CREATE Solutions for a Changing World

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Pollinator Gardens: Landscaping for Biodiversity in the 21st Century

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CREATE Solutions for a Changing World

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Summary

As global change threatens pollinator populations, conservationists have turned to cities as a new locale for habitat creation, with pollinator gardening showing particular promise. We integrate ecological data with research on landscaping preferences to show that while pollinator gardens have clear, substantial benefits for biodiversity over traditional landscaping, homeowners have been reluctant to widely adopt them owing to social controls on acceptable yard aesthetics and a general lack of knowledge. However, yard management is also socially contagious, meaning new preferences have the potential to spread through communities. With the goal of shifting norms and spreading ideas, we provide recommendations for gardeners and advocates that combine ecological value with benefits for homeowners, as well as a set of research questions whose answers would help us understand how gardens function as habitats. Pollinator gardening has unique potential to be a popular and cost-effective habitat creation tool, boosting biological resilience to global change and helping to unlock the untapped conservation potential of our cities.

MICHAEL NEWTON

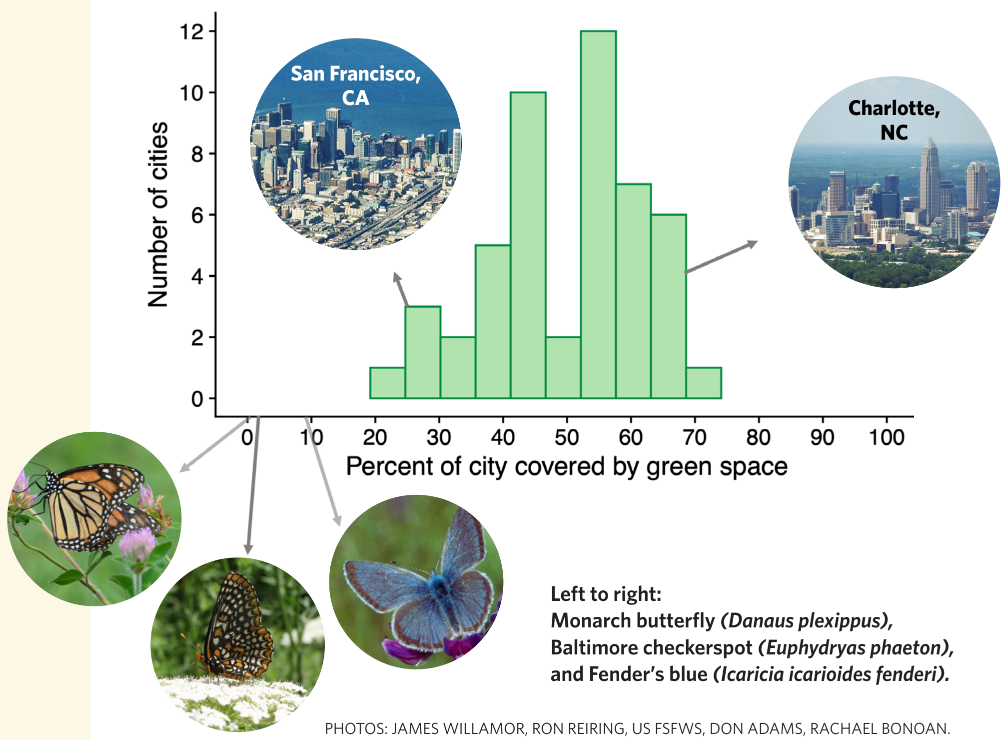
Tiger swallowtail *(Papilio glaucus × canadensis)* on tickseed *(Coreopsis sp.)* in a garden in New London, NH.

