# KNOWLEDGE FROM DATA, KNOWLEDGE FROM DOING: THE INCLUSIONARY PRODUCTION OF ENVIRONMENTAL KNOWLEDGE FOR MANAGEMENT

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KNOWLEDGE FROM DATA; KNOWLEDGE FROM DOING:
THE INCLUSIONARY PRODUCTION OF ENVIRONMENTAL KNOWLEDGE FOR MANAGEMENT IN THREE CASES

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ABSTRACT

Environmental science, regulation, and management have experienced an inclusionary turn, with wider circles of stakeholders engaged in constructing knowledge about social-ecological systems. Yet research into the inclusionary production of environmental knowledge ("I.P.E.K.") tends to treat all knowledge-making endeavors as *scientifically* motivated, when in fact other epistemic aims govern the production of environmental knowledge for regulation or management. This study parses out the inclusionary production of environmental knowledge for management as a phenomenon worthy of study without recourse to the epistemic aims of science.

Drawing on three cases of locally based and small-scale urban environmental management practices (often referred to as "stewardship" or "civic ecology"), this exploratory qualitative study sheds new light on two forms of inclusionary knowledge production within these practices. The first form resembles adaptive co-management initiatives that rely on the collection of surveillance or monitoring data to inform adaptations in practice. This study finds a three-part division of labor in making data collection a part of practice, comprised of: Tool Patrons, who sponsor the creation of new data collection tools, technologies, and protocols; Tool Makers, who construct data protocols and technologies outside of daily practice; and Tool Users—the practitioners who must weave data collection initiatives into their work together.

This division of labor creates both opportunities and challenges for incorporating data collection into practice as a means of making useful environmental knowledge for management.

The second form reframes civic ecology and stewardship practices as contemporary urban analogues to traditional subsistence societies and looks at knowledge produced tacitly within these practices in similar terms. A preliminary exploration of tacit knowledge making and management within civic ecology and stewardship practices suggests that practitioners *do* construct knowledge together as a feature of practice and encode their insights in story. While practitioners reach to find knowledge from sources outside of practice, not all new insights are readily incorporated into practice. Finally, the tendency to rely on transient forms of volunteer or seasonal staff labor in stewardship and civic ecology practices may create challenges for both managing the knowledge created in practice and retaining volunteers.

# BIOGRAPHICAL SKETCH

Philip Silva is the co-founder of TreeKIT, an initiative helping city dwellers measure, map, and collaboratively manage urban forests. He also works with Farming Concrete on efforts to help community gardeners throughout the world measure all the good things happening in their gardens. He is an essayist and podcast producer at The Nature of Cities, a website publishing original content on cities as ecological spaces, and he consults as a program evaluator for various urban agriculture initiatives in Brooklyn, New York. Philip has worked with many of New York City's most celebrated environmental stewardship organizations. He is a Senior Fellow of the Environmental Leadership Program and a certified practitioner of Dialogue Education.

I dedicate this work to my parents and grandparents.

# ACKNOWLEDGMENTS

In recognition of all the wisdom, patience, and critical insight that went into guiding me through every step of this process, I sincerely thank my advisor and graduate committee chair, Dr. Marianne Krasny. I also thank Dr. Bruce Lewenstein, Dr. David Maddox, and Dr. Christine Leuenberger for their advice and encouragement while serving as members of my committee. My deepest thanks go out to all the many environmental stewards I've worked with over the past ten years, beginning with the people who so generously welcomed me into their practices for this study.

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“Mr. DeSutter began fooling around with cover crops about 17 years ago, after Purdue University used one of his fields for research trials. One spring he was repairing a drainage tile in the test field and came across the deep, webbed root system that some Oregon ryegrass had put into the soil.

‘I thought to myself, I have been pulling the guts out of my tractor to remove compaction 14 inches deep with a ripper,’ Mr. DeSutter said, ‘and this plant has just bored a system of micropores four feet deep between cash crops all on its own.’

The roots he stumbled across had created a natural aeration system that helped conserve water and trap nutrients in the soil, which would otherwise be prone to leaching. ‘That was the aha! moment,’ he said.”

*Cover Crops, a Farming Revolution With Deep Roots in the Past*
Stephanie Strom, New York Times, 6 February 2016

“In the case of flossing’s benefits, the supposedly weak evidence cited by The Associated Press was the absence of support in the form of definitive randomized controlled trials, the so-called gold standard for scientific research. Why was there so little of this support? Because the kind of long-term randomized controlled trial needed to properly evaluate flossing is hardly, if ever, conducted — because such studies are hard to implement. For one thing, it’s unlikely that an Institutional Review Board would approve as ethical a trial in which, for example, people don’t floss for three years. It’s considered unethical to run randomized controlled trials without genuine uncertainty among experts regarding what works.

And dentists know from a range of evidence, including clinical experience, that interdental cleaning is critical to oral health and that flossing, properly done, works. Yet the notion has taken hold that such expertise is fatally subjective and that only randomized controlled trials provide real knowledge.”

*Flossing and the Art of Scientific Investigation*
Jamie Holmes, New York Times, 25 February 2016

CHAPTER 1

# INTRODUCTION

## ***The Knowledge to Manage***

Environmental managers have long relied on scientific research to provide trustworthy knowledge about myriad social-ecological problems and their potential solutions. Yet confidence in science has also eroded in some areas of environmental management, and scientists themselves have been forced to admit limits to the certainty of scientific knowledge in response to complex and emergent problems (Wynne 1996; Collins and Pinch 1998). "The idea that science would one day be able to solve all problems by the application of logic and experiment began to fail at the beginning of the twentieth century," write sociologists Harry Collins and Robert Evans (2007, p. 1). Yet it would take the better part of the century for environmental managers to lose unwavering trust in the knowledge produced through scientific research. The publication of Rachel Carson's *Silent Spring* in 1962 spurred a decade of environmentalism rooted in science, culminating in the passage of omnibus environmental laws targeted at curbing pollution, reducing risks to public health, and mitigating problems resulting from a century of unregulated industrialization. Yet by the 1980s, faith in the power of one-size-fits-all "command and control" applications of scientific knowledge to fix environmental problems began to wane. Scientists, activists, and managers all came to recognize the complexity and case-by-case uniqueness of different issues, spurring a call for more flexible, adaptive, and case-specific approaches to understanding and addressing environmental problems. Although environmental advocates, policymakers, and managers continue to rely on scientific research on the *effects* of pollution and resource consumption to substantiate the need for action, scientific knowledge no longer has a monopoly on the search for management solutions.

As trust in science has decreased, the number and diversity of environmental advocacy and management initiatives around the globe seems to have grown. A decade ago, the environmental writer Paul Hawken marveled at the array of different initiatives, both big and small, that he encountered as he travelled the world. “I believe there are over one—and maybe even two—million organizations working toward ecological sustainability and social justice,” Hawken (2007) estimated on the basis of anecdote and personal observation. At a more local level, researchers at the U.S. Forest Service field research station in New York City inventoried and map all of the various “environmental stewardship” groups operating in their region in the late-2000s. Researchers with the Stewardship Mapping and Assessment (STEW-MAP) project broadly defined a stewardship group as “a civic organization or group that works to conserve, manage, monitor, advocate for, and/or educate the public about their local environments,” (Svendsen et al. 2016). They found more than 2,000 such groups working at different scales and on different issues throughout New York City. Within that population one finds a variety of community-based environmental management initiatives that Krasny and Tidball (2012; 2015) label “civic ecology practices,” or self-organized groups of people caring for trees, gardens, parks, and other biotic systems within cities. New York City alone is home to more than five hundred community gardens, dozens of neighborhood-based groups caring for street trees, and an assortment of initiatives working to restore and manage urban forests, wetlands, parks, and even oyster beds in the harbor estuary.

Civic ecology and stewardship practitioners in New York City and elsewhere are often the only people responsible for creating, maintaining, and generally managing systems of “green infrastructure" that generate measurable "ecosystem service benefits" for cities. Tzoulas et al. (2007) define green infrastructure as "all natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas, at all spatial scales" (p. 169). Green infrastructure can include trees, gardens, parks, riparian corridors, and other biotic systems that constrain, control, or mitigate the flow of energy and material through an urban landscape. Green infrastructure is often touted as a replacement or supplement to more traditional forms of "gray infrastructure" such as municipal sewage systems, and while gray infrastructure tends to be single-purpose in design and liable to generate unintended negative environmental impacts, green infrastructure tends to offer a mix of primary and ancillary benefits without compromising the environment (Austin 2014). Managing these resources, then, is an important responsibility with tangible impacts on quality of life for city dwellers.

Gray infrastructural systems are often managed and maintained by paid employees of municipal agencies or their contractors in the private sector, whereas green infrastructural systems are often managed and maintained by non-governmental organizations and volunteers—civic ecology and stewardship practitioners—working under their own initiative. While gray infrastructure is purposefully engineered to be linear and operationally efficient (Gandy 2002; Hayes 2006), green infrastructure is comprised of complex nonlinear interactions between human society, the built environment, and individual non-human organisms, communities of organisms, or ecosystems. Thus managing green infrastructure in cities can be similar to managing social-ecological systems at multiple scales in rural and wilderness settings (Berkes and Colding 2016). The knowledge practitioners require to effectively manage green infrastructure is, consequentially, more likely to come out of practice than out of formal scientific research (Lavoie and Brisson 2015).

Adaptive environmental management emerged in the late twentieth century as a learning-by-doing approach to incrementally developing useful knowledge about the interactions between management practices and complex ecosystems (Holling 1978; Walters 1986; Walters and Holling 1990). Working within an adaptive management paradigm, researchers and practitioners treat different management interventions as field experiments, collecting data to rigorously monitor the results of changes in practice and adapting to meet desired ends over time. Adaptive management (also known as adaptive *collaborative* management in its more inclusive and deliberative manifestations) has been applied in forests, fisheries, and agricultural settings (Armitage, Berkes, and Doubleday 2008), and Krasny and Tidball (2012) proposed that in cities, "monitoring of civic ecology practices enables ongoing adaptation based on information about outcomes" (p. 4). Yet few civic ecology practices seem to purposively monitor the outcomes of different management strategies, and a 2012 study of civic ecology practices in New York City suggests that practitioners who *do* collect data related to their work will do so without help or input from professional researchers (Silva and Krasny 2014).

***Central Research Questions & Justification***

How, then, is knowledge made and managed in civic ecology and urban stewardship practices? How do practitioners work to create useful insights into their practices and the interactions between their work and the resources they manage? How does knowledge making and management in civic ecology and stewardship practices differ from other forms of inclusionary knowledge making for environmental science or regulation? These are the broad central questions (Creswell 2009) I set out to explore in this study.

Little primary ethnographic research into the knowledge making dimensions of civic ecology practices has been undertaken. Most of the literature on knowledge making and management in organizations draws on cases of large firms operating in the private/for-profit sector, while literature on participatory forms of knowledge making tends to draw on cases of public participation in *scientific* research (rather than research couched within practice). Further, the literature on adaptive collaborative management mainly draws on cases from rural or wilderness settings. This study aims to fill the gap and develop new preliminary insights into knowledge making as a dimension of civic ecology and urban environmental stewardship practices.

The insights that come out of research into knowledge making in civic ecology and stewardship practices is relevant to practitioners and the philanthropic funders that support grassroots environmental management practices. I know from firsthand experience that practitioners struggle to measure and monitor the outcomes and impacts of their work together. There are few incentives to think critically about what works—and what doesn't work—as either a volunteer or a paid staffer at a small non-profit organization. There are precious few hours in any given day to get the work done, and budgeting time for data collection, evaluation, and critical reflection is a luxury few initiatives can afford. Yet I also know from my own work in and around stewardship practices that knowledge making and knowledge management are at the heart of the work, with practitioners finding innovative ways to go about their tasks through iterative and incremental adaptations. Philanthropic funders increasingly ask grantees to measurably demonstrate the outcomes of their work through data-intensive evaluation procedures, but small initiatives can sometimes struggle to produce the data-rich knowledge required assessment, as we see in Chapter 4. Funders also aim to make the lessons learned by one grant recipient available to others across space and time. Yet as we see in Chapter 5, the *tacit* aspects of knowledge gained in practice may be challenging to surface and explicate for others to share. I believe my research suggests new ways of thinking about the knowledge making dimensions of civic ecology and stewardship practices and points the way toward more effective and efficient approaches to assessing and extrapolating from specific cases.

***Dissertation Overview***

I originally set out to conduct this study as a form of participatory action research (Fals-Borda 1991; Chevalier and Buckles 2013), working alongside practitioners in each of the three cases introduced above to create useful knowledge directly relevant to their practices. Yet participatory action research can be an awkward fit for a dissertation, as Herr and Anderson (2005) note. "A major goal of action research is to generate local knowledge that is fed back into the setting," they write. "However, dissertations demand public knowledge that is transferable to other settings and written up in such a way that others can see its application to their settings" (p. xv). Beyond these epistemic concerns, one finds a methodological challenge in trying to actively and meaningfully participate in multiple cases simultaneously. Thus, to develop public knowledge from a comparison of three distinct cases of civic ecology practice, I found myself stepping back from my early commitment to participatory action research. I nonetheless participated, to greater and lesser degrees, in each of the three cases, as the following chapter on research methods describes in greater detail.

