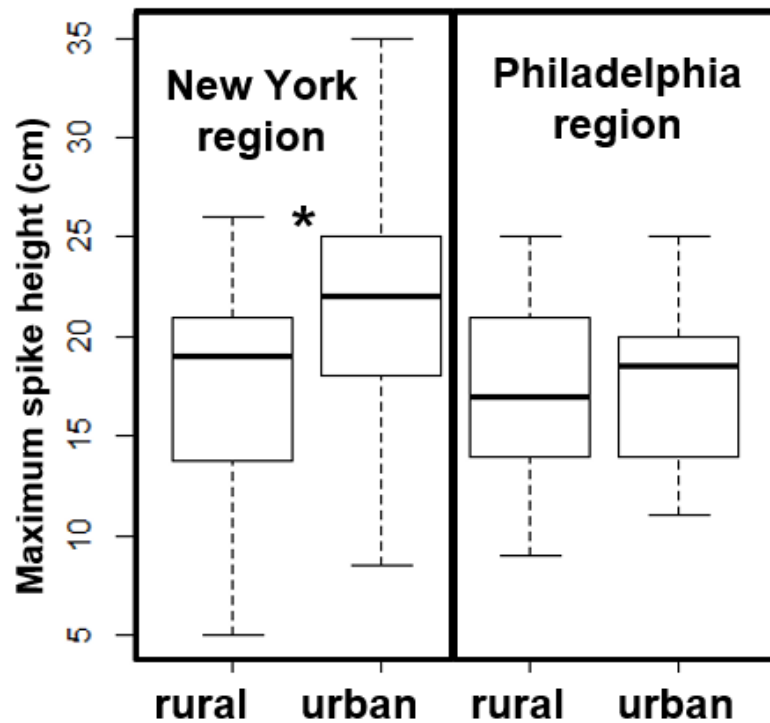


Figure 2 (above): In 2016's common garden, the average height of the tallest reproductive spike was 4.1 (95% CI 2.0–6.1) cm taller for urban plants than rural plants from the New York City region. In 2017's common garden, the average height of the tallest spike was 7.4 (95% CI 4.7–9.9) cm taller for urban plants than rural plants from the New York City region (not shown here). Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

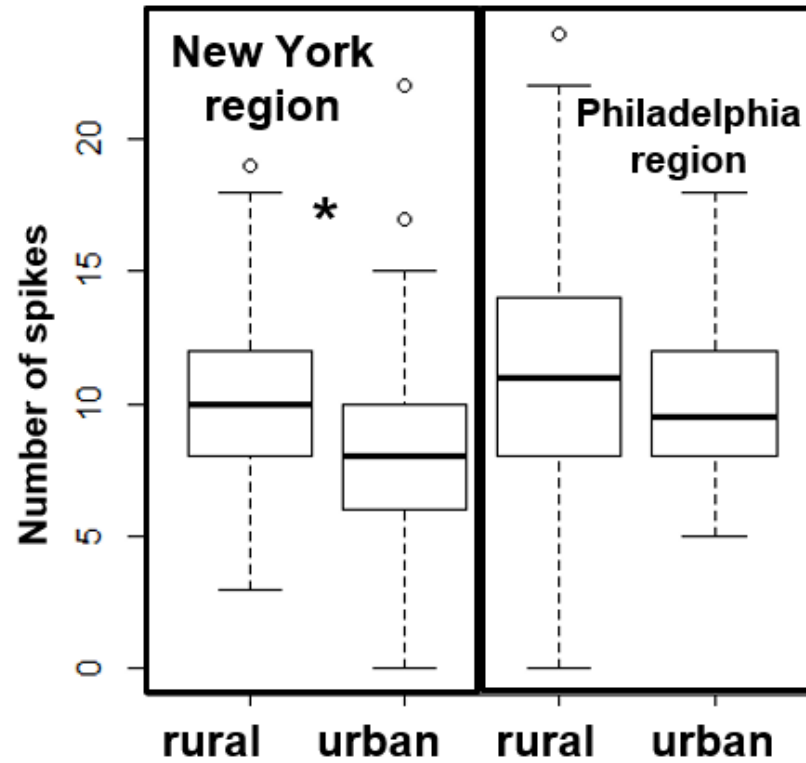


Figure 3 (above): In 2016's common garden, the average number of reproductive spikes was 1.7 (95% CI 0.1–3.7) lower for urban plants than rural plants from the New York City region. Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

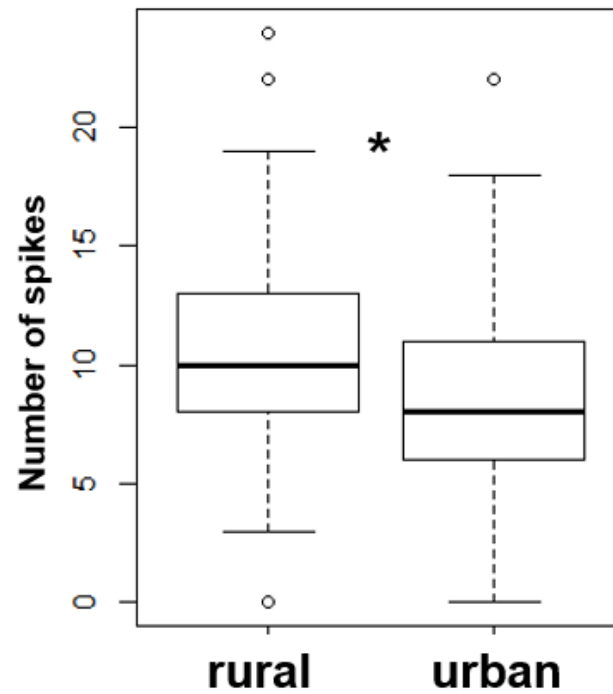


Figure 4 (above): In 2016's common garden, the average number of reproductive spikes was 2.2 (95% CI 0.9–3.5) lower for urban than rural plants overall. Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

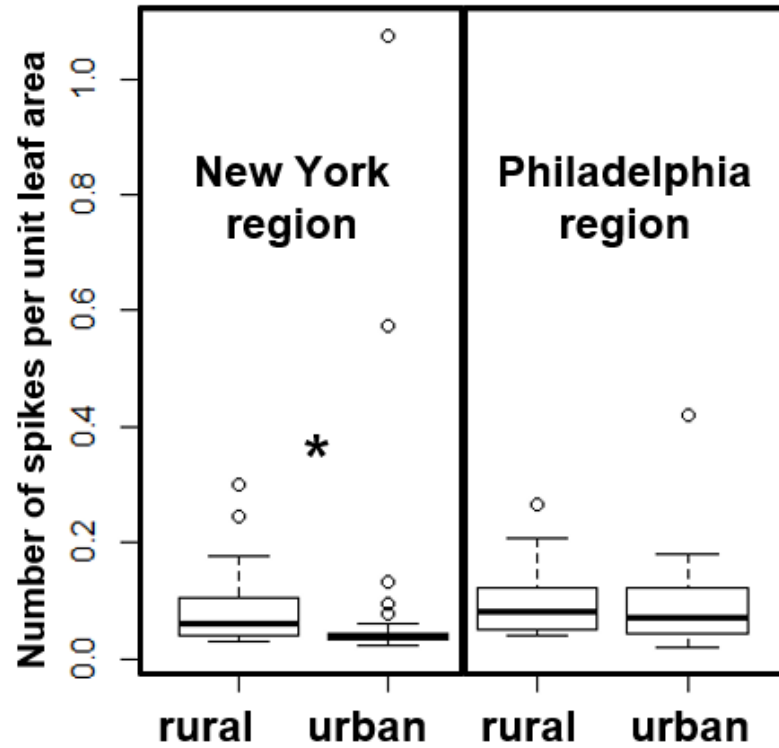


Figure 5 (above): In 2016's common garden, the number of reproductive spikes per unit leaf area was 0.024 (95% CI 0.002–0.047) lower for urban plants than rural plants from the New York City region. Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

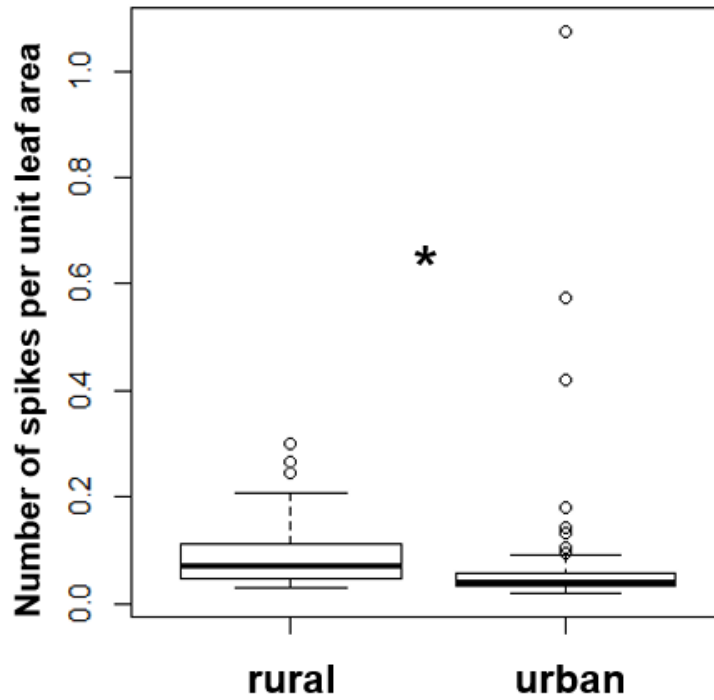


Figure 6 (above): In 2016's common garden, the number of reproductive spikes per unit leaf area was 0.022 (95% CI 0.001–0.042) lower for urban than rural plants overall.

Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

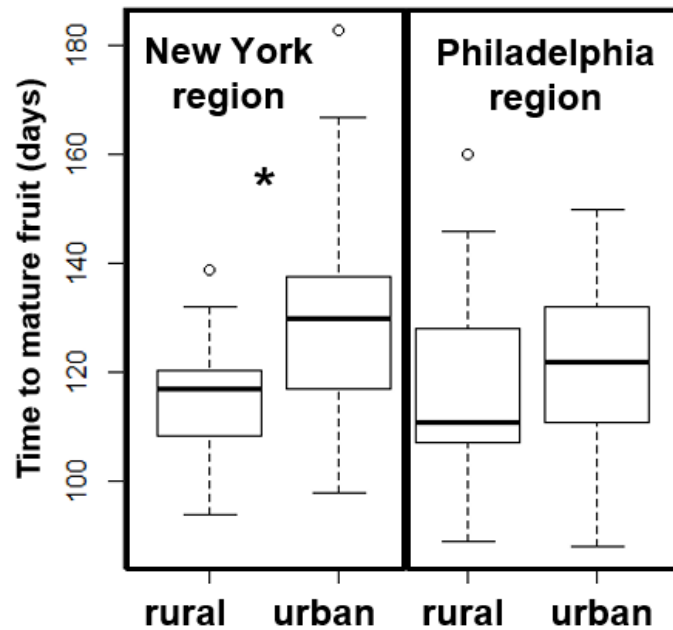


Figure 7 (above): In 2016's common garden, the average time to mature fruit was 10.7 (95% CI 5.1–16.4) days longer for urban plants than rural plants from the New York City region. Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

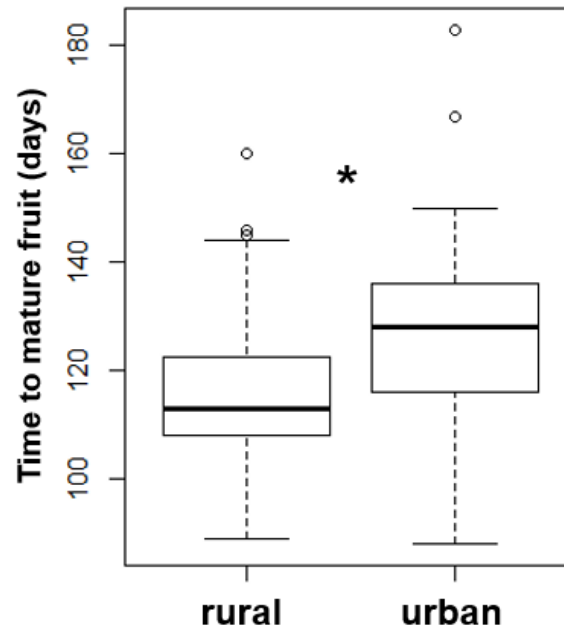


Figure 8 (above): In 2016's common garden, the average time to mature fruit was 10.2 (95% CI 5.4–15.0) days longer for urban plants overall. Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

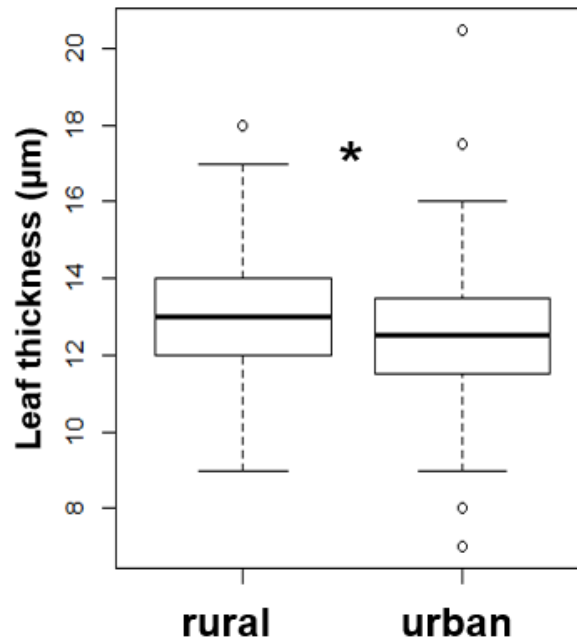


Figure 9 (above): In 2016's common garden, leaf thickness was 0.7 (95% CI 0.1–1.3) μm lower for urban plants overall. Boxplots show median (bold horizontal line), interquartile range (median 50% of the data; within box), and min/max values. Significant differences between two means are indicated by an asterisk.

Discussion

I have found significant evidence for phenotypic divergence between select traits in urban and rural native plant populations as well as phenotypic convergence in certain traits between urban plants across two major northeastern US cities. My results indicate that time to mature fruit is longer in *Plantago rugelli* urban populations overall, but time to mature fruit in urban *P. rugelli* in the New York City Metropolitan region is also longer than conspecific rural populations in same region. Similarly, the number of reproductive spikes per plant and per unit leaf area were both reduced in urban populations as well as

in urban as compared to rural populations in the New York City region. Leaf thickness was lower in urban plants as compared to rural plants across both regions.

My results do not align with those of Gorton et al. (2018) and Yakub & Tiffin (2017) who found that urban common ragweed (*Ambrosia artemisiifolia*) flowered earlier than rural ones; and urban Virginia pepperweed (*Lepidium virginicum*) bolted earlier and produced fewer leaves than rural ones. It is possible that traits in this study that did not show expected patterns of divergence among regions, environments, or combined region-environment groups (i.e., total leaf area, carbon isotope ratio, fitness (as total fruiting spike length), stomatal densities, leaf width, SLA, vegetative reproduction, time to first flower, and time between flowering and fruiting) are mostly neutral with respect to conferring fitness to *P. rugelii* plants in urban areas, while those and other traits are highly relevant to urban fitness consequences for different species. Alternatively, *P. rugelii* plants may be highly plastic with respect to these traits, such that *in situ* differences may be apparent and even adaptively plastic, but that these trait differences in plants are not maintained in future generations. It is also possible that the patterns urban-rural trait divergence that I found are the results of random genetic drift acting on small or isolated populations and not products of differential natural selection in urban versus rural areas. Furthermore, *P. rugelii* can be perennial, while *A. artemisiifolia* and *L. virginicum* are annual, and annual or biennial, respectively. Differences in plant species lifespan and reproductive or stress tolerance strategies may have an impact on how they respond to urbanization.

For traits that did show urban-rural divergence and urban convergence among populations, a longer overall time to mature fruit in *P. rugelii* could be selectively

advantageous in cities where urban warming extends the growing season compared to adjacent non-urban areas. Sprouting earlier in the spring may increase opportunities for growth and establishment, including the ability to outcompete conspecifics and other weedy, urban species. Furthermore, my results for differences in leaf thickness between urban and rural plant populations in part support my prediction that more frequent ecological disturbances may lead to a divergence in urban and rural plant life history strategies. Reduced leaf thickness is a trait associated with fast-growing species that reproduce early in life and generally follow an r-selected life history strategy (Gadgil & Solbrig, 1972; Niinemets, 2001; Osnas et al., 2013).

Having taller reproductive structures for an herbaceous plant common in disturbed and urban habitats may also provide a selective advantage; taller spikes could increase the potential for the persistent, mucilaginous seeds of *P. rugelii* to attach to passersby such as humans or other animals (Western, 2012) due to the increased area of seed and capsule cover along longer (and thus taller when erect) spikes. Furthermore, there may be a trade-off between investments in spike height versus spike count. As a perennial plant, in order to produce taller spikes with more readily dispersed seeds (via ectozoochory) or pollen (via wind) in urban areas in any given year, this species may also be under selection to produce fewer spikes overall within that year. This could potentially increase dispersal success and thus metapopulation-level fitness while still allowing individual plants to conserve energy for upcoming seasons of growth. The significant reduction in number of spikes per unit leaf area as well as in number of spikes per plant in urban versus rural areas further indicates (like the non-significant differences for total leaf area and leaf width between populations) that the vegetative growth of *P. rugelii* is

unchanged across environments while the number (and height) of reproductive spikes produced relative to the rest of the plant has evolved. In other words, the overall size of plants is not diverged, but rather the relative allocation of energy towards spike production. These hypotheses can be tested in future experiments.

Another possible interpretation is that rural or exurban areas also impose unique and intense environmental selective pressures on spontaneous plant populations that lead to the observed population differentiation between urban and rural sites. For example, higher densities of white-tailed deer (*Odocoileus virginianus*) in areas with their preferred habitat of mixed agricultural and forested land, such as rural and exurban areas, compared to densely urban areas may lead to increased herbivory on *P. rugelii* leaves and reproductive spikes in rural populations compared to urban populations (Porter et al., 1994; Flaherty, Rentch, & Anderson, 2017). This may lead to selection for shorter yet more numerous reproductive spikes to be produced throughout the growing season to most successfully ensure that some spikes are left un-eaten until mature fruits are produced.

My results suggest that parallel, convergent evolution in urban plants across cities may be occurring with plant traits related to fruit and flower production as well as leaf thickness, but trends for divergence between urban and rural populations are stronger in the New York City Metropolitan area as compared to the Philadelphia Metropolitan area (except for leaf thickness where parallel trends are observed in both regions; Figures 2, 3, 5, & 7). There are multiple potential reasons as to why urban and rural plant populations might diverge significantly within the former region but not the latter. First, New York City is a much larger city than Philadelphia, both in area and population density, and city

size may have an influence on the amount of divergence that develops between its urban and rural plant populations (Johnson, Thompson, & Saini, 2015). There may be larger average geographic distances between urban and rural populations in larger cities, thus decreasing chances for dispersal, gene flow, and genetic or phenotypic homogenization throughout the region as a whole. Second, more extreme degrees of urbanization, including large, contiguous amounts of hardscape land cover in the form of plazas, roads, walls, and building facades, may be more prevalent in larger cities, increasing the average environmental distance between urban-rural population pairs. Increased geographic distance would increase the chances of urban and rural populations diverging phenotypically due to genetic drift, while increased environmental distance could increase the likelihood of divergence due to natural selection and local adaptation.

Direct evidence supporting individual mechanisms as the dominant force behind phenotypic diversity in spontaneous plant populations of large metropolises is still lacking (but see Cheptou et al., 2009; Thompson, Renaudin, & Johnson, 2016). A combination of evolutionary mechanisms due to the inherent complexity of urban and urbanizing ecosystems in biophysical, environmental, and social elements are likely at play, but the relative contribution of these factors to urban plant evolution could rely more heavily upon species-specific reproductive biology and levels of abiotic tolerance than on the environmental conditions of urban areas themselves. Future studies should qualify the heritability and adaptive significance of the traits that show signs of divergence through quantitative analyses of genetic variance as well as reciprocal transplant experiments of urban and rural plants. In addition, isolation by distance between source populations must be accounted for in future analyses. Furthermore,

spatial analysis of the land use and land cover types, local air quality, and soil type surrounding or underlying each source plant population may elucidate more specific environmental or social factors that could influence population divergence and evolution.

Chapter 4

Eat your weeds: Edible and wild plants in urban environmental education and outreach

Abstract

Edible weedy plants are ubiquitous in human-dominated areas and provide opportunities to combat plant blindness and improve citizens' local ecological knowledge in formal and informal urban environmental education (UEE) programs. Weeds exemplify intriguing ecological, cultural, and ethnobotanical concepts, making them ideal resources for hands-on, socially-relevant, and personally meaningful educational activities. Cosmopolitan, spontaneous, weedy plant species are often freely accessible for use in the curricula of many grade levels in varied educational venues as well as in extra-curricular activities for all learners, given that proper safety and legal precautions are taken. We developed and hosted a UEE outreach activity based on edible weedy plants at Rutgers University as part of an annual, university-wide event attended by over 80,000 people in the spring of 2014. Incorporating edible weeds into such programs teaches plant identification skills and ecological appreciation in settings that are 'close to home' for most people.

Introduction

Positive human-nature interactions are vital to counteract modern day environmental problems, yet urbanization and development continue to threaten our connection with and understanding of the biosphere (Miller, 2005; White et al., 2010; Liefländer et al., 2012). Current generations are becoming increasingly estranged from living organisms except

other humans, supermarket food plants, and pets (Miller, 2005). As of 2014, 82% of the population of the United States lived in urban areas (United Nations, 2014); native species diversity and abundance have declined in cities (Gaston, 2010; Duncan et al., 2011); and the ease of accessibility to green space tends to diminish as city populations grow (Fuller & Gaston, 2009). Together, these phenomena may prevent much of the world's population from experiencing and observing nature in a positive light (Morrone & Meredith, 2003), ultimately leading to a widespread lack of environmental concern (Chawla, 1998). Therefore, developing effective materials and curricula for urban environmental education (UEE) that target a broad audience is necessary to create an ecologically and socially responsible society for the future (Tidball & Krasny, 2010; Ardoin et al., 2012).

Spontaneous urban plants (also known as “weeds”) are ubiquitous in cities worldwide; they inhabit every crack and corner of the cityscape. The omnipresence of weeds in modern cities and their suburbs makes them some of the most universally accessible wild species available for study and observation. These weedy plants, whether native or non-native, have traits that make them well suited to highly-disturbed human dominated environments such as suburban lawns or pavement cracks (e.g., Cheptou et al., 2008; Del Tredici, 2010). The sheer prevalence of weeds makes them convenient and effective tools for combatting plant blindness, defined as “the inability to see or notice the plants in one's own environment, leading to the inability to recognize the importance of plants in the biosphere and in human affairs” (Wandersee & Schussler, 1999; Smith, 2014). Learning about weeds has the potential to encourage people to notice the abundance of plant life that surrounds them on a daily basis (Allen, 2003), even within

cities. Studying weeds is also a way to encourage learners of all ages and backgrounds to appreciate, respect, and inquire about nature in all of its diverse forms (e.g., useful versus not useful plants, or attractive versus “ugly” species).

Weedy plant foraging and city herbalism have experienced a resurgence in popular culture in the West in recent years (e.g., Wong & Leroux, 2012; Lerner, 2013; Vorass-Herrera, 2013; Blair, 2014). However, the fact that most urban, weedy plant species have ancient ethnobotanical histories and cultural relevance for diverse human groups is lesser known today (Zimdahl, 2013). Chickweed, for example, is one of the most common vascular plants, found in over 100 city floras worldwide (Aronson et al., 2014). Chickweed has a well-documented ethnobotanical record in traditional South American, European, and Asian cultures: the young shoots and leaves are and employed as ophthalmic and anti-inflammatory medicines in Patagonia; used as fodder to increase egg-laying in poultry in central Italy; and cooked along with cabbage for human nourishment in southwest China (e.g., Guarrera et al., 2005; Weckerle et al., 2006; Molares & Ladio, 2009). Yet, most well-known and beloved plants in today's Western cultures are showy horticultural ornamentals and garden crops—not the wild, weedy plants historically used for medicinal or food purposes. Exposing people to the edible, medicinal, and other cultural or historical uses of weeds can stimulate people's interest and curiosity in wild organisms. Furthermore, using edible urban weeds as study organisms roots UEE in the socio-ecological nature of the city by connecting students and the public to the natural world via cultural, culinary, biological, ecological, and historical references and provides a truly interdisciplinary framework for formal and informal education (Tidball & Krasny, 2010; Blanchet-Cohen & Reilly, 2013).

Using edible weedy plants in environmental educational initiatives also supports the development and maintenance of plant identification skills. Being able to identify a species and giving it a unique name is not only important for educational efforts in combatting plant blindness, but it is also a crucial pre-requisite to foraging for wild foods. Along with the ease and accessibility of incorporating edible weedy plants into UEE, a strong emphasis must be placed upon safety precautions. A strong foundation of botanical identification skills and morphological knowledge is necessary for the success and safety of any edible wild plant program. Many plants are edible, but many others are toxic. Foragers, instructors, and learners must be aware of toxic “look-alikes” and should not consume any plant product until the identity of the collected species is certain. New foragers may choose to begin with a mentor or guide to learn the basics of plant identification. Thorough, reliable field guides and repeated field identification practice are essential for cautious foraging and can help remind even the most experienced field botanists of subtle yet potentially important morphological differences between specimens. In urban settings, in particular, educators must also ensure that foragers are careful to avoid potentially toxic urban sites which have been contaminated by pesticides, fertilizers, automotive fuel, heavy metals, or animal waste, among other pollutants. The possibility of individual reactions to allergens in common plants should be discussed prior to foraging. In addition to safety precautions, foragers should always acquire permission from land owners to access and remove plant materials from a given site.

