Discovering the wild side of urban plants through public engagement

Kevin A. Vega1,2 | Juanita Schläpfer-Miller3 | Christoph Kueffer1,2

1ETH Zürich, Institute of Integrative Biology, Zürich, Switzerland
2Institute for Landscape and Open Space (ILF), Eastern Switzerland University of Applied Sciences (OST), Rapperswil, Switzerland
3Zurich-Basel Plant Science Center, ETH Zürich, Zürich, Switzerland

Correspondence
Kevin A. Vega, ETH Zürich, Institute of Integrative Biology, Universitätstrasse 16, Zürich, Switzerland.
Email: kavega21@gmail.com

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Societal Impact Statement
The Anthropocene has seen declining biodiversity inextricably linked to our societies, values, and choices. This requires ecologists to engage with the public in ecosystems such as cities to learn from and help inform their values and experiences regarding their role in urban nature. This article presents a transdisciplinary citizen science project on spontaneous urban vegetation in the context of urban botany, art-science, and participatory research that engages with the ecology of cities. We address the interdependence of ecological and social networks, suggesting how plant ecology can become more relevant for society in the Anthropocene, while presenting a specific methodology for engaging the public with urban botany.

Summary
- Cities are socio-ecological systems that require new ways of thinking and engagement to successfully conserve biodiversity. In this article, we present the citizen science project Where Seeds Fall which was undertaken in the city of Zurich, Switzerland. It was developed in an “ecology with” cities approach seeking to conduct research with the humans living in the ecosystem while learning from and helping inform their values.
- Our project brings together the perspectives of ecologists, artists, and planners on the three themes of urban wastelands, spontaneous vegetation, and ecological connectivity. It is placed in the context of urban botany, environmental arts and participatory research.
- Volunteers placed trays of bare soil (without seeds) in their gardens and balconies and monitored what plants arrived and germinated. They then were able to share information about their trays (images, species lists) with one another through a spatially explicit web platform. The project was accompanied by public outreach events and artistic interventions in public space.
- This article presents the methodology of the project so that it can be replicated elsewhere. Based on the experiences with the project we discuss evolving transdisciplinary perspectives on wild plant biodiversity in cities.

KEYWORDS
Anthropocene, biodiversity, citizen science, ecological connectivity, environmental arts, nature conservation, spontaneous vegetation, urban ecology
1 INTRODUCTION

In the Anthropocene, the extent of ecosystems within which humans have become the dominant ecological force, often by purposely changing them, has expanded (Lewis & Maslin, 2015; Steffen et al., 2015). Up to 78% of the planet’s surface have become anthropogenic biomes (anthromes; Ellis & Ramankutty, 2008). Ecologists must learn to understand the emerging novelty of such ecological systems and the role of humans as embedded actors that intentionally and unintentionally shape them (Corlett, 2015; Kueffer, 2020). While abandoned land is valued as novel wildlands and an opportunity for re-wilding (Hobbs et al., 2014; Pereira & Navarro, 2015), there are also increasing efforts to actively restore and design habitats and landscapes for ecological qualities and biodiversity, or innovative land-use practices that maintain or enhance biodiversity as a by-product (Kueffer & Kaiser-Bunbury, 2014).

A paradigmatic example of human-dominated ecosystems are cities and, as they grow at ever faster rates, many scientists have declared the 21st century to be the Urban Century (Liu et al., 2020; McDonald et al., 2018). While urban ecologists have documented ecosystem and species dynamics in urban areas (Goddard et al., 2010; Nielsen et al., 2014; Niemelä et al., 2011), only more recently have urban ecologists begun to explicitly address the reciprocal and ongoing feedbacks between humans and urban ecosystems which can be summarized as the transition from an urban ecology framework of “ecology in” cities to an “ecology of” cities (Grimm et al., 2008; Pickett et al., 2016). This shift can be seen in studies with a distinctly human component such as measures of ecosystem services, socio-demographic spatial modeling of ecological patterns, and the inclusion of concepts such as socio-ecological resilience, sustainability, and urban metabolism (McPhearson et al., 2016). These studies have provided growing evidence of the beneficial effects of urban green space for human health and well-being (Kondo et al., 2018; World Health Organisation, 2016) and the provisioning of many urban ecosystem services (Gómez-Baggethun & Barton, 2013; Tzoulas et al., 2007).