Chapter 3 develops a conceptual framework for research into different forms of what I have chosen to call the "inclusionary production of environmental knowledge," or I.P.E.K. Considerable research has been devoted to understanding the phenomena of "citizen science" and "public participation in scientific research," but these studies have often included other forms of inclusionary knowledge making with tenuous connections to science. Cases of citizen science are traditionally concerned with fostering a more inclusionary approach to the production of environmental knowledge *for its own sake*—for the advancement of generalizable knowledge in a field of inquiry. Yet there are also many cases of inclusionary environmental knowledge production aimed at enforcing, extending, or enhancing environmental regulation, and many other cases of inclusionary environmental knowledge production focused on day-to-day management and decision-making. I develop these three separate categories of I.P.E.K. to establish a more grounded approach to sociological research for different—and sometimes contradictory—purposes.

What are the processes of data collection related to management in civic ecology and stewardship practices? How is the labor of supporting, creating, and applying data collection tools and protocols divided? Chapter 4 develops insights into data collection and monitoring as forms of I.P.E.K. for management within the practices described in Chapter Two. In all three cases one finds evidence of different actors playing different roles in sponsoring, developing, and using data collection and monitoring protocols. This division of labor may hinder the adoption of data collection strategies by practitioners, even in cases where similar types of practitioners contributed to the development of protocols.

How do practitioners construct knowledge about their work aside from collecting and analyzing data? What kinds of knowledge do they produce? Chapter 5 explores knowledge production as an inherent facet in civic ecology practice, focusing on the tacit knowledge created through day-to-day work. Using conceptual frameworks borrowed from organizational management literature to analyze and interpret the cases, I found three general insights: First, civic ecology practices are *communities* of practice, and practitioners actively construct knowledge about their work through sustained engagement in that work together. Second, knowledge management in civic ecology practices becomes challenging when volunteers and other transient forms of labor play a role in supporting the work of core practitioners. Third, importing knowledge from outside sources (including other similar practices) may be made difficult by the nature of *tacit* knowledge derived from practice.

This dissertation concludes with a summation of key findings and recommendations for both scholars and practitioners of civic ecology practices. I came to this research as a former community gardener and street tree steward, having also worked as a technical assistance provider to civic ecology practices in New York City. My aim has always been to create useful insights into these practices that will help practitioners improve and extend their work over time. Although the findings presented in the chapters that follow may not have come from a participatory action research process, I do hope that the research helps support more informed action for civic ecology and stewardship practitioners around the globe.

# CHAPTER 2
# METHODS

### *A Qualitative Design Within a Constructivist Worldview*

Chapters 4 and 5 of this dissertation use an exploratory qualitative research design to develop new insights into the knowledge making dimensions of three grassroots environmental management practices. Creswell (2009) describes qualitative research as "exploratory and useful when the researcher does not know the important variables to examine" (p. 18) in an uncharted social setting. Scholarly research on civic ecology practices emerged in the past half-decade as a complement to broader studies of civic environmental stewardship (Krasny and Tidball 2012; Krasny and Tidball 2015; Svendsen and Campbell 2008). While some studies have considered the role of memory (Barthel, Folke, and Colding 2010) and knowledge transfer across geographies (Shava et al. 2010) for civic ecology and stewardship practices, little research exists on knowledge making as an inherent feature of these practices. Thus an exploratory qualitative approach is justified (Marshall and Rossman 2010).

One finds multiple epistemic worldviews operating within the qualitative research tradition, each carrying different assumptions about, and expectations for, knowledge produced through qualitative inquiry. This dissertation is situated within a social constructivist worldview (Creswell 2009, p. 8) and aligns with the viewpoint that qualitative research is inherently and unavoidably *interpretive* in both the observations it makes and the conclusions it draws (Lincoln and Denzin 2000). Qualitative research is defined by data collection practices that "turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self" (Lincoln and Denzin 2000, p. 3). Wolcott (2005, p. 160) writes:

> Qualitative approaches avoid any semblance of the rigid step-by-step sequence generally associated with tight research designs. They are intended to allow researchers to follow a suitable course of inquiry rather than to dictate in advance what the course should be. The essence of qualitative research, as Becker puts it, is that it is "designed in the doing" (Becker 1993, p. 219).

Thus qualitative researchers working within a constructivist frame value an open-ended and eclectic approach to data collection and analysis methodologies, adopting or abandoning various strategies as the need arises (Crotty 1998; Lincoln and Denzin 2000).

The scholarship that results from such an open-ended approach does not attempt to capture "an objective report of the truth of the matter" (Willis 2007, p. 160). Nor does it strive to discover broad generalizations or laws about social phenomena (Becker 2014). Rather, research performed within a constructivist worldview offers one of many possible interpretations of reality co-constructed from the interactions between researchers and respondents (Lincoln and Denzin 2000). It sheds light on unexplored variables or processes within social phenomena rather than cementing causal relationships between variables (Becker 2014). To that end, constructivist qualitative research is primarily *ideographic* or descriptive in nature (King and Horrocks 2010), with categorical generalizations and theoretical interpretations following inductively from fieldwork (Charmaz 2014).

**Methodology & Methods**

Creswell (2009) presents various qualitative research strategies (or methodologies) as self-contained approaches that a researcher must choose between before moving forward with designing the details of a particular research project. In contrast, Wolcott (2008, p. 84) uses the analogy of a branching tree to describe the interconnected nature of different methodologies, with participant observation as the "trunk" from which many other limbs grow. "Participant observation doubles as a synonym for fieldwork, for ethnography, for virtually any approach that is ‘qualitative,’” Wolcott writes (p. 85). To that end, I relied on participant observation as my overall methodological approach to data *collection,* while constructivist grounded theory and comparative case study structured my methodological approach to data *analysis.*

*Data Collection—“*Participant observation goes along with an interpretive approach to sociology,” writes sociologist of science Harry Collins (Collins 1985, p. 172). I therefore participated, with varying degrees of intensity and duration, in three civic ecology and stewardship practices over the course of nearly two years of fieldwork. I applied for and was granted an Institutional Review Board exemption for the field research described below and sought informed consent from all participants.

In Brooklyn, I worked closely with volunteers and staff at the Gowanus Canal Conservancy on the organization’s street tree stewardship initiatives, joining participants on regular tree care outings, engaging in strategic planning meetings, and even participating in social events. My engagement with community gardeners on Kelly Street in the South Bronx was less sustained, but included a three-day research retreat with the garden’s part-time coordinator in 2015, multiple visits to the garden during the 2015 growing season, and participation in the garden’s “Chef in the Kitchen” series as a guest cooking instructor. On the nearby Bronx River, I joined senior members of the Bronx River Alliance Conservation Crew on a morning-long tour of invasive plant removal sites, riding with them in their utility vehicle as they told stories of their work at each site. I also joined a volunteer group one spring morning to help remove swaths of the invasive Corydalis plant from one of the many parks along the Bronx River Greenway. I did not have sustained access to daily invasive plant management practices on the Bronx River, and therefore had to rely on staff interviews for insights into their work.

I used unstructured interviews (Lofland and Lofland 1995) with open-ended questions at all three research sites to confirm observations from field participation and more fully develop conceptual categories in analysis. I digitally recorded conversations on some occasions and took field notes when the presence of a recorder would be obtrusive or unsettling for participants. In all three cases I wrote research memos (Glaser and Strauss 1967) throughout the data collection and analysis process in order to critically reflect on emergent themes and guide future work.

In the case of invasive plant management practices on the Bronx River, I undertook semi-structured interviews (Weiss 1995) with an administrative staff member at the Bronx River Alliance and conducted a focus group with three relevant personnel in the Natural Resources Group division of the NYC Department of Parks and Recreation. At the community garden on Kelly Street, I led two structured focus groups (Morgan 1996) with members of a Gardening Committee comprised of approximately six to ten people with varying degrees of engagement. I also led two workshops aimed at helping gardeners collect data related to their practices. Further, I engaged in a semi-structured interview (Weiss 1995) with a support staffer at Workforce Housing Group, the owner of the garden property. I also spent three days casually interviewing the part-time Garden Coordinator during a research retreat sponsored by the National Socio-Environmental Synthesis Center in February of 2015. At the Gowanus Canal Conservancy, I periodically conducted unstructured interviews with both volunteers and staff to follow up on unstructured conversations we had "in the field" and confirm observations. Throughout the course of my engagement with the organization I interviewed a paid staff person, two volunteer coordinators, and two volunteers about their work together. I also kept a field journal to record observations and pertinent insights from conversations with practitioners through participant observation.

*Data Analysis*—This study uses case studies as a method of *organizing* and *reporting* data (Wolcott 2008). Creswell defines a case study as a time-bounded, in-depth exploration of a social phenomenon that draws on insights from multiple data collection and analysis methods (Creswell 2009). Case studies aim for a holistic accounting of the complexities of a social situation or process, eschewing efforts to find clear causal relationships between variables within the phenomenon (Swanborn 2010; Yin 2009). Some methodologists have further argued that studies comprised of a comparison of multiple cases result in more compelling theoretical conclusions (Herriott and Firestone 1983). I therefore developed case studies of the knowledge making dimensions of three civic ecology practices based in New York City, aiming to develop conceptual insights into these practices through comparative analysis.

I employed the constant comparative method associated with grounded theory research (Glaser 1965; Glaser and Strauss 1967; Charmaz 2014) for *coding*, *analyzing*, and *constructing theoretical insights* out of data captured in the form of interview and focus group transcripts, field notes from immersive participation and observation, and research memos. Glaser (1965) describes the constant comparative method as moving through four iterative stages: 1) Openly assigning categorical codes to textual data, comparing every successive coding incident to previous uses of the same code (thus *constant* comparison); 2) Integrating and consolidating categories while using emergent themes to code additional data; 3) Delimiting theory as successive comparisons reduce the number of conceptual codes needed to organize and analyze data; 4) Writing up thematic concepts (theory) as a summation of the process.

I followed these steps to iteratively analyze the data I collected and to shape ongoing data collection strategies as conceptual themes emerged. In doing so, I arrived at insights that forced me to confront knowledge production as a dimension of civic ecology and stewardship practices *apart* from formal monitoring and adaptive management efforts. Indeed, the insights in Chapter 5, with its focus on knowledge developed in daily practice, would not have emerged had I not taken a grounded theory approach to a research project that initially focused exclusively on knowledge derived from data collection and monitoring in environmental management practices.

### *Site Selection*

Questions of site *selection* and *access* are interconnected in this study, with access playing a primary role in determining my choice of cases, along with categorical "fit" and convenience. Small (2009) argues that qualitative researchers should *not* aim to mimic statistical research procedures concerned with ensuring that a sample accurately represents a whole population. Yin (2009) further posits that case studies (such as the ones developed for this study) are meant to generalize to theoretical propositions rather than to statistically valid statements about full populations. Thus, the three practices described below are not *samples* chosen from a larger universe of similar practices, but emblematic *cases* that can provide conceptual insights into civic ecology practice as a general social phenomenon.

I selected these three cases because they "fit" definition of civic ecology practice and urban environmental stewardship put forward by Krasny and Tidball (2012; 2015) and Svendsen and Campbell (2008). Since few civic ecology and stewardship practice seem to engage in purposeful data collection related to practice (Silva and Krasny 2014), the universe of possible samples available for study was significantly constrained. Following Krasny and Tidball, I opted to develop cases of three different practices (gardening, invasive plant removal, tree care) rather than focus on a single type of practice, such as gardening on its own. Unlike Krasny and Tidball, I chose to stay geographically focused on cases in New York City to invest more deeply in direct participant observation whenever possible. Centering my research on New York City allowed me to use my professional network, cultivated during nearly ten years of work with environmental organizations in the region, to gain access to research sites and their participants. The three cases I selected all fit the criterion of practices engaged in data collection aimed at evaluating and/or adapting their own work over time, thus allowing me to work toward answering my research questions directly.

***Background on the Cases***

This study is comprised of three cases of civic ecology and urban environmental stewardship practices located in the boroughs of Brooklyn and The Bronx in New York City. All three cases were active during a study period that began in June of 2014 and ended in August of 2015. This section briefly introduces the three cases included in this study, providing background information for the empirical chapters that follow.