We recognized the potential of using spontaneous weedy plants as an exciting and relevant way to engage the public, so we organized an outreach table featuring edible weedy plants for our local community. We held our outreach event at the annual Rutgers

Day, a university-wide open house for Rutgers University in New Brunswick, New Jersey, that engages and informs the extended local community through activities provided by university students, clubs, and departments. The local and state-wide impact of this celebration is significant: in 2013, this event was attended by nearly 80 000 people. For Rutgers Day 2014, our environmental education table was entitled “Eat Your Weeds: How to Safely Savor Wild Edible Plants”. Our overarching teaching goal was to encourage community members to make meaningful connections not only with living wild plants, but also with ecological processes and associated biodiversity in urban and suburban areas through eating weeds (Table 1).

Table 1 (below): “Eat Your Weeds” educational outreach goals and outcomes.

Teaching Goals	Learning Outcomes
To inspire enthusiasm in a wide range of participants To enable people to enjoy, risk- and cost-free edible weedy plants	For participants across age ranges to express excitement and enthusiasm in trying new culinary dishes featuring weeds
To disseminate information regarding the safe identification, procurement, and preparation of weedy plants	For participants to collect resources enabling effective plant identification, collection, and preparation with the intent to use them in the future
To broaden perspectives and attitudes about-weedy plants	For participants to entertain wider viewpoints regarding the usefulness of spontaneous vegetation

Activity description

Plant species selection

Six edible urban weeds that are locally abundant were chosen to be showcased at our outreach table during Rutgers Day 2014 (Table 2): *Taraxacum officinale* (common dandelion), *Allium vineale* (field garlic, wild onion), *Alliaria petiolata* (garlic mustard), *Stellaria media* (common chickweed), *Cardamine hirsuta* (hairy cress), and *Rumex*

acetosella (sheep sorrel). Though not as common in suburban and urban areas, and not always strictly weedy in our part of the world, we also included *Rosa canina* (wild rose) and *Sambucus nigra* (elderberry) as highlighted species due to the commercial availability of food products using these plants (Table 2). We also served two prepared food products: Elderflower Lemonade from a syrup concentrate (“Flädersaft”, IKEA Foods, Sweden) and Rose Hip Soup (cold) from a smoothie mix (“Nyponsoppa”, Ekströms, Eslöv, Sweden).

Table 2 (below): Food and drink featured plant contents and role. †Rose Hip Soup and Elderflower Lemonade are not original recipes; these beverages are available commercially. *Dandelion Flower Lemonade was used as the sample tasting dish for *T. officinale*.

Plant species name	Recipe(s) created	Role(s) in activity
<i>Alliaria petiolata</i> Garlic mustard (Brassicaceae)	Garlic Mustard Hummus	Sample tasting, recipe handout, and live plant display
<i>Allium vineale</i> Wild garlic or onion (Amaryllidaceae)	Cream Cheese Spread with Wild Garlic Shoots	Sample tasting, recipe handout, and live plant display
<i>Cardamine hirsuta</i> Hairy cress (Brassicaceae)	Hairy Cress Salad with Goat Cheese, Walnuts, and Honey-Dijon Vinaigrette	Recipe handout and live plant display
<i>Rosa canina</i> Wild rose (Rosaceae)	Rose Hip Soup*	Sample tasting and live plant display
<i>Rumex acetosella</i> Sheep sorrel (Polygonaceae)	Fresh Fruit Salad with Sheep Sorrel and Sweet Whipped Cream	Recipe handout
<i>Sambucus nigra</i> Elderberry (Adoxaceae)	Elderflower Lemonade*	Sample tasting
<i>Stellaria media</i> Chickweed (Caryophyllaceae)	Sautéed Chickweed with Ginger, Garlic, and Soy Sauce	Recipe handout and live plant display
<i>Taraxacum officinale</i> Dandelion (Asteraceae)	Dandelion Flower Lemonade†; Deep-Fried Dandelion Flowers; Orecchiette Pasta with Italian Sausage, Dandelion Greens, and Lemon Zest	Sample tasting, recipe handouts, and live plant display

Fact sheet preparation

Consuming and foraging for wild foods involves certain risks, such as injury while foraging, plants growing in polluted soils, and poisoning due to eating misidentified plants. To address these potential risks, we incorporated safety information into our activity plan in the following ways: (i) the back of each recipe card listed foraging tips and species-specific advice for plant identification; (ii) we supplied a general handout to provide information on how to safely collect and consume edible, weedy plants; and (iii) we chose to highlight plants that grow commonly in the lawns, gardens, and along the

sidewalk edges of homes, where legal and informed foraging is most likely to occur (with information about pesticides, soil quality, and other risk factors). Preparation of recipe cards and handouts on safe foraging required approximately eight person hours.

Recipe preparation

Over several weeks we developed eight original recipes based on six of our highlighted weedy plant species. We selected three of the eight original recipes to feature in our free tastings, using three species of the most easily-accessible and identifiable weeds: *Alliaria petiolata*, *Allium vineale*, and *Taraxacum officinale*. For ingredients we spent approximately three hours foraging for plant material locally in areas where pesticides and herbicides had not been applied. We prepared Cream Cheese Spread with Wild Garlic Shoots (Figure 1), Garlic Mustard Hummus, Elderflower Lemonade, Rose Hip Soup, and Dandelion Flower Lemonade in bulk to offer as samples on crackers and in small tasting cups at our table (Table 2). Food preparation prior to the event required approximately six hours to prepare the necessary quantities (i.e. two gallons of Rose Hip Soup, two gallons of Dandelion Flower Lemonade, two gallons of Elderflower Lemonade, and 64 ounces each of Garlic Mustard Hummus and Cream Cheese Spread with Wild Garlic Shoots).



Figure 1 (above): Cream Cheese Spread with Wild Garlic Shoots and hairy cress garnish (center) and Garlic Mustard Hummus (either side) on crackers. These recipes were prepared in bulk to distribute sample tastings at our “Eat Your Weeds” table at Rutgers Day 2014. Photo: cc // Lena Struwe 2014.

Event day set-up

With set-up teams consisting of two people and two handcarts, we set up three tables along one of the major pedestrian paths on Cook Campus, Rutgers University during Rutgers Day. Our outreach area was equipped with a large, custom-designed overhead sign reading “WEEDS” made from clear plastic tubing filled with a variety of dried weedy plant parts (Figure 2). A newly developed, original logo that read “EAT YOUR

WEEDS” appeared on all outreach materials (Figure 3). Outreach materials included recipe cards with a picture of its featured edible weed and specific foraging tips; new, illustrated field identification guides to 34 local weeds; and handouts on safe foraging practices. We dug up and potted over 20 living examples of weedy species featured in our field guide and displayed these on one of the tables (Figure 2). We also incentivized food sampling by handing out stickers about weeds to all tasters with fun and informative messages such as “I eat weeds”, “Weeds are also made of stardust”, “I drink weeds”, “Weeds are superevolutionary”, and “Without humans, no weeds”. All of our materials (recipe cards, field guide, and foraging safety handout) are freely available as portable document format (pdf) files on our website and blog (Struwe, 2014). We staffed our table with two to four rotating volunteers throughout the day.



Figure 2 (above): A memorable sign, reading “WEEDS” and made out of dried plant material in tubes, sits above potted weedy plants example specimens at our “Eat Your

Weeds” table at Rutgers Day 2014. Pictured from left to right are Lauren J. Frazee, volunteer Zachary Bunda, and Dr. Lena Struwe. Photo: cc // Jennifer Blake-Mahmud 2014.



Figure 3 (above): An original logo created for our “Eat Your Weeds” table at Rutgers Day 2014 appeared on all outreach materials. Image: cc // Lena Struwe 2014.

Results

At the 8-hour long Rutgers Day event on 26 April 2014, we distributed over 2000 free samples of weedy food and beverage items at our outreach table. We estimate that we communicated directly or indirectly (through visuals, handout-materials or ‘sticker interactions’) with 2000-3000 visitors about the public misconceptions and overlooked virtues of weeds in today's society, including but not limited to edibility. We also handed out over 400 recipe cards and about 500 field guide pamphlets. Almost 84,000 people attended Rutgers Day 2014 overall (Szteinbaum et al., 2014).

Though Rutgers Day attracts community members of diverse backgrounds, there were common themes in responses from the public. While we conducted no formal

assessment of visitors to our table to evaluate our learning goals and outcomes, volunteers jotted down notes of interesting stories and interactions during the event. Five to six table volunteers then discussed these anecdotes during our reflection and debriefing process, and here we present and interpret that information. Table visitors included faculty members, students, friends, and parents as well as local families with elderly relatives and toddlers in tow. Most people were very interested in the sample tastings, and some returned to the table twice or more that day. The most popular recipe cards were for Deep-Fried Dandelion Flowers and Cream Cheese Spread with Wild Garlic Shoots. Many visitors quickly recognized our example specimens and sample ingredients (Table 2; Figure 2) as plants that are common in their own yards or neighborhoods. The most common question for plant identification was about *Lamium purpureum* (deadnettle), a common weed in many front yards at that time of the year (i.e., early-mid spring), and many people wanted to know how to rid their yards of it.

Children as well as adults added the stickers to their clothing and wore them around campus for the remainder of the day, potentially providing (and provoking) interactions on weedy plant topics with additional visitors that not yet had visited (or could not visit) our table. Many adults reminisced with us about what they or their older relatives used to eat earlier in their lives and told us (and children, if present) about foraging for wild plants as children, drinking older relatives' dandelion wine, and where the best spots were for finding certain species. A disabled veteran told us about foraging for stinging nettle in New Jersey and that he appreciated our effort to educate the public about edible plants.

Discussion

Using edible weeds in urban environmental education is an effective way to stimulate curiosity in plants, to broaden perspectives on spontaneous weedy vegetation, and to encourage plant identification skills. This activity combats plant blindness by encouraging participants to observe and experience weedy plants, which are often overlooked and underappreciated. The intended take-home message for festival-goers and visitors to our table was: “Notice these plants, all plants, and all life, for that matter; experience them; enjoy them; and find out what they do and represent” (Table 1). This type of activity strengthens connections between the people of the New Jersey-New York metropolitan area and their local, urban flora.

We attribute our success in implementing our outreach program on edible, urban weeds to three factors. First, utilizing local, urban weeds in UEE is a means of outdoor, place-based learning (Theobald, 1997; Kolb, 2014). In place-based learning, students make use of nearby resources to study both the natural world and the community; all such lessons come directly from the context of the local environment (Gruenewald & Smith, eds., 2014). Place-based curricula have also been found to increase student motivations for scholastic achievement (Powers, 2004). Moreover, the opportunities (or “places” themselves) for studying weeds occur at every point in time and space along the urban-rural gradient. The cityscape itself is transformed into a living laboratory when weeds become study organisms. Students can uproot local weeds, bring them to their classroom, and interact with them directly. Getting students out and into their surroundings to experience wild organisms will help combat the ongoing trend of human disconnection from nature through direct contact with plants (Miller, 2005).

Second, the edible weeds that we presented at our activity have traditional significance for many ethnic and cultural groups and are highly recognizable. Simply put, humans both love and hate weeds. In general, weeds have been and continue to be associated with all human settlements in urban, suburban, and rural environments worldwide; weeds are a universal human phenomenon. All of the weedy plants featured in this activity are economically important as sources of flavoring agents, medicine, vegetables, fruits, and/or serve as ornamental species (Table 2; Wiersema & León, 2013). In modern cities, weedy plants are considered important in the provisioning of ecosystem services such as habitat for wild species, microhabitat regulation, and air filtration (Robinson & Lundholm, 2012). The connections between metropolitan areas, people, and weeds are a result of the complex sociopolitical ecology of urban development (Gaston, 2010). In this way, we presented social as well as biological and cultural contexts for learning about each plant.

Third, our tasting opportunities, take-home recipes and guides, thought-provoking stickers, and weedy plant example specimens encouraged an active, multisensory, kinesthetic, and engaging experience (Stern et al., 2014). Eating, in itself, is a personal action that can translate into multi-sensory, experiential learning. Visitors to our outreach table could choose to partake in learning and exploration by any or all of the following methods: eating or drinking free samples; smelling plants, choosing favorite recipes for future use; perusing species guides and safety pamphlets; observing live plants labeled with species names; talking to us and asking questions; and even sharing their own experiences with fellow visitors.

In all, food is inherently motivating and, perhaps most importantly, eating weeds is a novelty in today's society. We tend to care about and remember the texture, tastes, and smells of certain foods, thereby encouraging connections with personal experiences. Using edible plants and food preparation methods in educational activities such as the Food, Math, and Science Teaching Enhancement Resource Initiative developed at East Carolina University (USA) has shown to increase students' abilities to retain information in the life sciences (Duffrin et al., 2010; Hovland et al., 2013). Moreover, both accompanying students in local foraging activities and encouraging members of the public to engage in independent wild plant foraging and then preparing wild plant foods promotes learning-by-doing, or experience-based learning. Outdoor, field-based experiences in general can be highly memorable and beneficial to learners (Dillon et al., 2006). Similarly, schoolyard vegetable gardening activities have been touted as a key method for improving children's environmental attitudes and aptitude in the sciences (Waliczek & Zajicek, 1999; Williams & Dixon, 2013).

Risk is an inherent part of foraging and consuming wild plant species, but the design of this activity helps to minimize those risks. We chose to highlight certain species for sample tastings (i.e., dandelion, wild onion/wild garlic, and garlic mustard) that are easy to identify by characteristic leaf morphology and have no poisonous "look-alikes". Dandelion flower heads and their tufted, wind-blown fruits are well-recognized in modern culture, and their use as a decorative motif—in stationery, interior design, and even tattoos—has recently surged. Wild onion and garlic mustard leaves have distinct, pungent scents when broken. All of these species are usually found in high density and abundance where they are present and generally do not cause allergic reactions in

humans. (However, people with food allergies should remain cautious.) In addition, these species look strikingly different from the most common poisonous plants in the mid-Atlantic and northeastern US, such as jimsonweed, nightshade, and poison ivy, which can cause symptoms such as gastric irritation and painful rashes. We strongly discourage consuming or serving any foods made with wild plant species unless their species identities have been confirmed with 100% accuracy. All plant species used in this activity can be harvested up to two weeks before food preparation, refrigerated, and verified with a specialist ahead of time. Local botanical societies or institutions of higher education may be able to assist with verification. Learning to forage for edible plants, or simply knowing the toxic plants in your environment, necessitates a strong knowledge in botanical identification of species and their morphologies and provides an excellent argument for improved botanical education at the K-99 level.

Using urban edible plants in informal public education easily lends itself to formal lesson planning in the plant sciences and UEE as well as to other informal contexts in diverse venues and seasons. These activities could be prepared for small or large crowds anywhere there are wild edible plants, but the accessibility of edible weeds in city and suburban environments makes them especially meaningful for UEE. In the mid-Atlantic and northeastern urbanized US, educators can typically forage during much of the growing season for plant materials or sample specimens of the species used here (after asking permission from property owners or land managers, where necessary). Wild onion grows prolifically in lawns in the early spring and late fall in this region, while dandelion and garlic mustard have leafy growth in lawns and suburban woods, respectively, from the early spring through the fall. Moreover, there are numerous other edible urban plant

species available for harvest and study outside of temperate zones. Of the 17 most common urban plants in cities around the world (Aronson et al., 2014), all but four have well-described edible and/or medicinal uses (Wiersema & León, 2013).

We recommend that educators account for certain logistical factors when hosting large-scale outreach events based on foods and beverages made from urban weeds. The limiting factor in making this activity successful for large crowds (such as Rutgers Day) is simply the number of volunteer hours needed for bulk food preparation and “plating” or serving during the event. Crackers topped with Garlic Mustard Hummus and Cream Cheese Spread with Wild Garlic Shoots were taken up by visitors at a rate exceeding the speed at which we could prepare them. Various strategies could be implemented to relieve volunteers from this burden, such as using squeeze bottles to dispense toppings onto crackers, planning to serve less labor-intensive samples, or simply doing more preparatory work ahead of time. Furthermore, we suggest serving at least one drink and at least one solid food and choosing recipes that are palatable across a wide range of tastes (e.g. sweet and savory) to diversify the menu. Tasters should have easy access to ingredient lists to avoid problems with food allergies and intolerances. Another important planning consideration is seasonality. For example, the herbaceous weedy species harvested for this event are not available in late fall and winter in temperate areas. However, we do see the potential for educators to develop seasonal edible weed activities that reflect the change in plant species composition throughout the year, especially in temperate climates.

Conclusions

Our “Eat Your Weeds” outreach table at Rutgers Day 2014 in New Brunswick, NJ, is an example of how to incorporate plant- and place-based learning, socioecological connections, and direct contact with wild organisms in urban environments in a practical and fun way. We have evaluated our outreach activity as highly successful in encouraging community members to become more familiar with local, wild plant biodiversity in an urban setting (Table 1). We received overwhelmingly positive feedback and recognition from visitors, observers, and university media (Szteinbaum et al., 2014). Edible urban weeds are an easy and economical teaching tool for active, culturally-relevant, place-based learning in UEE and in combating plant blindness. Weeds are natural choices for use in UEE due to their relative abundance in cities and suburbs, interesting ecological niches, and strong historical associations with a diversity of cultural practices. These are globally accessible resources with broad appeal for informal public outreach as well as formal nature education.

Appendices

Appendix 1 (below): Regional pool of 2199 spontaneous vascular plant species as accessed in April 2016 from USDA Plants (2016) for the New Jersey, US counties of Middlesex, Mercer, Monmouth, Somerset, and Union, including accepted species names only and excluding hybrid species names. *Amaranthus blitum*, *Chenopodium glaucum*, *Erechtites hieraciifolius*, *Cyperus compressus*, and *Zelkova serrata* were added to the regional pool list to be used in all further analyses because as they all had existing records in the USDA Plants database indicating their presence either in other counties in New Jersey or in New Jersey generally (due to missing county-level data; USDA, 2016). Native status: “N” reflects native status and “I” reflects non-native status within the continental US; “NI” indicates there are both native and non-native populations in the continental US. T/E status: “T/E” indicates that Threatened or Endangered status in New Jersey was indicated by USDA Plants (2016).

Species name	Family (USDA 2016)	Parking lot	Native status	T/E status
<i>Justicia americana</i>	Acanthaceae	N	N	N
<i>Acer rubrum</i>	Aceraceae	Y	N	N
<i>Acer campestre</i>	Aceraceae	N	I	N
<i>Acer ginnala</i>	Aceraceae	N	I	N
<i>Acer palmatum</i>	Aceraceae	N	I	N
<i>Acer platanoides</i>	Aceraceae	N	I	N
<i>Acer pseudoplatanus</i>	Aceraceae	N	I	N
<i>Acer negundo</i>	Aceraceae	N	N	N
<i>Acer nigrum</i>	Aceraceae	N	N	N
<i>Acer pensylvanicum</i>	Aceraceae	N	N	N
<i>Acer saccharinum</i>	Aceraceae	N	N	N
<i>Acer saccharum</i>	Aceraceae	N	N	N
<i>Acer spicatum</i>	Aceraceae	N	N	N
<i>Acorus calamus</i>	Acoraceae	N	I	N

<i>Acorus americanus</i>	Acoraceae	N	N	N
<i>Actinidia arguta</i>	Actinidiaceae	N	I	N
<i>Yucca filamentosa</i>	Agavaceae	N	N	N
<i>Sesuvium maritimum</i>	Aizoaceae	N	N	N
<i>Sagittaria montevidensis</i>	Alismataceae	N	I	N
<i>Alisma subcordatum</i>	Alismataceae	N	N	N
<i>Alisma triviale</i>	Alismataceae	N	N	Y
<i>Sagittaria australis</i>	Alismataceae	N	N	Y
<i>Sagittaria calycina</i>	Alismataceae	N	N	N
<i>Sagittaria cuneata</i>	Alismataceae	N	N	Y
<i>Sagittaria engelmanniana</i>	Alismataceae	N	N	N
<i>Sagittaria graminea</i>	Alismataceae	N	N	N
<i>Sagittaria latifolia</i>	Alismataceae	N	N	N
<i>Sagittaria rigida</i>	Alismataceae	N	N	N
<i>Sagittaria subulata</i>	Alismataceae	N	N	N
<i>Amaranthus blitum</i>	Amaranthaceae	Y	I	N
<i>Amaranthus spinosus</i>	Amaranthaceae	Y	N	N
<i>Amaranthus albus</i>	Amaranthaceae	N	I	N
<i>Amaranthus blitoides</i>	Amaranthaceae	N	I	N
<i>Amaranthus cannabinus</i>	Amaranthaceae	N	N	N
<i>Amaranthus hybridus</i>	Amaranthaceae	N	N	N
<i>Amaranthus pumilus</i>	Amaranthaceae	N	N	Y
<i>Amaranthus retroflexus</i>	Amaranthaceae	N	N	N
<i>Amaranthus tuberculatus</i>	Amaranthaceae	N	N	N
<i>Froelichia gracilis</i>	Amaranthaceae	N	N	N
<i>Toxicodendron radicans</i>	Anacardiaceae	Y	N	N
<i>Cotinus coggygria</i>	Anacardiaceae	N	I	N
<i>Rhus aromatica</i>	Anacardiaceae	N	N	N
<i>Rhus copallinum</i>	Anacardiaceae	N	N	N
<i>Rhus glabra</i>	Anacardiaceae	N	N	N
<i>Rhus typhina</i>	Anacardiaceae	N	N	N
<i>Toxicodendron vernix</i>	Anacardiaceae	N	N	N
<i>Asimina triloba</i>	Annonaceae	N	N	Y
<i>Daucus carota</i>	Apiaceae	Y	I	N

<i>Aegopodium podagraria</i>	Apiaceae	N	I	N
<i>Aethusa cynapium</i>	Apiaceae	N	I	N
<i>Anethum graveolens</i>	Apiaceae	N	I	N
<i>Anthriscus sylvestris</i>	Apiaceae	N	I	N
<i>Apium graveolens</i>	Apiaceae	N	I	N
<i>Bupleurum rotundifolium</i>	Apiaceae	N	I	N
<i>Carum carvi</i>	Apiaceae	N	I	N
<i>Conium maculatum</i>	Apiaceae	N	I	N
<i>Hydrocotyle sibthorpioides</i>	Apiaceae	N	I	N
<i>Pastinaca sativa</i>	Apiaceae	N	I	N
<i>Angelica atropurpurea</i>	Apiaceae	N	N	N
<i>Angelica venenosa</i>	Apiaceae	N	N	N
<i>Berula erecta</i>	Apiaceae	N	N	N
<i>Chaerophyllum procumbens</i>	Apiaceae	N	N	N
<i>Cicuta bulbifera</i>	Apiaceae	N	N	N
<i>Cicuta maculata</i>	Apiaceae	N	N	N
<i>Cryptotaenia canadensis</i>	Apiaceae	N	N	N
<i>Eryngium aquaticum</i>	Apiaceae	N	N	N
<i>Heracleum maximum</i>	Apiaceae	N	N	N
<i>Hydrocotyle americana</i>	Apiaceae	N	N	N
<i>Hydrocotyle ranunculoides</i>	Apiaceae	N	N	Y
<i>Hydrocotyle umbellata</i>	Apiaceae	N	N	N
<i>Hydrocotyle verticillata</i>	Apiaceae	N	N	N
<i>Lomatium orientale</i>	Apiaceae	N	N	N
<i>Osmorhiza claytonii</i>	Apiaceae	N	N	N
<i>Osmorhiza longistylis</i>	Apiaceae	N	N	N
<i>Oxypolis rigidior</i>	Apiaceae	N	N	N
<i>Ptilimnium capillaceum</i>	Apiaceae	N	N	N
<i>Sanicula canadensis</i>	Apiaceae	N	N	N
<i>Sanicula marilandica</i>	Apiaceae	N	N	N
<i>Sanicula odorata</i>	Apiaceae	N	N	N
<i>Sanicula trifoliata</i>	Apiaceae	N	N	Y
<i>Sium suave</i>	Apiaceae	N	N	N
<i>Taenidia integerrima</i>	Apiaceae	N	N	N

<i>Thaspium barbinode</i>	Apiaceae	N	N	N
<i>Thaspium trifoliatum</i>	Apiaceae	N	N	N
<i>Zizia aptera</i>	Apiaceae	N	N	N
<i>Zizia aurea</i>	Apiaceae	N	N	N
<i>Apocynum cannabinum</i>	Apocynaceae	Y	N	N
<i>Vinca minor</i>	Apocynaceae	N	I	N
<i>Apocynum androsaemifolium</i>	Apocynaceae	N	N	N
<i>Ilex aquifolium</i>	Aquifoliaceae	N	I	N
<i>Ilex crenata</i>	Aquifoliaceae	N	I	N
<i>Ilex glabra</i>	Aquifoliaceae	N	N	N
<i>Ilex laevigata</i>	Aquifoliaceae	N	N	N
<i>Ilex mucronata</i>	Aquifoliaceae	N	N	N
<i>Ilex opaca</i>	Aquifoliaceae	N	N	N
<i>Ilex verticillata</i>	Aquifoliaceae	N	N	N
<i>Arisaema dracontium</i>	Araceae	N	N	N
<i>Arisaema triphyllum</i>	Araceae	N	N	N
<i>Calla palustris</i>	Araceae	N	N	N
<i>Orontium aquaticum</i>	Araceae	N	N	N
<i>Peltandra virginica</i>	Araceae	N	N	N
<i>Pistia stratiotes</i>	Araceae	N	N	N
<i>Symplocarpus foetidus</i>	Araceae	N	N	N
<i>Aralia elata</i>	Araliaceae	N	I	N
<i>Hedera helix</i>	Araliaceae	N	I	N
<i>Aralia hispida</i>	Araliaceae	N	N	N
<i>Aralia nudicaulis</i>	Araliaceae	N	N	N
<i>Aralia racemosa</i>	Araliaceae	N	N	N
<i>Aralia spinosa</i>	Araliaceae	N	N	N
<i>Panax quinquefolius</i>	Araliaceae	N	N	N
<i>Panax trifolius</i>	Araliaceae	N	N	N
<i>Aristolochia serpentaria</i>	Aristolochiaceae	N	N	N
<i>Asarum canadense</i>	Aristolochiaceae	N	N	N
<i>Asclepias amplexicaulis</i>	Asclepiadaceae	N	N	N
<i>Asclepias exaltata</i>	Asclepiadaceae	N	N	N
<i>Asclepias incarnata</i>	Asclepiadaceae	N	N	N

