

Wild Bees in the City: Reimagining Urban Spaces for Native Bee Health

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Figure 1. St. Louis, Missouri north corridor urban community garden.

Abstract

Bees (Hymenoptera: Apoidea) are critical to crop production globally. In the last decade, significant declines in managed and native bee health have been documented, and it is now widely considered a “crisis.” The potential causes of reduced wild bee health (species richness and abundance) relate to land-use decisions, practices, and management including habitat fragmentation, lack of foraging resources, pesticides, pests, and disease. Recent studies of native bees found diverse communities in cities around the world. This interdisciplinary pilot study investigates relationships between bee health and urban land-uses. It joins ecological and social science field research to examine linkages between native bee health and socio-cultural drivers of urban land-use decision-making practices to understand (1) what explains findings of diverse bee species in cities and (2) how citizens can encourage the enhancement of habitat for native bee conservation. To establish a baseline for monitoring species’ diversity and abundance, wild bees were sampled weekly at designated urban farms, community gardens, and prairie pockets located in St. Louis, Missouri, USA from 2013 to 2015. To learn the social dynamics effecting management at the biologically sampled sites, ethnographic interviews were conducted in the summer of 2015 with 30 decision-makers. Informants described bees’ role in crop yield, quality, and quantity; reported planting to attract them; and spoke of the city as viable for habitat, which is relevant to urban conservation and policy. This essay reflects on these conversations with images captured at the research sites to understand the rich urban social-ecological tapestry toward informing future research and development approaches.

Keywords: sustainability science, sustainable development, pollinator health, pollinator crisis, social-ecological systems, urban ecology

Introduction: Urban Bees

Bee health, a policy-friendly expression of bee species richness and abundance, is in decline globally and recognized as a crisis by governments, the scientific community, and the general public [1–9]. Specifically, bees (Hymenoptera: Apoidea) are the most effective of animal pollinators and are critical both ecologically and economically to wild and managed crops worldwide [1–5]. In the United States, there are more than 4,000 species of native bees that work alongside the European honeybee in pollinating our fruits and vegetables [10]. Declines in wild bee diversity and abundance, first noted in 2006, have been linked to increased urbanization and land-use intensification through habitat disturbance, fragmentation, and loss, resulting in reduced and sporadic availability of foraging resources and viable nesting locations [1, 3–5, 11].

For wild bees (Figure 2), research in urban contexts is a recent phenomenon, and it is primarily being conducted in the young field of urban ecology. These studies find that cities can function as biological havens for community composition, richness, and abundance [1, 2, 4, 5, 12, 14]. Researchers are finding surprisingly diverse communities of wild bees in cities around the world such as Berlin, Germany [14], Cardiff and London in the UK [15–17], Melbourne, Australia [18], Guanacaste Province, Costa Rica [19], Vancouver, Canada [20], Chicago, IL [21], New York City, NY [22,23], Phoenix, AZ [24], and San Francisco, CA in the USA [25]. Managed habitats on the urban to suburban gradient such as residential yards, community gardens, urban farms, public parks, and cemeteries provide much needed resources for nesting and foraging [22, 26–30]. For example, urban areas afford diverse nesting sites ranging from bare soils, plant stems, trees, and leaf piles to cavity-nest sites located in walls, fences, porches, and building crevices, which species, such as bumblebees, successfully colonize [13, 16, 20–22, 31]. In cities, forage too is often abundant and as diverse as its people. Studies reveal that the consistent driver of bee health is the presence and availability of flowers for foraging [4, 5, 17]. This suggests that conservation efforts aimed at increasing the floral resources in cities can have a positive impact on improving bee species richness and abundance [4, 5].



Figure 2. *Agopostemon virescens*, a native bee in St. Louis, Missouri.

Urban redevelopment efforts historically prioritize economic opportunities and outcomes. However, findings from urban ecology suggest planners reconsider the urban core as an interconnected social-ecological system that generates a myriad of ecosystem services offering possibilities for biodiversity conservation [4, 5, 12, 30–33]. Fragmented and disturbed metropolitan environments serve as patchy yet vital resources, capable of supporting wild bee populations.