*Street Tree Stewardship in the Gowanus Canal Watershed (Brooklyn)*—The Gowanus Canal is a 1.8-mile long shipping channel that flows at the intersection of seven demographically diverse and divergent neighborhoods in the borough of Brooklyn. The city blocks immediately surrounding the canal were traditionally industrial, but recent real estate development projects are gradually transforming low-rise manufacturing and storage facilities into high-rise luxury apartment complexes, particularly in the Carrol Gardens neighborhood west of the canal. At the canal's northern end, the residential neighborhoods of Boerum Hill and Cobble Hill have experienced rapid gentrification in the past 15-20 years (Goldschein 2012), while to the south and east, the mixed-land-use neighborhoods of Red Hook and Gowanus are predominately low-income, with a mix of low-rise private housing and high-rise public housing projects adjacent to industrial facilities (Schmeltz et al. 2013). To the canal's east, the traditionally residential brownstone neighborhood of Park Slope has also seen property values and rents rise throughout the twenty-first century (Paterson 2007).

Over the course of the nineteenth century, the canal and its surrounding industrial land uses gradually replaced acres of tidal salt marshes that drained into nearby New York Harbor (Alexiou 2015). The canal served as a catchment for the borough's earliest efforts at conveying stormwater and wastewater in a combined underground sewage system, beginning with the Bond Street Sewer project of the mid-nineteenth century (ibid). In 2014, the canal was still the receiving water body for 14 combined sewage outfalls conveying more than 350 million gallons of untreated sewage each year (Schlanger 2014). In 2010, the canal was added to the U.S. Environmental Protection Agency's list of "Superfund" sites after an engineering investigation revealed significant pollution from more than a century of industrialization, illegal dumping, and combined sewage overflows ("Gowanus Canal Superfund Site | Region 2 | US EPA" 2013). The canal continues to be a sink for non-point sources of pollution that include street surface runoff and sewage overflows triggered by heavy storms.

A group of residents formed the Gowanus Canal Conservancy in 2006 as a grassroots effort to improve the environment in and around the canal. The Conservancy set out to manage the canal as a natural resource, using small-scale interventions to gradually improve water quality, reduce air pollution, increase habitat for native fauna, and create new open-spaces for people living near the canal (Silva and Krasny 2013). During the period of my research, the Conservancy's staff was comprised of three full-time permanent positions and two "NYC Civic Corps" positions that change personnel annually after a ten-month service rotation. Staff coordinated a larger network of unpaid volunteers engaged in a variety of environmentally themed projects throughout the Gowanus Canal watershed, including street tree care.

In their efforts to reduce the amount of sewage that flows into the canal during heavy storms, the Conservancy organized volunteers to care for street trees in the spring, summer, and autumn months. In 2015, a nearly 100-block area surrounding the Gowanus Canal was found to be planted with approximately 3,000 street trees. Each street tree bed serves as a sponge-like catchment for storm water and the leaves, branches, and trunks of the trees themselves can accumulate gallons of water on their surface during and immediately following a storm (McKeand and Vaughn 2013). Thus, caring for the area's thousands of street trees and taking steps to keep them alive and healthy may help to improve water quality in the Gowanus Canal.

Street tree care, or "stewardship," is a practice comprised of various actions, including: pruning dead, dying, or diseased tree limbs to prevent fungal rot in structural heartwood; pulling weeds in tree beds that can compete with a tree for water and soil nutrients; watering trees during drought periods; aerating soil in tree beds to reduce compaction and improve water absorption; and adding layers of compost and mulch to tree bed soil to prevent compaction, improve soil quality, and guard against erosion. A small core group of two to four volunteers affiliated with the Conservancy work on street tree stewardship efforts throughout the year, mainly focusing their work on trees in industrial areas east of the canal. The core group also helps coordinate and lead teams of one-time volunteers attending semi-regular "Clean and Green" workdays sponsored by the Conservancy. Volunteers with relatively little training work mainly on weeding, mulching, and watering tree beds. Volunteers pruning tree limbs must complete a multi-week training program for "citizen pruners" that licenses them to saw or lop limbs that are noticeably dead, diseased, or damaged.

The New York City Department of Parks and Recreation (NYC Parks) has jurisdiction over street trees planted in the Gowanus Canal watershed. Staff within the Department of Central

Forestry, a city-wide division of the agency, select new street tree planting locations, specify tree species for each location, and remove and replace dead trees as resources become available. Central Forestry coordinates with the Brooklyn Borough Forestry division on large-scale tree stewardship efforts, including large limb pruning on a ten-year maintenance cycle. Yet NYC Parks mostly relies on volunteers like those marshaled by the Gowanus Canal Conservancy to keep newly planted trees throughout the watershed alive (Moskell and Allred 2013).

*Invasive Plant Management in the Bronx River Corridor (The Bronx)*—More than a century of industrialization and urbanization transformed the Bronx River into "a contaminated conduit for industrial and residential wastes" (Bronx River Alliance 2016b). Beginning in the mid-1970s, volunteers labored to remove trash and debris from the river and its shoreline. These small-scale efforts gradually coalesced into a plan for reclaiming the river as a linear park, or "greenway," stretching from the northern boundaries of the city to the river's outlet in the South Bronx. The Bronx River Alliance was founded in 2001 as an outgrowth of nearly thirty years of work on the part of local organizations to restore New York City's only freshwater river. The Bronx River Greenway, a signature project of the Alliance under development since the early 2000's, has increased the amount of recreational open space available to residents of communities that have historically been underserved by access to parks.

Much like the Gowanus Canal, the Bronx River flows through a variety of zoned land uses and a diversity of neighborhoods with varying demographic profiles. The river flows into New York City and the Bronx from Westchester County, cutting through the low-density working-class neighborhoods of Wakefield and Woodlawn Heights before entering the grounds of the New York Botanic Garden and the Bronx Zoo at Bronx Park. The river's edges become significantly more developed and urbanized south of 180$^{th}$ street as it flows through an area traditionally known as “the South Bronx,” which includes the lower-income neighborhoods of West Farms, East Tremont, Soundview, and Hunts Point. Unlike the Gowanus Canal, the neighborhoods adjacent to the river have not been witness to gentrification or speculative land use redevelopment in recent years.

The board of the Bronx River Alliance is comprised of representatives from community-based organizations working along the full length of the river’s path through the Bronx. The organization’s executive staff works closely with the New York City Department of Parks and Recreation in guiding the development of the Bronx River Greenway and maintaining those portions of the Greenway that have already been built. One of the organization’s priority projects involves ongoing efforts to replace invasive and non-native plant species along the river’s shores with plants that are historically native to the area. In 2005, the Bronx River Alliance formed a Conservation Crew comprised of approximately ten permanent and seasonal staff tasked with working on a variety of environmental restoration projects along the river. The crew has planted more than 15,000 trees and undertaken restoration efforts on more than 600 acres of parkland along the river since its formation more than a decade ago. (Bronx River Alliance 2016a).

Natural Resources Group—the ecological research and management division of the New York City Department of Parks and Recreation—published the *Bronx River Riparian Invasive Plant Management Plan* (RIPMaP) in 2012 to support and guide the Bronx River Alliance Conservation Crew (and other local groups) in their efforts to reintroduce native plants to the in parks along the river (Yau et al. 2012). The plan puts forward two goals: 1) Improving conditions for native plants by reducing the spread of invasive plants along the Bronx River Greenway; and 2) Increasing habitat diversity within the river’s channel to provide refuge for fish (Yau et al.

2012). The plan creates a framework for collecting data on the efficacy of the Conservation Crew's ongoing plant removal efforts.

*Community Gardening on Kelly Street (The Bronx)*—In the Longwood neighborhood of the Bronx, a coalition of activists and African American property owners worked to prevent the wave of building abandonment and arson that overtook much of the rest of the area in the 1970's and '80's (Gonzalez 2004). The Banana Kelly Community Improvement Association—earning its name from the banana-like curve in the stretch of Kelly Street where the organization got its start—purchased and rehabilitated its first three apartment buildings in the neighborhood in 1977. It was one of the first groups to step into the local real estate economy during those challenging years, improving living conditions for area residents (Gonzalez 2004). The housing market in the South Bronx eventually achieved some stability through a combination of government programs and private investments in new affordable housing stock (Gonzalez 2004). Yet the South Bronx continues to have one of the greatest concentrations of poverty, unemployment, and crime in the U.S. (Sisk 2010). As New York City's fortunes rose in the late 1990's and into the twenty-first century, the gentrification of poor and working-class neighborhoods in other areas pushed low-income residents into the South Bronx (Institute for Children, Poverty, and Homelessness 2014).

Community gardens are recognized as a source of neighborhood stability and revitalization in cities throughout the United States (Lawson 2005) and multiple studies have demonstrated the social, public health, and environmental benefits these gardens can create (Cohen, Reynolds, and Sanghvi 2012). Community gardening is one of many strategies employed by residents of the South Bronx to address the challenges they've faced for nearly half a century. Kelly Street Garden sprawls across the conjoined backyards of five apartment buildings, each with long histories of landlord neglect. Although the buildings were some of the few in Longwood carefully maintained during the years of building arson and mismanagement, a change in ownership in 1987 brought on a twenty-year decline in basic upkeep. By 2007, the five buildings that border Kelly Street Garden were listed amongst the 200 most poorly maintained buildings in all of New York City by the municipal Housing Preservation and Development Agency (Perlman 2011; Ayres 2015). Workforce Housing Group, a company specializing in renovating and managing affordable housing in New York City, acquired the properties in 2011 and spent nearly two years refurbishing all 81 apartments in the complex (Wills 2013).

The new owners partnered with Banana Kelly Community Improvement Association to connect residents with social services and create a publicly accessible community garden behind the five buildings. Their aim was twofold: offering residents access to a source for healthy food while fostering community cohesion on a block that continues to struggle with crime, poverty, and short tenancies. The new garden harkens back to an earlier effort at cultivating the same patch of land in the 1980's, when the "banana" portion of Kelly Street was an island of relative stability in a broken place. Residents and neighbors from other buildings on the block gained access to the garden in the spring of 2014. Six women emerged as leaders for the new initiative, forming a small Gardening Committee with help from two staff employed by Workforce Housing.

***Reflexivity***

Reflexivity in qualitative research challenges the objectivist priorities of a positivist worldview (Lincoln and Guba 1985b) and clarifies the subjective role of a researcher's "experience, decisions, and interpretations" in a study (Charmaz 2014, p. 188). Reflexivity on the part of the researcher invites "the reader to assess how and to what extent researcher's interests, positions, and assumptions influenced the inquiry" (ibid). To that end, I offer some critical insights into my own entanglement in the issues explored in the chapters that follow.

I did not come to this research project with a neutral perspective on civic ecology and stewardship practices in New York City or, more specifically, their knowledge producing dimensions. Prior to undertaking this study, I worked with several grassroots environmental practices in New York, including some aspects of the three cases presented here. I was a community gardener in Brooklyn and a volunteer "citizen pruner" with license to cut dead, diseased, and damaged limbs from street trees throughout New York City. As a paid professional, I worked on street tree planting initiatives in the South Bronx and served as a technical assistance provider and trainer for community gardeners in Brooklyn. In terms of the cases included in this study, I played a central role in developing the data collection tools and protocols for mapping street trees and measuring the positive outcomes of community gardens that feature strongly in Chapter 4. I also produced a policy report on boating fees for the Bronx River Alliance in 2005 and later, in 2007, my work in the South Bronx brought me into regular contact with the organization.

I believe my past experiences in environmental stewardship and civic ecology practices helped me maintain a more grounded perspective in interpreting the results of my field research. The following assumptions inevitably shaped my work: First, having been a civic ecology practitioner *and* a technical assistance provider tasked with helping other practitioners, I came to this research project with the strong belief that civic ecology practices can improve over time. Second, I believed (and continue to believe) that civic ecology practices are knowledge intensive, and that practitioners create useful knowledge about their work together through sustained and critically reflective engagement in that work. These presuppositions certainly influenced my interest in exploring the knowledge making dimensions of civic ecology practices and likely led me to ask questions focused on data collection, knowledge construction, and collective learning in these practices.

### *From Validity to Trustworthiness*

The concept of validity is contested terrain in constructivist approaches to qualitative research (Lincoln and Guba 1985a). For some action researchers, the concept of validity, with its links to concerns about reliability (replication of findings) and objectivity, is something to be ignored as incompatible with participatory inquiry (McTaggart 1997; Melrose 2001). Others have engaged the issue as an opportunity for ongoing negotiation and re-interpretation, building on Lincoln and Guba's (1985) efforts to translate "validity" into a concern with "trustworthiness" in qualitative research. In keeping with the qualitative and constructivist framework guiding this study, I choose to grapple with validity through the alternative concepts of *confirmability, transferability,* and *credibility* proposed by Lincoln and Guba (1985) as dimensions of a study's *trustworthiness*.

