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Grassroots Citizen Science in Urban Spontaneous Vegetation

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Abstract. This paper documents the research processes and outcomes of four collegial citizen-science projects about urban spontaneous vegetation. The artist- and designer-initiated collegial projects in this study use a variety of art, design, and natural history strategies to collect and analyze data, as well as to visualize and disseminate their findings. In addition to physical outcomes, the project leaders use legitimating narratives and discourses about urban ecosystem services to counter negative claims about urban spontaneous vegetation, which are often pejoratively labeled 'weeds.' A challenge and opportunity for projects focused on altering the normative bias against so-called "weeds" is mainstreaming a new nature ethic for this type of urban flora.

Key Words. Citizen Science; Ecological Knowledge; Ecosystem Services; Public Participation; Small Data; Urban Biodiversity; Urban Spontaneous Vegetation.

The collegial model of citizen science is often discussed as a historic mode of public participation in science research (Newman et al. 2012). A collegial citizen scientist, who may or may not be credentialed, initiates the study of natural phenomenon independent of a formal research institution (Shirk et al. 2012). So-called amateur researchers have been designing and executing natural history studies for centuries. The contributions of amateur experts have long been well-regarded in the fields of astronomy and ornithology, but with the professionalization of science, certain modes of public participation in science research were prioritized (Miller-Rushing 2012). Yet, the data recorded by naturalists continue to have resonance, especially in light of climate change. For example, David Thoreau's long-term seasonal records of budburst and bird migration in Concord, Massachusetts, U.S., are part of decades of observations that indicate that plants are responding more strongly than birds to warming temperatures (Miller-Rushing et al. 2012).

This paper explores the work of contemporary collegial citizen scientists studying 'weeds' in urbanized areas. This collegial citizen science is not a social movement, per se, but the narratives and practices employed by artists and landscape designers can be understood as a type of "collective-action frame" (Martin 2003) for 'weeds.' The framing project seeks to legitimize the existence of this flora in cities, and is attempting to accomplish this goal in two ways. One strategy is interrogative. Artists and landscape designers are questioning the cultural bias against 'weeds' and the refusal to acknowledge the public's role in co-producing actualized niches for these plants. The second strategy is "the invention of an ecological category" (Lachmund 2003) that enables the classifiers to define the parameters of the resource. Artists and landscape designers, as well as academic scientists, are creating new terminology for 'weeds' to normalize the flora, as well as to eliminate a pejorative response. In addition, artists and landscape designers are supporting their claims about 'weeds' with emerging science about the potential benefits of this urban flora and are experimenting with generating ecosystem services from weedy plant communities.

'Weeds' Versus Urban Spontaneous Vegetation

The classification 'weed' is a cultural term, not a botanical one (Del Tredici 2014). A plant's status can change over time; valued as an ornamental at one point in time but downgraded to a 'weed' at a later time. A classic example is *Ailanthus altissima* or Tree-of-Heaven. Introduced to the U.S. by William Hamilton in 1784, the tree "supplanted" classic trees, such as horsechestnuts (*Aesculus hippocastanum*) and lindens (*Tilia* spp.), to become a "metropolitan favorite," only to be "denounced and scorned as a vile, malodorous foreigner, perhaps even poisonous, sickening the vulnerable with its loathsome emanations" (Jonnes 2016). One of the primary limitations of the term 'weed' is that it is shorthand to mean an undesirable or unwanted plant; the term, however, obscures the particularities of place and time, as the evolution in the perception of *Ailanthus altissima* makes clear. Classifying a plant as a 'weed' does not provide any context-specific information. The public talks about weeding many different types of spaces, but not only are the actual plants different, but so are their effects. As Del Tredici (2014) notes, context matters in another way: it informs one's aesthetic preference such that a 'weed' in an urban vacant lot is a wildflower in a rural meadow in Europe. Furthermore, dismissing plants as 'weeds' obfuscates the fact that human forms of land management create the conditions under which such plants grow.

The spontaneous occurrence of vegetation on sites disturbed by natural-occurring phenomena, such as fires and windstorms, has been studied extensively in forest science. Spontaneous vegetation on the types of disturbed landscapes associated with urbanization began receiving serious scholarly scrutiny in German cities after World War II. In particular, studies of the vegetation colonizing rubble sites in post-war German cities were among the earliest strands of the field of urban ecology, and the publications produced by academics legitimized this urban flora (Lachmund 2003). However, the elevated status of this vegetation type in the post-war period in Germany did not occur simultaneously in the U.S. or elsewhere. The perception of urban spontaneous vegetation is changing in response to both non-institutional studies (collegial citizen science) and professionalized science (Lachmund 2003; Crimmins and Crimmins 2008; Burkholder 2012; Del Tredici 2014; Rega-Brodsky and Nilon 2016; Rega-Brodsky and Nilon 2017).