Problem Statement

Habitat loss is a leading threat to the maintenance of biodiversity. In addition to the direct effects of habitat loss *per se,* habitat loss indirectly limits resilience to other stressors, such as changing climate. In the 20th century, the conservation movement focused on protecting habitat in the remaining wilderness areas (Sarkar 1999). These efforts — though admirable and necessary — have not been sufficient to halt declines across widespread taxa like birds (Pimm et al. 2006) and insects (Wagner 2020). Among these declines, loss of pollinator populations is particularly conspicuous, because of the role pollinators play in maintaining food security. Approximately 70% of crop species at least partially depend on animal pollination (Klein et al. 2007), often by wild pollinators that require natural habitat to persist.

In recent decades, the urban environment has emerged as a new frontier for habitat creation, especially in the form of pollinator gardening (Hall and Martins 2020). At first glance, urban lands might seem like unlikely targets for pollinator conservation because they look much less similar to wilderness than the rural, semi-natural landscapes used for agriculture, forestry, and grazing. However, they are important for at least two reasons. First, cities and suburbs are widespread and growing. Urban land cover is projected to grow by over 1 million km^2 from 2000 to 2030, meaning that by that date, a substantial majority of all urban lands on earth

Figure 1. Space is available for pollinator habitat:
Cities in the U.S. have substantial amounts of green space (area that has vegetation). This chart shows the amount of green space across 49 large U.S. cities (data from Richardson et al. 2012), ranging from 19% to 69% green space. If even a small portion of these lands were converted to pollinator habitat, this would be more than enough to support many pollinator species. For example, our research suggests that in order to have stable or growing populations, butterflies typically need between 0.1 and 10% habitat (see Crone et al. 2019). The butterfly pictures to the right represent the habitat required to sustain populations of three of the butterfly species we have studied.



Left to right:
Monarch butterfly *(Danaus plexippus)*,
Baltimore checkerspot *(Euphydryas phaeton)*,
and Fender's blue *(Icaricia icarioides fenderi)*.

PHOTOS: JAMES WILLAMOR, RON REIRING, US FSFWS, DON ADAMS, RACHAEL BONOAN.

will have been created during the 21st century (Seto et al. 2012). In North America, these urban residential lands are currently dominated by nonnative turf grasses, which constitute the largest irrigated crop in the U.S. and cover an estimated 163,800 km^2 (Milesi et al. 2005), an area larger than the state of Georgia. The land management decisions that are made about these enormous areas will be of real conservation consequence for the tens of thousands of animal species that live in them. If just a modest fraction of urban green space were converted to pollinator gardens, cities may be able to support many pollinator species (see Figure 1).

Second, conservation may be more economically compatible with urban than with semi-natural lands. In semi-natural landscapes, efforts to maximize profit often conflict with conserving pollinator habitat, so pollinator habitat creation and restoration come at an economic cost to farmers, ranchers and other rural landowners (Buckley and Crone 2008). In urban and suburban landscapes, lawns are maintained at considerable cost and effort by individual small landowners (Blaine et al. 2012, Harris et al. 2013). Changing management practices of these landowners could create habitat at a huge scale but with little additional economic cost. Pollinator gardening also creates potentially desirable, well-liked landscapes, with minimal change to the usefulness of land. This is a recipe for a "win-win" situation in which pollinator habitat can be created with little top-down control or additional cost and largely through the voluntary spending of private, individual landholders.

IMAGES: GOOGLE STREET VIEW 2018-20.

Community inspiration:

Examples of florally and structurally diverse pollinator gardens in Somerville and Cambridge, MA. Note the wide variation in management and design choices, all within the scope of the recommendations we provide.