<i>Asclepias purpurascens</i>	Asclepiadaceae	N	N	N
<i>Asclepias quadrifolia</i>	Asclepiadaceae	N	N	N
<i>Asclepias rubra</i>	Asclepiadaceae	N	N	N
<i>Asclepias syriaca</i>	Asclepiadaceae	N	N	N
<i>Asclepias tuberosa</i>	Asclepiadaceae	N	N	N
<i>Asclepias variegata</i>	Asclepiadaceae	N	N	N
<i>Asclepias verticillata</i>	Asclepiadaceae	N	N	N
<i>Asclepias viridiflora</i>	Asclepiadaceae	N	N	N
<i>Asplenium montanum</i>	Aspleniaceae	N	N	N
<i>Asplenium platyneuron</i>	Aspleniaceae	N	N	N
<i>Asplenium rhizophyllum</i>	Aspleniaceae	N	N	N
<i>Asplenium trichomanes</i>	Aspleniaceae	N	N	N
<i>Arctium minus</i>	Asteraceae	Y	I	N
<i>Artemisia vulgaris</i>	Asteraceae	Y	I	N
<i>Cirsium vulgare</i>	Asteraceae	Y	I	N
<i>Galinoga quadriradiata</i>	Asteraceae	Y	I	N
<i>Hieracium caespitosum</i>	Asteraceae	Y	I	N
<i>Lactuca serriola</i>	Asteraceae	Y	I	N
<i>Matricaria discoidea</i>	Asteraceae	Y	I	N
<i>Senecio vulgaris</i>	Asteraceae	Y	I	N
<i>Ageratina altissima</i>	Asteraceae	Y	N	N
<i>Baccharis halimifolia</i>	Asteraceae	Y	N	N
<i>Conyza canadensis</i>	Asteraceae	Y	N	N
<i>Eclipta prostrata</i>	Asteraceae	Y	N	N
<i>Erechtites hieraciifolius</i>	Asteraceae	Y	N	N
<i>Eupatorium serotinum</i>	Asteraceae	Y	N	N
<i>Lactuca canadensis</i>	Asteraceae	Y	N	N
<i>Solidago canadensis</i>	Asteraceae	Y	N	N
<i>Symphotrichum racemosum</i>	Asteraceae	Y	N	N
<i>Ambrosia artemisiifolia</i>	Asteraceae	Y	NI	N
<i>Taraxacum officinale</i>	Asteraceae	Y	NI	N
<i>Anthemis arvensis</i>	Asteraceae	N	I	N
<i>Anthemis cotula</i>	Asteraceae	N	I	N
<i>Anthemis tinctoria</i>	Asteraceae	N	I	N

<i>Arctium lappa</i>	Asteraceae	N	I	N
<i>Artemisia absinthium</i>	Asteraceae	N	I	N
<i>Artemisia annua</i>	Asteraceae	N	I	N
<i>Artemisia stelleriana</i>	Asteraceae	N	I	N
<i>Bellis perennis</i>	Asteraceae	N	I	N
<i>Carduus nutans</i>	Asteraceae	N	I	N
<i>Centaurea cyanus</i>	Asteraceae	N	I	N
<i>Centaurea jacea</i>	Asteraceae	N	I	N
<i>Centaurea nigra</i>	Asteraceae	N	I	N
<i>Centaurea nigrescens</i>	Asteraceae	N	I	N
<i>Centaurea stoebe</i>	Asteraceae	N	I	N
<i>Cichorium intybus</i>	Asteraceae	N	I	N
<i>Cirsium arvense</i>	Asteraceae	N	I	N
<i>Crepis capillaris</i>	Asteraceae	N	I	N
<i>Crepis tectorum</i>	Asteraceae	N	I	N
<i>Galinsoga parviflora</i>	Asteraceae	N	I	N
<i>Gnaphalium uliginosum</i>	Asteraceae	N	I	N
<i>Hieracium aurantiacum</i>	Asteraceae	N	I	N
<i>Hieracium lachenalii</i>	Asteraceae	N	I	N
<i>Hieracium murorum</i>	Asteraceae	N	I	N
<i>Hieracium pilosella</i>	Asteraceae	N	I	N
<i>Hieracium piloselloides</i>	Asteraceae	N	I	N
<i>Hieracium sabaudum</i>	Asteraceae	N	I	N
<i>Hypochaeris radicata</i>	Asteraceae	N	I	N
<i>Inula helenium</i>	Asteraceae	N	I	N
<i>Lapsana communis</i>	Asteraceae	N	I	N
<i>Leontodon autumnalis</i>	Asteraceae	N	I	N
<i>Leucanthemum vulgare</i>	Asteraceae	N	I	N
<i>Matricaria recutita</i>	Asteraceae	N	I	N
<i>Onopordum acanthium</i>	Asteraceae	N	I	N
<i>Parthenium hysterophorus</i>	Asteraceae	N	I	N
<i>Sonchus arvensis</i>	Asteraceae	N	I	N
<i>Sonchus asper</i>	Asteraceae	N	I	N
<i>Sonchus oleraceus</i>	Asteraceae	N	I	N

<i>Tagetes erecta</i>	Asteraceae	N	I	N
<i>Tanacetum parthenium</i>	Asteraceae	N	I	N
<i>Tanacetum vulgare</i>	Asteraceae	N	I	N
<i>Taraxacum laevigatum</i>	Asteraceae	N	I	N
<i>Tragopogon dubius</i>	Asteraceae	N	I	N
<i>Tragopogon porrifolius</i>	Asteraceae	N	I	N
<i>Tripleurospermum perforatum</i>	Asteraceae	N	I	N
<i>Tussilago farfara</i>	Asteraceae	N	I	N
<i>Xanthium spinosum</i>	Asteraceae	N	I	N
<i>Ageratina aromatica</i>	Asteraceae	N	N	N
<i>Ambrosia bidentata</i>	Asteraceae	N	N	N
<i>Ambrosia grayi</i>	Asteraceae	N	N	N
<i>Ambrosia trifida</i>	Asteraceae	N	N	N
<i>Anaphalis margaritacea</i>	Asteraceae	N	N	N
<i>Antennaria howellii</i>	Asteraceae	N	N	N
<i>Antennaria neglecta</i>	Asteraceae	N	N	N
<i>Antennaria parlinii</i>	Asteraceae	N	N	N
<i>Antennaria plantaginifolia</i>	Asteraceae	N	N	N
<i>Arnoglossum atriplicifolium</i>	Asteraceae	N	N	Y
<i>Artemisia campestris</i>	Asteraceae	N	N	N
<i>Bidens aristosa</i>	Asteraceae	N	N	N
<i>Bidens bidentoides</i>	Asteraceae	N	N	N
<i>Bidens bipinnata</i>	Asteraceae	N	N	N
<i>Bidens cernua</i>	Asteraceae	N	N	N
<i>Bidens connata</i>	Asteraceae	N	N	N
<i>Bidens coronata</i>	Asteraceae	N	N	N
<i>Bidens discoidea</i>	Asteraceae	N	N	N
<i>Bidens eatonii</i>	Asteraceae	N	N	Y
<i>Bidens frondosa</i>	Asteraceae	N	N	N
<i>Bidens hyperborea</i>	Asteraceae	N	N	N
<i>Bidens laevis</i>	Asteraceae	N	N	N
<i>Bidens tripartita</i>	Asteraceae	N	N	N
<i>Bidens vulgata</i>	Asteraceae	N	N	N
<i>Boltonia asteroides</i>	Asteraceae	N	N	N

<i>Brickellia eupatorioides</i>	Asteraceae	N	N	N
<i>Chrysopsis mariana</i>	Asteraceae	N	N	N
<i>Cirsium altissimum</i>	Asteraceae	N	N	N
<i>Cirsium discolor</i>	Asteraceae	N	N	N
<i>Cirsium horridulum</i>	Asteraceae	N	N	N
<i>Cirsium muticum</i>	Asteraceae	N	N	N
<i>Cirsium pumilum</i>	Asteraceae	N	N	N
<i>Conoclinium coelestinum</i>	Asteraceae	N	N	N
<i>Coreopsis grandiflora</i>	Asteraceae	N	N	N
<i>Coreopsis lanceolata</i>	Asteraceae	N	N	N
<i>Coreopsis rosea</i>	Asteraceae	N	N	N
<i>Coreopsis tinctoria</i>	Asteraceae	N	N	N
<i>Doellingeria infirma</i>	Asteraceae	N	N	N
<i>Doellingeria umbellata</i>	Asteraceae	N	N	N
<i>Dyssodia papposa</i>	Asteraceae	N	N	N
<i>Echinacea purpurea</i>	Asteraceae	N	N	N
<i>Erigeron annuus</i>	Asteraceae	N	N	N
<i>Erigeron philadelphicus</i>	Asteraceae	N	N	N
<i>Erigeron pulchellus</i>	Asteraceae	N	N	N
<i>Erigeron strigosus</i>	Asteraceae	N	N	N
<i>Eupatorium album</i>	Asteraceae	N	N	N
<i>Eupatorium altissimum</i>	Asteraceae	N	N	N
<i>Eupatorium hyssopifolium</i>	Asteraceae	N	N	N
<i>Eupatorium leucolepis</i>	Asteraceae	N	N	N
<i>Eupatorium perfoliatum</i>	Asteraceae	N	N	N
<i>Eupatorium pilosum</i>	Asteraceae	N	N	N
<i>Eupatorium resinosum</i>	Asteraceae	N	N	Y
<i>Eupatorium rotundifolium</i>	Asteraceae	N	N	N
<i>Eupatorium sessilifolium</i>	Asteraceae	N	N	N
<i>Eurybia divaricata</i>	Asteraceae	N	N	N
<i>Eurybia macrophylla</i>	Asteraceae	N	N	N
<i>Eurybia radula</i>	Asteraceae	N	N	Y
<i>Eurybia schreberi</i>	Asteraceae	N	N	N
<i>Eurybia spectabilis</i>	Asteraceae	N	N	N

<i>Euthamia caroliniana</i>	Asteraceae	N	N	N
<i>Euthamia graminifolia</i>	Asteraceae	N	N	N
<i>Eutrochium dubium</i>	Asteraceae	N	N	N
<i>Eutrochium fistulosum</i>	Asteraceae	N	N	N
<i>Eutrochium maculatum</i>	Asteraceae	N	N	N
<i>Eutrochium purpureum</i>	Asteraceae	N	N	N
<i>Gaillardia pulchella</i>	Asteraceae	N	N	N
<i>Gamochaeta purpurea</i>	Asteraceae	N	N	N
<i>Grindelia squarrosa</i>	Asteraceae	N	N	N
<i>Hasteola suaveolens</i>	Asteraceae	N	N	N
<i>Helenium autumnale</i>	Asteraceae	N	N	N
<i>Helenium flexuosum</i>	Asteraceae	N	N	N
<i>Helianthus angustifolius</i>	Asteraceae	N	N	N
<i>Helianthus annuus</i>	Asteraceae	N	N	N
<i>Helianthus decapetalus</i>	Asteraceae	N	N	N
<i>Helianthus divaricatus</i>	Asteraceae	N	N	N
<i>Helianthus giganteus</i>	Asteraceae	N	N	N
<i>Helianthus pauciflorus</i>	Asteraceae	N	N	N
<i>Helianthus petiolaris</i>	Asteraceae	N	N	N
<i>Helianthus strumosus</i>	Asteraceae	N	N	N
<i>Helianthus tuberosus</i>	Asteraceae	N	N	N
<i>Heliopsis helianthoides</i>	Asteraceae	N	N	N
<i>Heterotheca subaxillaris</i>	Asteraceae	N	N	N
<i>Heterotheca villosa</i>	Asteraceae	N	N	N
<i>Hieracium gronovii</i>	Asteraceae	N	N	N
<i>Hieracium marianum</i>	Asteraceae	N	N	N
<i>Hieracium paniculatum</i>	Asteraceae	N	N	N
<i>Hieracium scabrum</i>	Asteraceae	N	N	N
<i>Hieracium venosum</i>	Asteraceae	N	N	N
<i>Ionactis linariifolius</i>	Asteraceae	N	N	N
<i>Iva frutescens</i>	Asteraceae	N	N	N
<i>Krigia biflora</i>	Asteraceae	N	N	N
<i>Krigia virginica</i>	Asteraceae	N	N	N
<i>Lactuca biennis</i>	Asteraceae	N	N	N

<i>Lactuca floridana</i>	Asteraceae	N	N	N
<i>Lactuca hirsuta</i>	Asteraceae	N	N	N
<i>Lactuca tatarica</i>	Asteraceae	N	N	N
<i>Liatris punctata</i>	Asteraceae	N	N	N
<i>Liatris scariosa</i>	Asteraceae	N	N	N
<i>Liatris spicata</i>	Asteraceae	N	N	N
<i>Machaeranthera pinnatifida</i>	Asteraceae	N	N	N
<i>Mikania scandens</i>	Asteraceae	N	N	N
<i>Nothocalais cuspidata</i>	Asteraceae	N	N	N
<i>Oclemena nemoralis</i>	Asteraceae	N	N	N
<i>Oligoneuron rigidum</i>	Asteraceae	N	N	N
<i>Packera aurea</i>	Asteraceae	N	N	N
<i>Packera obovata</i>	Asteraceae	N	N	N
<i>Packera paupercula</i>	Asteraceae	N	N	N
<i>Packera plattensis</i>	Asteraceae	N	N	N
<i>Pityopsis falcata</i>	Asteraceae	N	N	N
<i>Pluchea odorata</i>	Asteraceae	N	N	N
<i>Prenanthes alba</i>	Asteraceae	N	N	N
<i>Prenanthes altissima</i>	Asteraceae	N	N	N
<i>Prenanthes serpentaria</i>	Asteraceae	N	N	N
<i>Prenanthes trifoliolata</i>	Asteraceae	N	N	N
<i>Pseudognaphalium helleri</i>	Asteraceae	N	N	N
<i>Pseudognaphalium macounii</i>	Asteraceae	N	N	Y
<i>Pseudognaphalium obtusifolium</i>	Asteraceae	N	N	N
<i>Ratibida columnifera</i>	Asteraceae	N	N	N
<i>Rudbeckia fulgida</i>	Asteraceae	N	N	Y
<i>Rudbeckia hirta</i>	Asteraceae	N	N	N
<i>Rudbeckia laciniata</i>	Asteraceae	N	N	N
<i>Rudbeckia triloba</i>	Asteraceae	N	N	N
<i>Sericocarpus asteroides</i>	Asteraceae	N	N	N
<i>Sericocarpus linifolius</i>	Asteraceae	N	N	N
<i>Silphium perfoliatum</i>	Asteraceae	N	N	N
<i>Solidago altissima</i>	Asteraceae	N	N	N
<i>Solidago arguta</i>	Asteraceae	N	N	N

<i>Solidago bicolor</i>	Asteraceae	N	N	N
<i>Solidago caesia</i>	Asteraceae	N	N	N
<i>Solidago erecta</i>	Asteraceae	N	N	N
<i>Solidago fistulosa</i>	Asteraceae	N	N	N
<i>Solidago flexicaulis</i>	Asteraceae	N	N	N
<i>Solidago gigantea</i>	Asteraceae	N	N	N
<i>Solidago hispida</i>	Asteraceae	N	N	N
<i>Solidago juncea</i>	Asteraceae	N	N	N
<i>Solidago latissimifolia</i>	Asteraceae	N	N	N
<i>Solidago missouriensis</i>	Asteraceae	N	N	N
<i>Solidago mollis</i>	Asteraceae	N	N	N
<i>Solidago nemoralis</i>	Asteraceae	N	N	N
<i>Solidago odora</i>	Asteraceae	N	N	N
<i>Solidago patula</i>	Asteraceae	N	N	N
<i>Solidago puberula</i>	Asteraceae	N	N	N
<i>Solidago rugosa</i>	Asteraceae	N	N	N
<i>Solidago sempervirens</i>	Asteraceae	N	N	N
<i>Solidago speciosa</i>	Asteraceae	N	N	N
<i>Solidago squarrosa</i>	Asteraceae	N	N	N
<i>Solidago uliginosa</i>	Asteraceae	N	N	N
<i>Solidago ulmifolia</i>	Asteraceae	N	N	N
<i>Symphyotrichum concolor</i>	Asteraceae	N	N	N
<i>Symphyotrichum cordifolium</i>	Asteraceae	N	N	N
<i>Symphyotrichum dumosum</i>	Asteraceae	N	N	N
<i>Symphyotrichum ericoides</i>	Asteraceae	N	N	N
<i>Symphyotrichum laeve</i>	Asteraceae	N	N	N
<i>Symphyotrichum lanceolatum</i>	Asteraceae	N	N	N
<i>Symphyotrichum lateriflorum</i>	Asteraceae	N	N	N
<i>Symphyotrichum lowrieianum</i>	Asteraceae	N	N	N
<i>Symphyotrichum novae-angliae</i>	Asteraceae	N	N	N
<i>Symphyotrichum novi-belgii</i>	Asteraceae	N	N	N
<i>Symphyotrichum patens</i>	Asteraceae	N	N	N
<i>Symphyotrichum pilosum</i>	Asteraceae	N	N	N
<i>Symphyotrichum praealtum</i>	Asteraceae	N	N	N

<i>Symphyotrichum prenanthoides</i>	Asteraceae	N	N	N
<i>Symphyotrichum puniceum</i>	Asteraceae	N	N	N
<i>Symphyotrichum subulatum</i>	Asteraceae	N	N	N
<i>Symphyotrichum tenuifolium</i>	Asteraceae	N	N	N
<i>Symphyotrichum undulatum</i>	Asteraceae	N	N	N
<i>Verbesina alternifolia</i>	Asteraceae	N	N	N
<i>Vernonia noveboracensis</i>	Asteraceae	N	N	N
<i>Xanthium strumarium</i>	Asteraceae	N	N	N
<i>Achillea millefolium</i>	Asteraceae	N	NI	N
<i>Artemisia biennis</i>	Asteraceae	N	NI	N
<i>Azolla caroliniana</i>	Azollaceae	N	N	N
<i>Impatiens capensis</i>	Balsaminaceae	N	N	N
<i>Impatiens pallida</i>	Balsaminaceae	N	N	N
<i>Berberis thunbergii</i>	Berberidaceae	N	I	N
<i>Berberis vulgaris</i>	Berberidaceae	N	I	N
<i>Caulophyllum thalictroides</i>	Berberidaceae	N	N	N
<i>Jeffersonia diphylla</i>	Berberidaceae	N	N	Y
<i>Mahonia aquifolium</i>	Berberidaceae	N	N	N
<i>Podophyllum peltatum</i>	Berberidaceae	N	N	N
<i>Alnus glutinosa</i>	Betulaceae	N	I	N
<i>Betula pendula</i>	Betulaceae	N	I	N
<i>Alnus incana</i>	Betulaceae	N	N	N
<i>Alnus serrulata</i>	Betulaceae	N	N	N
<i>Betula alleghaniensis</i>	Betulaceae	N	N	N
<i>Betula lenta</i>	Betulaceae	N	N	N
<i>Betula nigra</i>	Betulaceae	N	N	N
<i>Betula papyrifera</i>	Betulaceae	N	N	N
<i>Betula populifolia</i>	Betulaceae	N	N	N
<i>Carpinus caroliniana</i>	Betulaceae	N	N	N
<i>Corylus americana</i>	Betulaceae	N	N	N
<i>Corylus cornuta</i>	Betulaceae	N	N	N
<i>Ostrya virginiana</i>	Betulaceae	N	N	N
<i>Campsis radicans</i>	Bignoniaceae	N	N	N
<i>Catalpa bignonioides</i>	Bignoniaceae	N	N	N

<i>Catalpa speciosa</i>	Bignoniaceae	N	N	N
<i>Woodwardia areolata</i>	Blechnaceae	N	N	N
<i>Woodwardia virginica</i>	Blechnaceae	N	N	N
<i>Buglossoides arvensis</i>	Boraginaceae	N	I	N
<i>Cynoglossum officinale</i>	Boraginaceae	N	I	N
<i>Echium vulgare</i>	Boraginaceae	N	I	N
<i>Lappula squarrosa</i>	Boraginaceae	N	I	N
<i>Myosotis arvensis</i>	Boraginaceae	N	I	N
<i>Myosotis scorpioides</i>	Boraginaceae	N	I	N
<i>Myosotis stricta</i>	Boraginaceae	N	I	N
<i>Symphytum officinale</i>	Boraginaceae	N	I	N
<i>Cynoglossum virginianum</i>	Boraginaceae	N	N	N
<i>Hackelia virginiana</i>	Boraginaceae	N	N	N
<i>Lappula occidentalis</i>	Boraginaceae	N	N	N
<i>Lithospermum incisum</i>	Boraginaceae	N	N	N
<i>Mertensia virginica</i>	Boraginaceae	N	N	N
<i>Myosotis laxa</i>	Boraginaceae	N	N	N
<i>Myosotis verna</i>	Boraginaceae	N	N	N
<i>Onosmodium virginianum</i>	Boraginaceae	N	N	Y
<i>Alliaria petiolata</i>	Brassicaceae	Y	I	N
<i>Coronopus didymus</i>	Brassicaceae	Y	I	N
<i>Lepidium virginicum</i>	Brassicaceae	Y	N	N
<i>Alyssum alyssoides</i>	Brassicaceae	N	I	N
<i>Arabidopsis thaliana</i>	Brassicaceae	N	I	N
<i>Armoracia rusticana</i>	Brassicaceae	N	I	N
<i>Barbarea verna</i>	Brassicaceae	N	I	N
<i>Barbarea vulgaris</i>	Brassicaceae	N	I	N
<i>Berteroa incana</i>	Brassicaceae	N	I	N
<i>Brassica juncea</i>	Brassicaceae	N	I	N
<i>Brassica nigra</i>	Brassicaceae	N	I	N
<i>Brassica oleracea</i>	Brassicaceae	N	I	N
<i>Brassica rapa</i>	Brassicaceae	N	I	N
<i>Camelina microcarpa</i>	Brassicaceae	N	I	N
<i>Capsella bursa-pastoris</i>	Brassicaceae	N	I	N

<i>Cardamine hirsuta</i>	Brassicaceae	N	I	N
<i>Cardamine impatiens</i>	Brassicaceae	N	I	N
<i>Descurainia sophia</i>	Brassicaceae	N	I	N
<i>Diplotaxis tenuifolia</i>	Brassicaceae	N	I	N
<i>Draba verna</i>	Brassicaceae	N	I	N
<i>Erysimum cheiranthoides</i>	Brassicaceae	N	I	N
<i>Hesperis matronalis</i>	Brassicaceae	N	I	N
<i>Lepidium campestre</i>	Brassicaceae	N	I	N
<i>Lepidium ruderae</i>	Brassicaceae	N	I	N
<i>Lobularia maritima</i>	Brassicaceae	N	I	N
<i>Lunaria annua</i>	Brassicaceae	N	I	N
<i>Microthlaspi perfoliatum</i>	Brassicaceae	N	I	N
<i>Nasturtium officinale</i>	Brassicaceae	N	I	N
<i>Raphanus raphanistrum</i>	Brassicaceae	N	I	N
<i>Rorippa sylvestris</i>	Brassicaceae	N	I	N
<i>Sinapis alba</i>	Brassicaceae	N	I	N
<i>Sinapis arvensis</i>	Brassicaceae	N	I	N
<i>Sisymbrium altissimum</i>	Brassicaceae	N	I	N
<i>Sisymbrium officinale</i>	Brassicaceae	N	I	N
<i>Teesdalia nudicaulis</i>	Brassicaceae	N	I	N
<i>Thlaspi alliaceum</i>	Brassicaceae	N	I	N
<i>Thlaspi arvense</i>	Brassicaceae	N	I	N
<i>Arabis canadensis</i>	Brassicaceae	N	N	N
<i>Arabis glabra</i>	Brassicaceae	N	N	N
<i>Arabis hirsuta</i>	Brassicaceae	N	N	N
<i>Arabis laevigata</i>	Brassicaceae	N	N	N
<i>Arabis lyrata</i>	Brassicaceae	N	N	N
<i>Cakile edentula</i>	Brassicaceae	N	N	N
<i>Cardamine angustata</i>	Brassicaceae	N	N	N
<i>Cardamine bulbosa</i>	Brassicaceae	N	N	N
<i>Cardamine concatenata</i>	Brassicaceae	N	N	N
<i>Cardamine diphylla</i>	Brassicaceae	N	N	N
<i>Cardamine maxima</i>	Brassicaceae	N	N	Y
<i>Cardamine parviflora</i>	Brassicaceae	N	N	N

<i>Cardamine pensylvanica</i>	Brassicaceae	N	N	N
<i>Cardamine pratensis</i>	Brassicaceae	N	N	N
<i>Cardamine rotundifolia</i>	Brassicaceae	N	N	Y
<i>Descurainia pinnata</i>	Brassicaceae	N	N	N
<i>Draba reptans</i>	Brassicaceae	N	N	Y
<i>Rorippa palustris</i>	Brassicaceae	N	N	N
<i>Rorippa sinuata</i>	Brassicaceae	N	N	N
<i>Lepidium densiflorum</i>	Brassicaceae	N	NI	N
<i>Buddleja davidii</i>	Buddlejaceae	Y	I	N
<i>Pachysandra terminalis</i>	Buxaceae	N	I	N
<i>Brasenia schreberi</i>	Cabombaceae	N	N	N
<i>Cabomba caroliniana</i>	Cabombaceae	N	N	N
<i>Opuntia humifusa</i>	Cactaceae	N	N	N
<i>Callitriche stagnalis</i>	Callitrichaceae	N	I	N
<i>Callitriche heterophylla</i>	Callitrichaceae	N	N	N
<i>Callitriche palustris</i>	Callitrichaceae	N	N	N
<i>Callitriche terrestris</i>	Callitrichaceae	N	N	N
<i>Campanula rapunculoides</i>	Campanulaceae	N	I	N
<i>Jasione montana</i>	Campanulaceae	N	I	N
<i>Campanula aparinoides</i>	Campanulaceae	N	N	N
<i>Campanula rotundifolia</i>	Campanulaceae	N	N	N
<i>Lobelia cardinalis</i>	Campanulaceae	N	N	N
<i>Lobelia inflata</i>	Campanulaceae	N	N	N
<i>Lobelia kalmii</i>	Campanulaceae	N	N	N
<i>Lobelia nuttallii</i>	Campanulaceae	N	N	N
<i>Lobelia puberula</i>	Campanulaceae	N	N	N
<i>Lobelia siphilitica</i>	Campanulaceae	N	N	N
<i>Lobelia spicata</i>	Campanulaceae	N	N	N
<i>Triodanis perfoliata</i>	Campanulaceae	N	N	N
<i>Cannabis sativa</i>	Cannabaceae	N	I	N
<i>Humulus japonicus</i>	Cannabaceae	N	I	N
<i>Humulus lupulus</i>	Cannabaceae	N	NI	N
<i>Cleome hassleriana</i>	Capparaceae	N	I	N
<i>Polanisia dodecandra</i>	Capparaceae	N	N	N