As the amount of people living in cities globally grows to nearly 67% by 2050 [4, 5, 35], additional pressures on landscapes, infrastructure, and services will be realized in urban areas [35]. We argue for a reimagining of “the city.” Both sustainability science and sustainable development play key roles in facilitating urban transitions toward sustainability [4]. Sustainability science is a young field [4, 36–38], aspiring to research where scientists from different disciplines collaborate with decision-makers and key stakeholders for the co-production of knowledge for sustainability [37–41]. Our pilot study investigates relationships between wild bee health and urban land-uses, as humans are the most dominant shapers of the urban landscape [4, 5, 42]. It conceives to inform sustainability science [36], with empirical case studies to further advance the relationship between knowledge and transitions toward sustainability [4, 5, 43, 44]. More broadly, our research contributes to understanding native bee population declines, by examining the bee health crises via integrated biophysical and social lenses, to view differently urbanization and policy. This is a necessary step for scientists to help society develop

empirically-grounded policies and best practices for improving native bee health [4].



Figure 3. St. Louis, Missouri north corridor urban prairie pocket.

In the following sections, we summarize the literature on drivers of land-use decision-making, management, and practices; detail the interdisciplinary research methods we utilized; and discuss how informant insights shaped future approaches for both biophysical and social scientific research efforts.

Socio-Cultural Drivers of Urban Land-Use: Human-Nature Connections

With increasing population and urbanization, human interactions with nature are changed. As urban living comes to dominate the human-nature experience, Pyle (1978) and Miller (2005) categorize the progressive decoupling and decline of the human-nature exchange in the urban setting as the “extinction of experience,” characterized by a fragmented, wildlife ‘empty’ landscape which negatively impacts sense of place [12, 32]. This does not mean, however, that cities preclude positive interactions with nature.

The post-industrial urban environment is now being recognized for its ecological functions, including cultural ecosystem services (educational, emotional, social) vital to human health and well-being, and biodiversity conservation [12, 47, 51, 52]. Residential and community gardens have been depicted as key to facilitating a positive urban human-nature experience, providing the desired aesthetic, recreational, and spiritual connections while influencing behavior to be more ‘wildlife-friendly’ [51–54]. Multiple studies reinforce the direct

and substantial impacts cultural ecosystem services and the urban natural environment have on quality of life, physical health, and mental well-being; fostering deep connections with nature; increasing conservation awareness; and strengthening sense of place [22, 26, 51, 53–60].



Figure 4. St. Louis, Missouri south corridor urban community garden.

Household Income and the Urban Landscape

The socioeconomic makeup of an urban environment influences land management and decision-making practices [61]. Landscaping investments for yards, common grounds, and public spaces demonstrate social status and identity, correlating closely with investments in home and neighborhood values [51, 54, 62, 63]. Financial resources can play an instrumental role influencing biodiversity in the urban environment.

Increases in plant, insect, and animal species' richness and abundance have been linked to increases in personal and disposable income; this has been called the 'luxury effect' [61, 64]. For higher income households, as hierarchical and dietary needs are met, landscaping and gardening preferences shift to incorporate aesthetically-pleasing ornamental plantings and traditional garden varieties, which in turn affects maintenance activities and expenditures [51, 54, 57–59, 63, 64]. This extends to community gardens as well: as gardeners' socioeconomic resources expand, their planting choices change, evolving plot composition from primarily food and medicinal staples to a mix of food, medicinal, and ornamental vegetation [58].

Reference Group Behavior and Urban Spaces

Many Western urban lands have inherited garden aesthetics exemplified by a structured, manicured landscape devoid of wildness [47, 51, 62, 65]. In Western cultures, the desire to emulate and perpetuate this socially constructed residential yard

ideal reflects the profound influence reference group behavior and social norms have on environmental management decisions and practices at the individual, neighborhood, and community scales [51, 53, 61, 62].

Reference group behavior is an informal institution [66] of internalized beliefs, values, and shared norms which influence and shape behavior, manifesting as an ‘ecology of prestige’ in which those group beliefs, values, and norms are translated into value-laden public landscaping choices [61]. The physical indicators of active neighborhood norms, ‘cues to care,’ are signaled by neat, orderly fenced properties with mown turf grass, trimmed bushes, and well-maintained flower beds [67].