Confirmability deals with the degree to which the findings from a qualitative research project are shaped by participants and their experience of a social phenomenon, rather than the opinions or perspectives of the researcher (Lincoln and Guba 1985a). Confirmability, therefore, mirrors the concept of objectivity in positivist science research and deals with similar issues of neutrality on the part of the researcher. To achieve confirmability, this study employs two strategies recommended by Lincoln and Guba for both data collection and analysis. First, I drew on multiple data sources—interviews, focus groups, field observations, and archival documents—in each case to *triangulate* my findings. Second, I engaged in *member checking,* consulting with participants for feedback on conceptual themes emergent from my analysis of the data. In most cases, member checking took the form of casual follow-up conversations with participants, wherein I would vocally reflect themes and concepts emerging from data analysis and ask for clarification and confirmation that my findings "fit" their experience. In other cases, I shared formal research memos with participants to achieve the same ends. In all cases, participants offered valuable feedback that helped further refine my research findings.

The concept of *transferability* in qualitative research relates to themes of generalization and external validity in the positivist research tradition. For readers to draw their own conclusions about the applicability of my findings to other contexts, I offer detailed descriptions of the settings, participants, issues, and histories framing this study. In the positivist research paradigm, themes of consistency and reliability deal with the *replicability* of research findings. As Lincoln and Guba (1985) argue, the quest for replicability hinges on "the assumption of naïve realism" (p. 299), or a belief that phenomena have some essential and unchanging objective existence that allows for experimental replication under similar circumstances. Social phenomena, however, are fluid constructions and humans are forever changing (Lincoln and Guba 1985). Replicability in qualitative social research, then, is arguably an inappropriate measure of the consistency of a researcher's findings. Lincoln and Guba posit the concept of *dependability* as an alternative, with an "inquiry audit" as the strategy for reducing risks to dependability in a qualitative study. The inquiry audit involves a third-party review of both the *process* for collecting and analyzing data and the *product* of the study—"the data, findings, interpretations, and recommendations" (Lincoln and Guba 1985). To that end, I took steps to create what Lincoln and Guba (1985) describe as an "audit trail" (p. 319) and engaged in debriefing with "critical friends" (Appleton 2011) to review and critique the consistency of my work as it developed. Critical friends included social researchers and individuals engaged in practices like those included in this study.

At the core of any effort to build the trustworthiness of a qualitative research project couched in the constructivist paradigm is a concern with *credibility*, or the study's truthful reflection of reality. In the positivist tradition, this concern with truth is commonly known as "internal validity," or the extent to which the findings of the study correlate to a stable and unchanging phenomenon in an objective and unitary reality. The constructivist paradigm, however, challenges this view and posits that social reality is made up of a mosaic of overlapping and, at times, contradictory perspectives. A credible study, then, must demonstrate that it has accounted for these multiple constructions of reality in its final interpretation while simultaneously being transparent about the constructed nature of the interpretation itself. In short, a credible study accounts for multiple points of view. Lincoln and Guba (1985) put forward a variety of strategies for reducing threats to credibility. This study employed the following: *triangulation* of both data sources and data collection methods; *member checking*, or submitting themes and insights that emerge from analysis to research participants for confirmation; and *persistent observation* and *prolonged engagement* in a research site to ensure depth and consistency of findings.

### *Conclusion*

The qualitative research project put forward in the following pages was framed by a constructivist worldview and undertaken using an eclectic mix of qualitative data collection and analysis strategies, beginning with participant observation and extending to include interviews, focus groups, and archival research. Using the method of constant comparative analysis to code and derive overarching themes from qualitative data, I iteratively constructed new insights in response to questions about *how* civic ecology and stewardship practitioners create and manage knowledge in their work together—either through data-intensive outcomes monitoring or more tacit forms of knowledge making tied up in practice. Although I took steps to ensure the trustworthiness of my conclusions through member checking, triangulation, and maintaining an audit trail, my findings are not meant to serve as isomorphic representations of a static social reality, but one of multiple possible *interpretations* of the practices I explored. The cases reviewed here are not meant to be statistically significant samples representative of all civic ecology and stewardship practices. They nonetheless align with descriptions and definitions of these practices put forth by leading scholars in this field of research. The insights and findings described in Chapters 4 and 5 may be transferrable to other similar civic ecology and stewardship practices, but the onus of determining transferability is on the *reader* rather than the *author* of this text.

CHAPTER 3
THE INCLUSIONARY PRODUCTION OF ENVIRONMENTAL KNOWLEDGE FOR SCIENCE, REGULATION, AND MANAGEMENT

***Introduction***

Environmental scientists are increasingly turning to members of the public for help in framing research projects, collecting and analyzing data, and sharing research results with wider audiences. This turn toward more inclusionary approaches to the production of scientific knowledge is generally labeled "citizen science" (Cooper 2016), and the phenomenon has grown alongside the need to collect more long-term and large-scale data in various branches of the environmental sciences (Callahan 1984; Magurran et al. 2010). Citizen science has also become an object of study with a proliferation of books, research articles, and academic conferences focused on the phenomenon. One widely cited paper proposes a five-part system for classifying different cases of "public participation in scientific research" based on the *degree* and *quality* of public participation in an idealized scientific knowledge production process (Shirk et al. 2012). Other studies explore challenges to the validity of knowledge produced through citizen science and the capacity of non-scientists to "get with the program," (Bonter and Cooper 2012), learning to rigorously, accurately, and impartially frame research initiatives, collect data, analyze findings, and construct theories in accordance with the epistemic culture (Knorr-Cetina 1985) of a particular branch of environmental science.

Many practices labeled "citizen science" focus on the production and progressive accumulation of knowledge as a feature of what Kuhn (1996) labeled "normal" science operating within a bounded theoretical paradigm. For the purposes of this paper, the environmental sciences are broadly defined as "normal" (in the Kuhnian sense) research practices engaged in the production of scholarly research vetted through peer review and codified in journal articles or other adjudicated publications. Much of what constitutes environmental science is classifiable as either "pure" or "basic" research, producing knowledge *primarily* for the sake of unfettered exploration and discovery (Maxwell 2007). Alternately, Carrier (2004) identifies two general models of "applied" science: 1) A "cascade" model, wherein the results of a "pure" research project provide useful insights for addressing a "real world" problem; or 2) A "dappled" model (drawing on Cartwright (1996)), wherein the epistemic boundaries between pure and applied research are less distinct and both bear responsibility for creating generalizable truths *and* solutions to particular problems. Carrier writes:

> Applied science is no less concerned with trustworthiness and reliability than pure science, and methodological values like theoretical unification and causal analysis are tried and tested means for accomplishing these practical purposes as well (p. 292).

This paper acknowledges the epistemic link between pure and applied research described in Carrier's two models and treats both forms of environmental science as primarily *scholarly* endeavors undertaken by normal (again, in the Kuhnian sense) research scientists to extend the storehouse of generalizable knowledge within a research paradigm. Citizen science, then, involves broadening the circle of participants engaged in scientific scholarship to include individuals who do not identify as trained experts in a research paradigm.

Gibbons et al. (1994) demonstrate the propensity in Western cultures to normatively classify all *valid* forms of knowledge production as science, while all other forms are pejoratively labeled "unscientific." Despite the prevalence of this cultural prejudice, scientific scholarship does not have a monopoly on knowledge production, and other social practices have their own standards and methods for producing, vetting, and accumulating knowledge as what Dewey (1941) more broadly described as "warranted assertions" of truth. It follows, then, that *citizen* science does not have a lock on knowledge production practices that include voices typically found outside of a dominant discourse or class of expertise. Yet other inclusionary knowledge making traditions often find themselves swept up in the rhetoric of citizen science despite their own explicit disassociation from the epistemologies, methodologies, and teleology of scientific scholarship. Efforts to map the landscape of inclusionary knowledge production practices operating outside of scientific scholarship often revert to the word "science" as a descriptor. A panoply of different labels have been used to classify practices that include "citizens" (Dickinson and Bonney 2012), "locals" (Antweiler 1998), "the public" (Shirk et al. 2012), and "amateurs" (Gura 2013) in the production of "civic science" (Wylie et al. 2014) "action science" (Argyris, Putnam, and Smith 1985), "street science" (Corburn 2005), "community science" (Carr 2004), and "post-normal science" (Funtowicz and Ravetz 1991), to name just a few examples. These labels often rely on—and, therefore, perpetuate—a scientist/non-scientist or expert/non-expert binary in their classification of different actors, creating analytic challenges when individuals in a study do not tidily fit into either box (Collins and Evans 2007).

Alternative practices of knowledge production can share with scientific scholarship a commitment to rationality, empiricism, reproducibility of findings, parsimony of explanation, commensurability with existing conceptual frameworks, and probabilistic predictions of future outcomes based on statistically valid samples of past and present conditions. And, like scientific scholarship, these alternative knowledge production practices can take more inclusionary forms, drawing a broader circle around a community of participants engaged in making knowledge together. Yet the *primary purpose* of the knowledge produced by these alternative practices is *not* the advancement of original scholarship generalizable to other settings and promulgated through research publications. Instead, the knowledge they produce *primarily* (although not exclusively) aims to do some other kind of work.

In this paper, I take the position that labeling *all* inclusionary forms of environmental knowledge production "citizen science" (or other such phrases that use "science" as a synonym for knowledge production) is conceptually imprecise. If other social practices engage in the production of environmental knowledge for purposes other than the progressive accumulation of scientific scholarship, how might we investigate their more inclusionary manifestations without recourse to the rhetoric of science? Funtowitz and Ravetz (1993) propose, "One way of distinguishing among … different sorts of research is by their goals" (p. 740), and Jasanoff (1995) identifies *goals* as one of nine variables for differentiating between what she called "research science" and "regulatory science" (p. 283). Building on these precedents, I propose three broad categories of inclusionary production of environmental knowledge (I.P.E.K.) based not on the *nature* of the knowledge they each produce (epistemology) or the *strategies* they each employ (methodology) but the *purpose* or *aims* they each hold for the knowledge that results from more inclusive forms of inquiry (teleology). They are:

1. I.P.E.K. for *scientific scholarship*, or the progressive accumulation of knowledge within a scientific paradigm, either for its own sake or for delayed purposes of application;
2. I.P.E.K. for *regulation,* or the enforcement, refinement, and enactment of laws and policies dealing with environmental pollution, resource, extraction, and public health; and
3. I.P.E.K. for *management*, or the influence of day-to-day decisions by environmental stewards adaptively shaping the evolution of social-ecological systems.

I drew on my own experience working with participatory research initiatives and literature on citizen science and public participation in scientific research to develop these three domains. I begin to demarcate the boundaries between them with the following two overarching questions:

1. What is the primary *use* for the knowledge produced in inclusionary forms of environmental scholarship, regulation, and management, and how are issues of uncertainty and reliability tied up in their teleology?
2. What are the inclusionary dimensions of each domain of I.P.E.K.? How does each domain draw a wider circle around the community of participants engaged in knowledge production?

The second prevailing meaning attributed to the word *inclusionary* in the Oxford English Dictionary defines the adjective as “not excluding any person on the grounds of race, gender, religion, age, disability, etc.: encouraging or accommodating participation from all forms of society” (“Inclusionary, Adj.” 2016). I choose to describe various forms of knowledge production practices as *inclusionary* (rather than “participatory” or “collaborative”) for two reasons. First, in keeping with the dictionary definition cited above, I aim to create space for exploring the different viewpoints, backgrounds, and forms of expertise (Collins 2014) that can productively come together in different knowledge production practices. Second, an inclusionary approach sidesteps political issues of identity and nationality that result from using *citizenship* as a descriptor.

I focus exclusively on the inclusionary production of *environmental* knowledge for two reasons. First, the concept of citizen science originally developed out of cases of environmental regulation (Irwin 2002) and environmental science (Cooper, Hochachka, and Dhondt 2012) and, consequentially, much of what we know about inclusionary knowledge production practices deals with environmental problems and phenomena. Second, the environmental management literature explores a variety of inclusionary knowledge making practices that take the form of adaptive collaborative management (D. R. Armitage et al. 2008), community-based monitoring (Conrad and Daoust 2008) and traditional environmental knowledge (Berkes, Colding, and Folke 2000). Thus, a focus on environmental issues offers a rich assortment of empirical cases and conceptual points of view relevant to the study of inclusionary knowledge production practices in all three domains of I.P.E.K. My own research interests involve knowledge production as a dimension of urban environmental management initiatives variously labeled "civic ecology" (Krasny and Tidball 2015) or "urban environmental stewardship" (Svendsen and Campbell 2008) practices. Cleaving the conceptual domain of I.P.E.K. for management apart from I.P.E.K. for scientific scholarship or regulation creates space for a more grounded and empirically valid investigation of knowledge making as a dimension of these practices.

I begin with an overview of the social constructivist worldview that frames this paper, including the perspective that all knowledge is socially constructed, that the categories of I.P.E.K. proposed here are themselves constructions (rather than isomorphic attempts at representing social reality), and that "social learning" in environmental management practices may be seen as a process of knowledge *production* rather than didactic knowledge *transmission.* I go on to review the basic aims of knowledge production for environmental science, regulation, and management before addressing the "inclusionary turn" in all three categories. I conclude by arguing that scholars of inclusionary forms of knowledge production should take a grounded approach to investigating cases in each of these three categories on their own terms and without recourse to "citizen science" as a catchall descriptor.