State of the Art

Given this potential win-win situation, what can we do to make it happen? While much remains unknown about pollinator ecology and optimal garden design, incomplete ecological knowledge is not the main factor limiting adoption of pollinator gardens. We know that urban areas can harbor surprising pollinator diversity — e.g., on the order of a third or more of a region's bee diversity (Ahrné et al. 2009, Fortel et al. 2014) and similar species richness as nearby rural areas for some taxa (Baldock et al. 2015). As adults, many insect pollinators are generalists, and the factor most consistently linked to high pollinator diversity in cities is high flower cover and diversity around the sampling site (Ahrné et al. 2009, Bates et al. 2011, Quistberg et al. 2016, Majewska and Altizer 2020). Adult pollinators are mobile and appear to locate flowers even when they are planted in highly urbanized, otherwise unfavorable areas (Wenzel et al. 2020). We know less about how to make gardens that sustain pollinators throughout their life cycles, but the first steps are incorporating a diversity of types of nectar- and pollen-producing vegetation (Majewska and Altizer 2020), planting host plants for butterflies (Baker and Potter 2018), and providing nesting sites for bees (Fortel et al. 2016). Even without extensive ecological tuning, a moderately diverse pollinator garden provides far more conservation value than a yard composed only of turf grass or impervious surfaces (Wenzel et al. 2020).


KYLE BRADFORD

Bicolored striped-sweat bee *(Agapostemon virescens)* on black-eyed susan *(Rudbeckia hirta)* in a garden in Brattleboro, VT.

“ IF WE COULD UNDERSTAND HOW TO INITIATE SOCIAL CONTAGION OF POLLINATOR GARDENING, THE SAME SOCIAL PHENOMENA THAT MAINTAIN LAWNS AS THE DOMINANT COVER TYPE TODAY COULD ONE DAY CAUSE POLLINATOR GARDENING TO EMERGE AS A SELF-SPREADING IDEA. ”

Rather than ecological knowledge, the primary limit to the spread of pollinator gardens is the willingness of homeowners to adopt them. In North America, failure to conform to norms of “neatness” associated with turf grass is often perceived as a moral failing indicative of a lack of care for neighbors or community (Feagan and Ripmeester 1999, 2001, Robbins 2007, Harris et al. 2013). Even when landholders are discontented with conventional lawn care, they are reluctant to fall into nonconformity and/or feel they lack necessary knowledge (Larsen and Harlan 2006, Blaine et al. 2012, Harris et al. 2013). At the same time, the social nature of yard maintenance means that pollinator gardening may be socially contagious. Neighbors overall tend to mimic the most popular landscaping choices in an area (Nassauer et al. 2009) and alternative yard care information can spread through conversation (Martini et al. 2014). These factors can lead to the formation of clusters of gardens (Hunter and Brown 2012). If we could understand how to initiate social contagion of pollinator gardening, the same social phenomena that maintain lawns as the dominant cover type today could one day cause pollinator gardening to emerge as a self-spreading idea.

Moving Forward

Given the state of the art, the best way to encourage pollinator gardening is to motivate social change. In other words, we need to make pollinator gardens easy and convenient for novice gardeners in order to build their social acceptability and popularity. With these principles in mind, we summarize recommendations that aim to: (I) distill the most important design elements for an effective pollinator garden into their easiest-to-adopt form (*Recommendations for gardeners*) and (II) summarize ways to motivate others to adopt pollinator gardening (*Recommendations for advocates*). For academics and other researchers who want to contribute to our ability to conserve biodiversity through pollinator gardening, we also (III) summarize ecological and biological research directions that best support the utility of pollinator gardens, given their social context (*Recommendations for researchers*).

I. RECOMMENDATIONS FOR GARDENERS

These recommendations are a starting set of easy-to-follow guidelines that could help novice gardeners plant pollinator gardens (examples in Fig. 2). Our aim is to complement existing guidelines targeted at experienced gardeners (see, e.g., Mader et al. 2011).

1 Plant a diverse set of flowering plants

Garden habitats with more plant species support greater pollinator diversity (Majewska and Altizer 2020) because each pollinator species visits a subset of flower species and because attractiveness varies widely across plant taxa (Garbuzov and Ratnieks 2015). Gardens with higher floral diversity are also generally preferred by the public, thanks to their variation in flower color, size, and shape (Lindemann-Matthies and Bose 2007).