How the ecology of prestige influences perceptions of front lawns versus backyards varies, suggesting that public-facing front landscaping follows the local or neighborhood norms as a symbolic expression of respect, pride in membership, and as a preemptive measure against social exclusion (Figure 5), whereas backyard spaces are private areas to express meaningful personal choices which may diverge from normative ideals (Fig. 6) [51, 54, 62, 63]. Backyard landscaping was subjected to much less scrutiny for adherence to the shared lawn paradigm, lending itself to the articulation of an individual’s vision for private outdoor spaces [51, 65].



Figures 5 and 6. St. Louis, Missouri residential landscapes surrounding the pilot study sites.

Aesthetic concerns are dominant in molding property owner activities [63] as one study found 80% of surveyed respondents reported it was their ‘duty’ to uphold neighborhood landscape norms [54]. Suburban residential front yards located near one another are strongly influenced by neighborhood norms first, resulting in a ‘mimicry’ effect (Fig. 5), and by broader normative conventions second [62, 63, 68]. Additionally, the motivations fueled by the ecology of prestige are evident in the widespread, intensive use of fertilizers, pesticides, and herbicides as levers to manage collective landscape standards [69, 70]. People expect green, scenic, accessible surroundings restricted to

the parameters of a human-dominated environment, resulting in a constrained vision of aesthetics consistently prioritized above ecological and conservation considerations [47, 54, 60, 62, 65, 71].

The Role of Informal and Formal Institutions

The shapes of the urban land uses are codified and actualized through both formal and information institutions. Crawford and Ostrom (1995) define an institution as the system for structuring and reinforcing human action either informally or formally via rules, norms, and shared strategies.

Informal institutions are exemplified by ‘bottom up’ individual, neighborhood, and community customs and social norms, which drive decision-making activities and actions [51, 53,59]. In residential landscapes, informal collective approaches have been used successfully for conservation and demonstrate the valuable role such grassroots efforts can play in reducing habitat patch isolation and improving biodiversity in the urban matrix [72]. Leveraging such institutions presents opportunities for engagement, knowledge generation, and wildlife conservation in urban residential contexts [26, 27, 53, 58].

Formal institutions range from national to local agencies and organizations with the accompanying governance, policies, codes, and restrictions. All establish and enforce standards on a wide range of land-use and management criteria, such as vegetation composition and maximum permissible plant heights for residential landscapes, common grounds, and public spaces [51]. Known as ‘top down’ mechanisms, these can improve biodiversity in metropolitan environments through ‘command-and-control’ restrictions [53, 59, 73].

In summary, the literature identifies how each of these socio-cultural drivers may impact land- use and decision-making practices from fine to broad scales in the urban environment. As the world’s urban centers continue to grow, exploring and understanding how well these theories predict outcomes in the coupled human-nature environment is not only relevant but also critical for informing sustainable development, urban policy, and conservation initiatives.

Interdisciplinary Research

Approaches Utilizing Social-Ecological Sampling

This pilot research study examines the linkages between wild bee health and the socio- cultural dimensions of urban land-use decision-making practices in post-industrial cities [4]. The methodology is designed to inform transformational sustainability science [4, 37], which has called for more

empirical case studies to further advance the relationship between knowledge and transitions toward sustainability [4, 41, 44].



Figures 7 and 8. Saint Louis University interdisciplinary researchers in the lab and field in 2015.

Because the city is a social-ecological system, we developed an interdisciplinary design for connecting social and biophysical data in a pilot project of St. Louis, Missouri [4]. To establish a baseline for long-term monitoring of species' diversity and abundance, we began wild bee sampling at 15 sites weekly at a rate of one-person sampling per hour per 0.25 hectare. Sample sites include urban farms, community gardens, and urban prairie pockets located within city boundaries with the exception of a farm in Ferguson, Missouri. Research sites span the range of socioeconomic and cultural perspective across the city (Figs. 9 and 10). All bees were collected via aerial netting, preserved, and identified to species. Voucher specimens were deposited in the Enns Entomological Museum, University of Missouri, Columbia. The results of the bee sampling are being analyzed (Camilo et al. forthcoming). To initiate linking biophysical findings to land-use practices, we conducted 30 ethnographic semi-structured interviews with the land managers of each site. To provide a broader perspective on bee health in the region and to connect to other local actors, we interviewed local experts on insect pollinator health research and outreach programming.