There have been academic studies of the levels of acceptance of floristic messiness in conventional landscapes (Nassauer 1995). However, the landscape types that are the focus of this study are not commonly understood as conventional landscapes. De-industrialized lots, abandoned residential parcels, un-stewarded street tree pits, and unmaintained pavements are landscapes where intentional, direct human management is absent (Del Tredici 2010a; Del Tredici 2014). The socio-ecological characteristics of these landscapes make the spontaneous vegetation growing there distinct from other forms of plant communities in cities and have catalyzed a different classification to indicate context-specificity of this urban flora (Lachmund 2003; Burkholder 2012; Del Tredici 2014). The new terminology exists in two forms: 1) spontaneous urban vegetation, and 2) urban spontaneous vegetation. (Spontaneous vegetation is a variant of the latter and is assumed to be synonymous with non-native plants that spontaneously occur in cities.) Urban spontaneous vegetation will be used in this paper. Urban refers to the fact that this palette of plants grows in urbanized environments. They establish and thrive in actualized niches created by human manipulation of the land. The spontaneous vegetation segment of the new terminology performs double work. It refers to the fact that these landscapes are not explicitly tended by humans in the same way that gardens and parks are, but also refers to typical plant behavior. Like their desirable counterparts, the establishment of 'weeds' is part of a natural process of succession in the same way that pioneer species regenerate after a forest fire, or when black birch (*Betula lenta*) takes advantage of sun access in a hemlock (*Conium* spp.) canopy (Karel et al. 2001; Swanson et al. 2010).

Models of Public Participation in Scientific Research

Public participation in scientific research (PPSR) is an umbrella term for scientific projects in which the public participates to varying degrees. That is, models of PPSR are defined by the degree of public participation in the research process (Shirk et

al. 2012). The five models of PPSR are contractual, contributory, collaborative, co-created, and collegial. The contributory approach, where the public is asked to collect and submit data to a research project developed by a professional scientist/scientist associated with an institution, is the model that best describes most citizen-science projects (Shirk et al. 2012). The collegial model is at the end of the PPSR spectrum where there is little to no distinction between participant and researcher, or "expert amateurs arguably adopt the traditional role of scientist-as-knowledge-producer" (Shirk et al. 2012). The authors go on to note that although this model is "often overlooked or highly critiqued, committed amateurs can make critical contributions that may not otherwise transpire owing to a lack of resources, time, skills, or inclinations in the professional scientific community" (Shirk et al. 2012).

Despite the admitted contemporary value of this form of scientific inquiry, not much has been written about collegial PPSR, especially contemporaneously and in an urban context. An exception is Silva and Krasny (2014), who analyzed the monitoring and evaluation strategies employed by civic-ecology organizations in New York City, New York, U.S. The authors found that of the eight nonprofits they studied, five used a collegial form of monitoring protocol, meaning that this subset of organizations relied on lay practitioners and not professional scientists to monitor the outcomes of their projects. The collegial approach is not limited to the evaluation phase of a project. Each of the five elements of a PPSR project (i.e., inputs, activities, outputs, outcomes, and impacts), as defined by Shirk et al. (2012), can be conducted in a collegial manner. PPSR projects studying organismal biota tend to skew toward birds, butterflies, and charismatic flora. There are several citizen-science projects that solicit observations of invasive plants (which is sometimes conflated with 'weeds') for the purposes of eradication management.

Urban Spontaneous Vegetation

Most of the modern studies of urban ecology, at least in the U.S., have skewed toward native remnants and designed landscapes, but this is changing. The realization that spontaneous, disturbance-adapted vegetation is a perennial feature of urban ecosystems, or the "flora of the future" (Del Tredici 2014), has instigated research of its potential, ecological and otherwise, and spurred advocacy to design with and to preserve this urban flora. This weedy floristic future is neither homogenous nor is it predominantly introduced, at least among woody angiosperms (Del Tredici 2010a) or invasive. Native plant diversity can be high in cities, while exotic species can be locally abundant, neither "broadly nor invasively distributed" (Pickett et al. 2008). Although many cities share some exotic species, floral (and avian) species richness has not been homogenized globally (Aronson et al. 2014). Spontaneous plants, native and not, are one of the defining characteristics of urbanized landscapes, including vacant lots (Burkholder 2012; Cervelli et al. 2013; Del Tredici 2014), and biodiversity studies of this habitat type reveal some benefits of spontaneous vegetation. In two studies, Rega-Brodsky and Nilon (2016; 2017) showed that vacant lots provide beneficial habitat for songbirds. Vacant lots vary in their successional stage; avian species composition and behavior are associated with different types of vegetative structure. For example, bird species abundance and richness were highest on vacant lots with greater tree cover that were in close proximity, within 100 m, to forested areas (Rega-Brodsky and Nilon 2016). The authors pointed out that protecting tree canopy on vacant lots is an effective way to expand bird habitat. In a second paper, shrub density was the primary factor in nesting success for native generalist species, such as American robins, gray catbirds, and northern cardinals (Rega-Brodsky and Nilon 2017).