<i>Lonicera fragrantissima</i>	Caprifoliaceae	N	I	N
<i>Lonicera japonica</i>	Caprifoliaceae	N	I	N
<i>Lonicera maackii</i>	Caprifoliaceae	N	I	N
<i>Lonicera morrowii</i>	Caprifoliaceae	N	I	N
<i>Lonicera tatarica</i>	Caprifoliaceae	N	I	N
<i>Lonicera xylosteum</i>	Caprifoliaceae	N	I	N
<i>Viburnum dilatatum</i>	Caprifoliaceae	N	I	N
<i>Viburnum lantana</i>	Caprifoliaceae	N	I	N
<i>Viburnum plicatum</i>	Caprifoliaceae	N	I	N
<i>Viburnum setigerum</i>	Caprifoliaceae	N	I	N
<i>Viburnum sieboldii</i>	Caprifoliaceae	N	I	N
<i>Diervilla lonicera</i>	Caprifoliaceae	N	N	N
<i>Lonicera dioica</i>	Caprifoliaceae	N	N	N
<i>Lonicera sempervirens</i>	Caprifoliaceae	N	N	N
<i>Sambucus racemosa</i>	Caprifoliaceae	N	N	N
<i>Symphoricarpos albus</i>	Caprifoliaceae	N	N	N
<i>Symphoricarpos orbiculatus</i>	Caprifoliaceae	N	N	N
<i>Triosteum angustifolium</i>	Caprifoliaceae	N	N	Y
<i>Triosteum aurantiacum</i>	Caprifoliaceae	N	N	N
<i>Triosteum perfoliatum</i>	Caprifoliaceae	N	N	N
<i>Viburnum acerifolium</i>	Caprifoliaceae	N	N	N
<i>Viburnum dentatum</i>	Caprifoliaceae	N	N	N
<i>Viburnum lentago</i>	Caprifoliaceae	N	N	N
<i>Viburnum nudum</i>	Caprifoliaceae	N	N	N
<i>Viburnum prunifolium</i>	Caprifoliaceae	N	N	N
<i>Viburnum rafinesqueanum</i>	Caprifoliaceae	N	N	N
<i>Viburnum recognitum</i>	Caprifoliaceae	N	N	N
<i>Sambucus nigra</i>	Caprifoliaceae	N	NI	N
<i>Viburnum opulus</i>	Caprifoliaceae	N	NI	N
<i>Arenaria serpyllifolia</i>	Caryophyllaceae	Y	I	N
<i>Cerastium fontanum</i>	Caryophyllaceae	Y	I	N
<i>Dianthus armeria</i>	Caryophyllaceae	Y	I	N
<i>Scleranthus annuus</i>	Caryophyllaceae	Y	I	N
<i>Spergula arvensis</i>	Caryophyllaceae	Y	I	N

<i>Spergularia rubra</i>	Caryophyllaceae	Y	I	N
<i>Stellaria media</i>	Caryophyllaceae	Y	I	N
<i>Spergularia salina</i>	Caryophyllaceae	Y	N	N
<i>Agrostemma githago</i>	Caryophyllaceae	N	I	N
<i>Cerastium glomeratum</i>	Caryophyllaceae	N	I	N
<i>Cerastium semidecandrum</i>	Caryophyllaceae	N	I	N
<i>Holosteum umbellatum</i>	Caryophyllaceae	N	I	N
<i>Lychnis coronaria</i>	Caryophyllaceae	N	I	N
<i>Lychnis flos-cuculi</i>	Caryophyllaceae	N	I	N
<i>Myosoton aquaticum</i>	Caryophyllaceae	N	I	N
<i>Petrorhagia prolifera</i>	Caryophyllaceae	N	I	N
<i>Sagina japonica</i>	Caryophyllaceae	N	I	N
<i>Sagina procumbens</i>	Caryophyllaceae	N	I	N
<i>Saponaria officinalis</i>	Caryophyllaceae	N	I	N
<i>Silene armeria</i>	Caryophyllaceae	N	I	N
<i>Silene dichotoma</i>	Caryophyllaceae	N	I	N
<i>Silene latifolia</i>	Caryophyllaceae	N	I	N
<i>Silene noctiflora</i>	Caryophyllaceae	N	I	N
<i>Silene vulgaris</i>	Caryophyllaceae	N	I	N
<i>Spergula morisonii</i>	Caryophyllaceae	N	I	N
<i>Stellaria graminea</i>	Caryophyllaceae	N	I	N
<i>Vaccaria hispanica</i>	Caryophyllaceae	N	I	N
<i>Cerastium nutans</i>	Caryophyllaceae	N	N	N
<i>Honckenya peploides</i>	Caryophyllaceae	N	N	N
<i>Minuartia caroliniana</i>	Caryophyllaceae	N	N	N
<i>Moehringia lateriflora</i>	Caryophyllaceae	N	N	N
<i>Paronychia canadensis</i>	Caryophyllaceae	N	N	N
<i>Paronychia fastigiata</i>	Caryophyllaceae	N	N	N
<i>Sagina decumbens</i>	Caryophyllaceae	N	N	N
<i>Silene antirrhina</i>	Caryophyllaceae	N	N	N
<i>Silene caroliniana</i>	Caryophyllaceae	N	N	N
<i>Silene stellata</i>	Caryophyllaceae	N	N	N
<i>Stellaria alsine</i>	Caryophyllaceae	N	N	N
<i>Stellaria longifolia</i>	Caryophyllaceae	N	N	N

<i>Stellaria pubera</i>	Caryophyllaceae	N	N	Y
<i>Cerastium arvense</i>	Caryophyllaceae	N	NI	N
<i>Celastrus orbiculatus</i>	Celastraceae	N	I	N
<i>Euonymus alatus</i>	Celastraceae	N	I	N
<i>Euonymus europaeus</i>	Celastraceae	N	I	N
<i>Euonymus fortunei</i>	Celastraceae	N	I	N
<i>Celastrus scandens</i>	Celastraceae	N	N	N
<i>Euonymus americanus</i>	Celastraceae	N	N	N
<i>Euonymus atropurpureus</i>	Celastraceae	N	N	N
<i>Ceratophyllum demersum</i>	Ceratophyllaceae	N	N	N
<i>Ceratophyllum echinatum</i>	Ceratophyllaceae	N	N	Y
<i>Chenopodium glaucum</i>	Chenopodiaceae	Y	I	N
<i>Dysphania pumilio</i>	Chenopodiaceae	Y	I	N
<i>Chenopodium album</i>	Chenopodiaceae	Y	NI	N
<i>Atriplex hortensis</i>	Chenopodiaceae	N	I	N
<i>Atriplex patula</i>	Chenopodiaceae	N	I	N
<i>Atriplex rosea</i>	Chenopodiaceae	N	I	N
<i>Bassia hirsuta</i>	Chenopodiaceae	N	I	N
<i>Bassia hyssopifolia</i>	Chenopodiaceae	N	I	N
<i>Bassia scoparia</i>	Chenopodiaceae	N	I	N
<i>Chenopodium bonus-henricus</i>	Chenopodiaceae	N	I	N
<i>Chenopodium murale</i>	Chenopodiaceae	N	I	N
<i>Dysphania anthelmintica</i>	Chenopodiaceae	N	I	N
<i>Dysphania botrys</i>	Chenopodiaceae	N	I	N
<i>Salsola kali</i>	Chenopodiaceae	N	I	N
<i>Salsola tragus</i>	Chenopodiaceae	N	I	N
<i>Atriplex cristata</i>	Chenopodiaceae	N	N	N
<i>Atriplex prostrata</i>	Chenopodiaceae	N	N	N
<i>Chenopodium berlandieri</i>	Chenopodiaceae	N	N	N
<i>Chenopodium desiccatum</i>	Chenopodiaceae	N	N	N
<i>Chenopodium pratericola</i>	Chenopodiaceae	N	N	N
<i>Chenopodium rubrum</i>	Chenopodiaceae	N	N	Y
<i>Chenopodium simplex</i>	Chenopodiaceae	N	N	N
<i>Chenopodium standleyanum</i>	Chenopodiaceae	N	N	N

<i>Cycloloma atriplicifolium</i>	Chenopodiaceae	N	N	N
<i>Monolepis nuttalliana</i>	Chenopodiaceae	N	N	N
<i>Salicornia bigelovii</i>	Chenopodiaceae	N	N	N
<i>Salicornia depressa</i>	Chenopodiaceae	N	N	N
<i>Sarcocornia pacifica</i>	Chenopodiaceae	N	N	N
<i>Sarcocornia perennis</i>	Chenopodiaceae	N	N	N
<i>Suaeda calceoliformis</i>	Chenopodiaceae	N	N	N
<i>Suaeda linearis</i>	Chenopodiaceae	N	N	N
<i>Dysphania ambrosioides</i>	Chenopodiaceae	N	NI	N
<i>Suaeda maritima</i>	Chenopodiaceae	N	NI	N
<i>Helianthemum bicknellii</i>	Cistaceae	N	N	N
<i>Helianthemum canadense</i>	Cistaceae	N	N	N
<i>Helianthemum propinquum</i>	Cistaceae	N	N	N
<i>Hudsonia ericoides</i>	Cistaceae	N	N	N
<i>Hudsonia tomentosa</i>	Cistaceae	N	N	N
<i>Lechea intermedia</i>	Cistaceae	N	N	N
<i>Lechea maritima</i>	Cistaceae	N	N	N
<i>Lechea minor</i>	Cistaceae	N	N	N
<i>Lechea mucronata</i>	Cistaceae	N	N	N
<i>Lechea pulchella</i>	Cistaceae	N	N	N
<i>Lechea racemulosa</i>	Cistaceae	N	N	N
<i>Lechea tenuifolia</i>	Cistaceae	N	N	Y
<i>Clethra alnifolia</i>	Clethraceae	N	N	N
<i>Hypericum perforatum</i>	Clusiaceae	N	I	N
<i>Hypericum adpressum</i>	Clusiaceae	N	N	Y
<i>Hypericum ascyron</i>	Clusiaceae	N	N	N
<i>Hypericum boreale</i>	Clusiaceae	N	N	N
<i>Hypericum canadense</i>	Clusiaceae	N	N	N
<i>Hypericum crux-andreae</i>	Clusiaceae	N	N	N
<i>Hypericum densiflorum</i>	Clusiaceae	N	N	N
<i>Hypericum denticulatum</i>	Clusiaceae	N	N	N
<i>Hypericum gentianoides</i>	Clusiaceae	N	N	N
<i>Hypericum hypericoides</i>	Clusiaceae	N	N	N
<i>Hypericum mutilum</i>	Clusiaceae	N	N	N

<i>Hypericum prolificum</i>	Clusiaceae	N	N	Y
<i>Hypericum punctatum</i>	Clusiaceae	N	N	N
<i>Triadenum virginicum</i>	Clusiaceae	N	N	N
<i>Commelina communis</i>	Commelinaceae	N	I	N
<i>Commelina virginica</i>	Commelinaceae	N	N	N
<i>Tradescantia bracteata</i>	Commelinaceae	N	N	N
<i>Tradescantia ohimensis</i>	Commelinaceae	N	N	N
<i>Tradescantia virginiana</i>	Commelinaceae	N	N	N
<i>Convolvulus arvensis</i>	Convolvulaceae	Y	I	N
<i>Ipomoea coccinea</i>	Convolvulaceae	N	I	N
<i>Ipomoea hederacea</i>	Convolvulaceae	N	I	N
<i>Ipomoea purpurea</i>	Convolvulaceae	N	I	N
<i>Calystegia spithamea</i>	Convolvulaceae	N	N	Y
<i>Ipomoea lacunosa</i>	Convolvulaceae	N	N	N
<i>Ipomoea pandurata</i>	Convolvulaceae	N	N	N
<i>Stylisma pickeringii</i>	Convolvulaceae	N	N	N
<i>Calystegia sepium</i>	Convolvulaceae	N	NI	N
<i>Cornus alternifolia</i>	Cornaceae	N	N	N
<i>Cornus amomum</i>	Cornaceae	N	N	N
<i>Cornus canadensis</i>	Cornaceae	N	N	N
<i>Cornus florida</i>	Cornaceae	N	N	N
<i>Cornus racemosa</i>	Cornaceae	N	N	N
<i>Cornus rugosa</i>	Cornaceae	N	N	N
<i>Cornus sericea</i>	Cornaceae	N	N	N
<i>Nyssa sylvatica</i>	Cornaceae	N	N	N
<i>Hylotelephium spectabile</i>	Crassulaceae	N	I	N
<i>Hylotelephium telephium</i>	Crassulaceae	N	I	N
<i>Phedimus spurius</i>	Crassulaceae	N	I	N
<i>Sedum acre</i>	Crassulaceae	N	I	N
<i>Sedum sarmentosum</i>	Crassulaceae	N	I	N
<i>Sempervivum tectorum</i>	Crassulaceae	N	I	N
<i>Penthorum sedoides</i>	Crassulaceae	N	N	N
<i>Sedum ternatum</i>	Crassulaceae	N	N	N
<i>Citrullus colocynthis</i>	Cucurbitaceae	N	I	N

<i>Citrullus lanatus</i>	Cucurbitaceae	N	I	N
<i>Echinocystis lobata</i>	Cucurbitaceae	N	N	N
<i>Sicyos angulatus</i>	Cucurbitaceae	N	N	N
<i>Chamaecyparis thyoides</i>	Cupressaceae	N	N	N
<i>Juniperus communis</i>	Cupressaceae	N	N	N
<i>Juniperus virginiana</i>	Cupressaceae	N	N	N
<i>Thuja occidentalis</i>	Cupressaceae	N	N	Y
<i>Cuscuta epilinum</i>	Cuscutaceae	N	I	N
<i>Cuscuta cephalanthi</i>	Cuscutaceae	N	N	Y
<i>Cuscuta compacta</i>	Cuscutaceae	N	N	N
<i>Cuscuta coryli</i>	Cuscutaceae	N	N	N
<i>Cuscuta gronovii</i>	Cuscutaceae	N	N	N
<i>Cuscuta megalocarpa</i>	Cuscutaceae	N	N	N
<i>Cuscuta pentagona</i>	Cuscutaceae	N	N	N
<i>Cuscuta polygonorum</i>	Cuscutaceae	N	N	N
<i>Cyperus amuricus</i>	Cyperaceae	Y	I	N
<i>Cyperus compressus</i>	Cyperaceae	Y	N	N
<i>Cyperus dentatus</i>	Cyperaceae	Y	N	N
<i>Cyperus squarrosus</i>	Cyperaceae	Y	N	N
<i>Cyperus strigosus</i>	Cyperaceae	Y	N	N
<i>Carex kobomugi</i>	Cyperaceae	N	I	N
<i>Carex spicata</i>	Cyperaceae	N	I	N
<i>Cyperus difformis</i>	Cyperaceae	N	I	N
<i>Cyperus iria</i>	Cyperaceae	N	I	N
<i>Bolboschoenus fluviatilis</i>	Cyperaceae	N	N	N
<i>Bolboschoenus maritimus</i>	Cyperaceae	N	N	Y
<i>Bolboschoenus novae-angliae</i>	Cyperaceae	N	N	N
<i>Bolboschoenus robustus</i>	Cyperaceae	N	N	N
<i>Bulbostylis capillaris</i>	Cyperaceae	N	N	N
<i>Carex abscondita</i>	Cyperaceae	N	N	N
<i>Carex alata</i>	Cyperaceae	N	N	N
<i>Carex albicans</i>	Cyperaceae	N	N	N
<i>Carex albolutescens</i>	Cyperaceae	N	N	N
<i>Carex amphibola</i>	Cyperaceae	N	N	Y

<i>Carex annectens</i>	Cyperaceae	N	N	N
<i>Carex aquatilis</i>	Cyperaceae	N	N	Y
<i>Carex argyrantha</i>	Cyperaceae	N	N	N
<i>Carex atlantica</i>	Cyperaceae	N	N	N
<i>Carex barratii</i>	Cyperaceae	N	N	N
<i>Carex bebbii</i>	Cyperaceae	N	N	N
<i>Carex blanda</i>	Cyperaceae	N	N	N
<i>Carex brevior</i>	Cyperaceae	N	N	N
<i>Carex bromoides</i>	Cyperaceae	N	N	N
<i>Carex bullata</i>	Cyperaceae	N	N	N
<i>Carex bushii</i>	Cyperaceae	N	N	Y
<i>Carex buxbaumii</i>	Cyperaceae	N	N	N
<i>Carex canescens</i>	Cyperaceae	N	N	N
<i>Carex caroliniana</i>	Cyperaceae	N	N	N
<i>Carex cephalophora</i>	Cyperaceae	N	N	N
<i>Carex collinsii</i>	Cyperaceae	N	N	N
<i>Carex communis</i>	Cyperaceae	N	N	N
<i>Carex comosa</i>	Cyperaceae	N	N	N
<i>Carex complanata</i>	Cyperaceae	N	N	N
<i>Carex conjuncta</i>	Cyperaceae	N	N	N
<i>Carex conoidea</i>	Cyperaceae	N	N	N
<i>Carex crawfordii</i>	Cyperaceae	N	N	N
<i>Carex crinita</i>	Cyperaceae	N	N	N
<i>Carex cristatella</i>	Cyperaceae	N	N	N
<i>Carex cumulata</i>	Cyperaceae	N	N	Y
<i>Carex davisii</i>	Cyperaceae	N	N	N
<i>Carex debilis</i>	Cyperaceae	N	N	N
<i>Carex diandra</i>	Cyperaceae	N	N	N
<i>Carex digitalis</i>	Cyperaceae	N	N	N
<i>Carex duriuscula</i>	Cyperaceae	N	N	N
<i>Carex echinata</i>	Cyperaceae	N	N	N
<i>Carex exilis</i>	Cyperaceae	N	N	N
<i>Carex festucacea</i>	Cyperaceae	N	N	N
<i>Carex flaccosperma</i>	Cyperaceae	N	N	N

<i>Carex flava</i>	Cyperaceae	N	N	N
<i>Carex folliculata</i>	Cyperaceae	N	N	N
<i>Carex frankii</i>	Cyperaceae	N	N	N
<i>Carex glaucoidea</i>	Cyperaceae	N	N	N
<i>Carex gracilescens</i>	Cyperaceae	N	N	N
<i>Carex gracillima</i>	Cyperaceae	N	N	N
<i>Carex granularis</i>	Cyperaceae	N	N	N
<i>Carex grayi</i>	Cyperaceae	N	N	N
<i>Carex grisea</i>	Cyperaceae	N	N	N
<i>Carex haydenii</i>	Cyperaceae	N	N	Y
<i>Carex hirsutella</i>	Cyperaceae	N	N	N
<i>Carex hirtifolia</i>	Cyperaceae	N	N	N
<i>Carex hitchcockiana</i>	Cyperaceae	N	N	N
<i>Carex hormathodes</i>	Cyperaceae	N	N	N
<i>Carex hystericina</i>	Cyperaceae	N	N	N
<i>Carex inops</i>	Cyperaceae	N	N	N
<i>Carex interior</i>	Cyperaceae	N	N	N
<i>Carex intumescens</i>	Cyperaceae	N	N	N
<i>Carex jamesii</i>	Cyperaceae	N	N	Y
<i>Carex lacustris</i>	Cyperaceae	N	N	N
<i>Carex laevivaginata</i>	Cyperaceae	N	N	N
<i>Carex lasiocarpa</i>	Cyperaceae	N	N	N
<i>Carex laxiculmis</i>	Cyperaceae	N	N	N
<i>Carex laxiflora</i>	Cyperaceae	N	N	N
<i>Carex leptalea</i>	Cyperaceae	N	N	N
<i>Carex limosa</i>	Cyperaceae	N	N	Y
<i>Carex livida</i>	Cyperaceae	N	N	N
<i>Carex longii</i>	Cyperaceae	N	N	N
<i>Carex louisianica</i>	Cyperaceae	N	N	Y
<i>Carex lupuliformis</i>	Cyperaceae	N	N	Y
<i>Carex lupulina</i>	Cyperaceae	N	N	N
<i>Carex lurida</i>	Cyperaceae	N	N	N
<i>Carex macrocephala</i>	Cyperaceae	N	N	N
<i>Carex mitchelliana</i>	Cyperaceae	N	N	N

<i>Carex molesta</i>	Cyperaceae	N	N	N
<i>Carex muehlenbergii</i>	Cyperaceae	N	N	N
<i>Carex nigromarginata</i>	Cyperaceae	N	N	N
<i>Carex normalis</i>	Cyperaceae	N	N	N
<i>Carex oligocarpa</i>	Cyperaceae	N	N	Y
<i>Carex pallescens</i>	Cyperaceae	N	N	N
<i>Carex pedunculata</i>	Cyperaceae	N	N	N
<i>Carex pellita</i>	Cyperaceae	N	N	N
<i>Carex pensylvanica</i>	Cyperaceae	N	N	N
<i>Carex platyphylla</i>	Cyperaceae	N	N	N
<i>Carex polymorpha</i>	Cyperaceae	N	N	Y
<i>Carex prairea</i>	Cyperaceae	N	N	N
<i>Carex prasina</i>	Cyperaceae	N	N	N
<i>Carex projecta</i>	Cyperaceae	N	N	N
<i>Carex radiata</i>	Cyperaceae	N	N	N
<i>Carex retroflexa</i>	Cyperaceae	N	N	N
<i>Carex rosea</i>	Cyperaceae	N	N	N
<i>Carex rostrata</i>	Cyperaceae	N	N	N
<i>Carex scabrata</i>	Cyperaceae	N	N	N
<i>Carex schweinitzii</i>	Cyperaceae	N	N	N
<i>Carex scoparia</i>	Cyperaceae	N	N	N
<i>Carex seorsa</i>	Cyperaceae	N	N	N
<i>Carex siccata</i>	Cyperaceae	N	N	Y
<i>Carex silicea</i>	Cyperaceae	N	N	N
<i>Carex sparganioides</i>	Cyperaceae	N	N	N
<i>Carex sprengelii</i>	Cyperaceae	N	N	N
<i>Carex squarrosa</i>	Cyperaceae	N	N	N
<i>Carex sterilis</i>	Cyperaceae	N	N	N
<i>Carex stipata</i>	Cyperaceae	N	N	N
<i>Carex straminea</i>	Cyperaceae	N	N	N
<i>Carex striata</i>	Cyperaceae	N	N	N
<i>Carex stricta</i>	Cyperaceae	N	N	N
<i>Carex styloflexa</i>	Cyperaceae	N	N	N
<i>Carex swanii</i>	Cyperaceae	N	N	N

<i>Carex tonsa</i>	Cyperaceae	N	N	N
<i>Carex torta</i>	Cyperaceae	N	N	N
<i>Carex tribuloides</i>	Cyperaceae	N	N	N
<i>Carex trichocarpa</i>	Cyperaceae	N	N	N
<i>Carex trisperma</i>	Cyperaceae	N	N	N
<i>Carex typhina</i>	Cyperaceae	N	N	N
<i>Carex umbellata</i>	Cyperaceae	N	N	N
<i>Carex utriculata</i>	Cyperaceae	N	N	N
<i>Carex venusta</i>	Cyperaceae	N	N	N
<i>Carex vesicaria</i>	Cyperaceae	N	N	N
<i>Carex vestita</i>	Cyperaceae	N	N	N
<i>Carex virescens</i>	Cyperaceae	N	N	N
<i>Carex vulpinoidea</i>	Cyperaceae	N	N	N
<i>Carex willdenowii</i>	Cyperaceae	N	N	N
<i>Cladium mariscoides</i>	Cyperaceae	N	N	N
<i>Cyperus bipartitus</i>	Cyperaceae	N	N	N
<i>Cyperus diandrus</i>	Cyperaceae	N	N	N
<i>Cyperus echinatus</i>	Cyperaceae	N	N	N
<i>Cyperus erythrorhizos</i>	Cyperaceae	N	N	N
<i>Cyperus filicinus</i>	Cyperaceae	N	N	N
<i>Cyperus flavescens</i>	Cyperaceae	N	N	N
<i>Cyperus grayi</i>	Cyperaceae	N	N	N
<i>Cyperus lancastricensis</i>	Cyperaceae	N	N	Y
<i>Cyperus lupulinus</i>	Cyperaceae	N	N	N
<i>Cyperus odoratus</i>	Cyperaceae	N	N	N
<i>Cyperus plukenetii</i>	Cyperaceae	N	N	Y
<i>Cyperus polystachyos</i>	Cyperaceae	N	N	Y
<i>Cyperus refractus</i>	Cyperaceae	N	N	Y
<i>Cyperus retrorsus</i>	Cyperaceae	N	N	N
<i>Dulichium arundinaceum</i>	Cyperaceae	N	N	N
<i>Eleocharis acicularis</i>	Cyperaceae	N	N	N
<i>Eleocharis aestuum</i>	Cyperaceae	N	N	N
<i>Eleocharis elliptica</i>	Cyperaceae	N	N	N
<i>Eleocharis engelmannii</i>	Cyperaceae	N	N	N