St. Louis City Corridor Geo-Demographic Characterizations

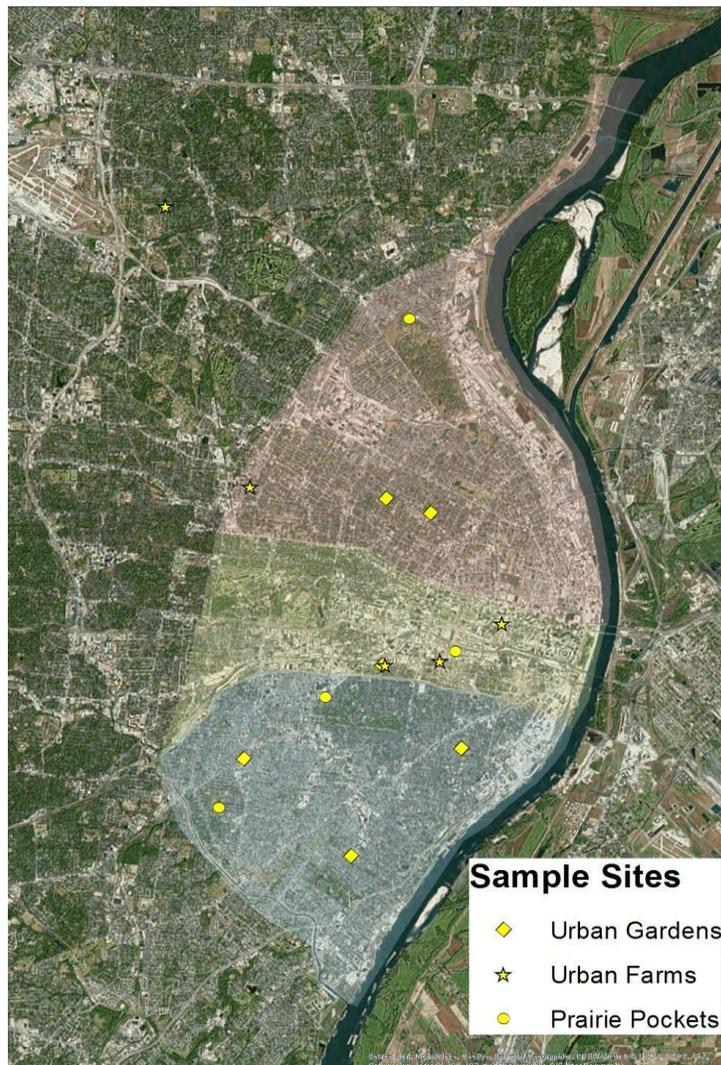


Figure 9. ArcGIS map of St. Louis, Missouri with the 15 sampling sites located within north, central, and south corridors. **Source:** N. Schaeg, 2016.

St. Louis, Missouri is the eighteenth largest metropolitan statistical area in the United States. It is representative of a post-industrial city whose urban core has experienced net population loss from its peak of 856,796 in 1950 to 319,365 in 2010 [74], with property and land vacancies standing at 19.4% [75]. St. Louis is representative of 92 US shrinking cities. Due to land availability, shrinking cities are likely to serve pilot roles for urban native bee conservation practices within the Pollinator Action Plan [76]. This research seeks to inform urban planning by exploring how land-use decision-makers and stakeholders can be engaged for a national strategy for increasing and improving bee health in urban areas. As all urban ecosystems are embedded within cultural landscapes [42], historical socioeconomic norms

and the politics of power account for today's distribution of people and the landscapes they shape.