2 Add vegetation structure to the yard

Incorporating structural (physical) diversity, including bare soil and woody plants, provides nesting habitat and food resources for many pollinator species (MacIvor et al. 2014, Fortel et al. 2016). This feature of pollinator gardens is also in line with public preferences, as survey participants' imagined ideal landscapes include substantial structural diversity (Lindemann-Matthies and Bose 2007).

3 When possible, use native plant species and avoid problem plants

Though non-native plants can support many native pollinators (Shapiro 2002), some specialist pollinators rely exclusively on native plants (Burghardt et al. 2009), which are also less likely to act invasively, offer inaccessible rewards (Corbet et al. 2001), or act as evolutionary traps whereby native pollinators are attracted to the plant but perform poorly on it (Nakajima et al. 2013). For landholders, native plants may also come with no increase to costs, as suggested by the finding that in cities, household income predicts exotic species diversity significantly better than native species diversity (Chamberlain et al. 2020).

ANDREW GRIFFITH

Long-tailed skipper *(Urbanus proteus)* on New England aster *(Symphyotrichum novae-angliae)* in Wareham, MA.

KYLE BRADFORD

Cuckoo bee *(Triepeolus sp.)* on sunflower *(Helianthus annuus)* in a garden in Brattleboro, VT.

RACHAEL BONOAN

Leafcutter bee *(Megachile sp.)* on cutleaf coneflower *(Rudbeckia laciniata)* in urban natural area in Providence County, RI.

4 Minimize herbicide and pesticide use

Pesticides can impair the health of garden-visiting pollinators (Larson et al. 2013) and herbicides reduce floral cover and diversity by removing weeds, which constitute important diet components for some urban pollinators (MacIvor et al. 2014, Larson et al. 2014). Reducing these chemical inputs would also lower costs and maintenance effort, two of the management factors homeowners report they are most concerned about (Blaine et al. 2012).

5 Lawns can remain, but should be mowed infrequently

Effective pollinator gardening does not require wholesale conversion of all outdoor space to flowers. Grass lawns, which are widely valued as safe spaces for leisure and play (Larson et al. 2009), can be mowed less frequently to minimize disturbance and allow weeds to bloom, which attracts more insects (Lerman et al. 2018). Maintaining taller, semi-natural meadow areas alongside conventional low-cut lawns can also be appealing to the public (Fischer et al. 2020) and can substantially reduce maintenance costs (Watson et al. 2020).

II. RECOMMENDATIONS FOR ADVOCATES

These recommendations are for individuals or organizations who want to promote pollinator gardening. At the present time, such groups often focus on educating master gardeners and other experienced individuals who self-select and actively seek out this information. Our recommendations are for organizations who particularly want to expand their reach to the general public as part of efforts to change wider social norms.

1 Distribute easy-to-follow, scalable guidance on growing pollinator gardens

Unlike other environmentally-conscious behaviors (e.g., recycling, Schultz 2002), a lack of knowledge is often a barrier to changing yard management practices (Harris et al. 2013, van Heezik et al. 2020). Given the potential tradeoff between complexity and likelihood of adoption of pollinator conservation guidance (Knapp et al. 2020), beginners should be taught simple and general principles (see Figure 2 for a dissection of an exemplary document). These might include an emphasis on easy-to-propagate species or may initially focus on harm reduction through reduced mowing or pesticide use.

2 Aim for knowledge diffusion and social contagion

Conventional, lawn-covered yard landscapes are a strong social norm (Feagan and Ripmeester 1999, Harris et al. 2013), and thus early-adopters of pollinator gardening take on some risk. However, these dynamics also lead to mimicry and thus social contagion: pollinator gardens become preferred in homeowner surveys once hypothetical neighbors have them too (Nassauer et al. 2009). Advocates should recognize that the subsequent social pressure exerted by converting gardeners may be equally important as the initial gardens for long-term habitat creation.