From a structural perspective, sites of urban spontaneous vegetation that are composed of grasses, herbaceous annuals and perennials, shrubs, and light tree cover mimic that of early successional forest communities and thus provide similar functions. Early successional forest ecosystems have been shown to have biological and food web diversity (Swanson et al. 2010). In a comparative study of sites of urban spontaneous vegetation, remnant forest patches, and lawn areas in Halifax, Nova Scotia, Canada, Robinson and Lundholm (2012) found that areas of spontaneous vegetation had higher habitat potential for plant and invertebrate diversity. Measurements of leaf-area index across sites showed that parcels

of spontaneous grasses and herbaceous vegetation have higher pollutant-filtration potential than that of mown lawn areas, though less than that of forest patches (Robinson and Lundholm 2012). If tree cover is used to quantify ecosystem services (e.g., carbon sequestration, pollution removal, and energy-use avoidance), then sites with greater tree cover, what Kim et al. (2015) categorize as "unattended sites with vegetation," are ranked higher than other types of vacant land, including derelict, natural (wetlands, hillsides, floodplains), transportation corridors, and post-industrial sites. But communities of spontaneous vegetation with lesser tree cover can also provide regulating ecosystem services. Vacant lots that have an "open, flat, [and] highly-vegetated" structure can reduce ambient air temperatures (Burkholder 2012). Various urban spontaneous vegetation habitats provide specific and overlapping services and can be managed as a portfolio to optimize benefits across a city.

MATERIALS & METHODS

This paper reports on four grassroots projects producing ecological knowledge about urban spontaneous vegetation. To better understand the design and outcomes of these projects, the following interview method was used. Semi-structured interviews lasting between 45 and 75 minutes were conducted in person and by phone. The interview guide was developed using the five elements of PPSR (Shirk et al. 2012) (Table 1). Each interview was audio recorded, with verbal permission, and notes were taken during each conversation. Interview audio recordings were initially transcribed verbatim, but have been lightly edited for clarity and readability in this paper. When setting up the interviews, participants were told that the interviews were for the purposes of submitting a manuscript to a special issue of this journal. Participants were also informed via email correspondence when an earlier version of this paper was conditionally accepted by this journal. Results from analysis of interview transcripts and other data sources are discussed at the project level. When an interview excerpt is presented outside specific discussion of a project, a code attributing the quote to a respondent is used (e.g., R1).

In addition to interview transcripts, other data were derived from organizational presentations; archival materials, such as organizational websites, print publications, and social media; articles written about the organizations; and participant observation (processing and packaging seeds; presenting at a salon discussion about grassroots production of ecological knowledge). The data for this project was primarily textual. For analysis, textual evidence for each category of the PPSR framework (Shirk et al. 2012) was assembled in a matrix and compared across projects.

Case Studies

The project names were Common Studio's Global Urbanium ("Common Studio"), Gewildgroei, Next Epoch Seed Library (NESL), and Spontaneous Urban Plants (SUP) (Table 2). Common Studio is a design firm. The two-person practice is based in Los Angeles, California, U.S., with global projects. For this study, the firm's Global Urbarium project was the primary focus. Global Urbarium consists of studies of urban spontaneous vegetation in the cities of Bangalore, India; Los Angeles, U.S.; and Rome, Italy. The term "urbarium" is a play on herbarium. Common Studio creates physical herbaria of urban spontaneous vegetation, and showcases photographs of the analog products via Instagram, a content-sharing website and application. Common

Table 1. Summary of interview guide.

PPSR element	Theme	Example question
Inputs	Project objective	What questions or issues are you trying to answer or address?
Activities	Project infrastructure	Why did you choose the model you did?
Outputs	Observations	What types of data are collected?
Outcomes	Skills, abilities, and knowledge	What are your metrics of success?
Impacts	Long-term change	What impacts are you hoping to see?

Studio has also created crowd-sourced versions of its multi-city project on iNaturalist. Users of the biodiversity observation app can add observations to the Bangalore, Los Angeles, and Rome projects.

Gewildgroei is also a two-person design collaborative. Its founders coined the term *gewildgroei*, which they translate as "wanted weeds." In Dutch, *gewild* means "wanted," and *wildgroei* means "growing in the wild." The designers use social media (Instagram) to portray the beauty of these plants. Gewildgroei also uses hashtags (#gewildgroei and #wantedweeds) to crowd-source observations of urban spontaneous vegetation. They have designed a planter, which when installed around spontaneous vegetation, conveys cues of purposeful planting.

NESL was founded in 2015 to collect and preserve the seeds of weedy species growing in urbanized areas. The seed bank has been housed in several forms and scales since its inception. For example, a small slide-top box of seed packages was presented at the Libraries and Archives in the Anthropocene Colloquium in May 2017. In contrast, NESL headquarters was hosted at Wave Hill in Winter 2017 and included an extensive seed catalog, a seed sorting and processing station, and a seed propagation lab. NESL has expanded its work to include a speaker series, and is developing open-access curricula.

SUP is a project of Future Green Studio, a Brooklyn, New York-based landscape design practice. SUP is a research project that has taken several forms. It launched publicly in 2011 as an essay, defining the term "spontaneous urban plants" and profiling some of the more common plants in the flora. It exists as a crowd-sourced, geotagged database on Instagram via the hashtag #spontaneousurbanplants. It is also a book of the same name, published in 2016. The book is both a traditional field guide as well as an index to the ecosystem services provided by this urban flora. Among Future Green Studio's portfolio are projects that preserved preexisting, spontaneously growing plants.