### *Social Constructivism*

This paper is framed by a social constructivist worldview in its approach to three key concerns explored below: 1) The social construction of all knowledge, including scientific scholarship; 2) the constructed nature of classification systems such as the one proposed here for demarcating boundaries between three domains of I.P.E.K.; and 3) The production of knowledge as a form of learning in the constructivist tradition of education theory and its relationship to inclusionary forms of environmental management. Social constructivists generally assert that human experiences of reality are mediated by mental models or *constructs* that become reified and shared by multiple individuals over time (Berger and Luckman 1967). While some social constructivists identify as *ontological* skeptics and deny the existence of an objective reality beyond human culture and society, others identify as *epistemological* skeptics and hold that human experience of an objective reality is always socially mediated (Lincoln and Guba 2013). Knowledge, in this view, is a social construct—not an isomorphic “mirror of nature” (Rorty 1981; Bloor 1976) but a metaphoric heuristic (Lincoln and Guba 2013; Lakoff and Johnson 1980) for making sense of reality and getting by in a shared experience of daily life (Collins 1985; Bloor 1983).

Nord and Connell (2011) describe a persistent controversy in the organizational studies literature over “what counts” as knowledge, with ongoing disagreement over “the possibility of knowledge that is certain” (p. xx)—or, in Pragmatist terms, knowledge that corresponds to an objective reality (see above). Given this controversy, organizational scholars often sidestep definitions of knowledge in their research on knowledge management (Brown and Duguid 2000). However, Krogh et al. (2000), drawing on constructivist perspectives, describe knowledge for organizational studies as “justified true belief… based on observation of the world” from a "unique viewpoint, personal sensibility, and individual experience" (p. 6). Their working definition of knowledge frames this paper and, consequentially, I treat all knowledge production processes—including scientific scholarship—as social processes that are eligible objects of social research.

The social production (or construction) of knowledge in traditional cultures has long been an object of study in anthropology (Lévi-Strauss 1966; Geertz 1983), while the sociological study of *scientific* knowledge production developed more recently in science and technology studies (STS). A social constructivist worldview has framed various forms of science and technology since the early 1970s and social constructivism has since become "a convenient label for what holds together a number of different parts of STS" (Sismondo 2010, p. 60). Although different shades of constructivist thought exist within STS (Kukla 2000), this worldview fostered a proliferation of sociological studies of scientific knowledge production practices (Latour and Woolgar 2013; Collins and Pinch 1998; Knorr-Cetina 1985), establishing scientific knowledge production practices as valid objects of ethnographic research (Bloor 1976). The social constructivist perspective within STS allows for a wide-ranging definition of knowledge that includes not just "… belief which has passed on objective test and is held because it has passed the test" (Hollis 1982, p. 68) but also "…whatever men take to be knowledge… those beliefs which men confidently hold and live by" (Bloor 1976, p. 5). Drawing on these traditions, I treat cases in all three domains of the inclusionary production of environmental knowledge as eligible objects of sociological research.

Demarcating the parameters of different inclusionary environmental knowledge production practices is, itself, a constructive process of "boundary work" (Gieryn 1983; Bowker 2015; Bowker and Star 1999). The three categories proposed here are themselves constructions—abstract and metaphoric models or "ideal types" in the Weberian sense (Johnson 2000)—and their boundaries are liable to shift. As Jasanoff (1990) notes, efforts to "draw clear distinctions between various subtypes of science" are "fraught with conceptual difficulties" (p. 76), and the same could be said for more generally drawing boundaries between subtypes of knowledge production. Taking these conceptual difficulties into account and recognizing the constructed nature of all boundary work, I offer up the three domains of I.P.E.K. as flexible heuristic tools useful for making sense of different social practices rather than as reified and immutable social facts (Durkheim 1982).

Within the three bounded domains of I.P.E.K. proposed here we find "boundary objects" (Star and Griesemer 1989): "scientific objects which… inhabit several intersecting social worlds" (p. 3939). Boundary objects are similar "tools, methods, even concepts" (Star and Griesemer 1989, p. 3939) employed in different social practices to produce knowledge for different purposes. The phrase "environmetnal monitoring," for example, is an object that transcends the three domains of I.P.E.K., showing up in citizen science projects producing scholarly knowledge about bird populations (Niven et al. 2004), environmental justice initiatives producing knowledge about polluting industries to enforce regulations (Ottinger 2010), and environmental management initiatives producing knowledge about the outcomes of adaptations in practice n. The existence of boundary objects across social categories does not negate the conceptual usefulness of boundary work, but invites both researcher and reader to remain mindful of the constructed nature of all social categories. Indeed, admitting that the three domains of I.P.E.K. are constructions makes them no less consequential to practical concerns such as demarcating research programs, regulating research standards, constructing divisions of labor in social practice, and evaluating managerial activities (Bowker and Star 1999).

I therefore propose these three domains of I.P.E.K. with two general caveats. First, as constructions, the boundaries around these categories are inherently fluid and subject to resurvyeing and redrawing with further research and conceptual development. Second (and as a consequence), these categories are not intended to serve as tools for performing normative evaluations of social practices—in particular, using I.P.E.K. for scientific scholarship as a yardstick for measuring the validity of inclusionary knowledge production toward regulation or management. Drawing on the concept of *symmetry* from Bloor's (1976) Strong Programme in the Sociology of Knowledge, I treat each domain as a different knowledge production practice worthy of study on its own epistemic terms and without recourse to scholarly science.

Finally, this paper takes a constructivist position on the relationship between concepts of learning, inquiry, innovation, and knowledge production. As in STS, a range of approaches to constructivism exist within education studies. Doolittle (1999; 2014) outlines three broad categories of constructivist thought in the educational literature: *trivial, radical,* and *social.* Trivial constructivists see learning as "the internatlization and reconstructoin of external reality" (Doolittle 1999, p. 486) and generally believe that knoweldge *can* be an isomorphic representation of an external world. Radical constructivists, on the other hand, see learning as "the reconstruction and reorganiztion of old knowledge structures in light of new experiences" (Doolittle 1999, p. 486) and *deny* a direct link between knowledge and the reality it purports to explain or represent. Social constructivists share with radicals a skepticism for epistemological realism, while emphasizing knowledge construction as "the *interaction* between the learner and the environment, including other learners" (Doolittle 1999, p. 486). Despite these differences, "constructivist learning theory is based on the now commonplace idea that knowledge is actively constructed by the learner" (Prawat and Floden 1994, p. 37) and, consequentially, "learners should be allowed to construct knowledge rather than being given knowledge through instruction" (Ally 2004, p. 18).

Conceptual overlaps exist between social constructivism in STS and in education studies, beginning with the work of Pragmatist philosopher John Dewey. Drawing on the work of fellow Pragmatist Charles Sander Peirce, Dewey (1938) defined inquiry as:

> … the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations so as to convert the elements of the original situation into a unified whole (p. 104-105).

Scientific scholarship in all its forms, according to both Peirce and Dewey, constitutes a *community* of inquiry, with scientists engaged in a social process of iteratively constructing, testing, and reconstructing new knowledge together (Lipman 2003). Dewey went one step further thn Peirce and saw communities of inquiry at work in a variety of social practices beyond science, including education (Hare 1992). "Inquiry and questioning, up to a certain point, are synonymous terms," Dewey wrote (1938, p. 105), presaging by nearly fifty years the observation by educational theorist Jerome Bruner that "… not knowing [is] the chronic condition not only of a student but of a real scientist" (Bruner 1996, p. 115). Thus, social constructivists in education studies see a blurry line between knowledge production as original *inquiry* and knowledge production as *learning,* leaving open the possibility that any group of people (not just scholarly scientists) engaged in sustained, rigorous, and empirically grounded efforts to puzzle through a problem are themselves engaged in the construction of new knowledge.

Since Dewey, educational theorists and practitioners have developed a diversity of approaches to social constructivism as it relates to knowledge production as a facet of adult learning. Kurt Lewin's "action research" methods systematized a process of critical reflection in the midst of professional practice aimed at making incremental improvements in both knowledge and work (Lewin 1946). “Participatory action resarch” generally extends Lewin’s methods beyond the workplace to include reflexive and iterative knowledge production in the service of emancipatory social movements (Fals-Borda 1991; J. M. Chevalier and Buckles 2013). Paulo Freire (2000) and Myles Horton (1997), both progressive educators working within emancipatory social movements (Freire with peasant farmers in Brazil in the 1950s and Horton with labor and Civil Rights activists in the southern U.S. throughout the early and mid-twentieth century), developed styles of teaching and learning based on the construction of new knowledge in response to challenges of poverty, disenfranchisment, and racism. Freire challenged what he called the “banking concept” of education as the passive transmission of static knowledge from teacher to student and framed the creative construction of new knowledge-in-learning as an emancipatory act, mirroring Dewey’s (1927) thoughts on the relationship between inqiry and participatory democracy.

As social constructivism in progressive adult education flourished, studies of social constructivism in workplace learning also developed beyond the work of Lewin and his contemporaries. Etienne Wenger (1998), along with Jean Lave (Lave and Wenger 1991), proposed the label “communities of practice” to describe a holistic view of learning and knowledge production as emerging from the intertwined processes of work practice, meaning-making, community cohesion, and individual identity development. Wenger and Lave focused on social processes with learning centered around an indvidual’s initiation into a community of practitioners through “limited peripheral participation” in a static work practice (Cox 2005). Brown and Duguid (2001) and, indirectly, Orr (1996) extended the concept to include more dynamic social practices focused on creativity, innovation, and iconoclastic problem solving, creating a conceputal overlap between Dewey’s communities of *inquiry* and Wenger and Lave’s communities of *practice.* Biza et al. (2014) propose that a community of practice becomes a community of inquiry when it makes inquiry, or the social practice of knowledge construction, a central a driving concern. More recent research into knowledge construction in work practices has fallen under the broad heading of "knowledge management," with varying emphases on information technology, training, research and development, and the negotiation between tacit and explicit forms of knowledge made in practice (Dalkir 2005).

Learning and discovery are thus interchangeable concepts when working from a constructivist perspective. Many of the scholars mentioned in the preceding paragraphs share a willingness to see non-human subjects and non-social processes as objects of inquiry within a work practice. While Lewin, Freire, Dewey, and others in the (participatory) action research tradition focused on the social construction of knowledge about mostly *social* phenomena, management scholars have developed case studies of workplace knowledge production about everything from broken photocopiers (Orr 1996) to bread machine prototypes (Ikujirō Nonaka and Takeuchi 1995). Workplace "learning," in this sense, is a productive process synonymous with "discovery" or "innovation" and mirrors the semantic use of "learning" as an outcome of scientific inquiry. Scientists colloquially speak of "learning" something new in original research, using the word interchangeably with "discovery" or "finding" in writing up the results of their work. The fisheries scientist Ray Hilborn wrote that "the scientific method is nothing more than an approach to learning about nature" (Hilborn 1992, p. 8) and Wenger noted that science is itself a community of practice—indeed, a community of *inquiry*.

Drawing on constructivist perspectives in STS, education theory, and management research, this paper treats the processes of *learning* and *knowledge production* as conjoined in all three domains of I.P.E.K. In doing so, I aim to sidestep a long and ongoing debate over the nature of "social learning" in the study and practice of adaptive collaborative management (ACM) for ecosystems and individual natural resources (Reed et al. 2010; Wals 2007; Pahl-Wostl and Hare 2004; Blackmore, Ison, and Jiggins 2007; Keen, Brown, and Dyball 2005; Muro and Jeffrey 2008). Reed et al. (2010) offer a wide-ranging critique of "social learning" in the environmental management literature, charging that most definitions of the concept are either vague or broad enough to "encompass almost any social process" (p. 1), a condition that Armitage et al. (2008) describe as the "paradox of learning" in their field. Some uses of the phrase focus on learning as a process of collective behavior change and the adaptation of social arrangements toward the creation of more environmentally sustainable societies (Keen, Brown, and Dyball 2005). Others conceptualize social learning as the thorny process of achieving consensus in the deliberations and negotiations that are often a feature of inclusive natural resource management (Pahl-Wostl and Hare 2004). Social learning, then, is an essentially contested concept (Gallie 1955) across the environmental management literature, and a universally accepted definition is likely to remain out of reach. Instead of wading into the social learning debate, I treat *learning* in I.P.E.K. for scientific scholarship, regulation, and management as interchangeable with *knowledge production*—not just about *social* phenomena, but about any object of inquiry, including biophysical environmental phenomena. People engaged in the practices of environmental regulation and management often produce new and innovative insights into the biophysical dimensions of social-ecological systems without recourse to scientific scholarship. Science may have a lot to say about effectively managing farms, forests, and fisheries—but so do farmers, foresters, hunters, and anglers working outside of science in their daily knowledge-making practices (Davidson-Hunt and Berkes 2003).