<i>Eleocharis erythropoda</i>	Cyperaceae	N	N	N
<i>Eleocharis flavescens</i>	Cyperaceae	N	N	N
<i>Eleocharis halophila</i>	Cyperaceae	N	N	N
<i>Eleocharis intermedia</i>	Cyperaceae	N	N	N
<i>Eleocharis macrostachya</i>	Cyperaceae	N	N	N
<i>Eleocharis melanocarpa</i>	Cyperaceae	N	N	Y
<i>Eleocharis obtusa</i>	Cyperaceae	N	N	N
<i>Eleocharis olivacea</i>	Cyperaceae	N	N	N
<i>Eleocharis ovata</i>	Cyperaceae	N	N	N
<i>Eleocharis palustris</i>	Cyperaceae	N	N	N
<i>Eleocharis parvula</i>	Cyperaceae	N	N	N
<i>Eleocharis robbinsii</i>	Cyperaceae	N	N	N
<i>Eleocharis rostellata</i>	Cyperaceae	N	N	N
<i>Eleocharis tenuis</i>	Cyperaceae	N	N	N
<i>Eleocharis tuberculosa</i>	Cyperaceae	N	N	N
<i>Eleocharis uniglumis</i>	Cyperaceae	N	N	N
<i>Eriophorum gracile</i>	Cyperaceae	N	N	Y
<i>Eriophorum virginicum</i>	Cyperaceae	N	N	N
<i>Eriophorum viridicarinatum</i>	Cyperaceae	N	N	N
<i>Fimbristylis autumnalis</i>	Cyperaceae	N	N	N
<i>Fimbristylis caroliniana</i>	Cyperaceae	N	N	N
<i>Fimbristylis castanea</i>	Cyperaceae	N	N	N
<i>Fimbristylis puberula</i>	Cyperaceae	N	N	N
<i>Fuirena pumila</i>	Cyperaceae	N	N	N
<i>Fuirena squarrosa</i>	Cyperaceae	N	N	N
<i>Kyllinga gracillima</i>	Cyperaceae	N	N	N
<i>Kyllinga pumila</i>	Cyperaceae	N	N	N
<i>Rhynchospora alba</i>	Cyperaceae	N	N	N
<i>Rhynchospora capitellata</i>	Cyperaceae	N	N	N
<i>Rhynchospora fusca</i>	Cyperaceae	N	N	N
<i>Rhynchospora globularis</i>	Cyperaceae	N	N	Y
<i>Rhynchospora gracilentia</i>	Cyperaceae	N	N	N
<i>Rhynchospora inundata</i>	Cyperaceae	N	N	N
<i>Rhynchospora knieskernii</i>	Cyperaceae	N	N	Y

<i>Rhynchospora macrostachya</i>	Cyperaceae	N	N	N
<i>Rhynchospora pallida</i>	Cyperaceae	N	N	N
<i>Rhynchospora recognita</i>	Cyperaceae	N	N	N
<i>Rhynchospora torreyana</i>	Cyperaceae	N	N	N
<i>Schoenoplectiella purshiana</i>	Cyperaceae	N	N	N
<i>Schoenoplectiella smithii</i>	Cyperaceae	N	N	N
<i>Schoenoplectus americanus</i>	Cyperaceae	N	N	N
<i>Schoenoplectus pungens</i>	Cyperaceae	N	N	N
<i>Schoenoplectus subterminalis</i>	Cyperaceae	N	N	N
<i>Schoenoplectus tabernaemontani</i>	Cyperaceae	N	N	N
<i>Scirpus atrocinctus</i>	Cyperaceae	N	N	N
<i>Scirpus atrovirens</i>	Cyperaceae	N	N	N
<i>Scirpus cyperinus</i>	Cyperaceae	N	N	N
<i>Scirpus expansus</i>	Cyperaceae	N	N	N
<i>Scirpus georgianus</i>	Cyperaceae	N	N	N
<i>Scirpus hattorianus</i>	Cyperaceae	N	N	N
<i>Scirpus longii</i>	Cyperaceae	N	N	Y
<i>Scirpus pallidus</i>	Cyperaceae	N	N	N
<i>Scirpus polyphyllus</i>	Cyperaceae	N	N	N
<i>Scleria minor</i>	Cyperaceae	N	N	N
<i>Scleria pauciflora</i>	Cyperaceae	N	N	N
<i>Scleria triglomerata</i>	Cyperaceae	N	N	N
<i>Trichophorum planifolium</i>	Cyperaceae	N	N	N
<i>Cyperus esculentus</i>	Cyperaceae	N	NI	N
<i>Dennstaedtia punctilobula</i>	Dennstaedtiaceae	N	N	N
<i>Pteridium aquilinum</i>	Dennstaedtiaceae	N	N	N
<i>Pyxidanthra barbulata</i>	Diapensiaceae	N	N	N
<i>Dioscorea oppositifolia</i>	Dioscoreaceae	N	I	N
<i>Dioscorea quaternata</i>	Dioscoreaceae	N	N	N
<i>Dioscorea villosa</i>	Dioscoreaceae	N	N	N
<i>Dipsacus fullonum</i>	Dipsacaceae	N	I	N
<i>Drosera filiformis</i>	Droseraceae	N	N	N
<i>Drosera intermedia</i>	Droseraceae	N	N	N
<i>Drosera rotundifolia</i>	Droseraceae	N	N	N

<i>Athyrium filix-femina</i>	Dryopteridaceae	N	N	N
<i>Cystopteris fragilis</i>	Dryopteridaceae	N	N	N
<i>Cystopteris protrusa</i>	Dryopteridaceae	N	N	N
<i>Cystopteris tenuis</i>	Dryopteridaceae	N	N	N
<i>Deparia acrostichoides</i>	Dryopteridaceae	N	N	N
<i>Dryopteris campyloptera</i>	Dryopteridaceae	N	N	N
<i>Dryopteris carthusiana</i>	Dryopteridaceae	N	N	N
<i>Dryopteris clintoniana</i>	Dryopteridaceae	N	N	N
<i>Dryopteris cristata</i>	Dryopteridaceae	N	N	N
<i>Dryopteris goldieana</i>	Dryopteridaceae	N	N	N
<i>Dryopteris intermedia</i>	Dryopteridaceae	N	N	N
<i>Dryopteris marginalis</i>	Dryopteridaceae	N	N	N
<i>Gymnocarpium dryopteris</i>	Dryopteridaceae	N	N	N
<i>Matteuccia struthiopteris</i>	Dryopteridaceae	N	N	N
<i>Onoclea sensibilis</i>	Dryopteridaceae	N	N	N
<i>Polystichum acrostichoides</i>	Dryopteridaceae	N	N	N
<i>Woodsia ilvensis</i>	Dryopteridaceae	N	N	N
<i>Woodsia obtusa</i>	Dryopteridaceae	N	N	N
<i>Diospyros virginiana</i>	Ebenaceae	N	N	N
<i>Elaeagnus angustifolia</i>	Elaeagnaceae	N	I	N
<i>Elaeagnus umbellata</i>	Elaeagnaceae	N	I	N
<i>Elatine americana</i>	Elatinaceae	N	N	N
<i>Elatine minima</i>	Elatinaceae	N	N	N
<i>Corema conradii</i>	Empetraceae	N	N	Y
<i>Equisetum arvense</i>	Equisetaceae	N	N	N
<i>Equisetum fluviatile</i>	Equisetaceae	N	N	N
<i>Equisetum hyemale</i>	Equisetaceae	N	N	N
<i>Equisetum sylvaticum</i>	Equisetaceae	N	N	N
<i>Arctostaphylos uva-ursi</i>	Ericaceae	N	N	N
<i>Chamaedaphne calyculata</i>	Ericaceae	N	N	N
<i>Epigaea repens</i>	Ericaceae	N	N	N
<i>Eubotrys racemosus</i>	Ericaceae	N	N	N
<i>Gaultheria procumbens</i>	Ericaceae	N	N	N
<i>Gaylussacia baccata</i>	Ericaceae	N	N	N

<i>Gaylussacia dumosa</i>	Ericaceae	N	N	N
<i>Gaylussacia frondosa</i>	Ericaceae	N	N	N
<i>Kalmia angustifolia</i>	Ericaceae	N	N	N
<i>Kalmia latifolia</i>	Ericaceae	N	N	N
<i>Leiophyllum buxifolium</i>	Ericaceae	N	N	N
<i>Leucothoe fontanesiana</i>	Ericaceae	N	N	N
<i>Lyonia ligustrina</i>	Ericaceae	N	N	N
<i>Lyonia mariana</i>	Ericaceae	N	N	N
<i>Rhododendron canadense</i>	Ericaceae	N	N	Y
<i>Rhododendron maximum</i>	Ericaceae	N	N	N
<i>Rhododendron periclymenoides</i>	Ericaceae	N	N	N
<i>Rhododendron prinophyllum</i>	Ericaceae	N	N	N
<i>Rhododendron viscosum</i>	Ericaceae	N	N	N
<i>Vaccinium angustifolium</i>	Ericaceae	N	N	N
<i>Vaccinium caesariense</i>	Ericaceae	N	N	N
<i>Vaccinium corymbosum</i>	Ericaceae	N	N	N
<i>Vaccinium fuscatum</i>	Ericaceae	N	N	N
<i>Vaccinium macrocarpon</i>	Ericaceae	N	N	N
<i>Vaccinium oxycoccos</i>	Ericaceae	N	N	N
<i>Vaccinium pallidum</i>	Ericaceae	N	N	N
<i>Vaccinium stamineum</i>	Ericaceae	N	N	N
<i>Eriocaulon aquaticum</i>	Eriocaulaceae	N	N	N
<i>Eriocaulon decangulare</i>	Eriocaulaceae	N	N	N
<i>Eriocaulon parkeri</i>	Eriocaulaceae	N	N	N
<i>Acalypha rhomboidea</i>	Euphorbiaceae	Y	N	N
<i>Chamaesyce maculata</i>	Euphorbiaceae	Y	N	N
<i>Euphorbia cyparissias</i>	Euphorbiaceae	N	I	N
<i>Euphorbia davidii</i>	Euphorbiaceae	N	I	N
<i>Euphorbia esula</i>	Euphorbiaceae	N	I	N
<i>Euphorbia lathyris</i>	Euphorbiaceae	N	I	N
<i>Euphorbia peplus</i>	Euphorbiaceae	N	I	N
<i>Acalypha gracilens</i>	Euphorbiaceae	N	N	N
<i>Acalypha ostryifolia</i>	Euphorbiaceae	N	N	N
<i>Acalypha virginica</i>	Euphorbiaceae	N	N	N

<i>Chamaesyce glyptosperma</i>	Euphorbiaceae	N	N	N
<i>Chamaesyce nutans</i>	Euphorbiaceae	N	N	N
<i>Chamaesyce polygonifolia</i>	Euphorbiaceae	N	N	N
<i>Chamaesyce prostrata</i>	Euphorbiaceae	N	N	N
<i>Chamaesyce vermiculata</i>	Euphorbiaceae	N	N	N
<i>Croton glandulosus</i>	Euphorbiaceae	N	N	N
<i>Euphorbia corollata</i>	Euphorbiaceae	N	N	N
<i>Euphorbia ipecacuanhae</i>	Euphorbiaceae	N	N	N
<i>Euphorbia marginata</i>	Euphorbiaceae	N	N	N
<i>Euphorbia dentata</i>	Euphorbiaceae	N	NI	N
<i>Kummerowia stipulacea</i>	Fabaceae	Y	I	N
<i>Medicago lupulina</i>	Fabaceae	Y	I	N
<i>Melilotus officinalis</i>	Fabaceae	Y	I	N
<i>Trifolium dubium</i>	Fabaceae	Y	I	N
<i>Trifolium repens</i>	Fabaceae	Y	I	N
<i>Gleditsia triacanthos</i>	Fabaceae	Y	N	N
<i>Robinia pseudoacacia</i>	Fabaceae	Y	N	N
<i>Albizia julibrissin</i>	Fabaceae	N	I	N
<i>Cytisus scoparius</i>	Fabaceae	N	I	N
<i>Kummerowia striata</i>	Fabaceae	N	I	N
<i>Lablab purpureus</i>	Fabaceae	N	I	N
<i>Lathyrus latifolius</i>	Fabaceae	N	I	N
<i>Lespedeza bicolor</i>	Fabaceae	N	I	N
<i>Lespedeza cuneata</i>	Fabaceae	N	I	N
<i>Lespedeza thunbergii</i>	Fabaceae	N	I	N
<i>Lotus corniculatus</i>	Fabaceae	N	I	N
<i>Medicago polymorpha</i>	Fabaceae	N	I	N
<i>Medicago sativa</i>	Fabaceae	N	I	N
<i>Phaseolus vulgaris</i>	Fabaceae	N	I	N
<i>Pueraria montana</i>	Fabaceae	N	I	N
<i>Securigera varia</i>	Fabaceae	N	I	N
<i>Trifolium arvense</i>	Fabaceae	N	I	N
<i>Trifolium aureum</i>	Fabaceae	N	I	N
<i>Trifolium campestre</i>	Fabaceae	N	I	N

<i>Trifolium hybridum</i>	Fabaceae	N	I	N
<i>Trifolium incarnatum</i>	Fabaceae	N	I	N
<i>Trifolium pratense</i>	Fabaceae	N	I	N
<i>Vicia cracca</i>	Fabaceae	N	I	N
<i>Vicia grandiflora</i>	Fabaceae	N	I	N
<i>Vicia hirsuta</i>	Fabaceae	N	I	N
<i>Vicia sativa</i>	Fabaceae	N	I	N
<i>Vicia tetrasperma</i>	Fabaceae	N	I	N
<i>Vicia villosa</i>	Fabaceae	N	I	N
<i>Wisteria floribunda</i>	Fabaceae	N	I	N
<i>Wisteria sinensis</i>	Fabaceae	N	I	N
<i>Amorpha canescens</i>	Fabaceae	N	N	N
<i>Amorpha fruticosa</i>	Fabaceae	N	N	N
<i>Amphicarpea bracteata</i>	Fabaceae	N	N	N
<i>Apios americana</i>	Fabaceae	N	N	N
<i>Astragalus lotiflorus</i>	Fabaceae	N	N	N
<i>Astragalus plattensis</i>	Fabaceae	N	N	N
<i>Baptisia tinctoria</i>	Fabaceae	N	N	N
<i>Cercis canadensis</i>	Fabaceae	N	N	Y
<i>Chamaecrista fasciculata</i>	Fabaceae	N	N	N
<i>Chamaecrista nictitans</i>	Fabaceae	N	N	N
<i>Crotalaria sagittalis</i>	Fabaceae	N	N	N
<i>Desmodium canadense</i>	Fabaceae	N	N	N
<i>Desmodium canescens</i>	Fabaceae	N	N	N
<i>Desmodium ciliare</i>	Fabaceae	N	N	N
<i>Desmodium cuspidatum</i>	Fabaceae	N	N	N
<i>Desmodium glabellum</i>	Fabaceae	N	N	N
<i>Desmodium glutinosum</i>	Fabaceae	N	N	N
<i>Desmodium humifusum</i>	Fabaceae	N	N	Y
<i>Desmodium laevigatum</i>	Fabaceae	N	N	N
<i>Desmodium marilandicum</i>	Fabaceae	N	N	N
<i>Desmodium nudiflorum</i>	Fabaceae	N	N	N
<i>Desmodium obtusum</i>	Fabaceae	N	N	N
<i>Desmodium paniculatum</i>	Fabaceae	N	N	N

<i>Desmodium pauciflorum</i>	Fabaceae	N	N	Y
<i>Desmodium perplexum</i>	Fabaceae	N	N	N
<i>Desmodium rotundifolium</i>	Fabaceae	N	N	N
<i>Desmodium strictum</i>	Fabaceae	N	N	N
<i>Galactia regularis</i>	Fabaceae	N	N	N
<i>Galactia volubilis</i>	Fabaceae	N	N	Y
<i>Gleditsia aquatica</i>	Fabaceae	N	N	N
<i>Gymnocladus dioicus</i>	Fabaceae	N	N	N
<i>Lathyrus japonicus</i>	Fabaceae	N	N	N
<i>Lathyrus ochroleucus</i>	Fabaceae	N	N	Y
<i>Lathyrus palustris</i>	Fabaceae	N	N	N
<i>Lathyrus polymorphus</i>	Fabaceae	N	N	N
<i>Lespedeza angustifolia</i>	Fabaceae	N	N	N
<i>Lespedeza capitata</i>	Fabaceae	N	N	N
<i>Lespedeza frutescens</i>	Fabaceae	N	N	N
<i>Lespedeza hirta</i>	Fabaceae	N	N	N
<i>Lespedeza procumbens</i>	Fabaceae	N	N	N
<i>Lespedeza repens</i>	Fabaceae	N	N	N
<i>Lespedeza stuevei</i>	Fabaceae	N	N	N
<i>Lespedeza violacea</i>	Fabaceae	N	N	N
<i>Lespedeza virginica</i>	Fabaceae	N	N	N
<i>Lotus unifoliolatus</i>	Fabaceae	N	N	N
<i>Lupinus perennis</i>	Fabaceae	N	N	N
<i>Mimosa nuttallii</i>	Fabaceae	N	N	N
<i>Oxytropis lambertii</i>	Fabaceae	N	N	N
<i>Pedimelum argophyllum</i>	Fabaceae	N	N	N
<i>Phaseolus polystachios</i>	Fabaceae	N	N	N
<i>Psoralidium lanceolatum</i>	Fabaceae	N	N	N
<i>Robinia hispida</i>	Fabaceae	N	N	N
<i>Robinia viscosa</i>	Fabaceae	N	N	N
<i>Senna hebecarpa</i>	Fabaceae	N	N	N
<i>Strophostyles helvola</i>	Fabaceae	N	N	N
<i>Strophostyles leiosperma</i>	Fabaceae	N	N	N
<i>Strophostyles umbellata</i>	Fabaceae	N	N	N

<i>Stylosanthes biflora</i>	Fabaceae	N	N	N
<i>Tephrosia virginiana</i>	Fabaceae	N	N	N
<i>Vicia americana</i>	Fabaceae	N	N	N
<i>Vicia caroliniana</i>	Fabaceae	N	N	Y
<i>Quercus imbricaria</i>	Fagaceae	Y	N	Y
<i>Castanea crenata</i>	Fagaceae	N	I	N
<i>Castanea dentata</i>	Fagaceae	N	N	N
<i>Castanea pumila</i>	Fagaceae	N	N	Y
<i>Fagus grandifolia</i>	Fagaceae	N	N	N
<i>Quercus alba</i>	Fagaceae	N	N	N
<i>Quercus bicolor</i>	Fagaceae	N	N	N
<i>Quercus coccinea</i>	Fagaceae	N	N	N
<i>Quercus falcata</i>	Fagaceae	N	N	N
<i>Quercus ilicifolia</i>	Fagaceae	N	N	N
<i>Quercus marilandica</i>	Fagaceae	N	N	N
<i>Quercus michauxii</i>	Fagaceae	N	N	N
<i>Quercus montana</i>	Fagaceae	N	N	N
<i>Quercus palustris</i>	Fagaceae	N	N	N
<i>Quercus phellos</i>	Fagaceae	N	N	N
<i>Quercus prinoides</i>	Fagaceae	N	N	N
<i>Quercus rubra</i>	Fagaceae	N	N	N
<i>Quercus stellata</i>	Fagaceae	N	N	N
<i>Quercus velutina</i>	Fagaceae	N	N	N
<i>Fumaria officinalis</i>	Fumariaceae	N	I	N
<i>Adlumia fungosa</i>	Fumariaceae	N	N	N
<i>Corydalis flavula</i>	Fumariaceae	N	N	N
<i>Corydalis sempervirens</i>	Fumariaceae	N	N	N
<i>Dicentra canadensis</i>	Fumariaceae	N	N	Y
<i>Dicentra cucullaria</i>	Fumariaceae	N	N	N
<i>Centaurium spicatum</i>	Gentianaceae	N	I	N
<i>Bartonia paniculata</i>	Gentianaceae	N	N	N
<i>Bartonia virginica</i>	Gentianaceae	N	N	N
<i>Gentiana andrewsii</i>	Gentianaceae	N	N	N
<i>Gentiana autumnalis</i>	Gentianaceae	N	N	N

<i>Gentiana catesbaei</i>	Gentianaceae	N	N	N
<i>Gentiana clausa</i>	Gentianaceae	N	N	N
<i>Gentiana saponaria</i>	Gentianaceae	N	N	N
<i>Gentianella quinquefolia</i>	Gentianaceae	N	N	N
<i>Gentianopsis crinita</i>	Gentianaceae	N	N	N
<i>Gentianopsis virgata</i>	Gentianaceae	N	N	N
<i>Obolaria virginica</i>	Gentianaceae	N	N	N
<i>Sabatia angularis</i>	Gentianaceae	N	N	N
<i>Sabatia campanulata</i>	Gentianaceae	N	N	N
<i>Sabatia dodecandra</i>	Gentianaceae	N	N	N
<i>Sabatia stellaris</i>	Gentianaceae	N	N	N
<i>Erodium cicutarium</i>	Geraniaceae	Y	I	N
<i>Geranium pusillum</i>	Geraniaceae	N	I	N
<i>Geranium rotundifolium</i>	Geraniaceae	N	I	N
<i>Geranium sibiricum</i>	Geraniaceae	N	I	N
<i>Geranium carolinianum</i>	Geraniaceae	N	N	N
<i>Geranium maculatum</i>	Geraniaceae	N	N	N
<i>Geranium robertianum</i>	Geraniaceae	N	NI	N
<i>Ginkgo biloba</i>	Ginkgoaceae	N	I	N
<i>Ribes nigrum</i>	Grossulariaceae	N	I	N
<i>Ribes rubrum</i>	Grossulariaceae	N	I	N
<i>Ribes uva-crispa</i>	Grossulariaceae	N	I	N
<i>Itea virginica</i>	Grossulariaceae	N	N	N
<i>Ribes americanum</i>	Grossulariaceae	N	N	N
<i>Ribes aureum</i>	Grossulariaceae	N	N	N
<i>Ribes cynosbati</i>	Grossulariaceae	N	N	N
<i>Ribes hirtellum</i>	Grossulariaceae	N	N	N
<i>Ribes rotundifolium</i>	Grossulariaceae	N	N	N
<i>Ribes triste</i>	Grossulariaceae	N	N	N
<i>Myriophyllum aquaticum</i>	Haloragaceae	N	I	N
<i>Myriophyllum spicatum</i>	Haloragaceae	N	I	N
<i>Myriophyllum heterophyllum</i>	Haloragaceae	N	N	N
<i>Myriophyllum humile</i>	Haloragaceae	N	N	N
<i>Myriophyllum pinnatum</i>	Haloragaceae	N	N	Y

<i>Myriophyllum sibiricum</i>	Haloragaceae	N	N	Y
<i>Myriophyllum tenellum</i>	Haloragaceae	N	N	Y
<i>Myriophyllum verticillatum</i>	Haloragaceae	N	N	Y
<i>Proserpinaca palustris</i>	Haloragaceae	N	N	N
<i>Proserpinaca pectinata</i>	Haloragaceae	N	N	N
<i>Hamamelis virginiana</i>	Hamamelidaceae	N	N	N
<i>Liquidambar styraciflua</i>	Hamamelidaceae	N	N	N
<i>Aesculus hippocastanum</i>	Hippocastanaceae	N	I	N
<i>Aesculus glabra</i>	Hippocastanaceae	N	N	N
<i>Aesculus parviflora</i>	Hippocastanaceae	N	N	N
<i>Deutzia scabra</i>	Hydrangeaceae	N	I	N
<i>Hydrangea paniculata</i>	Hydrangeaceae	N	I	N
<i>Philadelphus coronarius</i>	Hydrangeaceae	N	I	N
<i>Hydrangea arborescens</i>	Hydrangeaceae	N	N	N
<i>Egeria densa</i>	Hydrocharitaceae	N	I	N
<i>Hydrilla verticillata</i>	Hydrocharitaceae	N	I	N
<i>Elodea canadensis</i>	Hydrocharitaceae	N	N	N
<i>Elodea nuttallii</i>	Hydrocharitaceae	N	N	N
<i>Limnobia spongia</i>	Hydrocharitaceae	N	N	N
<i>Vallisneria spiralis</i>	Hydrocharitaceae	N	N	N
<i>Ellisia nyctelea</i>	Hydrophyllaceae	N	N	Y
<i>Hydrophyllum virginianum</i>	Hydrophyllaceae	N	N	N
<i>Belamcanda chinensis</i>	Iridaceae	N	I	N
<i>Iris pseudacorus</i>	Iridaceae	N	I	N
<i>Iris prismatica</i>	Iridaceae	N	N	N
<i>Iris versicolor</i>	Iridaceae	N	N	N
<i>Sisyrinchium angustifolium</i>	Iridaceae	N	N	N
<i>Sisyrinchium atlanticum</i>	Iridaceae	N	N	N
<i>Sisyrinchium fuscatum</i>	Iridaceae	N	N	N
<i>Sisyrinchium montanum</i>	Iridaceae	N	N	Y
<i>Sisyrinchium mucronatum</i>	Iridaceae	N	N	N
<i>Isoetes engelmannii</i>	Isoetaceae	N	N	N
<i>Isoetes riparia</i>	Isoetaceae	N	N	N
<i>Isoetes tenella</i>	Isoetaceae	N	N	N

<i>Carya cordiformis</i>	Juglandaceae	N	N	N
<i>Carya glabra</i>	Juglandaceae	N	N	N
<i>Carya ovalis</i>	Juglandaceae	N	N	N
<i>Carya ovata</i>	Juglandaceae	N	N	N
<i>Carya tomentosa</i>	Juglandaceae	N	N	N
<i>Juglans cinerea</i>	Juglandaceae	N	N	N
<i>Juglans nigra</i>	Juglandaceae	N	N	N
<i>Juncus bufonius</i>	Juncaceae	Y	N	N
<i>Juncus acuminatus</i>	Juncaceae	N	N	N
<i>Juncus biflorus</i>	Juncaceae	N	N	N
<i>Juncus brevicaudatus</i>	Juncaceae	N	N	N
<i>Juncus caesariensis</i>	Juncaceae	N	N	Y
<i>Juncus canadensis</i>	Juncaceae	N	N	N
<i>Juncus debilis</i>	Juncaceae	N	N	N
<i>Juncus dichotomus</i>	Juncaceae	N	N	N
<i>Juncus effusus</i>	Juncaceae	N	N	N
<i>Juncus gerardii</i>	Juncaceae	N	N	N
<i>Juncus greenii</i>	Juncaceae	N	N	N
<i>Juncus marginatus</i>	Juncaceae	N	N	N
<i>Juncus militaris</i>	Juncaceae	N	N	N
<i>Juncus pelocarpus</i>	Juncaceae	N	N	N
<i>Juncus scirpoides</i>	Juncaceae	N	N	N
<i>Juncus secundus</i>	Juncaceae	N	N	N
<i>Juncus subcaudatus</i>	Juncaceae	N	N	N
<i>Juncus tenuis</i>	Juncaceae	N	N	N
<i>Juncus torreyi</i>	Juncaceae	N	N	Y
<i>Luzula acuminata</i>	Juncaceae	N	N	Y
<i>Luzula bulbosa</i>	Juncaceae	N	N	N
<i>Luzula echinata</i>	Juncaceae	N	N	N
<i>Luzula multiflora</i>	Juncaceae	N	N	N
<i>Triglochin maritima</i>	Juncaginaceae	N	N	Y
<i>Lamium amplexicaule</i>	Lamiaceae	Y	I	N
<i>Prunella vulgaris</i>	Lamiaceae	Y	N	N
<i>Ajuga genevensis</i>	Lamiaceae	N	I	N