However, many of these approaches analyze urban socio-ecological systems from an outside perspective without explicitly addressing the agency of humans as embedded actors. There have been calls to move from a “ecology of” the city to an “ecology for* the city approach (Childers et al., 2015; McPhearson et al., 2016; Pickett et al., 2016) that produces research results that can be fed directly back into the system through participatory research, policy change, and public education, that is, transdisciplinary research (Hadorn et al., 2008). Although sometimes included within the “ecology for* cities framework, we find that the researchers may need to take a further step towards an “ecology with” cities that better acknowledges that humans are conscious actors that adapt their behavior in urban systems based on psychological, social, and cultural factors. Social theory of human-nature relationships and the coexistence with other species (e.g., Becker & Jahn, 2006; Latour, 1993) can help to better address human agency in socioecological systems such as cities. This requires collaborations between ecology and civic activism and local communities (Curran & Hamilton, 2017; Krasny & Tidball, 2015) and the social and cultural sciences and arts (Kueffer, 2020; Marchese, 2015) through new approaches such as citizen science (Bonney et al., 2009; Lander, 2019).

From the onset, botany was an important pillar of urban ecology (Thellung, 1912). In particular, with the creation of the political island of West Berlin following the Second World War, botanists who otherwise might have studied the plants of forests and mountains turned their attention to the plants of their city (Sukopp & Wittig, 1990). They were (and still are) impressed by the ways in which the human-built structure and land-use histories formed a surprising plant diversity in the city (Gandy & Jasper, 2020). Today, botany continues to be an important focus, with urban ecologists keenly interested in the effects of urban vegetation on the city and its residents through ecosystem services such as air/water purification and shade (Bowler et al., 2010; Tzoulas et al., 2007) and, in turn, the effects of the built environment on urban vegetation through habitat fragmentation, pollution, and green space management (Jansson, 2014; Sieghardt et al., 2005; Vega, 2020). Other processes through which humans influence urban plant ecology are by acting as dispersal agents (Ansong & Pickering, 2014; Bretzel et al., 2016; Bullock et al., 2018; von der Lippe et al., 2013), voluntarily or involuntarily, or through the creation of artificial habitat types such as lawns and gardens (Goddard et al., 2010; Van Rossum & Triest, 2012).

In this article, we discuss from an interdisciplinary perspective how urban botany can engage with wildflower promotion in cities through participatory action research. Our team consists of two ecologists and an artist/science communicator. We present a citizen science project that takes seriously both the challenge and opportunity of participating in an “ecology with” the city approach. In the presented project, volunteers placed trays of bare soil (devoid of seeds) on their balconies and in their gardens and cataloged what plants spontaneously arrived. Volunteers were at once researchers of and actors within the ecology that they study: the self-propagated dispersal of wildflowers in the city of Zurich. Our citizen science project was, at an ecological level, interested in the dispersal of wildflowers in the urban matrix; while at a transdisciplinary level, it aimed at bringing volunteers into a dialogue about wildflowers in their city, and the role of social connectivity and cooperation as a means to further ecological connectivity. At an aesthetic level, it is interested in noticing small details about plants in the city and cultivating a sense of wonder in the nature we experience in our everyday life.

We first develop an interdisciplinary theoretical perspective on nature and wildflowers in cities integrating perspectives from urban ecology, urban design, and environmental arts that underlie our project. Then we situate our project in the context of other citizen science and art-science projects. Based on these conceptual foundations, we present the methodology of our citizen science project so that it can be replicated elsewhere and discuss potentials and limitations of our approach.
2 | URBAN WILDERNESS: FROM WASTELANDS TO ROADSIDES

Our project brings together three key issues of urban ecology: wastelands, spontaneous vegetation, and ecological connectivity (Figure 1). As we will demonstrate each of these themes has fascinated urban ecologists, urban designers, and artists equally, but they have only occasionally been interlinked.

2.1 | Wastelands

While traditional “wilderness” is connected to mountains and forests, abandoned or unused lands are the urban manifestation of wilderness and, as such, a backbone of urban biodiversity and nature experience (Farley & Roberts, 2012; Kowarik, 2011a). Such areas are called urban wildscapes, wastelands, Brachen, post-industrial sites or vacant lots, amongst others (Anderson & Minor, 2017; Gandy & Jasper, 2020; Jorgensen & Keenan, 2011; Kowarik, 2017; Kwok, 2018; Rupprecht & Byrne, 2014). They represent the urban form of a hybrid or novel ecosystem, that is, an ecosystem that is shaped by past land use but is now abandoned and therefore in a process of secondary succession (Hobbs et al., 2014). In landscape architecture terms such as third landscape (Clément, 2014) or intermediate landscape (or intermediate nature; Desvigne, 2009) are used for such abandoned interstitial land. Urban wastelands have been a focus of urban botany early on (Lachmund, 2003). Through their often relatively large size and lack of use, they often harbor rare and relatively large-sized wild species, and they are wild in the sense that natural processes such as colonization, succession, and disturbance regimes are not (or only weakly) shaped through deliberate human intervention. Such urban wilderness areas have gained new importance with the growing phenomenon of shrinking cities on the one side and the spread of waste landscapes on the other (Berger, 2006).