Limitations

This exploratory study has a number of limitations. The overall methodology is a case study approach, so the goal is not "statistical generalization" (Yin 2009). However, while the four projects in this first phase might represent a "literal replication" (Yin 2009), potential rival explanations would have to be explored through "theoretical replication" (Yin 2009) that would require additional cases. In addition, there is a geographical bias in the pool of projects interviewed. Two of the four projects are based in the United States. Furthermore, although this study finds considerable overlap in the viewpoints expressed by the study participants, it was not designed to compare cultural perceptions of urban spontaneous vegetation. Finally, this current study only focuses on grassroots investigations of urban spontaneous vegetation, and therefore does not offer a complete analysis of the social-ecological workings of this type of urban flora.

RESULTS

The PPSR framework (Shirk et al. 2012) was used to analyze the projects in this study. The five major elements of PPSR were used to organize this section.

Table 2. Case study projects—name, mission, and location.

Project name	Project mission	Location
Common Studio's Global Urbarium (Common Studio)	To celebrate urban spontaneous vegetation. To challenge negative stereotypes of weeds.	Los Angeles (main office)
Gewildgroei	To change people's perceptions of weeds or spontaneous vegetation.	Netherlands
Next Epoch Seed Library (NESL)	To collect and preserve seeds of weedy species adapted to the Anthropocene.	NY-NJ Metro Area
Spontaneous Urban Plants (SUP)	To investigate the ecological role of weeds in the urban ecosystem.	New York City

Inputs

Scientific interests and public interests are the two subcategories of interests or inputs identified by Shirk et al. (2012). Given the collegial nature of the projects explored in this study, there were not distinct scientific and public communities, as one would find in other forms of citizen science. The project designers brought both science and public interests to bear in formulating their research questions (Table 3).

The unique nature of the collegial model, where the researcher is a public participant, makes it challenging to parse motivations. There is extensive literature on the motivations of environmental volunteers (Caissie and Halpenny 2003; Evans et al. 2005; Measham and Barnett 2008; Shirk et al. 2012), but the projects in the current study are not traditional environmental volunteer programs. Likewise, there is literature about the motivations of scientists participating in citizen science projects (Rotman et al. 2012; Shirk et al. 2012), but again, although the projects in this study have contributory components, they are qualitatively different than typical contributory or collaborative citizen-science projects. However, the study participants did express similar motivations to what has been found in studies of conservation volunteers and scientists.

One motivation expressed by the participants was learning about urban spontaneous vegetation: "I know all these other landscape plants . . . and I know a lot native plants when I walk through the forest, how come I don't know the name of any of these [plants] that I see every single day?" (R3). One participant went further, asking, "Why is this [vegetation] different and why is no one looking into it?" (R5). The latter question speaks to another motivation driving the projects in this study—knowledge production. There are two aspects to generating knowledge about urban spontaneous vegetation. One is to create information and to disseminate it. The second aspect of knowledge generation is to bring the study of urban spontaneous vegetation on par with studies of other urban flora. One respondent noted that, "People are shocked and appalled that [spontaneous vegetation] could be considered very serious forms, worthy of scrutiny, worthy of ecological conversation" (R4).

One goal of knowledge production is learning. Study participants were not only motivated by personal learning goals, but were also motivated by social learning. Social learning encapsulates learning through work done by others as well as learning by doing work with others

Table 3. Quotations from interviews, depicting the research question addressed by the project.

Interview question	Excerpt
If you had to formalize a question of your collection, what would the question be?	"The general question that we are interested in asking with the urbarium [sic] is what's growing in our cities and why. There are so many different factors that have influenced the emergence and development of these plants…. There's something really interesting about adaptation to the urban abuses that exist whether it's very hot, very dry, very salty, all of these really extreme conditions that characterize the urban environment. These plants are thriving without any human intervention and under these crazy extreme conditions. It's very interesting to think about them as a snapshot of a new type of ecology for the twenty-first and twenty-second century."
What was the motivation for the project?	"There is one category of green which nobody pays for or actually uses which is spontaneous vegetation or weeds . . . . Why do we not use this? Why is this a different category? Why is nobody looking into this? . . . It's actually what you could call urban nature, and why is this overlooked and can we at least see an opportunity in this? Can it have a different role in the city? Can it have a role in the city? And what would this role be?"
Can you go deeper into the issues you wanted to address or solve or communicate with the project?	"Trying to trouble those attitudes of 'weeds' being the same as trash. If the same as trash, then we want to cut it down, get rid of it, but what are we losing when we do that? And how might we start to shift that understanding by going a little deeper into what exactly is living there and starting to be really specific about context rather than 'Oh, it's all green, it's all weeds. It's all non-native, therefore it's all trash.' [Instead we could consider that] sometimes these plants might be classified as invasive, sometimes they might be problematic, but in a huge other variety of situations they might be positive. Let's…start understanding those situations. . . ."
How would you frame your hypothesis?	"I would argue that spontaneous urban plants dial right into that matrix of patchwork spaces throughout the city which are contributing kind of performatively to the way the city is functioning, and often, what makes the plants themselves really interesting is that they are existing on the streets which are these natural connective threads that run through the city that connects these dislocated patches…so you can begin to see a system of patches, threads that begin to emerge and create corridors, and moments for wildlife to come in or for ecosystem services to function."