3 Emphasize beauty and ease of maintenance of native pollinator gardens

Lawn owners generally prioritize achieving conventional aesthetics while minimizing costs in time or effort (Larson et al. 2009, Harris et al. 2013). Advocates should emphasize that pollinator-friendly planting can be cost-effective (Williams and Lonsdorf 2018) and beautiful, and they should combat any pre-existing beliefs that neighbors might dislike pollinator garden aesthetics (Peterson et al. 2012) and fears about potentially higher costs of unfamiliar practices (Harris et al. 2013).

KYLE BRADFORD

Calligrapher fly *(Toxomerus marginatus)*, an example of a pollinating hoverfly in a garden in Brattleboro, VT.

DON ADAMS

Common buckeye *(Junonia coenia)* on Shasta daisy *(Leucanthemum × superbum)* in garden in West Bridgewater, MA.

4 Combat policies that prevent pollinator-friendly practices from being adopted

Pollinator gardening can be constrained by top-down forces such as municipal laws (e.g., lawn height limits, Sandberg and Foster 2005) and homeowners association rules, which convert social pressures into explicit contractual obligations about aesthetics (Turner and Stiller 2020). Advocates need to understand the motivation behind regulations — Are they due to safety issues such as visibility along crowded urban streets, or do they reflect popular but changeable beliefs about aesthetics and home values? — and then work to change rules where appropriate.

5 Lead by example: the more gardens there are, the faster adoption occurs

Directly creating gardens is a valuable tool for shifting norms and educating the public about the aesthetics of pollinator gardening, as well as its ecological benefits. In-person encounters with pollinator habitat create a social climate that is more accepting of and more interested in pollinator gardening (Hall and Martins 2020), and these improvements to social climate might have redoubling effects down the road, thanks to the social contagion effect.