One response of urbanism to the proliferation of abandoned urban sites is the restoration and transformation of these degraded, polluted or post-industrial urban areas into recreational and more formal urban green spaces. Landscape architecture projects such as Landscape Park Duisburg Nord by Latz + Partner in the Ruhr area of Germany (Weilacher, 2005), Natur-Park Südgelände in Berlin (Jorgensen & Keenan, 2011; Kowarik & Körner, 2005; Kowarik & Langer, 2005) or Fresh Kills Park on a former landfill site (Melosi, 2020) and High Line park on a disused railway track (Oudolf & Darke, 2017; both in New York City) reclaim abandoned places for recreational use but integrate ecological restoration and make reference to the history of the sites. Thus, these are designs that acknowledge the novel ecosystem character of the sites while integrating their previous existences as human-used landscapes. Concepts such as drosscapes (Berger, 2006), edgelands (Farley & Roberts, 2012), and especially terrain vague (Ignasi de Sola-Morales Rubio, 1995) have opened the eyes of urbanists and urban designers to the potential of forgotten and marginalized places. These “unintentional landscapes” are seen as places that are less organized and determined than most urban places and therefore allow for experimentation and provide space for marginalized actors in a city (Gandy, 2016; Gandy & Jasper, 2020). Through bottom-up processes, civil society has adopted such places for temporary uses such as urban gardening projects (Jorgensen & Keenan, 2011; Winter, 2015). Cultural scientists recognize urban spaces increasingly as places where humans live together with other non-human living beings, and urban wildlands are seen as places where such co-habitation might be possible (Hinchliffe et al., 2005).

FIGURE 1 Our three key themes of urban ecology: (a) Wastelands—these novel ecosystems are the urban manifestations of “wilderness” and key cultural representations of marginalized urban spaces; (b) Ecological connectivity—green networks benefit not only humans but can help improve gene flow for both plants and animals; (c) Spontaneous vegetation—simultaneously fascinating and problematic, these dynamic species are an important component of urban biodiversity
There is an important paradox inherent in any project that reclaims a \textit{terrain vague}: the very existence of these projects threatened the ambiguity of the area, the function as refugia for marginalized actors (and species) and might overwrite the traces of the past. These places thus pose the question of how to restore social and ecological capital in previously used and often degraded places by embracing current realities and without neglecting the past of the sites (Tsing, 2019). They require an approach that Marianne Krasny calls civic ecology (Krasny & Tidball, 2015). Examples of landscape architectural and artistic projects that embrace \textit{terrain vague}s as novel types of urban open spaces in local neighborhoods are for instance: Dalston Eastern Curve Garden by J&L Gibbons Landscape Architecture in London (Gibbons, 2007), \textit{Ceci n’est pas un parc} by Sofia Coutsoucos and Anna Milani in Milan (Coutsoucos & Milani, 2019), \textit{Plants Living} in Shanghai by Zheng Bo (Bo, 2013), or \textit{Time Landscape} (1965/1978-present) by the New York-based artist Alan Sonfist (Sonfist, 1978). More generally, there is a growing interest in the role of wastelands for urban residents. Research demonstrates the potentially positive perception of such spaces by the public and the ecosystem services that they can provide (Brun et al., 2018; Kowarik, 2017). Films such as \textit{Wild Plants} by Nicolas Humbert (2016) or \textit{Natura Urbana: The Brachen of Berlin} by Gandy (2017) engage the public with their multiple meanings. These spaces have a unique potential to provide for both urban nature and human creativity.

Wastelands have inspired our project in the sense that we were interested in the socioecological processes and patterns that emerge through the interplay of human uses of space, voluntary interventions in nature, and the wild responses of nature with the plant trays of our project taking the form of small "wastelands" within an intensively used urban landscapes. In other words, we were interested in how self-organized novel urban nature might emerge and be sustained in "empty" patches as the everyday by-product of what human actors do in their neighborhood, and how such emerging novel and wild nature patches are perceived.

2.2 | Spontaneous vegetation

A second theme that has interested urban ecology from the very beginning is spontaneous or ruderal vegetation, that is, the species that occur in frequently disturbed places such as roadsides, along railway tracks or in wastelands. Such spontaneous plants are sometimes called weeds, and, indeed, species occurring spontaneously in and at the edge of agricultural fields are also common in urban areas. Charles Darwin was intrigued enough by spontaneous vegetation that he conducted a "weed garden" experiment to document the germination of such species from the seed bank beneath a cleared section of his property (Darwin, 1887). Following on from this, early plant ecologists and vegetation scientists of the plant sociology tradition of the late 19th and early 20th century were among the founding fathers of both urban ecology and weedy/alien species biology (e.g., Kowarik & Pyšek, 2012; Naegeli & Thellung, 1905; Rikli, 1903; Thellung, 1912), and ruderal floras were also a main focus of later urban botany in Europe (Sukopp, 2008; Wittig, 2008).