The 15 sites are located within three designated geographic corridors of the city: north, central, and south (see Figures 9 and 10). The three zones are administrative artifacts of the city, which delineate the significant land-use and population differences characterizing each area (Fig. 10). According to the 2010 US Census Bureau data, St. Louis has a total estimated population of 319,365, of which 43.9% are Caucasian and 49.2% are African-American. In terms of education, 82.9% of the residents have obtained a high school diploma or the equivalent, while only 29.6% have achieved a bachelor's degree or higher [75]. The median household income is \$34,582, with a corresponding homeownership rate of 44.6% [75]. Single-parent families make up 24.3% of the St. Louis city households [75]. The poverty rate is estimated at 27.4% [75]. Overall property and land vacancies stand at 19.4% [75]. These socioeconomic attributes are clustered throughout the corridors as the following characterizations will describe.

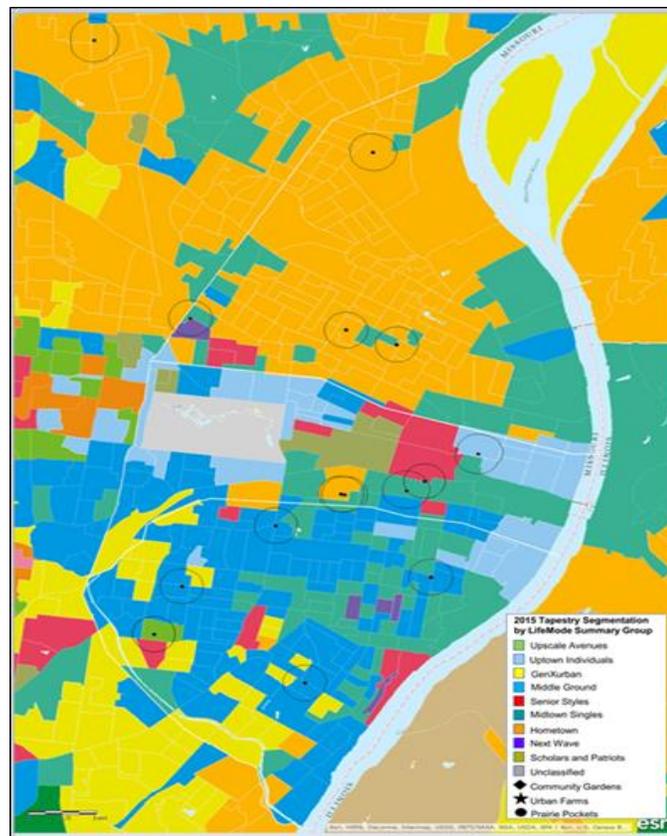


Figure 10. Esri Tapestry™ maps of St. Louis, Missouri north, central, and south corridors.

To better see the demographic differences across the corridors, we used Esri's Tapestry™ geodemographic market segmentation tool to characterize neighborhoods at the U.S. Census Block Group level. Geodemographic tools have been applied in a variety of fields, including community policing [77, 78], health screening [79, 80], education [81, 82], regional planning [83], and urban ecology [61], and use census and consumer market data to characterize spatially- explicit groups based on socioeconomic structures, consumption practices, and lifestyle factors [84]. Esri's Tapestry™ system relies on Census 2010, American Community Survey, Experian's ConsumerView database, and other consumer surveys to generate over 60 variables used to classify US neighborhoods into 67 market segments and 14 LifeMode summary groups [85]. LifeMode groups are based on traits such as median age, average education level, median annual household income, residential neighborhood/property age, homeownership rates, and levels of employment (Fig. 2). Characterizing residents into classification schemes infer that similar people live in similar places and behave similarly [86], this can be used as a general approach for designing communications about native bee conservation with residential audiences [84].

Methods: Naturalistic Inquiry

We conducted a total of 30 semi-structured interviews [cf. 45] with land-use decision-makers representing our 15 biophysical bee sampling sites to understand (1) local planting choices of land-use decision-makers; (2) how decision-makers communicate about bees; (3) how decision- makers value urban wild bees; (4) what informants identify as best practices for increasing wild bee habitat; and (5) what decision-makers perceive as facilitators and barriers for implementing habitat protection measures on their properties and regionally.