(Krasny and Tidball 2009). Commenting on the former mode, one participant said, "We are . . . working with a network of folks so we can be on the ground in more places . . . They can tell us, 'Oh yeah, we also saw this particular plant growing in the median on a local highway'" (R2). In terms of acquiring knowledge through interaction, one participant spoke about the acquisition of local ecological knowledge by working with the project's co-leader: "When I started working with plants, I didn't really know [them] . . . But then we started working together and I am starting to learn different species . . . and it's really great . . . You talk about seeing a mass of green but you know a little bit and then you can see more" (R1).

Monitoring is another motivation that emerged in the interviews. Three of the projects are actively tracking occurrence of urban spontaneous vegetation via social media, and two of these three projects are using geotags in this work. One participant noted, "It's been pretty fun to see what people are taking pictures of, what draws people's eyes, and there've been some really cool conclusions that we've been able to draw" (R3).

Activities & Outputs

Activities in PPSR design refer to project infrastructure and implementation, while outputs are the data and the process of creating the data (Shirk et al. 2012). These two elements of PPSR design overlap significantly, and so for the purposes of this paper, the two categories have been combined.

All four groups collected data about weedy species in urbanized settings, but the approaches to making the data varied. NESL's seed library is organized into packets by species, date, collector, and location, and a collection of packets is presented in different formats and sizes depending on the forum. The design of each component of the library was influenced by the concept of "taking something unwanted and elevating [it] through art practice and getting people to look at it." The Feral Landscape Typologies map of landscapes from which the seeds in the library were collected also informs the project. In addition to literal observations in the form of seeds, seed collection, and plant appreciation experiences (e.g., walks to explore the dispersal mechanisms of weedy seeds) are also among NESL's outputs. These experiences are also part of the project's infrastructure and implementation.

SUP used three sampling approaches to data collection. The first one was to literally highlight in yellow spray paint the urban spontaneous vegetation growing on the lot on which its former studio was located, as well as the surrounding sidewalks. Whole plants were photographed alongside their leaf or flower detail against white paper, mimicking specimen sheets in an herbarium. A second sampling method was to walk transects in different boroughs and use the Instagram account @spontaneousurbanplants to spatialize observed vegetation. A third method was to curate photographs of spontaneous plants found on wanderings. Photographs of spontaneous vegetation were also crowdsourced globally with the hashtag, #spontaneousurbanplants. The first version of the SUP digital plant map was automatically populated by images first uploaded to Instagram.

Common Studio also uses Instragram (@thecommonstudio) to catalogue its collection of urban spontaneous growth. Plant specimens are prepared using the formal herbarium methodology, scanned at high resolution, and then uploaded to the social-media app. Each image includes a graphic indicator of position along two axes: native-exotic classification and whether the plant was growing isolated or as an agglomeration. Common Studio complements the photographic record with the citizen science geolocating tool, iNaturalist. The design firm has three active, open iNaturalist pages representing the locations of its plant observations: Weeds in La La Land (Los Angeles), The Roman Urbarium (Rome), and Urban Meadows of Bangalore; all three projects are part of the larger Global Urbarium.

Gewildgroei began as an art project for one of its founders who walked transects across Eindhoven, Netherlands, was struck by the amount of spontaneous vegetation, and began to ask what made it different and why no one was exploring it. More than simply looking at spontaneous vegetation, Gewildgroei, like the other three projects, evolved to change people's perceptions about urban wild plants; this has driven the project manager's own perception about data. When asked about its data collection strategy, Gewildgroei responded that it uses Instagram to send data, not to collect data: "Normally you would walk past these plants and

not notice them, but if you present them on Instagram it changes people's perception of these plants. That's our idea." Gewildgroei argued that they do not collect data, based on a particular definition of data. The conversation revealed that they defined data as something to be used to make a map, which they have not done yet. In this same thread, Gewildgroei referred to "informal data," and provided the following example. They noticed in the Instagram #gewildgroei feed that back alleys "are actually very interesting locations where these plants, because of circumstances—back alleys are not weeded by the municipality—get the chance to grow very well" and developed a nature scavenger hunt for this land-use type. The data set of 'weeds' and their habitats in the Netherlands and beyond is growing as people increasingly use the #gewildgroei hashtag.

Outcomes

There are three categories of outcomes in PPSR projects: science, individual, and social-ecological systems (Shirk et al. 2012). A project does not need to produce all three outcomes, and a project might be driven by a particular outcome (Shirk et al. 2012). None of the projects fulfilled each category of outcomes. Also, there was variation among projects in terms of which category had more contributing factors.