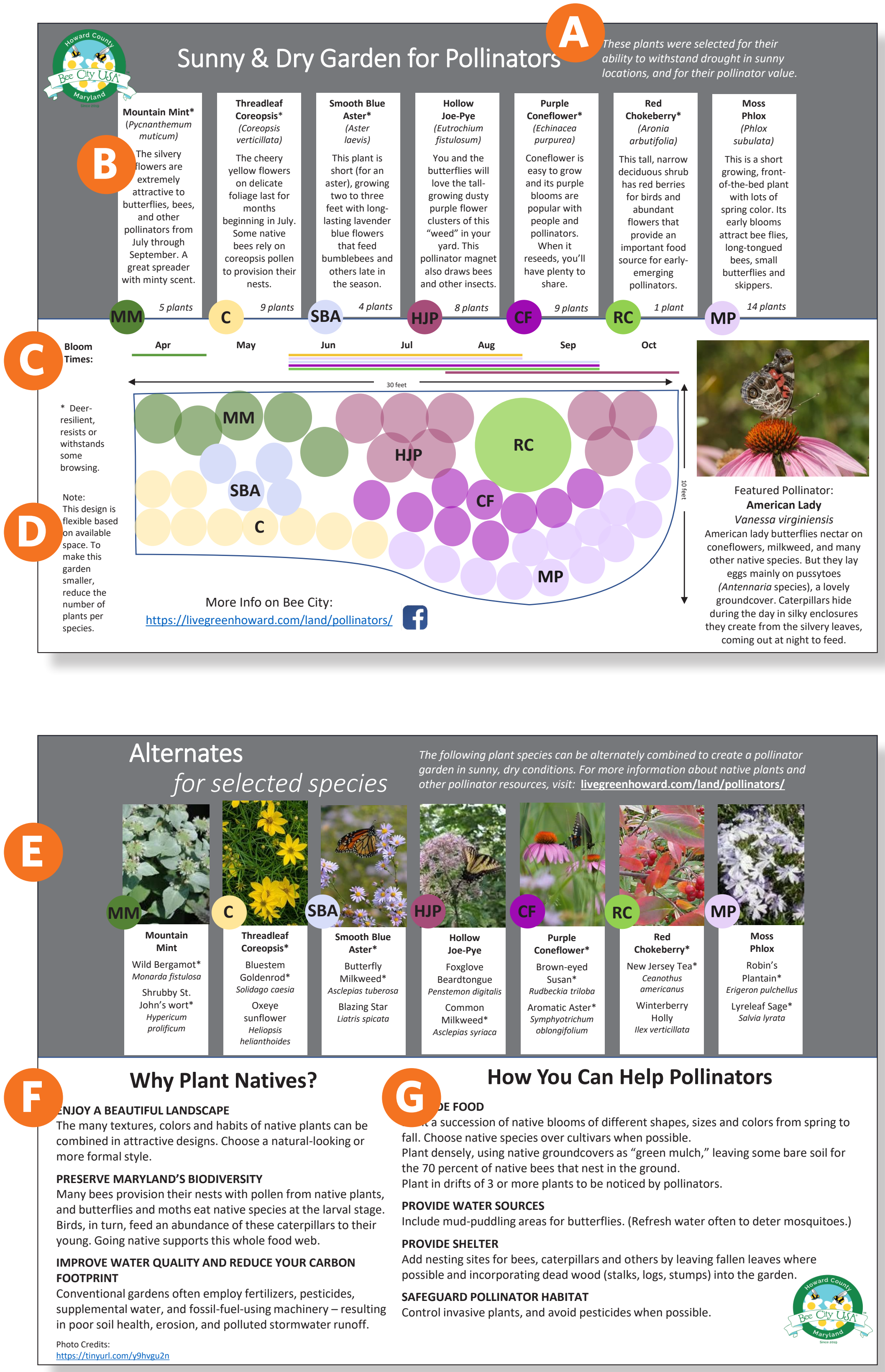
RACHAEL BONOAN

Sweat bee *(Lasioglossum sp.)* on Foxglove Beardtongue *(Penstemon digitalis)* in garden in Medford, MA.

Figure 2. Anatomy of an effective guide to pollinator gardening targeted at beginners.

This image was taken from guidelines developed by Howard County, MD for distribution to a broad audience, including novice gardeners. Note the clear plant guidance with pictures of flowers and the spatially precise planting layout. These features help beginners feel comfortable with starting a pollinator garden.

- **A** Specify type of sunlight and soil conditions.
- **B** Describe recommended plants that are easy-to-grow and work well together.
- **C** Highlight timing of blooms.
- **D** Offer exact planting layouts.
- **E** Provide photos.
- **F** Emphasize beauty.
- **G** Provide non-plant tips for further success.



GUIDE USED WITH PERMISSION: HOWARD COUNTY, MD BEE CITY USA.

III. RECOMMENDATIONS FOR RESEARCHERS

We know that diverse native gardens are better than typical landscaping choices for most pollinator species. However, urban landscapes are also a novel ecosystem constructed by humans, whose form will thus never replicate natural landscapes. These research topics are recommended directions if we want to know whether pollinator gardens can substitute for — as opposed to supplementing — conservation in natural areas.

1 Mechanisms that drive urban pollinator habitat quality

Most data on urban pollinator ecology are correlative, describing patterns of diversity (see review by Majewska and Altizer 2020). For nearly all taxa, factors determining habitat quality are unknown, including garden-relevant factors like what resources are limiting across life stages (e.g., pollen vs. nest sites) and how far species disperse in cities. Understanding these mechanisms is central to understanding whether urban gardens can provide stand-alone "source" habitat for pollinators, as opposed to simply serving as habitat for populations that spill over from natural areas.

2 Evolutionary and behavioral changes in cities

Recent work has demonstrated genetic (Johnson and Munshi-South 2017) and behavioral (Sol et al. 2013) differences in animal populations from urban environments compared to rural ones, but the adaptive significance of most differences remains unclear and little is known about differences in pollinator populations. Identifying such differences could help characterize which elements of urban habitats are most important for a given species and help explain some of the substantial variation in urbanization tolerance across pollinator taxa.