Spontaneous urban vegetation has simultaneously been treated as a problematic issue, a potential opportunity, and an inspiration by ecologists, urban and garden designers, and environmental artists. Some consider weeds, especially when they are alien or grow amongst cultivated plants, as unwanted; others see them as metaphors of neglected nature, marginalized actors, spontaneous, and anarchistic elements in a designed and ordered environment and/or cultural and ecological system. Furthermore, the role of intentional (food, gardening, and fodder) and unintentional (from contamination, clothing, or vehicles) human-mediated dispersal of weeds has further complicated our relationship to these species (Ansong & Pickering, 2014; Clifford, 1959; Mack, 2001; von der Lippe et al., 2013). A political perspective on how we deal with spontaneous vegetation relates it to questions of inclusion, exclusion, and social justice (e.g., Stoetzer, 2018).

In the arts, an important early project recognizing the value of ruderal plants was the contribution \textit{What is Beyond Plants} is at One with Them of Lois Weinberger to documenta 10 in Kassel in 1997 (Cauteren et al., 2013). Weinberger thereafter continued to be interested in ruderal vegetation, for instance in his contribution to \textit{documenta} 14 in 2014 entitled \textit{Ruderal Society: Excavating a Garden}. In a current participatory project, Ellie Irons advocates for urban weeds in her Next Epoch Seed Library (Irons, 2015), while Uriel Orlow focuses in works including Learning from Artemisia and Beautiful But Dangerous on how alien species or species of value to marginalized groups (such as indigenous people) are stigmatized (Orlow, 2019). Alexandra Regan Toland highlights the ecosystem services of urban spontaneous vegetation in her project \textit{Dust Blooms} (Toland, 2017), and Lynn Cazabon documents spontaneous vegetation in different cities around the world on a georeferenced webpage in her ongoing project un\textit{cultivated} (Cazabon, 2015).

Civil society activism such as guerrilla gardening or urban foraging have discovered spontaneous vegetation as a way to express new relationships with urban places (Fischer & Kowarik, 2020; Reynolds, 2009). In landscape architecture and gardening, self-sown plants have also gained new recognition. For instance, in Gilles Clément’s \textit{Jardin des Étiquettes} (Clément, 2014) professional botanists and laymen visitors identify and name with tags spontaneously emerging plants in a public park built in a former military site in Saint Nazaire (France). This practice has expanded with similar public outreach projects such as \textit{Sauvages de ma rue} and more\textit{than}weeds, identifying roadside spontaneous vegetation with chalk (Leguil, 2020; Machon, 2011). There is a growing interest in planting design to design with the unintentional (Giesecke & Jacobs, 2015; Kühn, 2006), while in gardening the catchword \textit{blackbox gardening} captures an interest in using the dynamism of self-sown plants (Reif & Kreß, 2014). Such actions may contribute to positive shifts in public perception of unorderly urban vegetation (Weber et al., 2014), and there are specific design strategies that help to increase this acceptance of unorderly growth (Nassauer, 1995).
Urban ecologists have highlighted the relatively high general biodiversity of cities for decades (Kowarik, 1990; Pyšek, 1993; Walters, 1970); however, only recently there has been an increasing recognition of the specific biodiversity value of spontaneous vegetation in marginal, ruderal, and roadside habitats (Anderson & Minor, 2017; Bonthoux et al., 2014, 2019), which also include rare and endangered species (Kowarik, 2011b; Planchuelo et al., 2019). As urbanization and densification continue to reduce existing ruderal wastelands, small green spaces have been identified as a potential option to continue promoting wildflowers and associated faunas (Bonthoux et al., 2019; O’Sullivan et al., 2017; Omar et al., 2018; Vega, 2020).

Spontaneous vegetation was a key inspiration for our project as we were interested in the plant species that self-disperse and autonomously establish and maintain populations in the densely built urban matrix. We used our project to discuss with citizens, urban planners, horticulturalists, and nature conservationists the role that urban design and gardening practices can play in promoting this wild urban flora.

2.3 | Urban ecological connectivity

Connectivity and accessibility of urban green spaces are recognized to be important both for their value for urban residents (van der Valk & van Dijk, 2009; Ward Thompson & Travou, 2007) and urban biodiversity (LaPoint et al., 2015). By connecting urban green spaces the habitat limitations of the surrounding concrete matrix can be somewhat overcome allowing for more extensive spontaneous dispersal and colonization by plants (Schleicher et al., 2011). While this can be done at a large scale by connecting remnant natural areas with linear green corridors, it is more commonly seen at a smaller scale with the addition of smaller landscape elements which can act as stepping stones (Omar et al., 2019; Vergnes et al., 2012). These elements include greened roadsides and tram lines, street trees, green roofs and walls, and public and private gardens. As cities continue to densify, planners and researchers have looked at the scale at which these interventions have an effect and the benefits that even small green spaces may have (Carbó-Ramírez & Zuria, 2011; Strohbach et al., 2013; Vega, 2020).