Science

The projects included in this study were neither large-scale data projects nor were they the typical contributory citizen-science projects, so the traditional metrics of science outcomes, such as numerous peer-reviewed publications, are not necessarily applicable. Some of the elements listed under Outputs are also appropriate to mention here: NESL has developed a seed bank of weedy species with specimens collected in New York City and northern New Jersey and SUP maintains a digital map of spontaneous vegetation locations in New York City. In addition, urban ecologists want to collaborate with NESL because of its long-term ecological data on vacant lots, including seasonal data on plants growing across 30 sites.

SUP's book, *Spontaneous Urban Plants: Weeds in NYC*, with a foreword by Timon McPhearson, Ph.D., is a field guide to the natural history and ecosystem services of weedy plants. Both NESL and SUP have presented their work in academic and professional forums. Common Studio is operationalizing their evolving data set of urban spontaneous vegetation into research projects, most recently in Bangalore (see Social-Ecological Systems).

Gewildgroei is explicit about its non-scientific approach: "We are designers, we are used to creative processes. A scientist works in a different way." However, Gewildgroei would like to collaborate with scientists who are experts in "formalizing information" so that they can use that information as a "starting point again or input." This feedback loop between outcomes and inputs is part of the evolution of PPSR projects (Shirk et al. 2012).

Individual

All four projects spoke about learning as an outcome of their work. Ecoliteracy, specifically, learning how to identify spontaneous urban plants, was mentioned by three of the four projects. This was the case with participants who had little to no previous botanical knowledge and those with professional levels of plant knowledge. One participant wondered about the lack of knowledge about an entire class of plants. This participant's approach to learning was one of "reconditioning . . . to look more closely at our surroundings." (R3) On the other end of the spectrum was a participant who had acquired knowledge by working with a more experienced partner: "I've heard you [partner] talk about mustard garlic before but it not record in my brain but then on that last walk, I think it's finally recorded in my brain" (R1).

Social-Ecological Systems

While science and individual outcomes center on knowledge and skills, respectively, social-ecological outcomes are more tangible and relational. In the social-ecological systems concept, humans are acknowledged as a central, reciprocal component to ecosystem dynamics (Grimm et al. 2000). One type of social-ecological outcome is innovation in resource management, and Common Studio's Bangalore urban watershed work is an example. The design firm is collaborating with two local organizations on a stormwater management system. Bangalore's watershed is a system of cascading lakes, interconnected by historic channels known as *nallahs*. Expansive urbanization and "explosive population growth" have transformed the function of the

channels; they have become default combined sewer-stormwater systems. Common Studio's live demonstration will test the utility of spontaneous aquatic vegetation to remediate and decontaminate water. Ecological performance, defined by improvements in water quality, will be monitored longitudinally.

Similarly, Gewildgroei developed a resource management technology. The catalyst for the Living Pavement tile system was the idea that "context determines if a plant is seen as a weed." Each tile is 300 mm × 300 mm × 60 mm, with a central opening varying in shape, from a waxing crescent moon to a full moon. Living Pavement, the Gewildgroei participant also noted, is a literal and figurative framing system. The existence of the out-of-place plant(s) is validated through a cultural marker of belonging. In their words, the plant becomes an "un-weed." Local stakeholders are involved in this project through the purchase and installation of the tiles. The presence of the tiles in public rights-of-way is having an impact on municipal management of public space. Gewildgroei recounted that the tiles pose a challenge to the operational norms of municipalities, which have separate departments for managing greenspace and gray infrastructure. The tile system, which integrates greenspace into pavement, runs counter to the way the municipal government currently manages the public realm. The uncertainty produced by the tiles could lead to radical approaches to designing public space. Gewildgroei observed, "Designers have the tendency to look at things from a distance and ask why do we organize things in this manner, is it possible to do [things] in a different way." This action outcome of Gewildgroei underscores the strong effect human perception has on decisions about ecological patterns and processes (Grimm et al. 2000).

The articulation of a new understanding of 'weeds' and their role in urban ecology is an SES outcome. One way in which the study participants have reframed 'weeds' is by developing a new ecological category for the flora. In published papers, the following variations have been used: spontaneous urban vegetation (e.g.,: Del Tredici 2010b), urban spontaneous vegetation (e.g., Robinson and Lundholm 2012), and spontaneous vegetation (e.g., Kühn 2006).

Participants in this study used *'weeds'* and *spontaneous urban plants* sometimes interchangeably in the interviews. When probed, in follow-ups to the original interviews, about which term they preferred to use—*'weeds'* versus *urban spontaneous plants*—two respondents used the term *spontaneous urban plants*. A third respondent used the term *spontaneous vegetation*. As to their actual preferences, one participant did not prefer either term noting that *'weeds'* is "a judgment" and *spontaneous vegetation* is "neutral/factual." (R5) A different participant reported that *'weeds'* and "weediness" showcased the "complexity and contradiction" of current and emergent ecosystems. (R2) Another respondent expressed a strong preference for using *spontaneous urban vegetation* to "suspend typical prejudices about their inevitable role" and to enable "re-appraisal" of their "latent virtues." (R4).