3 Optimal reserve design in social contexts and with many managers

Optimal reserve design, the question of where and how to spend limited conservation resources, is an old problem, but studying its urban analogue requires acknowledging the distinct, irrational, and decentralized land management context of cities and drawing on the considerable social science literature on social contagion and emotions in yard care (Feagan and Ripmeester 1999, Robbins 2007, Harris et al. 2013). Leveraging this research could directly aid conservationists, e.g., by identifying nascent clusters of gardeners and prioritizing these areas for investment, using materials that emphasize pollinator gardening's benefits within homeowners' pre-existing priorities.

ATTICUS MURPHY

Brown-belted bumblebee *(Bombus griseocollis)* on common milkweed *(Asclepias syriaca)* on Tufts University campus in Medford, MA.

NICHOLAS DORIAN

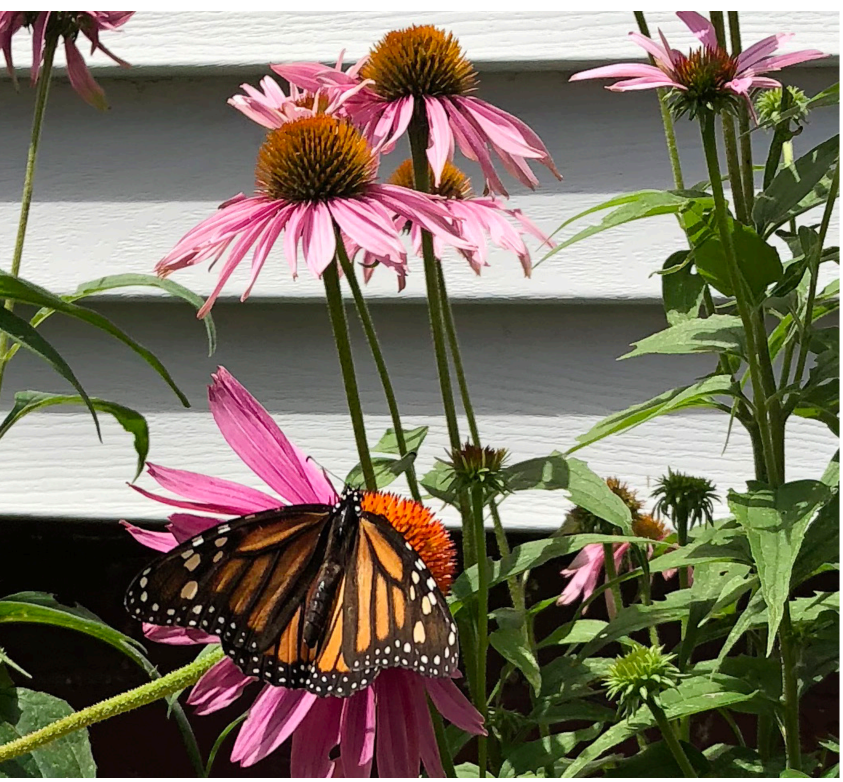
Cloudy-winged miner bee *(Andrena nubecula)* on goldenrod *(Solidago sp.)* in Orleans, MA.

4 What pitfalls should be avoided when creating urban pollinator habitats?

We advocate simple, proscription-light messaging in part because most pitfalls in pollinator gardening are not well characterized: outside of an obvious few (e.g., excluding locally invasive species), most problems are more complex (e.g., evergreen tropical milkweed is a popular garden plant with clearly disruptive effects on monarch butterfly migration [Majewska and Altizer 2019], but as it is a suitable host plant, its presence may or may not make garden habitats a net negative for monarch populations). Biologists should investigate such potentially harmful practices, but pollinator gardening advocates should be careful not to overstate the evidence or overcomplicate messaging, because ease of adoption is key to large scale habitat creation.