Research has linked the presence of street level and rooftop green spaces to arthropod, bird, and mammal connectivity and diversity (Braaker et al., 2014; Fernández-Juricic & Jokimäki, 2001; Niedziałkowska et al., 2010; Planillo et al., 2021; Vergnes et al., 2012; Wenzel et al., 2019). By assisting pollinators, green stepping stones help improve gene flow among plant populations, including those in private gardens (Hennig & Ghazoul, 2012; O’Sullivan et al., 2017; Van Rossum & Triest, 2012). However, these benefits are not limited to non-human urban residents. Researchers have begun to link increased access to the often unequally distributed urban green space to livability, social cohesion, and health benefits in humans (Harvey & Aultman-Hall, 2016; Jennings & Bamkole, 2019; Lee & Maheswaran, 2011; World Health Organisation, 2016). With the concept of “leave no one behind” advocated for in the 2030 Agenda for Sustainable Development, 193 UN Member States called for the simultaneous connecting and expanding of urban green and socioeconomic networks to increase access to the city for both the neglected human and non-human residents (United Nations, 2015). Projects working on such interfaces between social and ecological connectivity exist at many scales: both Green Life in Bangalore (India; Enqvist et al., 2014) and BIOVEINS (Root-Bernstein, 2020) in Europe have utilized citizen science and volunteer networks to conserve urban connectivity through the involvement of non-academic experts.

Our project was in particular inspired by such interlinkages between ecological and social connectivity in cities. We aimed at engaging our volunteers with developing new visions for green cities in which social and ecological connectivity interplay: “The species that occur in the park down the street might also colonize your garden, and, conversely, what you do in your garden, in turn, effects the park as well as your neighbor’s”. As such, networks of even small private and public spaces can together help increase biodiversity in a neighborhood.

3 | ENGAGING WITH RESIDENTS: THE ROLE OF CITIZEN SCIENCE AND THE ARTS

There is a growing recognition that public and non-academic experts should play a greater role in science, as experts, data gatherers, and as representatives of the values and interests of diverse stakeholders (Dickinson et al., 2012; Silver Town, 2009). Citizen science and participatory art-science are two strategies of citizen engagement, education, and alternative knowledge production that amongst others emphasize the social and emotional aspects of knowledge production. Citizen science has been defined as a flexible concept that can be adapted and applied to diverse situations and disciplines (Robinson et al., 2018). Criteria include that: it involves volunteers in activities that generate new knowledge and have a scientific outcome; it benefits volunteers and scientists; participants receive feedback from the project and the results are published (Serrano-Sanz et al., 2014). There are citizen science projects in many disciplines including in urban ecology (Edmondson et al., 2019; Frigerio et al., 2018; Lander, 2019). One example in Switzerland is StadtNatur, a Swiss urban wildlife association that runs the citizen science project StadtWildTiere (stadtwildtiere.ch) where volunteers can upload their wildlife sightings to an interactive online map and participate in specific wildlife monitoring studies (Geiger et al., 2018), while StadtWildnis, a sister project of StadtWildTiere, allows volunteers to upload images of their favorite local urban green spaces. While there are many projects that focus on different animals, for example, butterflies and birds (Wei et al., 2016), there have also been recent pushes to help combat so-called “plant blindness” through plant-focused citizen science projects (Jose et al., 2019; Thomas, 2019) and art (Sanders, 2019) to connect more directly with the public.
Budburst, for example, originated from the Chicago Botanical Garden and works with volunteers to document the timing of plant life cycle events across the United States (Johnson, 2016).