Finally, engagement in policy processes is another systems outcome identified by Shirk et al. (2012). Gewildgroei has changed its strategy from directly lobbying municipalities to building "a movement" among residents who are better placed to pressure government to incorporate "wanted wild growing" plants into biodiversity policy. NESL has pooled several projects including the seed bank into a conceptual advocacy organization called the Feral Landscape Lobby. The lobby is envisioned as "a tool" to show alternate futures: "It goes beyond just an individual plant and starts getting to how cities work, [to how] governments and private citizens and communities, how they view, how we view greenspace and the value of it."

Impacts

It is rare that a project measures its impacts at the 10-year mark or beyond (Shirk et al. 2012). Although none of the projects interviewed have been in existence for 10 years, participants were asked about the impacts they hope to see from their work. The impacts fall into three categories: eco-literacy and sense of place, design advocacy, and institutionalization and collaboration. These categories mirror elements of individual and social-ecological systems outcomes. In fact, Shirk et al. (2012) argued that successful impacts are often a combination of outcomes across science, individual, and social-ecological systems.

The long-term outcome identified by NESL rests in improving urban ecological literacy and sense of place. At its core, the seed bank is as an art project. People can engage with the seeds and seed pack-

ets as visual objects. However, the founders desire more than a poetic experience of the seeds. In *Next Epoch Seed Library*, a documentary film by Candace Thompson, the project's ultimate impact would be "to not have a seed library like this have to be an art project." NESL also exists to promote awareness that these seeds were harvested from local landscapes and that they can generate plants communities that make positive contributions to city ecology.

The impacts foreseen by both SUP and Common Studio are design-oriented. In the case of SUP, the necessity to design with spontaneous urban plants will become clear when the plants being specified now become unfit climatically. SUP feels that the issue is partly one of demand. The landscape and nursery trade industry will grow and stock these plants if designers ask for them. Common Studio's approach is to create intervention units to demonstrate viability and then scale up.

The initial response from Gewildgroei was that they had not considered impacts because they are "reacting to the moment." However, the individual outcomes they expanded on had read like impact statements. For example, they are focusing on building a constituency to have more leverage in the policy arena. They are building institutional capacity in other ways. Gewildgroei has incorporated as a nonprofit with a board. They would like to build "a broader movement" with projects in other European cities and in the U.S.

DISCUSSION

A total of four grassroots ecological knowledge projects were interviewed for this study. The results show that the project designers are engaged in the collegial model of PPSR. Research on urban spontaneous vegetation is being conducted independently of institutionalized science, but this does not preclude expanding the pool of stakeholders to include affiliated scientists, as is the case with NESL. Urban ecologists have approached NESL to share their vacant-lot data. This study has shown that collegial PPSR is neither a historic mode of public involvement in scientific research, nor is it largely limited to fields of science such as astronomy and ornithology. However, like pre-nineteenth century expert-amateurs in astronomy and ornithology, contemporary collegial researchers are pursuing questions motivated by nearby environmental phenomena (Miller-Rushing et al. 2012). In addition, contemporary collegial researchers could be considered to be on the frontline of studies of urban spontaneous vegetation.

The projects examined in this study are creating ecological knowledge for personal and community understanding of urban spontaneous vegetation. Is this type of knowledge actionable? Scholarly research suggests that knowledge can inspire action. In a study of individual outcomes for volunteers in a contributory citizen-science project in India, Johnson et al. (2014) observed a three-step process whereby a highly motivated individual seeks out a volunteer opportunity, develops expertise, engages in advocacy, and assumes the role of an "environmental opinion leader." Environmental opinion leaders gain issue-specific experience and expertise, their perceived levels of confidence in their expertise also increases, and this change empowers them to disseminate environmental information (Johnson et al. 2014) identify three pathways of environmental communication: bonding communication with peers, bridging communication, and committing to environmental work full-time. The project designers presented in this study have created their own opportunities to invest in the study of an environmental issue of concern and to communicate environmental information. The larger question of whether collegial production of ecological knowledge can lead to transformative change at least as it pertains to urban spontaneous vegetation remains unanswered. In the short and mid-term, the projects are engaged in on-the-ground installations inspired by the knowledge they are producing through their research. For example, Common Studio is testing stormwater management systems using aquatic urban spontaneous vegetation in Bangalore.

The creation and management of the "big data" sets associated with contributory citizen-science projects has received significant attention in the literature (Dickinson et al. 2010; Dickinson and Bonney 2012; Newman et al. 2012). Collegial and "small data" PPSR projects have received less attention. Silva and Krasny (2014) examined the analytical protocols used by a range of small-scale PPSR projects in New York City, and they found that practitioners used tools and methods that ranged in terms of cost and complexity of implementation. The participants in the current study relied on heav-

ily on digital photography (some of it smartphone-based) and geolocation-enabled social media (i.e., Instagram) and citizen science apps (i.e., iNaturalist). These technologies are relatively low-cost and easy to use. From a traditionalist science perspective, the aggregation of spatial data about plant species and communities is a major contribution of these collegial citizen-science projects. Not only does the iNaturalist app provide geolocation information, it is also a platform for crowdsourcing biotic observations. Common Studio has three active projects on the platform, and each project is set to open membership and submission. These open-access settings provide opportunities to learn, to gain expertise, and to develop a community of practice that is initially based on observation but could evolve into in situ resource management (Krasny and Tidball 2009). The open-access settings also mean that professional scientists can mine the data for basic and applied ecology research. Instagram is also used to collect and to analyze data. Photographs of actual spontaneous plants are data, as are other information captured in and through the act of taking the image, such as geographic location, habitat, and growth pattern. One type of analysis that is conducted via Instagram is indexing. Using Instagram also enables crowdsourcing and communication of environmental information.