5 What are achievable conservation targets for urban pollinators?

Although replacing a lawn with a diverse flower garden almost invariably leads to greater pollinator diversity in that yard, it is unknown whether city- or region-wide pollinator diversity increases given an increase in the number of gardens. Aside from these largely untested — yet much-heralded — ambitions for boosting urban biodiversity at larger scales, pollinator gardens provide other potential conservation benefits worthy of research, such as a capacity for buffering pollinators from global change impacts by increasing population sizes, as well as favorably altering public perceptions of insect conservation (Hall and Martins 2020).



LEONE BROWN

Monarch butterfly *(Danaus plexippus)* on purple coneflower *(Echinacea purpurea)* in a garden in Somerville, MA.

Climate Solutions

Global change and the associated modern extinction crisis are very serious yet very complex problems. This complexity can be overwhelming, and the problems' scales can make an average person feel powerless. However, the impacts of climate change do not occur in isolation. Habitat creation increases (and, conversely, habitat loss decreases) species' resilience to climate change. If species do not have sufficient habitat, they may experience overcrowding or search time limitation, both of which decrease population growth. Larger populations are able to withstand greater shocks, and are also more likely to have the capacity to evolve to new environments through genetic change. The availability of suitable habitat also constrains the ability of species to shift their ranges in response to shifting windows of suitable climate conditions.

> "POLLINATOR GARDENS... HAVE THE DIRECT EFFECT OF MAKING POLLINATOR POPULATIONS LESS HABITAT LIMITED, AND THEREFORE MORE RESILIENT TO CLIMATE CHANGE. THEY ALSO HELP CONNECT PEOPLE TO BIODIVERSITY IN A REAL AND IMMEDIATE WAY."

Pollinator gardens are a direct and immediate solution to one dimension of climate change. They have the direct effect of making pollinator populations less habitat limited, and therefore more resilient to climate change. They also help connect people to biodiversity in a real and immediate way. We do not yet know whether pollinator gardens can be a substitute for natural habitats, i.e., for how many taxa they can support self-sustaining urban populations; ecological research in this area is a high priority. However, we do know that urban and suburban lands are a large and growing segment of the landscape and that pollinator gardens, even if imperfect, are far superior to traditional landscaping choices, such as turf lawns. Making pollinator gardens accessible to the general public has the added benefit of possibly leading to social contagion. Rather than competing with other economic interests, they could become a landscaping option that spreads simply because it is beautiful and popular. Even if the ultimate goal is a landscape of sophisticated and fine-tuned gardens, pollinator gardens that are "good enough" are a first step towards shifting the social norms away from monoculture lawns and towards heterogeneous and diverse urban landscapes.

KYLE BRADFORD

Confusing bumble bee (Bombus perplexus) on gooseneck loosestrife (Lysimachia clethroides) in garden in Brattleboro, VT.

Pollinator gardening serves as a powerful potential habitat creation solution for a group of animals threatened by global climate change and habitat loss. As a conservation measure, it is especially well-suited to the urban context: it engages with private landowners about activities they already spend substantial amounts of time and money on and encourages them to create landscapes that typically do not conflict with other desired uses, which are also widely seen as beautiful. Because these ecologically beneficial practices are also likely to be socially contagious, every dollar spent on creating more pollinator gardeners has the potential to redouble its conservation benefits, through the passive, natural spread of information and aesthetic preferences. By taking into account the practicalities that make urban conservation a very different enterprise than traditional wilderness conservation, as we have done here, ecologists and conservationists can more easily identify and overcome the barriers to large-scale changes in urban land management and can leverage patterns of human behavior to their advantage, and to the advantage of biological resilience in an era of global change.

WILLIAM DUNNE

Pollinator garden created and maintained by the Tufts Pollinator Initiative (https://sites.tufts.edu/pollinators).

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