Participatory art-science has its roots in conceptual art, and since the early 1990s, several discourses have emerged around collaborative, participatory, and socially engaged art. The increasing interest in contemporary collaborative art, described, respectively, as the “collaborative turn” (Billing et al. 2007), “social turn” (Bishop, 2012), or “ethical turn” (Dews, 2002) is characteristic of a current phase in the contemporary art practices that are concerned with activism, civic engagement, and interdisciplinary interactions with other fields such as urbanism, environmental activism, and social work (Enwezor, 2007; Kester, 2011). According to Kester (2011) two shifts are actually occurring: first, a growing interest in collaborative approaches in art; and second, a movement towards participatory process-based experience and away from a “textual” mode of production, where the artist presents an object or “text” to the viewer. Thereby the arts add a sensual and experiential dimension to scientific knowledge production and use (Mersch, 2015). Such artistic interventions also facilitate reflexivity not unlike philosophy. The art-science project Climate Garden 2085, for instance, seeks to offer the participating audience a way to develop an understanding of climate scenarios through physical perception. This public experiment provides an embodied experience of climate scenarios by recreating them in greenhouses where the temperature effect on plants can be observed (Schlaepfer-Miller & Dahinden, 2017). Visitors not only feel the climate scenarios with their bodies but participate by taking measurements of the plants’ CO₂ uptake and biomass. Somewhere between an aesthetic and a scientific experience, the Climate Garden 2085 is what the critic Meredith Miller would refer to as a “speculative cultural practice” providing a much needed “alternative to the abstracting tendencies of data-focused [ones]” (Miller, 2016). An example of a project that aimed at triggering reflexivity in ecology is Tree Stories 2018: a walking tour through Zurich with stops at different alien tree species where artists and ecologists that live in Zurich as foreigners engage with these equally foreign trees through their personal stories (Schlaepfer-Miller & Kueffer, 2018).

Strategies taken from the fields of culture and artistic creation can lead to more effective citizen science projects through their expertise in leveraging enthusiasm and curiosity (Bonhoure et al., 2019). The empty boxes of soil given to the participants of the Where Seeds Fall project can be seen as a blank canvas or frame for observation of the seeds drifting across their cityscape and thereby as a “speculative cultural practice”, to counter the “plant blindness” that afflicts modern society (Jose et al., 2019; Sanders, 2019; Wandersee & Schussler, 2001).

4 | THE CITIZEN SCIENCE PROJECT “WHERE SEEDS FALL”

Where Seeds Fall (Wo Samen fallen) was a citizen science project started in 2017 in which volunteers placed trays of bare soil in their gardens and balconies and documented which plants naturally arrived and grew (Figure 2). Inspired by the themes discussed above we hoped to give our volunteers first-hand experience in the reality of the dynamic “living” city. We wished to introduce them to the wild side of the city, whose vegetation is capable of self-dispersal and colonization and whose green spaces (including their gardens/balconies) can help to promote connectivity for both plants and people. We set up the project with several key expectations: (a) The types of plants that colonized participants’ trays would be primarily wind-dispersed ruderal species; (b) Location would matter—greater amounts of gardens and flowering green space in the surrounding of the tray would increase the number and diversity of plants that were found and—due to the nature of wind-dispersal—trays on the ground level would have a greater chance of species colonization than those on a balcony; (c) Following their participation in the project and the associated outreach events, participants would show a greater interest in and a more positive perception of spontaneous urban species as well as the kinds of green spaces which surround their gardens. We hoped to inspire questions such as: Why do we call certain species (unwanted) weeds? Why do we deliberately plant certain species? To what extent do we accept the wild life of urban species that is not planned and designed by us humans? What do these species need to live their life in our neighborhood?

At the start of the project, and occurring throughout its duration, we participated in several larger outreach events (such as local markets and university science fairs) and organized several of our own events (Figure 3). At the first few of these events we courted potential volunteers, explained the concepts of ecological connectivity and spontaneous vegetation dispersal, and distributed trays to participants. Later events enabled more creative engagement with spontaneous vegetation in the city through artistic practices or species identification of plants found in trays with the help of botanists, in both cases leading to discussions on urban greening, connectivity, and ecological design. The project began with a small pilot in Zurich, Switzerland during the summer of 2017 which was then followed by the full project in Zurich from April through October 2018. Thereafter, a spinoff of the project was conducted over the summer of 2019 in collaboration with the nature museum Naturama in the city of Aarau, Switzerland. A full protocol of the project’s methods is contained within the Supporting Information (Methods S1), however, what follows is a summary of the project with a focus only on the Zurich project.

We provided each of our participants with at least one plastic planter tray 39.5 × 29.5 × 9 cm in size (Figure S1). Trays were lightweight but durable enough to survive multiple field seasons and had holes in their undersides to allow for drainage. Trays were then filled with about 8 liters of seed-free potting soil, thus the only source of emerging plants were dispersing seeds from the surroundings. Trays were placed in private gardens, community gardens, balconies, and rooftops (Figure 2). For those placed on ground level, we advised our volunteers to select a flat open-air area protected from disturbances such as cats or lawn mowers, and we encouraged them to place chicken wire over the tops of the trays for further protection.
Several volunteers placed several trays in different locations on their property. If the tray was protected from rain by a roof, we recommended regular watering. However, due to the intensity of the summer heat, we eventually recommended that all trays be watered several times a week.