Thus, participants in each of the three domains of I.P.E.K. are engaged in different communities of practice/inquiry, constructing new social *and* environmental knowledge for different purposes according to their own needs and aims. And while individuals may learn pre-existing skills, concepts, and attitudes from each other as they engage in a community of practice, they also "learn" (or produce/construct) new social and biophysical environmental knowledge in response to scholarly, regulatory, or management aims. The *inclusionary* dimension of I.P.E.K. deals with the extent to which voices outside a dominant form of discourse find themselves engaged in constructing knowledge within that discourse. In the practice of environmental science, we see "citizen scientists" or "the public" working with academic scientists to construct scholarly knowledge, often aimed at advancing knowledge for its own sake in the form of "pure" research. In the practice of environmental regulation, we see "civic" or "community" scientists working with (or against) regulatory scientists (Jasanoff 1990) to construct knowledge aimed at enforcing, extending, or amending environmental regulations. Finally, in the practice of environmental management, we see indigenous communities, agriculturalists, and renewable resource harvesters in rural settings and "stewards" (Svendsen and Campbell 2008) or "civic ecology practitioners" (Krasny and Tidball 2015) in urban and peri-urban settings constructing knowledge toward improving their practices over time.

***Aims of Knowledge Production in Environmental Science, Regulation, and Management***

One strategy for demarcating the boundaries between different knowledge production practices involves exploring their divergent goals and objectives (Jasanoff 1990; Funtowicz and Ravetz 1993). What, then, are the aims of knowledge production in scholarly environmental science, environmental regulation, and environmental management? How are those aims tied up with issues of reliability and certainty in the knowledge produced by each domain? The following section briefly outlines the general aims of knowledge production in each domain of I.P.E.K. before considering the inclusionary "turn" in each domain.

*Production of environmental knowledge for scholarly science*—Scholarly science is engaged in a search for certainty (Nord and Connell 2011), and various branches of environmental science generally work toward the same knowledge production objectives as any other scientific discipline operating under what Gibbons et al. (1994) name "the Newtonian model" of knowledge production (see Introduction). To that end, most environmental sciences are primarily concerned with producing new knowledge for its own sake in the form of "pure" or "basic" research (Carrier 2004). "Applied" forms of scientific scholarship are both influenced *by* and influential *over* basic research (Carrier 2004) and academic scholars are professionally compelled to codify, promulgate, and accumulate new knowledge in the form of peer-reviewed journal articles (Niiniluoto 2015). Scholarly environmental science focuses on producing "truths of originality and significance" (Jasanoff 1995, p. 283) presented "in the form of laws or principles that enable us to predict what will happen and to see why it happened" (Goldstein and Goldstein 1981, p. 6).[1] Further, the environmental sciences generally operate under the positivist premise that an external reality can be known on its own terms and that "generating new knowledge is a good thing in itself" (Ison 2005).

*Production of environmental knowledge for regulation*—Regulatory issues in environmental governance often demand a speedier knowledge production process than those found in scholarly science, and the results of "regulatory science" (Jasanoff 1990) are often more tenuous and contestable as a result (Rushefsky 1986; Collins and Pinch 1998; Breuste,

[1] Kuhn (1996) challenged the notion that science engages in an uninterrupted accumulation of new knowledge by proposing the idea of incommensurable scientific paradigms punctuated by periodic revolutions. Yet Kuhn also acknowledged that the work done within a paradigm—what he called "normal" science—builds upon itself in a progressive process of knowledge accumulation up to the point of revolution.

Feldmann, and Uhlmann 1998). “Science, if it can deliver truth, cannot deliver it at the speed of politics,” write Collins and Evans (2007, p. 1). Thus we find a second domain of environmental knowledge production that, though typically labeled regulatory science, aims to produce knowledge that serves a qualitatively different purpose than the knowledge produced by scholarly science (Jasanoff 1990; 1995). Regulatory science shares boundary objects with scholarly science, from technical research equipment to procedures and methodologies. However, while normal science codifies and accumulates knowledge in peer reviewed journal articles, findings in regulatory science rarely become reified in the same types of products. Instead, regulatory knowledge is encoded in policy papers, legal documents, environmental statements, and legislation—all artifacts subject to political and legal (rather than purely scientific) adjudication (Stone 2002). Thus, the knowledge produced as a feature of environmental regulation is immediately put to work in enforcing and informing regulatory policy.

*Production of environmental knowledge for management*—The purpose of knowledge production for environmental management has shifted from a focus on improving, increasing, and sustaining renewable resource yields (Walters 1986) to a more holistic concern with fostering species diversity and dynamic resilience in complex ecosystems (Holling 1978). This shift in aims has paralleled a shift in the epistemology and methodology of knowledge production for environmental management from a top-down “command and control” paradigm applying one-size-fits-all-solutions to different problems (Holling and Meffe 1996; Layzer 2008; Brunner et al. 2005) to a more iterative and spatiotemporally limited approach labeled “adaptive management” (Holling 1978; Walters 1986; Walters and Holling 1990; Cook et al. 2004). The epistemology of environmental knowledge production for adaptive management shares with philosophical Pragmatism a skepticism for universal truths and certainties (Blackmore 2007) and admits that "knowledge is always incomplete" and "surprise is inevitable" (Holling 1998, p. 3). It also shares with action research the belief that "there is nothing so practical as a good theory" (Lewin 1946) tested iteratively and applied in a social context (Olsson, Folke, and Berkes 2004; Carpenter and Gunderson 2001). Thus adaptive management, like action research, has been described as a "mode of learning" (Lee 1999, p. 13) in the constructivist sense (see above).

Despite this epistemic shift, scholars working within an adaptive management paradigm still use the scientific metaphor of "large-scale management experiments" (Walters and Holling 1990) to describe their knowledge making practices, emphasizing formal data sampling, monitoring, and analysis methods interlaced with day-to-day management work (McLain and Lee 1996; Halbert 1993; Plummer 2009). Lee (1999, p. 6) describes adaptive management as "slipshod hypothesis testing" that, while not "as reliable as academic science," is better than blind trial-and-error in developing knowledge for conservation work. Walters and Green (Walters and Green 1997) frame adaptive management as "experimental management" and outline steps for dealing with uncertainty about causal relationships in iterative management "experiments," their interactions with outside variables, and the effects they jointly produce in a complex ecosystem. Even within an adaptive management framework that acknowledges uncertainty, scholarly scientists often aim to reify new knowledge claims in peer-reviewed journals and subsequently share useful insights from research with managers for application and further testing (Plummer and FitzGibbon 2008). Further, scholars of environmental management continue to assert that "modern science is indeed a better organized system of elaborating knowledge of the world" (Gadgil et al. 2002) while simultaneously declaring the limited validity of other knowledge systems. Thus we see boundary objects "crossing over from normal science into the production of environmental knowledge for management and a general admission that such knowledge aims to achieve the same purpose as knowledge produced by scholarly science (though it often falls short of the mark, as Gunderson and Light (2006) note).

### ***The Inclusionary Turn in the Three Domains of I.P.E.K.***

The three domains of environmental knowledge production outlined above have each experienced an inclusionary turn in both theory and practice (see Table 1). I.P.E.K. for science has seen the rise of "citizen science" as a strategy for democratizing scholarly knowledge production and, simultaneously, facilitating more data-intensive forms of long-term ecological research with help from armies of volunteers. I.P.E.K. for regulation has been both challenged and supported by various forms of "advocacy science," with a broader circle of people engaged in producing knowledge aimed at enforcing, enhancing, or extending environmental regulations. Finally, within the domain of I.P.E.K. for management, we see two different manifestations of inclusivity in knowledge production: first, the shift from adaptive management to adaptive *collaborative* management in both decision-making and knowledge-making, and second, the scholarly acknowledgement of the role of various forms of "local knowledge" or "common sense" that emerges from day-to-day practice *outside* of scientific management. The following section explores the inclusionary turn in each of the three domains in more depth.

| Table 1: Three Domains of Inclusionary Production of Environmental Knowledge | | | |
|---|---|---|---|
| | **Science** | **Regulation** | **Management** |
| **Purpose** | Knowledge for its own sake, independent of values or needs. | Knowledge for enforcing, enhancing, or extending environmental laws or policies | Knowledge for managing complex ecosystems and natural resources |
| **Inclusionary Labels** | citizen science; public participation in scientific research | citizen science; advocacy research; action research; participatory action research; street science | adaptive co-management ———— traditional environmental knowledge; indigenous knowledge; local knowledge; ordinary knowledge |

*I.P.E.K for Science*—The inclusionary production of environmental knowledge for scholarship has generally been referred to as "citizen science" or, more recently, "public participation in scientific research," drawing on the work of scholars at the Cornell University Lab of Ornithology (Bonney et al. 2009; Cooper et al. 2007; Dickinson and Bonney 2012; Shirk et al. 2012). These scholars have framed citizen science as an expansion of the personnel involved in various stages of normal scientific knowledge production, from identifying research questions all the way through analyzing and publishing research results (Miller-Rushing, Primack, and Bonney 2012; Oberhauser and Prysby 2008; Jordan, Ballard, and Phillips 2012). Thus public participation in scientific research is not a watered-down version of rigorous academic science, but an attempt to broaden the community of practitioners engaged in producing knowledge for the advancement of science through the publication of peer-reviewed journal articles (Bonney et al. 2009; Dickinson, Zuckerberg, and Bonter 2010, 2; Miller-Rushing, Primack, and Bonney 2012; Conrad and Hilchey 2011; Bonter and Cooper 2012).

**Box 1: Examples of I.P.E.K. for Science**

*Audubon Christmas Bird Count*—The National Audubon Society (Audubon) is a U.S.-based non-governmental organization dedicated to conserving and restoring ecosystems with a focus on birds. For more than 100 years, Audubon has sponsored the annual Christmas Bird Count (CBC) mobilizing tens of thousands of volunteers across North America to collect data on bird sightings over the course of three weeks in December and January. The Audubon Society (2015) claims “hundreds of studies by scientists around the world have put CBC data to use,” resulting in more than 200 peer-reviewed journal articles.

*Project BudBurst*—Housed at the Chicago Botanic Garden since 2007, Project BudBurst mobilizes volunteers to collect annual data on “the timing of the biological events in plants and animals such as flowering, leafing, hibernation, reproduction, and migration” (Project BudBurst 2016b) and freely shares the resulting datasets online with phenologists. The initiative has contributed data to at least ten publications in peer-reviewed journals since its inception (Project BudBurst 2016a).

Although citizen science arguably stretches back in time to the beginnings of science itself (Raddick et al. 2009; Cohn 2008), the practice of inviting non-scientists to engage in the production of academic scientific knowledge has grown significantly in the twenty-first century, particularly in the environmental sciences (Silvertown 2009). Most efforts to include non-scientists in the production of environmental knowledge for science have taken the form of what Shirk et al. (2012) label "contributory" practices, with participants trained to collect large volumes of data on environmental phenomena using standardized monitoring or surveillance protocols. In some cases, the production of a large data library is a stand-alone goal, while in other cases participants collect data toward a specific research project (Connors, Lei, and Kelly 2012; Miller-Rushing, Primack, and Bonney 2012). Drawing a more inclusionary boundary around who participates in the production of environmental knowledge for academic science has been a boon to researchers in ecology, a discipline increasingly dependent on large spatiotemporal data sets for understanding ecosystem dynamics at multiple scales over time (Freitag and Pfeffer 2013; Hochachka et al. 2012). Advancements in data management technology, mobile computing, global positioning systems, and wireless Internet have made it increasingly affordable and efficient to mobilize citizen scientists to participate in such ambitious data collection efforts (Danielsen et al. 2005; Sismondo 2010; Cohn 2008; Goffredo et al. 2010).

*I.P.E.K. for Regulation*—The label "citizen science" has also been applied to inclusionary practices of knowledge production around issues of environmental regulation, beginning with Irwin's (2002) book-length study of citizen involvement in the review of environmental threats in land use policy. Yet just as the aims and processes of what Jasanoff (1990) labels *regulatory* science are different from those of normal science, inclusionary versions of regulatory science will typically differ from the type of citizen science described above. People engaged in more inclusive forms of knowledge production for environmental regulation are *primarily* interested in enforcing, extending, or amending public policies aimed at controlling pollution, environmental injustices, and/or unsustainable resource extraction practices. Thus we often see I.P.E.K. for regulatory purposes interwoven with broader issues of participatory democracy and shared decision-making in technocratic governance (Fischer 2000; Arnstein 1969).

**Box 2: Examples of I.P.E.K. for Regulation**

*Bucket Brigades*—In 1994, regulatory agencies in Northern California "failed to identify or regulate" (O'Rourke and Macey 2003, p. 388) the release of a toxin from an oil refinery in the San Francisco Bay Area, leading local activists to design and deploy low cost air sampling technologies housed in five gallon plastic buckets. The data collected using bucket air samplers allowed community residents to bring a class action suit against the polluting refinery, resulting in an $80 million settlement awarded to more than 6,000 residents impacted by the toxin release (O'Rourke and Macey 2003). Similar "bucket brigades" emerged throughout the late 1990s and into the 2000s in other communities surrounding oil refineries throughout the world.