<i>Ajuga reptans</i>	Lamiaceae	N	I	N
<i>Calamintha nepeta</i>	Lamiaceae	N	I	N
<i>Elsholtzia ciliata</i>	Lamiaceae	N	I	N
<i>Galeopsis ladanum</i>	Lamiaceae	N	I	N
<i>Galeopsis tetrahit</i>	Lamiaceae	N	I	N
<i>Glechoma hederacea</i>	Lamiaceae	N	I	N
<i>Lamium maculatum</i>	Lamiaceae	N	I	N
<i>Lamium purpureum</i>	Lamiaceae	N	I	N
<i>Leonurus cardiaca</i>	Lamiaceae	N	I	N
<i>Lycopus europaeus</i>	Lamiaceae	N	I	N
<i>Marrubium vulgare</i>	Lamiaceae	N	I	N
<i>Melissa officinalis</i>	Lamiaceae	N	I	N
<i>Mentha aquatica</i>	Lamiaceae	N	I	N
<i>Mentha spicata</i>	Lamiaceae	N	I	N
<i>Nepeta cataria</i>	Lamiaceae	N	I	N
<i>Origanum vulgare</i>	Lamiaceae	N	I	N
<i>Perilla frutescens</i>	Lamiaceae	N	I	N
<i>Thymus pulegioides</i>	Lamiaceae	N	I	N
<i>Agastache nepetoides</i>	Lamiaceae	N	N	N
<i>Agastache scrophulariifolia</i>	Lamiaceae	N	N	N
<i>Clinopodium vulgare</i>	Lamiaceae	N	N	N
<i>Collinsonia canadensis</i>	Lamiaceae	N	N	N
<i>Cunila origanoides</i>	Lamiaceae	N	N	N
<i>Dracocephalum parviflorum</i>	Lamiaceae	N	N	N
<i>Hedeoma hispida</i>	Lamiaceae	N	N	N
<i>Hedeoma pulegioides</i>	Lamiaceae	N	N	N
<i>Lycopus americanus</i>	Lamiaceae	N	N	N
<i>Lycopus amplexans</i>	Lamiaceae	N	N	N
<i>Lycopus rubellus</i>	Lamiaceae	N	N	N
<i>Lycopus uniflorus</i>	Lamiaceae	N	N	N
<i>Lycopus virginicus</i>	Lamiaceae	N	N	N
<i>Mentha arvensis</i>	Lamiaceae	N	N	N
<i>Monarda clinopodia</i>	Lamiaceae	N	N	Y
<i>Monarda didyma</i>	Lamiaceae	N	N	N

<i>Monarda fistulosa</i>	Lamiaceae	N	N	N
<i>Monarda punctata</i>	Lamiaceae	N	N	N
<i>Physostegia virginiana</i>	Lamiaceae	N	N	N
<i>Pycnanthemum clinopodioides</i>	Lamiaceae	N	N	Y
<i>Pycnanthemum incanum</i>	Lamiaceae	N	N	N
<i>Pycnanthemum muticum</i>	Lamiaceae	N	N	N
<i>Pycnanthemum tenuifolium</i>	Lamiaceae	N	N	N
<i>Pycnanthemum torrei</i>	Lamiaceae	N	N	Y
<i>Pycnanthemum verticillatum</i>	Lamiaceae	N	N	N
<i>Pycnanthemum virginianum</i>	Lamiaceae	N	N	N
<i>Salvia lyrata</i>	Lamiaceae	N	N	N
<i>Salvia reflexa</i>	Lamiaceae	N	N	N
<i>Scutellaria elliptica</i>	Lamiaceae	N	N	N
<i>Scutellaria galericulata</i>	Lamiaceae	N	N	N
<i>Scutellaria integrifolia</i>	Lamiaceae	N	N	N
<i>Scutellaria lateriflora</i>	Lamiaceae	N	N	N
<i>Scutellaria nervosa</i>	Lamiaceae	N	N	N
<i>Scutellaria parvula</i>	Lamiaceae	N	N	N
<i>Stachys hyssopifolia</i>	Lamiaceae	N	N	N
<i>Stachys palustris</i>	Lamiaceae	N	N	N
<i>Stachys pilosa</i>	Lamiaceae	N	N	N
<i>Stachys tenuifolia</i>	Lamiaceae	N	N	N
<i>Teucrium canadense</i>	Lamiaceae	N	N	N
<i>Trichostema brachiatum</i>	Lamiaceae	N	N	N
<i>Trichostema dichotomum</i>	Lamiaceae	N	N	N
<i>Trichostema setaceum</i>	Lamiaceae	N	N	N
<i>Akebia quinata</i>	Lardizabalaceae	N	I	N
<i>Lindera benzoin</i>	Lauraceae	N	N	N
<i>Sassafras albidum</i>	Lauraceae	N	N	N
<i>Lemna minor</i>	Lemnaceae	N	N	N
<i>Lemna perpusilla</i>	Lemnaceae	N	N	Y
<i>Lemna trisulca</i>	Lemnaceae	N	N	N
<i>Lemna valdiviana</i>	Lemnaceae	N	N	Y
<i>Spirodela polyrrhiza</i>	Lemnaceae	N	N	N

<i>Wolffia brasiliensis</i>	Lemnaceae	N	N	N
<i>Wolffia columbiana</i>	Lemnaceae	N	N	N
<i>Wolffiella gladiata</i>	Lemnaceae	N	N	N
<i>Utricularia cornuta</i>	Lentibulariaceae	N	N	N
<i>Utricularia geminiscapa</i>	Lentibulariaceae	N	N	N
<i>Utricularia gibba</i>	Lentibulariaceae	N	N	N
<i>Utricularia intermedia</i>	Lentibulariaceae	N	N	N
<i>Utricularia macrorhiza</i>	Lentibulariaceae	N	N	N
<i>Utricularia purpurea</i>	Lentibulariaceae	N	N	N
<i>Utricularia radiata</i>	Lentibulariaceae	N	N	N
<i>Utricularia striata</i>	Lentibulariaceae	N	N	N
<i>Utricularia subulata</i>	Lentibulariaceae	N	N	N
<i>Allium vineale</i>	Liliaceae	N	I	N
<i>Asparagus officinalis</i>	Liliaceae	N	I	N
<i>Convallaria majalis</i>	Liliaceae	N	I	N
<i>Hemerocallis fulva</i>	Liliaceae	N	I	N
<i>Hosta lancifolia</i>	Liliaceae	N	I	N
<i>Hosta ventricosa</i>	Liliaceae	N	I	N
<i>Lilium lancifolium</i>	Liliaceae	N	I	N
<i>Muscari botryoides</i>	Liliaceae	N	I	N
<i>Narcissus poeticus</i>	Liliaceae	N	I	N
<i>Ornithogalum nutans</i>	Liliaceae	N	I	N
<i>Ornithogalum umbellatum</i>	Liliaceae	N	I	N
<i>Aletris farinosa</i>	Liliaceae	N	N	N
<i>Allium canadense</i>	Liliaceae	N	N	N
<i>Allium cernuum</i>	Liliaceae	N	N	N
<i>Allium perdulce</i>	Liliaceae	N	N	N
<i>Allium tricoccum</i>	Liliaceae	N	N	N
<i>Amianthium muscitoxicum</i>	Liliaceae	N	N	N
<i>Chamaelirium luteum</i>	Liliaceae	N	N	N
<i>Erythronium albidum</i>	Liliaceae	N	N	N
<i>Erythronium americanum</i>	Liliaceae	N	N	N
<i>Helonias bullata</i>	Liliaceae	N	N	Y
<i>Hypoxis hirsuta</i>	Liliaceae	N	N	N

<i>Lilium canadense</i>	Liliaceae	N	N	N
<i>Lilium philadelphicum</i>	Liliaceae	N	N	N
<i>Lilium superbum</i>	Liliaceae	N	N	N
<i>Maianthemum canadense</i>	Liliaceae	N	N	N
<i>Maianthemum racemosum</i>	Liliaceae	N	N	N
<i>Maianthemum stellatum</i>	Liliaceae	N	N	N
<i>Medeola virginiana</i>	Liliaceae	N	N	N
<i>Polygonatum biflorum</i>	Liliaceae	N	N	N
<i>Polygonatum pubescens</i>	Liliaceae	N	N	N
<i>Trillium cernuum</i>	Liliaceae	N	N	N
<i>Trillium erectum</i>	Liliaceae	N	N	N
<i>Uvularia perfoliata</i>	Liliaceae	N	N	N
<i>Uvularia puberula</i>	Liliaceae	N	N	N
<i>Uvularia sessilifolia</i>	Liliaceae	N	N	N
<i>Veratrum hybridum</i>	Liliaceae	N	N	N
<i>Veratrum virginicum</i>	Liliaceae	N	N	Y
<i>Veratrum viride</i>	Liliaceae	N	N	N
<i>Xerophyllum asphodeloides</i>	Liliaceae	N	N	N
<i>Zigadenus leimanthoides</i>	Liliaceae	N	N	Y
<i>Allium schoenoprasum</i>	Liliaceae	N	NI	N
<i>Floerkea proserpinacoides</i>	Limnanthaceae	N	N	N
<i>Linum usitatissimum</i>	Linaceae	N	I	N
<i>Linum compactum</i>	Linaceae	N	N	N
<i>Linum intercursum</i>	Linaceae	N	N	Y
<i>Linum medium</i>	Linaceae	N	N	N
<i>Linum striatum</i>	Linaceae	N	N	N
<i>Linum sulcatum</i>	Linaceae	N	N	Y
<i>Linum virginianum</i>	Linaceae	N	N	N
<i>Huperzia lucidula</i>	Lycopodiaceae	N	N	N
<i>Lycopodiella alopecuroides</i>	Lycopodiaceae	N	N	N
<i>Lycopodiella appressa</i>	Lycopodiaceae	N	N	N
<i>Lycopodiella caroliniana</i>	Lycopodiaceae	N	N	N
<i>Lycopodiella inundata</i>	Lycopodiaceae	N	N	N
<i>Lycopodium annotinum</i>	Lycopodiaceae	N	N	Y

<i>Lycopodium clavatum</i>	Lycopodiaceae	N	N	N
<i>Lycopodium dendroideum</i>	Lycopodiaceae	N	N	N
<i>Lycopodium digitatum</i>	Lycopodiaceae	N	N	N
<i>Lycopodium hickeyi</i>	Lycopodiaceae	N	N	N
<i>Lycopodium obscurum</i>	Lycopodiaceae	N	N	N
<i>Lycopodium tristachyum</i>	Lycopodiaceae	N	N	N
<i>Lygodium palmatum</i>	Lygodiaceae	N	N	N
<i>Lythrum salicaria</i>	Lythraceae	N	I	N
<i>Ammannia coccinea</i>	Lythraceae	N	N	N
<i>Cuphea viscosissima</i>	Lythraceae	N	N	N
<i>Decodon verticillatus</i>	Lythraceae	N	N	N
<i>Lythrum alatum</i>	Lythraceae	N	N	N
<i>Lythrum lineare</i>	Lythraceae	N	N	N
<i>Liriodendron tulipifera</i>	Magnoliaceae	N	N	N
<i>Magnolia acuminata</i>	Magnoliaceae	N	N	N
<i>Magnolia tripetala</i>	Magnoliaceae	N	N	N
<i>Magnolia virginiana</i>	Magnoliaceae	N	N	N
<i>Abutilon theophrasti</i>	Malvaceae	N	I	N
<i>Alcea rosea</i>	Malvaceae	N	I	N
<i>Althaea officinalis</i>	Malvaceae	N	I	N
<i>Hibiscus syriacus</i>	Malvaceae	N	I	N
<i>Hibiscus trionum</i>	Malvaceae	N	I	N
<i>Malva moschata</i>	Malvaceae	N	I	N
<i>Malva neglecta</i>	Malvaceae	N	I	N
<i>Malva parviflora</i>	Malvaceae	N	I	N
<i>Malva sylvestris</i>	Malvaceae	N	I	N
<i>Callirhoe alcaeoides</i>	Malvaceae	N	N	N
<i>Callirhoe involucrata</i>	Malvaceae	N	N	N
<i>Hibiscus moscheutos</i>	Malvaceae	N	N	N
<i>Kosteletzkya virginica</i>	Malvaceae	N	N	N
<i>Sida spinosa</i>	Malvaceae	N	N	N
<i>Sphaeralcea coccinea</i>	Malvaceae	N	N	N
<i>Marsilea quadrifolia</i>	Marsileaceae	N	I	N
<i>Marsilea vestita</i>	Marsileaceae	N	N	N

<i>Rhexia mariana</i>	Melastomataceae	N	N	N
<i>Rhexia virginica</i>	Melastomataceae	N	N	N
<i>Menispermum canadense</i>	Menispermaceae	N	N	N
<i>Nymphoides cordata</i>	Menyanthaceae	N	N	N
<i>Mollugo verticillata</i>	Molluginaceae	Y	N	N
<i>Monotropa hypopitys</i>	Monotropaceae	N	N	N
<i>Monotropa uniflora</i>	Monotropaceae	N	N	N
<i>Broussonetia papyrifera</i>	Moraceae	N	I	N
<i>Ficus carica</i>	Moraceae	N	I	N
<i>Morus alba</i>	Moraceae	N	I	N
<i>Maclura pomifera</i>	Moraceae	N	N	N
<i>Morus rubra</i>	Moraceae	N	N	N
<i>Comptonia peregrina</i>	Myricaceae	N	N	N
<i>Morella caroliniensis</i>	Myricaceae	N	N	N
<i>Morella cerifera</i>	Myricaceae	N	N	N
<i>Morella pensylvanica</i>	Myricaceae	N	N	N
<i>Najas minor</i>	Najadaceae	N	I	N
<i>Najas flexilis</i>	Najadaceae	N	N	N
<i>Najas gracillima</i>	Najadaceae	N	N	N
<i>Najas guadalupensis</i>	Najadaceae	N	N	N
<i>Nelumbo nucifera</i>	Nelumbonaceae	N	I	N
<i>Mirabilis hirsuta</i>	Nyctaginaceae	N	N	N
<i>Mirabilis linearis</i>	Nyctaginaceae	N	N	N
<i>Mirabilis nyctaginea</i>	Nyctaginaceae	N	N	N
<i>Nuphar lutea</i>	Nymphaeaceae	N	N	N
<i>Nymphaea odorata</i>	Nymphaeaceae	N	N	N
<i>Ligustrum obtusifolium</i>	Oleaceae	N	I	N
<i>Ligustrum vulgare</i>	Oleaceae	N	I	N
<i>Syringa vulgaris</i>	Oleaceae	N	I	N
<i>Chionanthus virginicus</i>	Oleaceae	N	N	N
<i>Fraxinus americana</i>	Oleaceae	N	N	N
<i>Fraxinus nigra</i>	Oleaceae	N	N	N
<i>Fraxinus pennsylvanica</i>	Oleaceae	N	N	N
<i>Fraxinus profunda</i>	Oleaceae	N	N	Y

<i>Epilobium coloratum</i>	Onagraceae	Y	N	N
<i>Oenothera biennis</i>	Onagraceae	Y	N	N
<i>Calylophus serrulatus</i>	Onagraceae	N	N	N
<i>Chamerion angustifolium</i>	Onagraceae	N	N	N
<i>Circaea lutetiana</i>	Onagraceae	N	N	N
<i>Epilobium ciliatum</i>	Onagraceae	N	N	N
<i>Ludwigia alternifolia</i>	Onagraceae	N	N	N
<i>Ludwigia palustris</i>	Onagraceae	N	N	N
<i>Ludwigia sphaerocarpa</i>	Onagraceae	N	N	N
<i>Oenothera fruticosa</i>	Onagraceae	N	N	N
<i>Oenothera laciniata</i>	Onagraceae	N	N	N
<i>Oenothera oakesiana</i>	Onagraceae	N	N	N
<i>Oenothera parviflora</i>	Onagraceae	N	N	N
<i>Oenothera perennis</i>	Onagraceae	N	N	N
<i>Oenothera rhombipetala</i>	Onagraceae	N	N	N
<i>Ludwigia peploides</i>	Onagraceae	N	NI	N
<i>Botrychium dissectum</i>	Ophioglossaceae	N	N	N
<i>Botrychium lanceolatum</i>	Ophioglossaceae	N	N	N
<i>Botrychium matricariifolium</i>	Ophioglossaceae	N	N	N
<i>Botrychium multifidum</i>	Ophioglossaceae	N	N	Y
<i>Botrychium oneidense</i>	Ophioglossaceae	N	N	N
<i>Botrychium virginianum</i>	Ophioglossaceae	N	N	N
<i>Ophioglossum pusillum</i>	Ophioglossaceae	N	N	N
<i>Ophioglossum vulgatum</i>	Ophioglossaceae	N	N	N
<i>Epipactis helleborine</i>	Orchidaceae	N	I	N
<i>Aplectrum hyemale</i>	Orchidaceae	N	N	Y
<i>Arethusa bulbosa</i>	Orchidaceae	N	N	N
<i>Calopogon tuberosus</i>	Orchidaceae	N	N	N
<i>Corallorhiza maculata</i>	Orchidaceae	N	N	N
<i>Corallorhiza odontorhiza</i>	Orchidaceae	N	N	N
<i>Cypripedium acaule</i>	Orchidaceae	N	N	N
<i>Cypripedium parviflorum</i>	Orchidaceae	N	N	N
<i>Galearis spectabilis</i>	Orchidaceae	N	N	N
<i>Goodyera pubescens</i>	Orchidaceae	N	N	N

<i>Isotria medeoloides</i>	Orchidaceae	N	N	Y
<i>Isotria verticillata</i>	Orchidaceae	N	N	N
<i>Liparis liliifolia</i>	Orchidaceae	N	N	N
<i>Liparis loeselii</i>	Orchidaceae	N	N	N
<i>Listera australis</i>	Orchidaceae	N	N	N
<i>Listera cordata</i>	Orchidaceae	N	N	Y
<i>Malaxis unifolia</i>	Orchidaceae	N	N	N
<i>Platanthera blephariglottis</i>	Orchidaceae	N	N	N
<i>Platanthera ciliaris</i>	Orchidaceae	N	N	N
<i>Platanthera clavellata</i>	Orchidaceae	N	N	N
<i>Platanthera cristata</i>	Orchidaceae	N	N	N
<i>Platanthera flava</i>	Orchidaceae	N	N	N
<i>Platanthera grandiflora</i>	Orchidaceae	N	N	N
<i>Platanthera integra</i>	Orchidaceae	N	N	Y
<i>Platanthera lacera</i>	Orchidaceae	N	N	N
<i>Platanthera peramoena</i>	Orchidaceae	N	N	Y
<i>Platanthera psycodes</i>	Orchidaceae	N	N	N
<i>Pogonia ophioglossoides</i>	Orchidaceae	N	N	N
<i>Spiranthes cernua</i>	Orchidaceae	N	N	N
<i>Spiranthes lacera</i>	Orchidaceae	N	N	N
<i>Spiranthes laciniata</i>	Orchidaceae	N	N	Y
<i>Spiranthes lucida</i>	Orchidaceae	N	N	N
<i>Spiranthes praecox</i>	Orchidaceae	N	N	N
<i>Spiranthes tuberosa</i>	Orchidaceae	N	N	N
<i>Spiranthes vernalis</i>	Orchidaceae	N	N	N
<i>Tipularia discolor</i>	Orchidaceae	N	N	N
<i>Orobanche minor</i>	Orobanchaceae	N	I	N
<i>Orobanche ramosa</i>	Orobanchaceae	N	I	N
<i>Conopholis americana</i>	Orobanchaceae	N	N	N
<i>Epifagus virginiana</i>	Orobanchaceae	N	N	N
<i>Orobanche uniflora</i>	Orobanchaceae	N	N	N
<i>Osmunda cinnamomea</i>	Osmundaceae	N	N	N
<i>Osmunda claytoniana</i>	Osmundaceae	N	N	N
<i>Osmunda regalis</i>	Osmundaceae	N	N	N

<i>Oxalis corniculata</i>	Oxalidaceae	Y	N	N
<i>Oxalis stricta</i>	Oxalidaceae	Y	N	N
<i>Oxalis dillenii</i>	Oxalidaceae	N	N	N
<i>Oxalis violacea</i>	Oxalidaceae	N	N	N
<i>Chelidonium majus</i>	Papaveraceae	N	I	N
<i>Glaucium flavum</i>	Papaveraceae	N	I	N
<i>Papaver somniferum</i>	Papaveraceae	N	I	N
<i>Argemone mexicana</i>	Papaveraceae	N	N	N
<i>Sanguinaria canadensis</i>	Papaveraceae	N	N	N
<i>Proboscidea louisianica</i>	Pedaliaceae	N	N	N
<i>Phytolacca americana</i>	Phytolaccaceae	Y	N	N
<i>Picea abies</i>	Pinaceae	N	I	N
<i>Pinus nigra</i>	Pinaceae	N	I	N
<i>Pinus sylvestris</i>	Pinaceae	N	I	N
<i>Pinus thunbergii</i>	Pinaceae	N	I	N
<i>Pinus echinata</i>	Pinaceae	N	N	N
<i>Pinus resinosa</i>	Pinaceae	N	N	Y
<i>Pinus rigida</i>	Pinaceae	N	N	N
<i>Pinus strobus</i>	Pinaceae	N	N	N
<i>Pinus virginiana</i>	Pinaceae	N	N	N
<i>Pseudotsuga menziesii</i>	Pinaceae	N	N	N
<i>Tsuga canadensis</i>	Pinaceae	N	N	N
<i>Plantago lanceolata</i>	Plantaginaceae	Y	I	N
<i>Plantago major</i>	Plantaginaceae	Y	I	N
<i>Plantago rugelii</i>	Plantaginaceae	Y	N	N
<i>Plantago arenaria</i>	Plantaginaceae	N	I	N
<i>Plantago aristata</i>	Plantaginaceae	N	N	N
<i>Plantago maritima</i>	Plantaginaceae	N	N	N
<i>Plantago patagonica</i>	Plantaginaceae	N	N	N
<i>Plantago pusilla</i>	Plantaginaceae	N	N	Y
<i>Plantago virginica</i>	Plantaginaceae	N	N	N
<i>Platanus occidentalis</i>	Platanaceae	N	N	N
<i>Limonium carolinianum</i>	Plumbaginaceae	N	N	N
<i>Bromus arvensis</i>	Poaceae	Y	I	N

<i>Digitaria sanguinalis</i>	Poaceae	Y	I	N
<i>Echinochloa crus-galli</i>	Poaceae	Y	I	N
<i>Eleusine indica</i>	Poaceae	Y	I	N
<i>Elymus repens</i>	Poaceae	Y	I	N
<i>Lolium perenne</i>	Poaceae	Y	I	N
<i>Poa annua</i>	Poaceae	Y	I	N
<i>Poa compressa</i>	Poaceae	Y	I	N
<i>Setaria faberi</i>	Poaceae	Y	I	N
<i>Setaria pumila</i>	Poaceae	Y	I	N
<i>Setaria viridis</i>	Poaceae	Y	I	N
<i>Muhlenbergia schreberi</i>	Poaceae	Y	N	N
<i>Phragmites australis</i>	Poaceae	Y	N	N
<i>Tridens flavus</i>	Poaceae	Y	N	N
<i>Triplasis purpurea</i>	Poaceae	Y	N	N
<i>Agrostis capillaris</i>	Poaceae	N	I	N
<i>Agrostis gigantea</i>	Poaceae	N	I	N
<i>Agrostis stolonifera</i>	Poaceae	N	I	N
<i>Aira caryophyllea</i>	Poaceae	N	I	N
<i>Aira praecox</i>	Poaceae	N	I	N
<i>Alopecurus pratensis</i>	Poaceae	N	I	N
<i>Anthoxanthum aristatum</i>	Poaceae	N	I	N
<i>Anthoxanthum odoratum</i>	Poaceae	N	I	N
<i>Arrhenatherum elatius</i>	Poaceae	N	I	N
<i>Arthraxon hispidus</i>	Poaceae	N	I	N
<i>Avena fatua</i>	Poaceae	N	I	N
<i>Avena sativa</i>	Poaceae	N	I	N
<i>Bromus hordeaceus</i>	Poaceae	N	I	N
<i>Bromus racemosus</i>	Poaceae	N	I	N
<i>Bromus secalinus</i>	Poaceae	N	I	N
<i>Bromus sterilis</i>	Poaceae	N	I	N
<i>Bromus tectorum</i>	Poaceae	N	I	N
<i>Cryptis schoenoides</i>	Poaceae	N	I	N
<i>Cynodon dactylon</i>	Poaceae	N	I	N
<i>Cynosurus cristatus</i>	Poaceae	N	I	N