After setting up their trays, volunteers then registered them on our website. There, they could document and position their trays on an online map of the city. Volunteers were asked to take photographs at least once a month of their trays and upload them to document any plant growth (or lack-there-of). Volunteers were also encouraged to explore one another’s trays to see what was growing across the city. In doing so, participants could engage with a growing volunteer network.

At the end of the growing season, we hosted a final event for volunteers and encouraged all to bring in their trays (Figure 3a). Botanists then helped to identify the species found in the tray currently or seen in photographs. Species lists were compiled for every tray and location. We discussed how the project went for the participants and how it had matched their expectations. An important part of our discussions focused on what sort of concrete infrastructure and management changes they would like to see in their local urban green spaces in the future. At the conclusion of the Aarau project, a similar discussion was enhanced with photographic examples of formal and informal green spaces we provided. Thus, our rather specific citizen science project led to much broader discussions about civic engagement with the ecology of the city. Finally, we encouraged our volunteers to keep their trays into the next growing season and the authors personally brought several indoors following the winter to observe if any seeds from the previous season would sprout after dormancy (i.e., from the seed bank). Several species were found to sprout but all were species already identified before.

5 | WILDFLOWERS IN CITIES: STRENGTHENING ECOLOGICAL AND SOCIAL CONNECTIVITY ACROSS THE URBAN MATRIX

The project in Zurich attracted over 80 participants (plus another c. 40 participants in Aarau) with several having set up more than one tray (Figure 2; Figure S2). We achieved this number without investing in a major advertisement campaign and our limited capacity to support volunteers was already tested by this number. Uploading photos onto the website or emailing photos to us directly were the more attractive options to identify the plants in the trays, rather than sharing trays with us in person at our events. Participants greatly appreciated the ability to contribute without having to make the time investment of meeting in person.

The majority of the participants’ who shared their trays with us already had plants growing in the first season (28 participants). A surprising result for many participants was the high species diversity found in the trays and the high beta diversity between trays. Most trays had different species assemblages, with 37 species from 15 families, most native to Switzerland (Table S1). Although the expected ruderal species were the most prevalent (e.g., Taraxacum officinale and Sonchus spp.), we also found seedlings of different woody species (e.g., from Salix, Betula, Populus and Platanus) and several garden plants (e.g., Antirrhinum majus, Digitalis purpurea). As we expected, the majority of species (54%) were wind dispersed. Trays
placed in gardens had a higher number of species (2.9 ± 1.2 SD) on average than those placed on balconies (2.0 ± 1.0 SD), but the difference was not statistically significant. However, it is important to note that we believe many participants with no growth simply did not report their data which clearly affects the results.

Most participants expected to only see a small number of unappealing weeds colonize their trays, if any plants came at all. Many participants were thus positively surprised by the rapid emergence of plants and their diversity. As time went on, excited emails began to arrive detailing the growth of new plants. Participants took great care in photographing them and began to send us their guesses as to what species it may be. While we did not attempt to quantify it, discussions before and after the project suggest that volunteers may have expanded their perspective on the potential beauty of spontaneous vegetation. While some species were known and expected, many were impressed by the beautiful flowers which came and the small trees which took root. Some had, for the first time, a close look at the flowers and other features of plants that they so far knew only as weeds in their gardens which may be the first step toward a reappraisal of the category “weed”. Furthermore, we were able to go beyond addressing the “plant blindness” associated with overlooking certain plants but to incorporate the blindness associated with the underlying ecological processes that maintain them (plant population dynamics including seed dispersal). We intended to highlight ecological connectivity as also indicated by the name of the project. In contrast, we initially considered the need to use commercial soil bought from a garden center in order to avoid the confounding of our results through germination from the existing seed bank as only a methodological concession. While explaining the reason for this to participants, however, we realized that it also helped us to address another type of blindness: soil blindness. We explained the importance of soil seed banks for the persistence of plant populations and more generally the great importance of soils for the ecology of a city. Our encouragement that our volunteers keep their trays into the next growing season revealed that indeed, in some cases, a small seed bank had formed which then began a new cycle of germination.

We attempted to expand on these notions with our public events. In order to use art to connect our participants with the beauty of both intentional and unintentional urban vegetation, we organized a Japanese flower pressing event. Using both naturally occurring ruderal and purposefully sown city wildflowers from the surroundings, we placed flowers and leaves within a folded cotton cloth and gently hammered it to create a print (Figure 3b,c). Additionally, we presented the project to the public at several public science communication events organized by the ETH. At one, we combined our
project with the Zurich Herbarium and placed our work in the context of the flora and history of the city of Zurich (Figure 3d). At another, we invited visitors (especially children) to carefully study the structures of the seeds of local plants with hand lenses and under the microscopes. We discussed the adaptations of wind-dispersed seeds and gave them the material to make their own flying seeds from paper. At all of these events, we gained new volunteers and distributed trays to those interested. An exciting aspect of this communication was when our volunteers began to report seeing the same species nearby that they found in their trays. Participants began hypothesizing where "their" plants might come from: their neighbor or a recently sown green street. We believe that our project successfully helped them identify the connected network of urban nature.