*Flint Water Study*—In 2015, residents of Flint Michigan turned to a civil engineering lab at Virginia Tech for help in confirming the presence of lead in the municipal drinking water supply. Despite assurances from local regulators that the local water supply was untainted, initial Virginia Tech lab tests found high levels of lead in a small sample collected from the home of a single resident. Local activists worked together to collect hundreds of statistically valid samples from homes throughout the city, using a protocol developed by the Virginia Tech lab to ensure the validity of their study. Their findings exposed malfeasance in multiple levels of government after confirming the systemic presence of lead in the city's water supply (Adams and Tuel 2016).

Regulatory scientists tend to find themselves producing knowledge about complex systems that are, by their nature, holistic, emergent, and difficult to break down and analyze as a collection of independent parts (Meadows 2008). Thus regulatory science produces *uncertain* knowledge despite demands for absolute certainty on issues of environmental risk from policymakers and the general public (Collins and Pinch 1998). Efforts to conceal the uncertainty of regulatory knowledge have caused widespread cases of public distrust in the validity of regulatory science (Wynne 1996; Collins 2014; Collins and Pinch 1998). Distrust in regulatory science has, in turn, buoyed critiques of rational planning and public policymaking that, beginning in the mid-twentieth century, promised to replace subjective political deliberation with objective scientific truth (Stone 2002; Fischer 2000; Scott 1998). Regulatory knowledge making and regulatory decision-making are therefore linked, and efforts to make one more inclusive inevitably impact the other.

In order to manage the uncertainty and "high stakes" inherent in regulatory science, Funtowitz and Ravetz (1991) proposed widening the circle of people involved in critically reviewing the results and potential applications of regulatory knowledge—a circle they described as an "extended peer community." While the pair did not foresee a role for anyone other than regulatory scientists in producing regulatory knowledge, they *did* see a gatekeeper role for people liable to be impacted by the application and use of what they labeled "post-normal" science. Yet in recent years, an inclusive turn in I.P.E.K for regulatory knowledge has gone far beyond simply vetting the products of a knowledge production process.

I.P.E.K for regulation goes by many names besides Irwin's use of citizen science, including "data advocacy" (Whitelaw et al. 2003), "advocacy research" (Fischer 2000), "community-based participatory research" (Bidwell 2009), "civic science" (Fortun and Fortun 2005), "street science," (Corburn 2005), "participatory" or "community-based monitoring" (Holck 2008; Becker et al. 2005), "advocacy monitoring" (Whitelaw et al. 2003) and, in some cases, "action research" (Lewin 1946) or "participatory action research" (Fals-Borda 1991)—to name just a few. While the various labels can confound efforts to investigate and understand commonalities among these various practices, a focus on actual case studies across the literature reveals a common interest in widening the circle of people who create the knowledge required to enforce, extend, or expand environmental regulations. More inclusive knowledge-making processes lend themselves to more inclusive decision-making processes around the same issues, thus making I.P.E.K. for regulation a factor in fostering more participatory forms of deliberative democracy (Fischer 2000).

Different cases of I.P.E.K. for regulation reflect the *contributory* and *collegial* models of public participation in scientific research proposed by Shirk et al. (2012). In some cases, regulatory scientists in government agencies engage a wider circle of people in official monitoring and surveillance programs aimed at *contributing* data necessary to enforce pollution laws, managing resource extraction, or collecting public health data related to exposure risks—particularly in cases where budget cutbacks force agencies to supplement paid personnel with volunteer labor (Conrad and Hilchey 2011). In other cases, community members, working independently or through non-governmental organizations, collect and analyze data on similar issues in order to challenge the work of regulatory scientists in government or their counterparts in the private sector (Whitelaw et al. 2003; Sismondo 2010). These cases conform to Shirk et al.'s definition of *collegial* knowledge production, wherein "non-credentialed individuals conduct research independently with varying degrees of expected recognition by institutionalized science and/or professionals" (p. 4).

*I.P.E.K. for management*—The inclusionary turn in the production of environmental knowledge for management takes three forms: 1) A conceptual shift from *adaptive* management to *adaptive collaborative* management (co-management); 2) A growing awareness of *local* or *indigenous* knowledge about environmental phenomena constructed outside of a scientific management paradigm; and 3) Efforts to bridge local and scientific knowledge of environmental phenomena in an adaptive co-management frame.

Adaptive management and collaborative management are approaches to environmental management that developed in parallel and have only recently been joined together conceptually. According to Armitage, Berkes, and Doubleday (2008):

> The co-management narrative has been primarily concerned with user participation in decision-making and with linking communities and government managers. The adaptive management narrative has been primarily about learning-by-doing in a scientific way to deal with uncertainty (p. 1).

Adaptive co-management, then, is summed up by the phrase "learning-by-doing together," with a wider circle drawn around the people engaged in simultaneously managing *and* producing scientific knowledge about social-ecological systems (Olsson, Folke, and Hahn 2004). Shirk et al.'s five-part model of public participation in scientific research is once again useful for classifying the varying degrees of outsider participation in scientific knowledge production found in different adaptive co-management cases, while Arnstein's (1969) classic "ladder of participation" can be used to gauge varying degrees of deliberative power members of the general public claim over management decisions in the same cases. Data collection through sustained environmental monitoring often provides the vehicle through which non-scientists participate in the production of knowledge within an adaptive co-management frame (Conrad and Hilchey 2011; Bonney et al. 2009), while deliberative public meetings, hearings, and hands-on management practices are some of the venues that afford community members opportunities to engage in decision making. Just as adaptive management, on its own, can resemble action research, adaptive co-management can resemble *participatory* action research in its inclusion of typically marginalized voices.

**Box 3: Examples of I.P.E.K for Adaptive Co-Management**

*Lake Racken Watershed*—Concerns over freshwater acidification in the Lake Racken Watershed in Sweden in the 1960s led residents of the region to form informal associations that monitored pH levels in Lake Racken and its tributaries. Through the 1970s and '80s, local stakeholders worked with government agencies and scientists to develop iterative processes of adaptive management, drawing on monitoring data collected by volunteers to gain insights into the outcomes of iteratively adapted management strategies for improving water quality (Olsson, Folke, and Berkes 2004).

*Holman Arctic Char Management Plan*—Government agencies, research scientists, and local stakeholders developed the Holman Area Char Fishing Plan in the early 1990s to manage fish stocks in the region surrounding Prince Albert Sound on Victoria Island in northern Canada.

The plan itself was based on fish stock data collected by community members and research scientists in the early 1980s, and updates to management strategies in alignment with the plan depended on iterative data collection and monitoring in subsequent years (Burton, Bell, and Hoyt 2008).

Berkes and Folke (2002) write of "unseen worlds" of ecosystem management beyond the "rationalist, Newtonian clockwork" of scientific approaches found in adaptive co-management (p. 121). These "unseen worlds" constitute another form of inclusionary production of environmental knowledge that emerges from daily life and management practice rather than the science-like methods of adaptive management. "Traditional environmental knowledge" (TEK) and "indigenous knowledge" are two labels commonly applied to knowledge constructed by subsistence cultures engaged in managing the ecosystems and resources they rely on for their livelihoods—a process labeled "adaptive learning" by Davidson and Berkes (2003). In other settings (including cities), the same sort of adaptive knowledge derived from the lived experience of environmental management has been labeled "local knowledge" (Corburn 2005) or "ordinary knowledge" (Lindblom and Cohen 1979) (see Box 4). While Shava (2010) inventories detailed differences between the concepts of traditional knowledge and local knowledge, Brush (1996) offers a broad definition of indigenous knowledge that also resonates with traditional, local, and ordinary environmental knowledge definitions: "the systematic information that remains in the informal sector, usually unwritten and preserved in oral tradition rather than texts" (p. 4).

**Box 4: Perspectives on Traditional, Indigenous, Local, and Ordinary Knowledge**

"Much ecological knowledge is created by professional ecologists. However, groups of resource users, such as people who live off wildlife, fish, and forests, also create knowledge from their own observations and ecological understanding, based on the accumulation of generations of trial-and-error experience" (Berkes and Folke 2002, p. 122).

"Local ecological knowledge and practice… refers to a cumulative body of knowledge applied and developed by actors in a local context. It consists of externally and internally generated knowledge about resource and ecosystem dynamics" (Olsson et al. 2004, p. 76).

[Local knowledge] "rarely conforms to conventional notions of technical rationality, including the need to search for causal models and reliance on universal principles for getting to the 'truth'" (Corburn 2005, p. 59-60).

[Ordinary knowledge] "is knowledge that does not owe its origin, testing, degree of verification, truth status, or currency to distinctive… professional techniques bur rather to common sense, casual empiricism, or thoughtful speculation or analysis" (Lindblom and Cohen 1979, p. 12).

How is such knowledge produced—or, more precisely, how is it *constructed* out of lived experience? The anthropologist Clifford Geertz (1983), drawing on the later work of philosopher

Ludwig Wittgenstein, named the sort of knowledge discussed here “common sense” or “wisdom,” the sort of knowledge that comes from sustained engagement in a social practice, its validity and reliability tested iteratively across generations. The typically unwritten nature of such knowledge means that it tends to be tacit and resistant to codification (Collins and Evans 2007; Polanyi 2009), and the processes of producing, sharing, and adapting such knowledge are difficult—if not impossible—to abstract from the practice context. Sustained data collection and monitoring can still play a role in various forms of I.P.E.K. for management that fall outside of the science-based approaches espoused by adaptive co-management (Danielsen, Burgess, and Balmford 2005). Berkes and Folke (2002) note that indigenous communities collect qualitative information about whole ecosystems and individual resources, and Kendrick (2002) emphasizes the role of myth, stories, and belief systems in collecting, interpreting, and sharing such data.

Therefore, we see a form of I.P.E.K. for management that aligns with notions of knowledge-making found in the social constructivist traditions of educational theory, with practitioners “learning” about the ecosystems and resources they manage, sharing that knowledge amongst themselves, and adapting that knowledge as conditions change. Such knowledge construction processes are not restricted to indigenous communities. As Pullin et al. (2004) note in a study of conservation managers in the United Kingdom, most environmental management decisions are ultimately based on local knowledge because “many management interventions remain unevaluated [by science]” (p. 245) or because whatever scientific knowledge there is remains either inaccessible to non-scientists or unreliable for management because of the tenuous nature of ecosystem knowledge derived by scientific practices (Holling 1998).

Bridging the inclusionary production of environmental knowledge for management from scientific adaptive co-management with that found in "local" or "ordinary" knowledge that comes out of practice is both an attractive and elusive goal (Plummer and Fitzgibbon 2004; Brunner et al. 2005). Gadgil et al. (2002) caution against efforts to abstract local knowledge from its context of origin in order to make it "fit" a more scientific framework and conclude that bridging the two inclusionary approaches to scientific knowledge production "is fraught with pitfalls" (p. 206). While we may need both forms of knowledge to effectively manage complex ecosystems, forcing them to be commensurate with each other may invalidate both, as suggested by the philosopher of science Michael Polanyi's critiques of efforts to merge tacit and explicit forms of knowledge (2009).

***Conclusion***

Despite efforts to categorize all inclusionary environmental knowledge production practices as scholarly academic science, clear differences exist in the aims and epistemologies of inclusionary knowledge production for environmental science, regulation, and management. Citizen science and various other forms of public participation in scientific research are focused on including a broader range of people in the practice of producing academic science, often focused first and foremost on advancing knowledge as a "pure" aim in and of itself. In contrast, advocacy research and other forms of inclusionary production of environmental knowledge for regulation are primarily focused on enforcing, extending, or expanding environmental laws and policies—in collaboration with regulatory scientists or to challenge their findings as they apply to public policy. Finally, knowledge production practices within scientific adaptive co-management can resemble citizen science in the use of iterative natural experiments to arrive at tenuous knowledge about complex ecosystems. However, other inclusionary knowledge productions practices can operate outside of scientific adaptive co-management to create useful and empirically valid insights into biophysical environmental phenomena. Traditional environmental knowledge and local knowledge are, by definition, *not* scientific forms of knowledge, and efforts to bridge knowledge constructed in lived practice with insights derived from science—even science interlaced with adaptive co-management—can be fraught with translational pitfalls.

What conclusions can we draw from recategorizing so many different inclusionary knowledge production practices into the three broad categories outlined above? My aim in this paper has been the construction of a classification system that allows scholars of inclusive environmental knowledge production to step over the quicksand of analysis by syllogism. Is citizen science also civic science? Is adaptive co-management just citizen science by another name? Is local knowledge in regulatory science ever the same as local knowledge in management science? The answer to these questions (and many others in the same vein) is, invariably, "It depends." Efforts to defend syllogistic propositions about different inclusionary environmental knowledge production practices run the risk of ignoring important details to make tidy "all cases of X are Y" arguments. Efforts to make different forms of inclusionary environmental knowledge production equivalent, in whole or in part, to Western science have sacrificed a grounded approach to understanding these social practices on their own terms, making it even more difficult to discern their unique properties—beginning with their various aims for making, managing, vetting, and promulgating knowledge about environmental phenomena.