<i>Dactylis glomerata</i>	Poaceae	N	I	N
<i>Digitaria ischaemum</i>	Poaceae	N	I	N
<i>Eragrostis cilianensis</i>	Poaceae	N	I	N
<i>Eragrostis curvula</i>	Poaceae	N	I	N
<i>Eragrostis minor</i>	Poaceae	N	I	N
<i>Eragrostis pilosa</i>	Poaceae	N	I	N
<i>Eustachys retusa</i>	Poaceae	N	I	N
<i>Festuca brevipila</i>	Poaceae	N	I	N
<i>Festuca ovina</i>	Poaceae	N	I	N
<i>Holcus lanatus</i>	Poaceae	N	I	N
<i>Hordeum vulgare</i>	Poaceae	N	I	N
<i>Microstegium vimineum</i>	Poaceae	N	I	N
<i>Miscanthus sinensis</i>	Poaceae	N	I	N
<i>Pennisetum glaucum</i>	Poaceae	N	I	N
<i>Phalaris canariensis</i>	Poaceae	N	I	N
<i>Phleum pratense</i>	Poaceae	N	I	N
<i>Poa bulbosa</i>	Poaceae	N	I	N
<i>Poa trivialis</i>	Poaceae	N	I	N
<i>Schedonorus arundinaceus</i>	Poaceae	N	I	N
<i>Schedonorus pratensis</i>	Poaceae	N	I	N
<i>Secale cereale</i>	Poaceae	N	I	N
<i>Setaria italica</i>	Poaceae	N	I	N
<i>Setaria verticillata</i>	Poaceae	N	I	N
<i>Sorghum bicolor</i>	Poaceae	N	I	N
<i>Sorghum halepense</i>	Poaceae	N	I	N
<i>Spartina maritima</i>	Poaceae	N	I	N
<i>Tragus racemosus</i>	Poaceae	N	I	N
<i>Triticum aestivum</i>	Poaceae	N	I	N
<i>Vulpia myuros</i>	Poaceae	N	I	N
<i>Zea mays</i>	Poaceae	N	I	N
<i>Agrostis hyemalis</i>	Poaceae	N	N	N
<i>Agrostis perennans</i>	Poaceae	N	N	N
<i>Alopecurus aequalis</i>	Poaceae	N	N	N
<i>Ammophila breviligulata</i>	Poaceae	N	N	N

<i>Andropogon gerardii</i>	Poaceae	N	N	N
<i>Andropogon glomeratus</i>	Poaceae	N	N	N
<i>Andropogon gyrans</i>	Poaceae	N	N	N
<i>Andropogon ternarius</i>	Poaceae	N	N	N
<i>Andropogon virginicus</i>	Poaceae	N	N	N
<i>Aristida dichotoma</i>	Poaceae	N	N	N
<i>Aristida longespica</i>	Poaceae	N	N	N
<i>Aristida oligantha</i>	Poaceae	N	N	N
<i>Aristida purpurascens</i>	Poaceae	N	N	N
<i>Aristida purpurea</i>	Poaceae	N	N	N
<i>Aristida tuberculosa</i>	Poaceae	N	N	N
<i>Bouteloua curtipendula</i>	Poaceae	N	N	Y
<i>Bouteloua dactyloides</i>	Poaceae	N	N	N
<i>Brachyelytrum erectum</i>	Poaceae	N	N	N
<i>Bromus ciliatus</i>	Poaceae	N	N	N
<i>Bromus kalmii</i>	Poaceae	N	N	N
<i>Bromus latiglumis</i>	Poaceae	N	N	N
<i>Bromus pubescens</i>	Poaceae	N	N	N
<i>Calamagrostis canadensis</i>	Poaceae	N	N	N
<i>Calamagrostis coarctata</i>	Poaceae	N	N	N
<i>Calamagrostis pickeringii</i>	Poaceae	N	N	Y
<i>Calamovilfa brevipilis</i>	Poaceae	N	N	N
<i>Calamovilfa longifolia</i>	Poaceae	N	N	N
<i>Cenchrus longispinus</i>	Poaceae	N	N	N
<i>Cenchrus tribuloides</i>	Poaceae	N	N	N
<i>Chasmanthium laxum</i>	Poaceae	N	N	N
<i>Chloris verticillata</i>	Poaceae	N	N	N
<i>Cinna arundinacea</i>	Poaceae	N	N	N
<i>Danthonia compressa</i>	Poaceae	N	N	N
<i>Danthonia sericea</i>	Poaceae	N	N	N
<i>Danthonia spicata</i>	Poaceae	N	N	N
<i>Deschampsia cespitosa</i>	Poaceae	N	N	N
<i>Deschampsia flexuosa</i>	Poaceae	N	N	N
<i>Dichanthelium acuminatum</i>	Poaceae	N	N	N

<i>Dichanthelium boreale</i>	Poaceae	N	N	N
<i>Dichanthelium boscii</i>	Poaceae	N	N	N
<i>Dichanthelium clandestinum</i>	Poaceae	N	N	N
<i>Dichanthelium commutatum</i>	Poaceae	N	N	N
<i>Dichanthelium depauperatum</i>	Poaceae	N	N	N
<i>Dichanthelium dichotomum</i>	Poaceae	N	N	N
<i>Dichanthelium latifolium</i>	Poaceae	N	N	N
<i>Dichanthelium linearifolium</i>	Poaceae	N	N	N
<i>Dichanthelium meridionale</i>	Poaceae	N	N	N
<i>Dichanthelium oligosanthos</i>	Poaceae	N	N	N
<i>Dichanthelium ovale</i>	Poaceae	N	N	N
<i>Dichanthelium sabulorum</i>	Poaceae	N	N	N
<i>Dichanthelium scoparium</i>	Poaceae	N	N	N
<i>Dichanthelium sphaerocarpon</i>	Poaceae	N	N	N
<i>Dichanthelium spretum</i>	Poaceae	N	N	N
<i>Dichanthelium villosissimum</i>	Poaceae	N	N	N
<i>Digitaria ciliaris</i>	Poaceae	N	N	N
<i>Digitaria cognata</i>	Poaceae	N	N	N
<i>Digitaria filiformis</i>	Poaceae	N	N	N
<i>Distichlis spicata</i>	Poaceae	N	N	N
<i>Echinochloa muricata</i>	Poaceae	N	N	N
<i>Echinochloa walteri</i>	Poaceae	N	N	N
<i>Elymus canadensis</i>	Poaceae	N	N	N
<i>Elymus glabriflorus</i>	Poaceae	N	N	N
<i>Elymus hystrix</i>	Poaceae	N	N	N
<i>Elymus riparius</i>	Poaceae	N	N	N
<i>Elymus trachycaulus</i>	Poaceae	N	N	Y
<i>Elymus villosus</i>	Poaceae	N	N	N
<i>Elymus virginicus</i>	Poaceae	N	N	N
<i>Eragrostis capillaris</i>	Poaceae	N	N	N
<i>Eragrostis frankii</i>	Poaceae	N	N	N
<i>Eragrostis hypnoides</i>	Poaceae	N	N	N
<i>Eragrostis pectinacea</i>	Poaceae	N	N	N
<i>Eragrostis spectabilis</i>	Poaceae	N	N	N

<i>Festuca subverticillata</i>	Poaceae	N	N	N
<i>Glyceria acutiflora</i>	Poaceae	N	N	N
<i>Glyceria canadensis</i>	Poaceae	N	N	N
<i>Glyceria laxa</i>	Poaceae	N	N	N
<i>Glyceria melicaria</i>	Poaceae	N	N	N
<i>Glyceria obtusa</i>	Poaceae	N	N	N
<i>Glyceria septentrionalis</i>	Poaceae	N	N	N
<i>Glyceria striata</i>	Poaceae	N	N	N
<i>Gymnopogon ambiguus</i>	Poaceae	N	N	N
<i>Hierochloe hirta</i>	Poaceae	N	N	N
<i>Hierochloe odorata</i>	Poaceae	N	N	N
<i>Hordeum jubatum</i>	Poaceae	N	N	N
<i>Hordeum pusillum</i>	Poaceae	N	N	N
<i>Koeleria macrantha</i>	Poaceae	N	N	N
<i>Leersia oryzoides</i>	Poaceae	N	N	N
<i>Leersia virginica</i>	Poaceae	N	N	N
<i>Melica mutica</i>	Poaceae	N	N	N
<i>Muhlenbergia capillaris</i>	Poaceae	N	N	Y
<i>Muhlenbergia frondosa</i>	Poaceae	N	N	N
<i>Muhlenbergia mexicana</i>	Poaceae	N	N	N
<i>Muhlenbergia sylvatica</i>	Poaceae	N	N	N
<i>Muhlenbergia tenuiflora</i>	Poaceae	N	N	N
<i>Muhlenbergia uniflora</i>	Poaceae	N	N	N
<i>Oryzopsis asperifolia</i>	Poaceae	N	N	Y
<i>Panicum amarum</i>	Poaceae	N	N	N
<i>Panicum anceps</i>	Poaceae	N	N	N
<i>Panicum capillare</i>	Poaceae	N	N	N
<i>Panicum dichotomiflorum</i>	Poaceae	N	N	N
<i>Panicum philadelphicum</i>	Poaceae	N	N	N
<i>Panicum rigidulum</i>	Poaceae	N	N	N
<i>Panicum verrucosum</i>	Poaceae	N	N	N
<i>Panicum virgatum</i>	Poaceae	N	N	N
<i>Pascopyrum smithii</i>	Poaceae	N	N	N
<i>Paspalum laeve</i>	Poaceae	N	N	N

<i>Paspalum setaceum</i>	Poaceae	N	N	N
<i>Phalaris arundinacea</i>	Poaceae	N	N	N
<i>Piptochaetium avenaceum</i>	Poaceae	N	N	N
<i>Poa cuspidata</i>	Poaceae	N	N	N
<i>Poa palustris</i>	Poaceae	N	N	N
<i>Poa sylvestris</i>	Poaceae	N	N	N
<i>Puccinellia fasciculata</i>	Poaceae	N	N	N
<i>Puccinellia maritima</i>	Poaceae	N	N	N
<i>Saccharum giganteum</i>	Poaceae	N	N	N
<i>Schizachyrium littorale</i>	Poaceae	N	N	N
<i>Schizachyrium scoparium</i>	Poaceae	N	N	N
<i>Setaria parviflora</i>	Poaceae	N	N	N
<i>Sorghastrum nutans</i>	Poaceae	N	N	N
<i>Spartina alterniflora</i>	Poaceae	N	N	N
<i>Spartina cynosuroides</i>	Poaceae	N	N	N
<i>Spartina patens</i>	Poaceae	N	N	N
<i>Spartina pectinata</i>	Poaceae	N	N	N
<i>Sphenopholis intermedia</i>	Poaceae	N	N	N
<i>Sphenopholis nitida</i>	Poaceae	N	N	N
<i>Sphenopholis obtusata</i>	Poaceae	N	N	N
<i>Sphenopholis pensylvanica</i>	Poaceae	N	N	N
<i>Sporobolus compositus</i>	Poaceae	N	N	N
<i>Sporobolus neglectus</i>	Poaceae	N	N	Y
<i>Sporobolus vaginiflorus</i>	Poaceae	N	N	N
<i>Torreyochloa pallida</i>	Poaceae	N	N	N
<i>Tripsacum dactyloides</i>	Poaceae	N	N	N
<i>Vulpia octoflora</i>	Poaceae	N	N	N
<i>Zizania aquatica</i>	Poaceae	N	N	N
<i>Bromus inermis</i>	Poaceae	N	NI	N
<i>Festuca rubra</i>	Poaceae	N	NI	N
<i>Poa nemoralis</i>	Poaceae	N	NI	N
<i>Poa pratensis</i>	Poaceae	N	NI	N
<i>Podostemum ceratophyllum</i>	Podostemaceae	N	N	N
<i>Phlox divaricata</i>	Polemoniaceae	N	N	Y

<i>Phlox maculata</i>	Polemoniaceae	N	N	N
<i>Phlox paniculata</i>	Polemoniaceae	N	N	N
<i>Phlox pilosa</i>	Polemoniaceae	N	N	Y
<i>Phlox subulata</i>	Polemoniaceae	N	N	N
<i>Polemonium reptans</i>	Polemoniaceae	N	N	Y
<i>Polygala ambigua</i>	Polygalaceae	N	N	N
<i>Polygala cruciata</i>	Polygalaceae	N	N	N
<i>Polygala lutea</i>	Polygalaceae	N	N	N
<i>Polygala mariana</i>	Polygalaceae	N	N	N
<i>Polygala nuttallii</i>	Polygalaceae	N	N	N
<i>Polygala paucifolia</i>	Polygalaceae	N	N	N
<i>Polygala polygama</i>	Polygalaceae	N	N	N
<i>Polygala sanguinea</i>	Polygalaceae	N	N	N
<i>Polygala verticillata</i>	Polygalaceae	N	N	N
<i>Polygonum aviculare</i>	Polygonaceae	Y	I	N
<i>Polygonum convolvulus</i>	Polygonaceae	Y	I	N
<i>Polygonum persicaria</i>	Polygonaceae	Y	I	N
<i>Rumex crispus</i>	Polygonaceae	Y	I	N
<i>Polygonum pensylvanicum</i>	Polygonaceae	Y	N	N
<i>Fagopyrum esculentum</i>	Polygonaceae	N	I	N
<i>Polygonum arenastrum</i>	Polygonaceae	N	I	N
<i>Polygonum cespitosum</i>	Polygonaceae	N	I	N
<i>Polygonum cuspidatum</i>	Polygonaceae	N	I	N
<i>Polygonum extremiorientale</i>	Polygonaceae	N	I	N
<i>Polygonum hydropiper</i>	Polygonaceae	N	I	N
<i>Polygonum orientale</i>	Polygonaceae	N	I	N
<i>Polygonum perfoliatum</i>	Polygonaceae	N	I	N
<i>Polygonum sachalinense</i>	Polygonaceae	N	I	N
<i>Rumex acetosella</i>	Polygonaceae	N	I	N
<i>Rumex obtusifolius</i>	Polygonaceae	N	I	N
<i>Rumex patientia</i>	Polygonaceae	N	I	N
<i>Polygonella articulata</i>	Polygonaceae	N	N	N
<i>Polygonum amphibium</i>	Polygonaceae	N	N	N
<i>Polygonum arifolium</i>	Polygonaceae	N	N	N

<i>Polygonum careyi</i>	Polygonaceae	N	N	N
<i>Polygonum erectum</i>	Polygonaceae	N	N	N
<i>Polygonum glaucum</i>	Polygonaceae	N	N	Y
<i>Polygonum hydropiperoides</i>	Polygonaceae	N	N	N
<i>Polygonum lapathifolium</i>	Polygonaceae	N	N	N
<i>Polygonum punctatum</i>	Polygonaceae	N	N	N
<i>Polygonum ramosissimum</i>	Polygonaceae	N	N	N
<i>Polygonum robustius</i>	Polygonaceae	N	N	N
<i>Polygonum sagittatum</i>	Polygonaceae	N	N	N
<i>Polygonum setaceum</i>	Polygonaceae	N	N	N
<i>Polygonum tenue</i>	Polygonaceae	N	N	N
<i>Polygonum virginianum</i>	Polygonaceae	N	N	N
<i>Rumex altissimus</i>	Polygonaceae	N	N	N
<i>Rumex hastatulus</i>	Polygonaceae	N	N	N
<i>Rumex maritimus</i>	Polygonaceae	N	N	N
<i>Rumex orbiculatus</i>	Polygonaceae	N	N	N
<i>Rumex salicifolius</i>	Polygonaceae	N	N	N
<i>Rumex verticillatus</i>	Polygonaceae	N	N	N
<i>Polygonum scandens</i>	Polygonaceae	N	NI	N
<i>Rumex acetosa</i>	Polygonaceae	N	NI	N
<i>Polypodium virginianum</i>	Polypodiaceae	N	N	N
<i>Eichhornia crassipes</i>	Pontederiaceae	N	I	N
<i>Heteranthera dubia</i>	Pontederiaceae	N	N	N
<i>Heteranthera limosa</i>	Pontederiaceae	N	N	N
<i>Heteranthera multiflora</i>	Pontederiaceae	N	N	N
<i>Heteranthera reniformis</i>	Pontederiaceae	N	N	N
<i>Pontederia cordata</i>	Pontederiaceae	N	N	N
<i>Portulaca oleracea</i>	Portulacaceae	Y	NI	N
<i>Portulaca grandiflora</i>	Portulacaceae	N	I	N
<i>Claytonia virginica</i>	Portulacaceae	N	N	N
<i>Potamogeton crispus</i>	Potamogetonaceae	N	I	N
<i>Potamogeton amplifolius</i>	Potamogetonaceae	N	N	N
<i>Potamogeton diversifolius</i>	Potamogetonaceae	N	N	N
<i>Potamogeton epihydrus</i>	Potamogetonaceae	N	N	N

<i>Potamogeton foliosus</i>	Potamogetonaceae	N	N	N
<i>Potamogeton gramineus</i>	Potamogetonaceae	N	N	N
<i>Potamogeton illinoensis</i>	Potamogetonaceae	N	N	Y
<i>Potamogeton natans</i>	Potamogetonaceae	N	N	N
<i>Potamogeton nodosus</i>	Potamogetonaceae	N	N	N
<i>Potamogeton oakesianus</i>	Potamogetonaceae	N	N	N
<i>Potamogeton perfoliatus</i>	Potamogetonaceae	N	N	N
<i>Potamogeton pulcher</i>	Potamogetonaceae	N	N	N
<i>Potamogeton pusillus</i>	Potamogetonaceae	N	N	N
<i>Potamogeton robbinsii</i>	Potamogetonaceae	N	N	Y
<i>Potamogeton spirillus</i>	Potamogetonaceae	N	N	N
<i>Stuckenia pectinata</i>	Potamogetonaceae	N	N	N
<i>Stuckenia vaginata</i>	Potamogetonaceae	N	N	N
<i>Anagallis arvensis</i>	Primulaceae	Y	I	N
<i>Lysimachia nummularia</i>	Primulaceae	N	I	N
<i>Lysimachia punctata</i>	Primulaceae	N	I	N
<i>Androsace occidentalis</i>	Primulaceae	N	N	N
<i>Glaux maritima</i>	Primulaceae	N	N	Y
<i>Hottonia inflata</i>	Primulaceae	N	N	Y
<i>Lysimachia ciliata</i>	Primulaceae	N	N	N
<i>Lysimachia hybrida</i>	Primulaceae	N	N	N
<i>Lysimachia quadrifolia</i>	Primulaceae	N	N	N
<i>Lysimachia terrestris</i>	Primulaceae	N	N	N
<i>Lysimachia thyrsiflora</i>	Primulaceae	N	N	N
<i>Trientalis borealis</i>	Primulaceae	N	N	N
<i>Samolus valerandi</i>	Primulaceae	N	NI	N
<i>Adiantum pedatum</i>	Pteridaceae	N	N	N
<i>Cheilanthes lanosa</i>	Pteridaceae	N	N	N
<i>Pellaea atropurpurea</i>	Pteridaceae	N	N	N
<i>Chimaphila maculata</i>	Pyrolaceae	N	N	N
<i>Chimaphila umbellata</i>	Pyrolaceae	N	N	N
<i>Orthilia secunda</i>	Pyrolaceae	N	N	N
<i>Pyrola americana</i>	Pyrolaceae	N	N	N
<i>Pyrola asarifolia</i>	Pyrolaceae	N	N	N

<i>Pyrola chlorantha</i>	Pyrolaceae	N	N	Y
<i>Pyrola elliptica</i>	Pyrolaceae	N	N	N
<i>Actaea spicata</i>	Ranunculaceae	N	I	N
<i>Aquilegia vulgaris</i>	Ranunculaceae	N	I	N
<i>Clematis terniflora</i>	Ranunculaceae	N	I	N
<i>Consolida ajacis</i>	Ranunculaceae	N	I	N
<i>Helleborus viridis</i>	Ranunculaceae	N	I	N
<i>Ranunculus bulbosus</i>	Ranunculaceae	N	I	N
<i>Ranunculus ficaria</i>	Ranunculaceae	N	I	N
<i>Ranunculus repens</i>	Ranunculaceae	N	I	N
<i>Actaea pachypoda</i>	Ranunculaceae	N	N	N
<i>Actaea racemosa</i>	Ranunculaceae	N	N	N
<i>Actaea rubra</i>	Ranunculaceae	N	N	N
<i>Anemone canadensis</i>	Ranunculaceae	N	N	N
<i>Anemone caroliniana</i>	Ranunculaceae	N	N	N
<i>Anemone quinquefolia</i>	Ranunculaceae	N	N	N
<i>Anemone virginiana</i>	Ranunculaceae	N	N	N
<i>Aquilegia canadensis</i>	Ranunculaceae	N	N	N
<i>Caltha palustris</i>	Ranunculaceae	N	N	N
<i>Clematis occidentalis</i>	Ranunculaceae	N	N	N
<i>Clematis virginiana</i>	Ranunculaceae	N	N	N
<i>Coptis trifolia</i>	Ranunculaceae	N	N	N
<i>Hepatica nobilis</i>	Ranunculaceae	N	N	N
<i>Hydrastis canadensis</i>	Ranunculaceae	N	N	Y
<i>Ranunculus abortivus</i>	Ranunculaceae	N	N	N
<i>Ranunculus ambigens</i>	Ranunculaceae	N	N	N
<i>Ranunculus cymbalaria</i>	Ranunculaceae	N	N	Y
<i>Ranunculus fascicularis</i>	Ranunculaceae	N	N	Y
<i>Ranunculus flabellaris</i>	Ranunculaceae	N	N	N
<i>Ranunculus flammula</i>	Ranunculaceae	N	N	N
<i>Ranunculus hispidus</i>	Ranunculaceae	N	N	N
<i>Ranunculus longirostris</i>	Ranunculaceae	N	N	N
<i>Ranunculus micranthus</i>	Ranunculaceae	N	N	N
<i>Ranunculus pensylvanicus</i>	Ranunculaceae	N	N	N

<i>Ranunculus pusillus</i>	Ranunculaceae	N	N	N
<i>Ranunculus recurvatus</i>	Ranunculaceae	N	N	N
<i>Ranunculus sceleratus</i>	Ranunculaceae	N	N	N
<i>Ranunculus trichophyllus</i>	Ranunculaceae	N	N	N
<i>Thalictrum dioicum</i>	Ranunculaceae	N	N	N
<i>Thalictrum pubescens</i>	Ranunculaceae	N	N	N
<i>Thalictrum revolutum</i>	Ranunculaceae	N	N	N
<i>Thalictrum thalictroides</i>	Ranunculaceae	N	N	N
<i>Trollius laxus</i>	Ranunculaceae	N	N	N
<i>Xanthorhiza simplicissima</i>	Ranunculaceae	N	N	N
<i>Ranunculus acris</i>	Ranunculaceae	N	NI	N
<i>Frangula alnus</i>	Rhamnaceae	N	I	N
<i>Rhamnus cathartica</i>	Rhamnaceae	N	I	N
<i>Rhamnus davurica</i>	Rhamnaceae	N	I	N
<i>Ceanothus americanus</i>	Rhamnaceae	N	N	N
<i>Duchesnea indica</i>	Rosaceae	Y	I	N
<i>Rubus phoenicolasius</i>	Rosaceae	Y	I	N
<i>Crataegus monogyna</i>	Rosaceae	N	I	N
<i>Filipendula ulmaria</i>	Rosaceae	N	I	N
<i>Malus floribunda</i>	Rosaceae	N	I	N
<i>Malus pumila</i>	Rosaceae	N	I	N
<i>Malus sylvestris</i>	Rosaceae	N	I	N
<i>Malus toringo</i>	Rosaceae	N	I	N
<i>Photinia villosa</i>	Rosaceae	N	I	N
<i>Potentilla argentea</i>	Rosaceae	N	I	N
<i>Potentilla intermedia</i>	Rosaceae	N	I	N
<i>Potentilla recta</i>	Rosaceae	N	I	N
<i>Potentilla reptans</i>	Rosaceae	N	I	N
<i>Prunus avium</i>	Rosaceae	N	I	N
<i>Prunus cerasus</i>	Rosaceae	N	I	N
<i>Prunus domestica</i>	Rosaceae	N	I	N
<i>Prunus persica</i>	Rosaceae	N	I	N
<i>Prunus spinosa</i>	Rosaceae	N	I	N
<i>Pyrus calleryana</i>	Rosaceae	N	I	N

<i>Pyrus communis</i>	Rosaceae	N	I	N
<i>Rhodotypos scandens</i>	Rosaceae	N	I	N
<i>Rosa canina</i>	Rosaceae	N	I	N
<i>Rosa centifolia</i>	Rosaceae	N	I	N
<i>Rosa cinnamomea</i>	Rosaceae	N	I	N
<i>Rosa gallica</i>	Rosaceae	N	I	N
<i>Rosa micrantha</i>	Rosaceae	N	I	N
<i>Rosa multiflora</i>	Rosaceae	N	I	N
<i>Rosa rubiginosa</i>	Rosaceae	N	I	N
<i>Rosa rugosa</i>	Rosaceae	N	I	N
<i>Rosa wichuraiana</i>	Rosaceae	N	I	N
<i>Rubus laciniatus</i>	Rosaceae	N	I	N
<i>Rubus parvifolius</i>	Rosaceae	N	I	N
<i>Sorbus aucuparia</i>	Rosaceae	N	I	N
<i>Spiraea japonica</i>	Rosaceae	N	I	N
<i>Spiraea prunifolia</i>	Rosaceae	N	I	N
<i>Agrimonia gryposepala</i>	Rosaceae	N	N	N
<i>Agrimonia microcarpa</i>	Rosaceae	N	N	N
<i>Agrimonia parviflora</i>	Rosaceae	N	N	N
<i>Agrimonia pubescens</i>	Rosaceae	N	N	N
<i>Agrimonia rostellata</i>	Rosaceae	N	N	N
<i>Agrimonia striata</i>	Rosaceae	N	N	N
<i>Amelanchier arborea</i>	Rosaceae	N	N	N
<i>Amelanchier canadensis</i>	Rosaceae	N	N	N
<i>Amelanchier laevis</i>	Rosaceae	N	N	N
<i>Amelanchier nantucketensis</i>	Rosaceae	N	N	N
<i>Amelanchier obovalis</i>	Rosaceae	N	N	N
<i>Amelanchier stolonifera</i>	Rosaceae	N	N	N
<i>Aronia arbutifolia</i>	Rosaceae	N	N	N
<i>Aronia melanocarpa</i>	Rosaceae	N	N	N
<i>Crataegus calpodendron</i>	Rosaceae	N	N	Y
<i>Crataegus chrysocarpa</i>	Rosaceae	N	N	N
<i>Crataegus crus-galli</i>	Rosaceae	N	N	N
<i>Crataegus holmesiana</i>	Rosaceae	N	N	N