This was enhanced by opportunities to explore the gallery of wildlife sightings and urban nature spaces provided by our integration with the larger citizen science network of StadtNatur (i.e., StadtWildnis and StadtWildTiere, see above). Additionally, our webpage allowed participants to readily view one another's trays in order to compare species and see if the closest trays harbored similar plants. Although for the spatial component of the project to work fully, a larger number of participants would have been needed, we believe that the interactive and spatial aspect of our project through the GIS web-interface was key in making the link between ecological connectivity and plant dispersal.

Although Where Seeds Fall was largely successful and exceeded our volunteer’s and our expectations, there were several lessons we learned for future endeavors. In science, a negative result is itself a result and provides interesting and useful data. However, when working with volunteers, no one wants to be that negative result. We explained the haphazard nature of seed dispersal and the reality of needing luck to have seeds land in their tray, emphasizing the inherent difficulty of urban plants to find suitable habitat within the hostile urban matrix. Nevertheless, there was a reduction in motivation for those whose trays remained bare, especially when they could see the successes of others through the website. This makes clear the need to include activities within a project that are guaranteed to provide value to participants—for instance, requesting volunteers to go out and photograph nearby spontaneous and promoted wildflowers which we could then help to identify. Finally, a key take-away for us was to dedicate significant time and personal resources to communicate with participants. The participants need active back and forth communication in order to be and feel included in the project and its results. They provide their time and effort not as a resource to the researcher, but as co-researchers themselves directly invested in the project. Such cooperative work necessarily entails greater time spent on communication which needs to be factored into any budgeting of resources.

**CONCLUSIONS**

Where Seeds Fall successfully ran over 2 years in the city of Zurich and 1 year in Aarau with more than 120 participants in total. A main outcome of the citizen science project for the plant sciences was that species diversity of spontaneously growing urban plants can be high even in very small vegetation patches (<1 m²), both per tray (alpha diversity) and especially between trays (beta diversity). This result was substantiated by a large-scale botanical survey run in parallel and in the same area that demonstrated that small vegetation patches are essential for maintaining urban wildflower biodiversity in densified cities (Vega, 2020). Our botanical data also corresponded well with established scientific knowledge; we confirmed for instance the importance of wind dispersal as a means of spontaneous vegetation colonization. Furthermore, our project demonstrated the potential of a citizen science project to trigger social learning. Despite generally neutral attitudes toward spontaneous vegetation initially, many participants quickly became connected to their trays and small plants that had arrived. This then led directly to a greater interest in where these plants came from, the forms of green connectivity that may have brought them there, and the surrounding green spaces, both promoted and "wild". Using art, such as Japanese flower prints, we helped to visualize the beauty of the spontaneous flowers which colonize the "wastelands" of the city and drew direct connections to the trays as small representations of such "terrain vague". Through these efforts, we believe the project successfully connected our volunteers to the themes we had envisioned.

We hope to see the project expanded to other cities. The low cost and simple nature of the tray and bare soil design along with the option to place trays on balconies for those without gardens (or possibly in a secluded spot in public space) allows it to be very accessible. We have already begun investigating potential expansions to working directly with schools to have several trays on their grounds with students keeping track of what arrives. The greatest resource for new ideas will likely come from the interested volunteers themselves when given the chance to answer the questions they are interested in through bottom up, community-driven citizen science (McQuillan, 2015).

The purpose of Where Seeds Fall was to connect the public with the living and dynamic plants that surround them in cities. Experience with and appreciation for self-sown wild plants is especially important as our cities densify and green spaces are lost. These plants both complement and are ecologically connected to urban nature reserves, biodiversity-friendly gardens, and public green spaces, while also providing habitats and resources to pollinators and other wildlife. However, only by closely linking these plants to the life of urban residents can we hope to successfully improve and expand urban green space and urban nature promotion (including the awareness to wisely integrate small urban vegetation patches such as tree discs or roadsides, or less often mowed patches in a lawn). Any such efforts without public interest and support are unlikely to succeed.

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AUTHOR CONTRIBUTIONS

KV wrote the paper together with CK and JS. The citizen science project was conceptualized by KV and CK with input from JS. All three authors took part in and presented at the public outreach events and volunteer meetings. JS and KV assisted the volunteers over email during the run of the project and guided them through their questions. KV collected and analyzed the results with input from CK. CK led the project.

ORCID
Kevin A. Vega https://orcid.org/0000-0003-0200-5561

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