Time-lapse digital photography has been used to collect and analyze plant phenological data (Crimmins and Crimmins 2008). One of the cofounders of NESL used the photo time series (not time-lapsed) method to study the vegetative life cycle of several lots in Bushwick, Brooklyn. This photographic method was the basis for a typology of "feral landscapes." The uses of these particular methods highlight that the cases presented in this paper are engaged in a hybrid form of environmental monitoring; plant monitoring and habitat tracking are occurring.

Finally, there are outstanding questions about grassroots weedy ecology projects. First, the predominant focus is on plants, and while microhabitats are being classified, there is little to no consideration of the fungi, fauna, and microorganisms that inhabit spaces of 'weeds.' Second, the valorization of these spaces has the potential to obfuscate the root causes of the existence of these spaces. Collegial investigators should be mindful that even an ecological vision with its innumerably quantified ecological benefits could also produce disservices. Third, and more philosophically, is there a "nature ethic" (Proctor 1996) that could positively incorporate urban spontaneous vegetation? 'Weeds' don't have a place in either wilderness or garden ethics. Managing for areas of early successional forest landscapes (Swanson et al. 2010) and preserving spontaneous successional stages to explore the broad scope of ecological and cultural services might yield new ways of framing and appreciating this misunderstood urban flora.

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Résumé. Les modèles contemporains de participation du public à la recherche scientifique en zones urbaines ont reçu peu d'attention de la part des chercheurs spécialisés. Cet article décrit les processus de recherche et les résultats de quatre projets collégiaux de science citoyenne sur la végétation urbaine spontanée. Les projets collégiaux initiés par des artistes et des concepteurs de cette étude utilisent diverses stratégies d'art, de design et d'histoire naturelle pour rassembler et analyser les données, de même que pour visualiser et faire la propagation des résultats. En plus des résultats physiques, les chefs des projets utilisent des récits légitimateurs et des dissertations sur les services écosystémiques urbains pour contrer les allégations négatives concernant la végétation spontanée urbaine, souvent qualifiée à tort de « mauvaises herbes ». Le défi et l'opportunité des projets visant à changer les préjugés normatifs contre les prétendues « mauvaises herbes » favorise l'intégration d'une nouvelle éthique de la nature pour ce type de flore urbaine.

Zusammenfassung. Zeitgenössische Modelle von öffentlicher Beteiligung an wissenschaftlicher Forschung in urbanen Regionen haben nur eine begrenzte wissenschaftliche Aufmerksamkeit. Diese Studie dokumentiert den Forschungsfortschritte und die Ergebnisse aus vier kollegialen bürgerwissenschaftlichen Projekten über die spontane urbane Vegetation. Die künstlerisch und designerinitiierten kollegialen Projekte in dieser Studie nutzen eine Vielfalt von Kunst, Design und natürlichen historischen Strategien zum Sammeln und Analysieren von Daten, ebenso wie die Visualisierung und Verbreitung ihrer Ergebnisse. Zusätzlich zum physischen Auskommen nutzen die Projektleiter legitimierende Narrative und Diskurse über urbane Ökosystemleistungen, um negativen Bemerkungen über spontane urbane Vegetation, die oft geringschätzig als „Unkraut" bezeichnet wird, entgegen zu treten. Eine Herausforderung und eine Gelegenheit für Projekte, die auf einer Änderung des normativen Bias gegenüber so genannten „Unkräutern" fokussieren, ist die Verbreitung einer neuen Naturethik für diesen Typ von urbaner Flora.

Resumen. Los modelos contemporáneos de participación pública en la investigación científica en áreas urbanas han recibido una atención académica limitada. Este reporte documenta los procesos de investigación y los resultados de cuatro proyectos colegiales de ciencia ciudadana sobre vegetación urbana espontánea. Los proyectos colegiados iniciados por artistas y diseñadores en este estudio utilizan una variedad de estrategias de arte, diseño e historia natural para recopilar y analizar datos, así como para visualizar y diseminar sus hallazgos. Además de los resultados físicos, los líderes del proyecto utilizan narrativas y discursos de legitimación sobre los servicios de los ecosistemas urbanos para contrarrestar las afirmaciones negativas sobre la vegetación urbana espontánea, que a menudo son denominadas peyorativamente "malezas". Un desafío y una oportunidad para proyectos centrados en alterar el sesgo normativo contra las llamadas "malas hierbas" es incorporar una nueva ética de la naturaleza para este tipo de flora urbana.