Informants were recruited based on expertise and association with the sites as decision- makers. During the interview each respondent was asked to characterize the site, detail its plantings and composition, describe the decision-making processes and timing, articulate potential formal and informal institutions impacting planting land-use decisions, provide their observations and interactions with urban pollinators, as well as respond to probes for understanding the scope and quality of the provisioning ecosystem services bees provide. Informants were also asked to comment on the global pollinator health crisis, what potential solutions they envision at local and regional scales both individually and by others via government programs, ordinances, or land-use measures, and then to articulate possible barriers to the identified solutions. Finally, at the conclusion of the interview, respondents were asked to reflect on the interview

session and convey what was most important to them. Many of the interviews were conducted at or adjacent to a garden site and often the informant provided a post-interview guided tour during which photographs were taken.

All interviews were digitally audio recorded, transcribed by trained student transcriptionists following a standardized protocol [87–89], and stored in a password-protected QSR NVivo 10.0 qualitative analytic database software for analysis. Additional informants were identified using snowball sampling with an effort to ensure the diversity of voices across the bee sampling sites [90]. Participants were grouped into four categories: urban farms, community gardens, prairie pockets, and experts. After completion of the interviews, we conducted content analysis of data within the 14 recurring themes inductively developed [87, 91], which enabled a schema for identifying key points of correlation between reported land-use management practices and sampling observation data.



Figure 11. St. Louis, Missouri north corridor urban farm.

Results and Discussion

Recasting the Urban Environment

We analyzed interview transcripts to understand how the urban environment can be enhanced for bee conservation from the informants' perspectives. 77% of the participants articulated visions of a reimagined urban environment viable for wildlife habitat and biodiversity conservation. The participants described the urban environment as viable for bees and their habitat while rejecting the dominant narratives of diminished post-industrial lands and absent wildlife as a foregone conclusion. The conversational evidence indicated the socio-cultural drivers of the urban human-nature experience, reference group behavior, and informal and formal institutions as factors that influence urban land-use and decision-making practices.

The informants expressed both the tensions and conundrums experienced due to the interplay of these socio-cultural drivers as they seek to reconstruct urban notions of nature from wildlife ‘empty’ spaces to ecologically rich social systems.

[What’s important is] *individuals creating as healthy of an ecosystem as they possibly can. Even if that means just a small, little, 10’ x 10’ lot in somebody’s front yard or not even a front yard just some lot down the street that nobody’s doing anything with. We live in a big city and a lot of times people think that it’s divided from the natural ecosystem--that it’s separate from the natural ecosystem and it’s not. We’re animals just like anything else; the city that we live in is an ecosystem. So individuals taking responsibility for that and trying to make it as healthy as possible for themselves and everything else that lives in it [is important]—‘cause it’s not just us (urban farmer).*

The participants’ ability to translate concepts of the reimagined urban landscape into tangible action, such as planting native flowers and plants, mowing lawns less frequently, and allowing “wildness” into their yards, community gardens, and public green spaces to support bees, provides not only concrete representation of those concepts but an opportunity to mediate the socio-cultural drivers in the public sphere. As the following quotes reveal, informants described how these efforts influenced common demonstrations of reference group behavior.

You know, planting native plants, the focus is, ‘yes we’ve always wanted to make our community look more beautiful,’ but planting native plants helps us do that, it also helps provide benefits for beneficial wildlife, to birds and bees, pollinators (expert).

We had some areas in our park, like, this very swampy area [where] all that was growing there was weeds. And so, it seemed like a nice place to put [the urban native prairie pocket] which was somewhat experimental for us because, as you’ll see, our park is very formal and very formally landscaped. A native plant garden is a little bit more wild, so it seemed like a good place to put something like that. People have been very receptive [of the native prairie pocket] ... One thing is, because it’s a formal park with our native plant garden, the city actually has this granite-limestone used for curb—I think it’s the same stuff that they used to pave the street with—and that’s what we use for the border of the garden. So that makes it kind of a wild, but kind of a formal, and then we’re going to put up a sign that identifies all the plants (urban prairie pocket gardener).



Figure 12. St. Louis, Missouri south corridor prairie pocket.