<i>Crataegus intricata</i>	Rosaceae	N	N	N
<i>Crataegus mollis</i>	Rosaceae	N	N	N
<i>Crataegus pedicellata</i>	Rosaceae	N	N	N
<i>Crataegus phaenopyrum</i>	Rosaceae	N	N	N
<i>Crataegus pruinosa</i>	Rosaceae	N	N	N
<i>Crataegus punctata</i>	Rosaceae	N	N	N
<i>Crataegus succulenta</i>	Rosaceae	N	N	Y
<i>Crataegus uniflora</i>	Rosaceae	N	N	N
<i>Fragaria vesca</i>	Rosaceae	N	N	N
<i>Fragaria virginiana</i>	Rosaceae	N	N	N
<i>Geum aleppicum</i>	Rosaceae	N	N	N
<i>Geum canadense</i>	Rosaceae	N	N	N
<i>Geum laciniatum</i>	Rosaceae	N	N	N
<i>Geum vernum</i>	Rosaceae	N	N	N
<i>Geum virginianum</i>	Rosaceae	N	N	N
<i>Malus angustifolia</i>	Rosaceae	N	N	N
<i>Malus coronaria</i>	Rosaceae	N	N	N
<i>Malus ioensis</i>	Rosaceae	N	N	N
<i>Physocarpus opulifolius</i>	Rosaceae	N	N	N
<i>Potentilla arguta</i>	Rosaceae	N	N	N
<i>Potentilla canadensis</i>	Rosaceae	N	N	N
<i>Potentilla norvegica</i>	Rosaceae	N	N	N
<i>Potentilla paradoxa</i>	Rosaceae	N	N	N
<i>Potentilla simplex</i>	Rosaceae	N	N	N
<i>Prunus americana</i>	Rosaceae	N	N	N
<i>Prunus angustifolia</i>	Rosaceae	N	N	Y
<i>Prunus maritima</i>	Rosaceae	N	N	N
<i>Prunus nigra</i>	Rosaceae	N	N	N
<i>Prunus pensylvanica</i>	Rosaceae	N	N	N
<i>Prunus serotina</i>	Rosaceae	N	N	N
<i>Prunus virginiana</i>	Rosaceae	N	N	N
<i>Rosa arkansana</i>	Rosaceae	N	N	N
<i>Rosa blanda</i>	Rosaceae	N	N	N
<i>Rosa carolina</i>	Rosaceae	N	N	N

<i>Rosa nitida</i>	Rosaceae	N	N	N
<i>Rosa palustris</i>	Rosaceae	N	N	N
<i>Rosa virginiana</i>	Rosaceae	N	N	N
<i>Rubus allegheniensis</i>	Rosaceae	N	N	N
<i>Rubus argutus</i>	Rosaceae	N	N	N
<i>Rubus canadensis</i>	Rosaceae	N	N	Y
<i>Rubus cuneifolius</i>	Rosaceae	N	N	N
<i>Rubus flagellaris</i>	Rosaceae	N	N	N
<i>Rubus hispidus</i>	Rosaceae	N	N	N
<i>Rubus occidentalis</i>	Rosaceae	N	N	N
<i>Rubus odoratus</i>	Rosaceae	N	N	N
<i>Rubus ostryifolius</i>	Rosaceae	N	N	N
<i>Rubus pensilvanicus</i>	Rosaceae	N	N	N
<i>Rubus pubescens</i>	Rosaceae	N	N	N
<i>Rubus setosus</i>	Rosaceae	N	N	N
<i>Sanguisorba canadensis</i>	Rosaceae	N	N	N
<i>Sorbus americana</i>	Rosaceae	N	N	N
<i>Spiraea alba</i>	Rosaceae	N	N	N
<i>Spiraea tomentosa</i>	Rosaceae	N	N	N
<i>Waldsteinia fragarioides</i>	Rosaceae	N	N	N
<i>Rubus idaeus</i>	Rosaceae	N	NI	N
<i>Galium glaucum</i>	Rubiaceae	N	I	N
<i>Galium mollugo</i>	Rubiaceae	N	I	N
<i>Galium odoratum</i>	Rubiaceae	N	I	N
<i>Galium verum</i>	Rubiaceae	N	I	N
<i>Sherardia arvensis</i>	Rubiaceae	N	I	N
<i>Cephalanthus occidentalis</i>	Rubiaceae	N	N	N
<i>Diodia teres</i>	Rubiaceae	N	N	N
<i>Diodia virginiana</i>	Rubiaceae	N	N	Y
<i>Galium aparine</i>	Rubiaceae	N	N	N
<i>Galium asprellum</i>	Rubiaceae	N	N	N
<i>Galium boreale</i>	Rubiaceae	N	N	N
<i>Galium circaeazans</i>	Rubiaceae	N	N	N
<i>Galium lanceolatum</i>	Rubiaceae	N	N	N

<i>Galium obtusum</i>	Rubiaceae	N	N	N
<i>Galium pilosum</i>	Rubiaceae	N	N	N
<i>Galium tinctorium</i>	Rubiaceae	N	N	N
<i>Galium trifidum</i>	Rubiaceae	N	N	Y
<i>Galium triflorum</i>	Rubiaceae	N	N	N
<i>Houstonia caerulea</i>	Rubiaceae	N	N	N
<i>Mitchella repens</i>	Rubiaceae	N	N	N
<i>Oldenlandia uniflora</i>	Rubiaceae	N	N	N
<i>Ruppia maritima</i>	Ruppiaceae	N	N	N
<i>Phellodendron amurense</i>	Rutaceae	N	I	N
<i>Ptelea trifoliata</i>	Rutaceae	N	N	Y
<i>Zanthoxylum americanum</i>	Rutaceae	N	N	N
<i>Populus alba</i>	Salicaceae	N	I	N
<i>Populus nigra</i>	Salicaceae	N	I	N
<i>Salix alba</i>	Salicaceae	N	I	N
<i>Salix atrocinerea</i>	Salicaceae	N	I	N
<i>Salix cinerea</i>	Salicaceae	N	I	N
<i>Salix fragilis</i>	Salicaceae	N	I	N
<i>Salix purpurea</i>	Salicaceae	N	I	N
<i>Populus balsamifera</i>	Salicaceae	N	N	N
<i>Populus deltoides</i>	Salicaceae	N	N	N
<i>Populus grandidentata</i>	Salicaceae	N	N	N
<i>Populus heterophylla</i>	Salicaceae	N	N	N
<i>Populus tremuloides</i>	Salicaceae	N	N	N
<i>Salix bebbiana</i>	Salicaceae	N	N	N
<i>Salix discolor</i>	Salicaceae	N	N	N
<i>Salix eriocephala</i>	Salicaceae	N	N	N
<i>Salix humilis</i>	Salicaceae	N	N	N
<i>Salix interior</i>	Salicaceae	N	N	N
<i>Salix lucida</i>	Salicaceae	N	N	N
<i>Salix nigra</i>	Salicaceae	N	N	N
<i>Salix petiolaris</i>	Salicaceae	N	N	N
<i>Salix sericea</i>	Salicaceae	N	N	N
<i>Comandra umbellata</i>	Santalaceae	N	N	N

<i>Koeleruteria paniculata</i>	Sapindaceae	N	I	N
<i>Sarracenia purpurea</i>	Sarraceniaceae	N	N	N
<i>Saururus cernuus</i>	Saururaceae	N	N	N
<i>Chrysosplenium americanum</i>	Saxifragaceae	N	N	N
<i>Heuchera americana</i>	Saxifragaceae	N	N	N
<i>Mitella diphylla</i>	Saxifragaceae	N	N	N
<i>Parnassia glauca</i>	Saxifragaceae	N	N	N
<i>Saxifraga pensylvanica</i>	Saxifragaceae	N	N	N
<i>Saxifraga virginensis</i>	Saxifragaceae	N	N	N
<i>Tiarella cordifolia</i>	Saxifragaceae	N	N	Y
<i>Scheuchzeria palustris</i>	Scheuchzeriaceae	N	N	Y
<i>Schizaea pusilla</i>	Schizaeaceae	N	N	N
<i>Veronica arvensis</i>	Scrophulariaceae	Y	I	N
<i>Veronica polita</i>	Scrophulariaceae	Y	I	N
<i>Lindernia dubia</i>	Scrophulariaceae	Y	N	N
<i>Veronica peregrina</i>	Scrophulariaceae	Y	N	N
<i>Chaenorhinum minus</i>	Scrophulariaceae	N	I	N
<i>Cymbalaria muralis</i>	Scrophulariaceae	N	I	N
<i>Glossostigma cleistanthum</i>	Scrophulariaceae	N	I	N
<i>Kickxia elatine</i>	Scrophulariaceae	N	I	N
<i>Linaria repens</i>	Scrophulariaceae	N	I	N
<i>Linaria vulgaris</i>	Scrophulariaceae	N	I	N
<i>Mazus miquelii</i>	Scrophulariaceae	N	I	N
<i>Mazus pumilus</i>	Scrophulariaceae	N	I	N
<i>Paulownia tomentosa</i>	Scrophulariaceae	N	I	N
<i>Pseudolysimachion longifolium</i>	Scrophulariaceae	N	I	N
<i>Verbascum blattaria</i>	Scrophulariaceae	N	I	N
<i>Verbascum lychnitis</i>	Scrophulariaceae	N	I	N
<i>Verbascum thapsus</i>	Scrophulariaceae	N	I	N
<i>Veronica agrestis</i>	Scrophulariaceae	N	I	N
<i>Veronica chamaedrys</i>	Scrophulariaceae	N	I	N
<i>Veronica hederifolia</i>	Scrophulariaceae	N	I	N
<i>Veronica officinalis</i>	Scrophulariaceae	N	I	N
<i>Veronica persica</i>	Scrophulariaceae	N	I	N

<i>Agalinis auriculata</i>	Scrophulariaceae	N	N	N
<i>Agalinis fasciculata</i>	Scrophulariaceae	N	N	N
<i>Agalinis maritima</i>	Scrophulariaceae	N	N	N
<i>Agalinis paupercula</i>	Scrophulariaceae	N	N	N
<i>Agalinis purpurea</i>	Scrophulariaceae	N	N	N
<i>Agalinis setacea</i>	Scrophulariaceae	N	N	N
<i>Agalinis tenuifolia</i>	Scrophulariaceae	N	N	N
<i>Aureolaria flava</i>	Scrophulariaceae	N	N	N
<i>Aureolaria pedicularia</i>	Scrophulariaceae	N	N	N
<i>Aureolaria virginica</i>	Scrophulariaceae	N	N	N
<i>Castilleja coccinea</i>	Scrophulariaceae	N	N	N
<i>Chelone glabra</i>	Scrophulariaceae	N	N	N
<i>Gratiola aurea</i>	Scrophulariaceae	N	N	N
<i>Gratiola neglecta</i>	Scrophulariaceae	N	N	N
<i>Gratiola virginiana</i>	Scrophulariaceae	N	N	N
<i>Leucospora multifida</i>	Scrophulariaceae	N	N	N
<i>Limosella australis</i>	Scrophulariaceae	N	N	N
<i>Melampyrum lineare</i>	Scrophulariaceae	N	N	N
<i>Micranthemum micranthemoides</i>	Scrophulariaceae	N	N	Y
<i>Mimulus alatus</i>	Scrophulariaceae	N	N	N
<i>Mimulus ringens</i>	Scrophulariaceae	N	N	N
<i>Nuttallanthus canadensis</i>	Scrophulariaceae	N	N	N
<i>Pedicularis canadensis</i>	Scrophulariaceae	N	N	N
<i>Pedicularis lanceolata</i>	Scrophulariaceae	N	N	N
<i>Penstemon albidus</i>	Scrophulariaceae	N	N	N
<i>Penstemon digitalis</i>	Scrophulariaceae	N	N	N
<i>Penstemon hirsutus</i>	Scrophulariaceae	N	N	N
<i>Penstemon laevigatus</i>	Scrophulariaceae	N	N	Y
<i>Penstemon pallidus</i>	Scrophulariaceae	N	N	N
<i>Scrophularia lanceolata</i>	Scrophulariaceae	N	N	N
<i>Scrophularia marilandica</i>	Scrophulariaceae	N	N	N
<i>Veronica americana</i>	Scrophulariaceae	N	N	N
<i>Veronica anagallis-aquatica</i>	Scrophulariaceae	N	N	N
<i>Veronica scutellata</i>	Scrophulariaceae	N	N	N

<i>Veronicastrum virginicum</i>	Scrophulariaceae	N	N	N
<i>Veronica serpyllifolia</i>	Scrophulariaceae	N	NI	N
<i>Selaginella apoda</i>	Selaginellaceae	N	N	N
<i>Selaginella rupestris</i>	Selaginellaceae	N	N	N
<i>Ailanthus altissima</i>	Simaroubaceae	Y	I	N
<i>Smilax glauca</i>	Smilacaceae	N	N	N
<i>Smilax herbacea</i>	Smilacaceae	N	N	N
<i>Smilax laurifolia</i>	Smilacaceae	N	N	N
<i>Smilax pseudochina</i>	Smilacaceae	N	N	N
<i>Smilax pulverulenta</i>	Smilacaceae	N	N	N
<i>Smilax rotundifolia</i>	Smilacaceae	N	N	N
<i>Smilax tamnoides</i>	Smilacaceae	N	N	N
<i>Solanum ptycanthum</i>	Solanaceae	Y	N	N
<i>Datura stramonium</i>	Solanaceae	N	I	N
<i>Hyoscyamus niger</i>	Solanaceae	N	I	N
<i>Lycium barbarum</i>	Solanaceae	N	I	N
<i>Nicandra physalodes</i>	Solanaceae	N	I	N
<i>Nicotiana rustica</i>	Solanaceae	N	I	N
<i>Petunia axillaris</i>	Solanaceae	N	I	N
<i>Petunia integrifolia</i>	Solanaceae	N	I	N
<i>Solanum dulcamara</i>	Solanaceae	N	I	N
<i>Solanum lycopersicum</i>	Solanaceae	N	I	N
<i>Solanum nigrum</i>	Solanaceae	N	I	N
<i>Leucophysalis grandiflora</i>	Solanaceae	N	N	N
<i>Physalis hederifolia</i>	Solanaceae	N	N	N
<i>Physalis heterophylla</i>	Solanaceae	N	N	N
<i>Physalis longifolia</i>	Solanaceae	N	N	N
<i>Physalis pubescens</i>	Solanaceae	N	N	N
<i>Physalis virginiana</i>	Solanaceae	N	N	N
<i>Solanum carolinense</i>	Solanaceae	N	N	N
<i>Solanum rostratum</i>	Solanaceae	N	N	N
<i>Sparganium erectum</i>	Sparganiaceae	N	I	N
<i>Sparganium americanum</i>	Sparganiaceae	N	N	N
<i>Sparganium androcladum</i>	Sparganiaceae	N	N	N

<i>Sparganium emersum</i>	Sparganiaceae	N	N	N
<i>Sparganium eurycarpum</i>	Sparganiaceae	N	N	N
<i>Staphylea trifolia</i>	Staphyleaceae	N	N	N
<i>Symplocos paniculata</i>	Symplocaceae	N	I	N
<i>Taxus baccata</i>	Taxaceae	N	I	N
<i>Phegopteris connectilis</i>	Thelypteridaceae	N	N	N
<i>Phegopteris hexagonoptera</i>	Thelypteridaceae	N	N	N
<i>Thelypteris noveboracensis</i>	Thelypteridaceae	N	N	N
<i>Thelypteris palustris</i>	Thelypteridaceae	N	N	N
<i>Thelypteris simulata</i>	Thelypteridaceae	N	N	N
<i>Dirca palustris</i>	Thymelaeaceae	N	N	N
<i>Tilia cordata</i>	Tiliaceae	N	I	N
<i>Tilia americana</i>	Tiliaceae	N	N	N
<i>Tilia tomentosa</i>	Tiliaceae	N	N	N
<i>Trapa natans</i>	Trapaceae	N	I	N
<i>Typha latifolia</i>	Typhaceae	N	N	N
<i>Typha angustifolia</i>	Typhaceae	N	NI	N
<i>Ulmus pumila</i>	Ulmaceae	Y	I	N
<i>Zelkova serrata</i>	Ulmaceae	Y	I	N
<i>Celtis occidentalis</i>	Ulmaceae	Y	N	N
<i>Ulmus glabra</i>	Ulmaceae	N	I	N
<i>Ulmus procera</i>	Ulmaceae	N	I	N
<i>Ulmus americana</i>	Ulmaceae	N	N	N
<i>Ulmus rubra</i>	Ulmaceae	N	N	N
<i>Boehmeria cylindrica</i>	Urticaceae	N	N	N
<i>Laportea canadensis</i>	Urticaceae	N	N	N
<i>Parietaria pensylvanica</i>	Urticaceae	N	N	N
<i>Pilea fontana</i>	Urticaceae	N	N	N
<i>Pilea pumila</i>	Urticaceae	N	N	N
<i>Urtica dioica</i>	Urticaceae	N	NI	N
<i>Valeriana officinalis</i>	Valerianaceae	N	I	N
<i>Valerianella locusta</i>	Valerianaceae	N	I	N
<i>Valerianella umbilicata</i>	Valerianaceae	N	N	Y
<i>Verbena officinalis</i>	Verbenaceae	N	I	N

<i>Phryma leptostachya</i>	Verbenaceae	N	N	N
<i>Phyla cuneifolia</i>	Verbenaceae	N	N	N
<i>Verbena hastata</i>	Verbenaceae	N	N	N
<i>Verbena simplex</i>	Verbenaceae	N	N	Y
<i>Verbena stricta</i>	Verbenaceae	N	N	N
<i>Verbena urticifolia</i>	Verbenaceae	N	N	N
<i>Viola arvensis</i>	Violaceae	N	I	N
<i>Viola tricolor</i>	Violaceae	N	I	N
<i>Hybanthus concolor</i>	Violaceae	N	N	Y
<i>Viola affinis</i>	Violaceae	N	N	N
<i>Viola bicolor</i>	Violaceae	N	N	N
<i>Viola blanda</i>	Violaceae	N	N	N
<i>Viola brittoniana</i>	Violaceae	N	N	N
<i>Viola canadensis</i>	Violaceae	N	N	Y
<i>Viola cucullata</i>	Violaceae	N	N	N
<i>Viola hirsutula</i>	Violaceae	N	N	N
<i>Viola labradorica</i>	Violaceae	N	N	N
<i>Viola lanceolata</i>	Violaceae	N	N	N
<i>Viola macloskeyi</i>	Violaceae	N	N	N
<i>Viola pedata</i>	Violaceae	N	N	N
<i>Viola pubescens</i>	Violaceae	N	N	N
<i>Viola rostrata</i>	Violaceae	N	N	N
<i>Viola rotundifolia</i>	Violaceae	N	N	N
<i>Viola sagittata</i>	Violaceae	N	N	N
<i>Viola sororia</i>	Violaceae	N	N	N
<i>Viola striata</i>	Violaceae	N	N	N
<i>Viola triloba</i>	Violaceae	N	N	N
<i>Phoradendron leucarpum</i>	Viscaceae	N	N	N
<i>Parthenocissus quinquefolia</i>	Vitaceae	Y	N	N
<i>Ampelopsis brevipedunculata</i>	Vitaceae	N	I	N
<i>Parthenocissus tricuspidata</i>	Vitaceae	N	I	N
<i>Parthenocissus vitacea</i>	Vitaceae	N	N	N
<i>Vitis aestivalis</i>	Vitaceae	N	N	N
<i>Vitis labrusca</i>	Vitaceae	N	N	N

<i>Vitis palmata</i>	Vitaceae	N	N	N
<i>Vitis riparia</i>	Vitaceae	N	N	N
<i>Vitis vulpina</i>	Vitaceae	N	N	N
<i>Xyris caroliniana</i>	Xyridaceae	N	N	Y
<i>Xyris difformis</i>	Xyridaceae	N	N	N
<i>Xyris montana</i>	Xyridaceae	N	N	Y
<i>Xyris torta</i>	Xyridaceae	N	N	N
<i>Zannichellia palustris</i>	Zannichelliaceae	N	N	N
<i>Zostera marina</i>	Zosteraceae	N	N	N

Appendix 2 (below):

Where Y_{ijk} is the trait value for the i^{th} plant in environment j in region k ,

FOR NORMALLY-DISTRIBUTED TRAIT DATA

Model 1: 2 (k) means with 2 (k) different variances

$$y_{ik} \sim N(\mu_k, \sigma_k^2) \quad i = 1, 2, \dots, n_k; \quad k = 1, 2$$

$$\mu_k \sim N(\theta, \tau^2)$$

$$\theta \sim N(0, 0.000001)$$

$$1/\sigma_k^2 \sim \text{Gamma}(\alpha, \beta)$$

$$\tau \sim \text{Unif}(0, 100)$$

$$\alpha \sim \text{Unif}(0, 100)$$

$$\beta \sim \text{Unif}(0, 100)$$

Model 2: 2 (j) means with 2 (j) different variances

$$y_{ij} \sim N(\mu_j, \sigma_j^2) \quad i = 1, 2, \dots, n_j; \quad j = 1, 2$$

$$\mu_j \sim N(\theta, \tau^2)$$

$$\theta \sim N(0, 0.000001)$$

$$1/\sigma_j^2 \sim \text{Gamma}(\alpha, \beta)$$

$$\tau \sim \text{Unif}(0, 100)$$

$$\alpha \sim \text{Unif}(0, 100)$$

$$\beta \sim \text{Unif}(0, 100)$$

Model 3: 4 (j x k) means with 4 (j x k) different variances

$$y_{ijk} \sim N(\mu_{jk}, \sigma_{jk}^2) \quad i = 1, 2, \dots, n_{jk}; \quad j = 1, 2; \quad k = 1, 2$$

$$\mu_{jk} \sim N(\theta_k, \tau^2)$$

$$\theta_k \sim N(\phi, \delta^2)$$

$$\phi \sim N(0, 0.000001)$$

$$1/\sigma_{jk}^2 \sim \text{Gamma}(\alpha, \beta)$$

$$\tau \sim \text{Unif}(0, 100)$$

$$\delta \sim \text{Unif}(0, 100)$$

$$\alpha \sim \text{Unif}(0, 100)$$

$$\beta \sim \text{Unif}(0, 100)$$

Model 4: 1 mean, 1 variance

$$y_i \sim N(\mu, \sigma^2) \quad i = 1, 2, \dots, n$$

$$\mu \sim N(0, 0.000001)$$

$$1/\sigma^2 \sim \text{Gamma}(0.001, 0.001)$$

Appendix 3 (below):

Where Y_{ijk} is the i^{th} plant in environment j in region k ...

FOR NON-NORMALLY DISTRIBUTED TRAIT DATA (abbreviated)

Gamma Model 2: 4 (j x k) means with 4 (j x k) different variances

$$y_{ijk} \sim \text{Gamma}(r_{jk}, \lambda_{jk}) \quad i = 1, 2, \dots, n_{jk}; \quad j = 1, 2; \quad k = 1, 2$$

$$r_{jk} = \mu_{jk}^2 / \sigma_{jk}^2$$

$$\lambda_{jk} = \mu_{jk} / \sigma_{jk}^2$$

$$\mu_{jk} \sim N(\theta_k, \tau^2)$$

$$\theta_k \sim N(\phi, \delta^2)$$

$$\phi \sim N(0, 0.000001)$$

$$1/\sigma_{jk}^2 \sim \text{Gamma}(\alpha, \beta)$$

$$\tau \sim \text{Unif}(0, 100)$$

$$\delta \sim \text{Unif}(0, 100)$$

$$\alpha \sim \text{Unif}(0, 100)$$

$$\beta \sim \text{Unif}(0, 100)$$

Negative Binomial Model 2: 4 (j x k) means with 4 (j x k) different variances

$$y_{ijk} \sim \text{NB}(p_{jk}, r_{jk}) \quad i = 1, 2, \dots, n_{jk}; \quad j = 1, 2; \quad k = 1, 2$$

$$p_{jk} = r_{jk} / (r_{jk} + \mu_{jk})$$

$$\sigma_{jk}^2 = r_{jk} \times (1 - p_{jk}) / (p_{jk}^2)$$

$$\mu_{jk} \sim \text{Gamma}(\theta_k, \tau^2)$$

$$\theta_k \sim \text{Gamma}(\phi, \delta^2)$$

$$\phi \sim \text{Unif}(0, 10)$$

$$\tau \sim \text{Unif}(0, 100)$$

$$\delta \sim \text{Unif}(0, 100)$$

$$\alpha \sim \text{Unif}(0, 100)$$

$$\beta \sim \text{Unif}(0, 100)$$

$$r_{jk} \sim \text{Gamma}(\alpha, \beta)$$

Lognormal Model 2: 4 (j x k) means with 4 (j x k) different variances

$$y_{ijk} \sim \text{Lognormal}(\mu_{log,jk}, \sigma_{log,jk}^2) \quad i = 1, 2, \dots, n_{jk}; \quad j = 1, 2; \quad k = 1, 2$$

$$\mu_{jk} \sim N(\theta_k, \tau^2)$$

$$\mu_{jk} = \exp(\mu_{log,jk} + (\sigma_{log,jk}^2/2))$$

$$\sigma_{jk}^2 = \{\exp(\sigma_{log,jk}^2) - 1\} \times \exp(2\mu_{log,jk} + \sigma_{log,jk}^2)$$

$$\theta_k \sim N(\phi, \delta^2)$$

$$\phi \sim N(0, 0.000001)$$

$$\sigma_{log,jk} \sim \text{Unif}(0, 1000)$$

$$\mu_{log,jk} \sim N(0, 0.000001)$$

$$1/\sigma_{jk}^2 \sim \text{Gamma}(\alpha, \beta)$$

$$\tau \sim \text{Unif}(0, 100)$$

$$\delta \sim \text{Unif}(0, 100)$$

$$\alpha \sim \text{Unif}(0, 100)$$

$$\beta \sim \text{Unif}(0, 100)$$

References

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