Participants reported that the processes to develop and establish native habitat in a variety of forms and settings encouraged them to engage and advocate informally with neighbors and fellow gardeners, as well as more formally with homeowners' associations and various local and state agencies. Our conversations revealed the tensions between the participants' initiatives to translate their visions into meaningful action; the prevalence of established reference group behavior symbolically represented in manicured residential landscapes and public green spaces; as well as the widespread informal and formal institutions, such as neighborhood planting norms and municipal ordinances, undergirding and reinforcing prevailing aesthetics. The resulting passages articulate the everyday challenges informants encountered.

We could definitely have less stringent municipal codes about nuisance vegetation, which is considered to be anything taller than like seven inches that's not a bush or a tree or something. That's, I think, the code in a lot of places – I mean it would be wonderful if we had front yard prairies instead of just front yard turf grass (urban farmer).

When we first were in the garden, weeds were like the complete enemy. But I think now maybe sometimes the weeds aren't always such a bad thing, like the vines that grow on the side of the wall. Whereas most people in buildings that are functioning don't want vines growing on their walls, that is a natural thing that draws different pollinators perhaps and so the wildness, letting kind of the wild things grow a little bit in an area or a garden, while it may look a little wild, it may be

important for this ecosystem of bugs to really function properly (urban community gardener).



Figures 13 and 14. Examples of urban ‘wildness’ in the north corridor.

When I look at a mowed park pond, it’s like this might be peaceful-looking but I don’t necessarily think, oh it’s beautiful. If I see a healthy, functioning wetland with a bunch of pickerelweed and arrowhead and I can hear frogs, I think, wow that is beautiful you know; and it’s because of what I know about that system and the value it has to me. And so I’d like to think that is where [it] is important for people to understand what the value is to them but also in a larger sense outside of themselves--and then that kind of directs their sense of aesthetics (expert).

Building on the socio-cultural driver of the urban human-nature experience, which is the aesthetic, recreational, and spiritual connections people have with the environment, participants described personal satisfaction and positive feedback received from noticeable increases in bees’ presence as reinforcing connections with nature, sense of place, and additional motivation for their efforts.

What I’ve noticed is that I have a lot of bees in the garden. It takes me awhile to get back there to weed, pull out the non-native stuff that I don’t want. But last summer when I was doing that, I could just hear all of these bees buzzing around me [laughter] (urban community gardener).



Figure 15. St. Louis, Missouri central corridor urban community garden.

There's something that's very subjective about the impact that it has on the human condition for somebody that's living in an urban environment to be able to go access a space that's in the middle of a residential area and feel like you're in nature. So I guess that could be a missing piece. It's basically like, what does the presence of pollinators give back to someone's spirit and sense of well-being, and how important is that when you decide what to plant and how (expert).

Conclusion

This interdisciplinary pilot research study investigates the connections between wild bee health and the socio-cultural dimensions of urban land-use and decision-making practices in the post-industrial city. The biophysical sampling data (Camilo et al., forthcoming) will serve to benchmark urban bee diversity and abundance in St. Louis, Missouri that we will use to guide our ongoing research efforts. The ethnographic data reveals participants' unique knowledge of and aspirations for the urban environment, especially when considering its viability for wild bee habitat. The socio-cultural drivers of the urban human-nature experience, reference group behavior, and informal and formal institutions shape participants' urban land-use and decision-making practices, often functioning in aggregate to exert influence. Examining these conversations develops our understanding of the informants' collective conceptualizations of nature in the urban setting.

Recasting the urban landscape as a refuge for bee habitat and biodiversity conservation is captured by participants' perceptions of future possibilities for nature integrated into the urban environment despite any impaired surroundings, challenges, or uncertainties of governance. By extension, it demonstrates the value of conducting research in the social-ecological systems framework. It offers a route to inform urban sustainable development efforts via engaging land-use decision-makers and key stakeholders around local and national policy

(e.g., Pollinator Action Plan’s National Strategy) for increasing and improving bee health in urban areas. A more socially robust understanding of the city from the bee’s perspective can inform policy-specific research approaches involving urban private-property owners in facilitating insect pollinator habitat enhancement, using sustainability science approaches to co-create knowledge and outcomes deemed salient, legitimate, and credible [37–40] that work for each unique setting.



Figures 16 and 17. Examples of native planting spaces to support pollinator health in St. Louis urban community gardens.



Figure 18. St. Louis, Missouri north corridor urban community garden.

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