In Western societies, *scientific* knowledge is a default equivalent for all valid knowledge (Gibbons et al. 1994), and even scholars of complex ecological systems who admit the limits of normal science in comprehending these systems nevertheless defend science as *the* premier knowledge-making practice above all others (Gadgil et al. 2002). Decoupling I.P.E.K. for regulation or management from I.P.E.K. for science runs the risk of delegitimizing those domains of knowledge production in a discourse dominated by science. Accusations of postmodern relativism seem to lurk behind any effort to point out the validity and reliability of inclusive environmental knowledge production practices that operate outside of the aims and methods of science. But the appropriate rejoinder to such accusations is not a rush to prove that the I.P.E.K. for regulation or management is just like I.P.E.K. for science (see, for example, Robin Dunbar's (1996) attempts to square indigenous knowledge with scientific knowledge). Arguing that all other forms of inclusionary knowledge production are essentially equivalent to science is no different from arguing that science is equal to other forms of knowledge production.

The validity and reliability of each domain of I.P.E.K. is tied up in its *purpose* for producing knowledge about social-ecological phenomena. I.P.E.K. for science is focused on producing *scientific* knowledge about social-ecological phenomena, with all the epistemological and methodological expectations we have for scientific knowledge. Yet science (and, by extension, I.P.E.K. for science) has often demonstrated an inability to effectively deal with issues of environmental regulation or management without first undergoing epistemological and methodological adjustments that end up raising questions about the scientific validity of the knowledge produced (see Schon's (1984) exploration of the tradeoffs between scientific rigor and knowledge applicability). By the same token, I.P.E.K. for regulation is a poor tool for producing purely scientific knowledge, and the same can be said of I.P.E.K. for management (particularly when I.P.E.K. for management takes the form of local or indigenous knowledge). From a constructivist perspective, different forms of I.P.E.K. are neither better nor worse at producing accurate knowledge about an objective reality, but they *are* better or worse than each other at producing valid knowledge for their own unique purposes.

I hope that reorganizing the many different labels used to categorize different kinds of inclusionary environmental knowledge production into three broad categories of I.P.E.K. will allow for a more grounded (Glaser and Strauss 1967) approach to the sociological study of each domain. A more focused approach to ethnographic research into inclusionary knowledge production for science, regulation, or management can help to tease out the unique social processes at play in each domain, including the tacit and explicit forms of knowledge specific to each domain and the methods used for managing, vetting, and promulgating innovative insights. The framework presented in this paper, then, can serve as a scaffold for ongoing efforts to understand, compare, and categorize the diversity of ways in which different actors produce environmental knowledge different purposes.

# CHAPTER 4

# DATA COLLECTION IN URBAN ENVIRONMENTAL MANAGEMENT PRACTICE

"In God we trust. All others bring data."

—William Edwards Deming, statistician and management consultant (quoted in Chevalier 2008)

## *Introduction*

Quantitative data collection in environmental management stretches at least as far back as the advent of scientific forestry in mid-eighteenth century Germany (Scott 1998), while humans interacting with their environments have arguably always collected qualitative data about the relationship between their actions and their outcomes (Gadgil, Berkes, and Folke 1993). More recently, environmental scientists have established Long Term Ecological Research stations in rural and urban settings (Waide and Thomas 2013) to build massive datasets around both social and ecological processes, and practitioners of "adaptive management" in rural ecosystems rely on data to track and assess the outcomes and impacts of an ever-evolving repertoire of work strategies (Holling 1978). "Data are units or morsels of information that in aggregate form the bedrock of modern policy decisions by government and nongovernmental organizations," writes Lisa Gitelman, a communications and media scholar (2013, p. 1).

This paper aims to develop new insights into data collection efforts within urban environmental stewardship initiatives (Svendsen and Campbell 2008) and civic ecology practices (Krasny and Tidball 2015). "Citizen engagement in monitoring of civic ecology practices enables ongoing adaptation based on information about outcomes," Krasny and Tidball (2012) propose. Yet a 2012 study of seven civic ecology and stewardship practices in the New York metropolitan region found that relatively few grassroots urban environmental management initiatives seem to engage in data collection directly related to practice, while those that do tend to favor protocols developed on-site and without input from professional research scientists (Silva and Krasny 2014). The literature includes various cases of grassroots urban stewardship groups collecting data to aid the advancement of scientific knowledge (see Campbell, Svendsen, and Roman 2016) or to play a role in regulating pollution and mitigating environmental injustices (see Wylie et al. 2014). Yet data collection directly tied to tracking the outcomes of day-to-day practice is underrepresented in both practice and scholarly research.

This exploratory paper investigates three cases of civic ecology and environmental stewardship practices that used data collection protocols, methods, and technologies developed, in whole or in part, by experts working outside of day-to-day stewardship practice. The three cases all involved practitioners collecting data directly relevant to their practices, often with the intent to use data to inform improvements in their work. I aim to classify the division of labor involved in creating and applying data collection protocols for these practices, and, in doing so, develop a clearer picture of data collection as a feature of the inclusionary production of environmental knowledge for management (see Chapter 3) in urban settings. I begin with a review of the literature on data collection as a feature environmental management practices and proceed with a comparative analysis of the roles different actors played in sponsoring, making, and using data collection tools and methods in three recent cases. I conclude with recommendations for practitioners and others engaged in inclusionary forms of data collection for urban environmental management.

### *Literature*

Environmental managers collect data for a variety of reasons. Surveys and longer-term surveillance can be used to create inventories of resource stocks and datasets with potential value for applied scientific research (Spellerberg 1991). Managers use statistically valid samples or, less frequently, full population censuses, to compile and periodically update resource inventories (Bechtold and Patterson 2005). Managers may also deploy surveys or longer-term surveillance to develop models of baseline ecosystem dynamics (Pauly 1995), though the validity of such baselines in guiding management goals has been brought into question (Campbell et al. 2009). Periodic surveys and sustained surveillance are therefore commonly found in an environmental manager's toolkit. However, they do not serve the same *management* purpose as environmental monitoring.

Hellawell (1991) proposes a circumscribed definition of monitoring as data collection and analysis used to "ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm" (p. 2). Thus, monitoring within an adaptive environmental management framework provides the feedback needed for continuous adaptations to practice. Adaptive environmental management is an iterative "learning by doing" approach (Berkes, Folke, and Colding 1998; Walters and Holling 1990) to intervening in social-ecological systems. Although adaptive management defies facile definition and comes "in a variety of flavours" (Argent 2009, p. 12), it often involves a cyclical process of goal setting, intervention, data collection (as monitoring), and reflexive changes in management policies and/or their underlying goals and objectives (Stankey et al. 2005; Plummer 2009; Allen et al. 2001). Ecologists traditionally viewed ecosystem disturbances as momentary aberrations in what would otherwise be a predictable march toward a stable state (Clements 1936). In contrast, the adaptive management worldview recognizes that "ecological systems are dirty, changing, growing, and declining" (Holling 1978)—complex and dynamic rather than static or predisposed to deterministic patterns of change. In this view, disturbances such as fires, floods, and even human land uses are not aberrations to be ignored, but important factors shaping the structure and function of ecosystems (Holling 1978). Working within this worldview, many scientists and environmental managers use a flexible and incremental approach to understanding and intervening in social-ecological systems, drawing on data produced through sustained monitoring to iteratively evaluate the impacts of a given policy or program (Burnside and Chamala 1994; McLain and Lee 1996; Walters and Holling 1990; Allen 1997).

The aim of monitoring in adaptive management is, essentially, evaluative in nature (Holling 1978; Hockings 2003; Hockings 1998). Burnside and Chamala (1994, p. 221) summarize monitoring as:

> … the provision of factual information to land holders enabling them to evaluate the impact of past decisions on the landscape and assisting them to make better future decisions.

This information can come in both qualitative and quantitative forms (Bosch et al. 1996) and provides "essential current and time series information on the status of environmental systems" (Draggan et al. 1987, p. xviii). Without monitoring data, "managers are flying blind—responding only to clearly visible threats and hoping that standard management approaches" (Hockings 2003, p. 825) will result in hoped-for outcomes (Charles 2008). Holling (1978) urges researchers to weave monitoring protocols into management plans from the start rather than wait until after a management intervention has been designed and executed. In addition, Holling writes, "environmental assessment should be an ongoing investigation into, not a one-time prediction of, impacts" (1978, p. 133). Monitoring indicators can include "levels of resource use, resource abundance, socio-economic impact, and institutional management performance" (Charles 2008, p. 88) that show the degree to which a system is operating within parameters of sustainability. Monitoring can also be used to evaluate environmental management practices with no clear or immediate corrective feedback loop, as is often the case when philanthropic and government funding sources make program evaluation compulsory but stop short of requiring grant recipients to adapt their practices in response to evaluation findings. Bosch et al. (1996) point out that monitoring efforts may generate valuable new data on the efficacy and impacts of a management regime, but "fail to become an integral part of management because they are not designed to help decision makers" (p. 1)—a point I return to in the discussion below.

Allen (1997) argues that resource managers and other stakeholders must be involved not just in data collection, but in deciding "what should be monitored and evaluated, and what processes should be used" (p. 639). Recognizing that different adaptive co-management initiatives will allow for varying degrees of involvement in monitoring by a wider circle of stakeholders, Conrad and Hilchey (2011) propose four descriptive categories of the division of labor in participatory monitoring initiatives: "consultative" monitoring, in which members of the public contribute information to a central authority or researcher; "collaborative" monitoring, in which non-experts help scientists and decision-makers frame a data collection agenda; "functional" monitoring, in which members of the public collect data *and* play a role in implementing the adaptive management decisions that result from analysis; and "transformative" monitoring, in which scientists and government agencies play a relatively minor role and laypeople take responsibility for both monitoring and ongoing management. Typologies of the division of labor in public participation in scientific research have also been used to differentiate between different degrees of engagement and involvement in data collection for environmental management (Bonney et al. 2009; Shirk et al. 2012). Yet these typologies tend to focus on data collection and research *practices* while offering few insights into the preceding processes of sponsoring, creating, and piloting new research protocols for managers.

This exploratory study aims to develop new insights into data collection for environmental management in urban areas, focusing on three stewardship and civic ecology practices in New York City (see Chapter 2 for case descriptions). While the existing literature draws on rural cases and focuses on issues of stakeholder participation, data validity, and adaptations in management practice, there has been little research into the processes or people that create the methods, protocols, and tools developed for management-based data collection. This paper aims to shed new light on the division of labor in developing and using data collection protocols and technologies for urban resources management, particularly in cases where professional researchers have little or no role to play in data collection in the field.

### *Research Question*

This paper aims to develop new insights into data collection efforts within urban environmental stewardship initiatives. As an exploratory qualitative study, it began with the broad question, "How are civic ecology and stewardship practitioners creating useful knowledge about their work through data collection?" Through ongoing fieldwork, including observation, immersive participation, interviews, and focus groups (see below), the question was further refined to focus on the division of labor in data collection efforts across cases, asking, "What is the division of labor in data collection initiatives attached to civic ecology and stewardship practices, and what are the pragmatic consequences of such a division of labor?"

### *Sites and Methods*

This paper is based on a qualitative study of three civic ecology and environmental stewardship practices based in New York City: 1) A mostly volunteer *street tree stewardship* initiative centered around the Gowanus Canal in the borough of Brooklyn; 2) A mostly volunteer *community gardening* initiative located behind a row of apartment buildings in the borough of

The Bronx; and 3) A mostly paid-staff *invasive plant management* initiative along the length of the Bronx River, also in The Bronx. I used interviews, focus groups, and sustained participant observation to generate qualitative data on the surveillance and monitoring dimensions of all three practices and relied on open coding methods and comparative analysis to arrive at the insights that follow. For a more detailed description of sites and methods, please see Chapter 2.

***Findings***

*Mapping Street Trees and Tracking Stewardship Around the Gowanus Canal*

The Division of Central Forestry and Horticulture (Central Forestry) in the NYC Department of Parks and Recreation (NYC Parks) manages street trees throughout the city. Central Forestry's responsibilities include identifying new curbside planting sites, specifying the nursery-grown trees planted at each site, contracting private arborists to undertake the planting work, and maintaining an accurate inventory of the hundreds of thousands of trees planted along more than 6,000 miles of New York City streets. Central Forestry undertook New York City's first recorded street tree census during the summer of 1995, mobilizing 200 volunteers to record tree locations based on the street address of the nearest building with a visible address marker. Speaking to the *New York Times* about the initiative, a Central Forestry staffer noted, "It's a management tool. Right now, our foresters only keep records of individual trees. Once the census is complete, all the information will be put on a data base" (Bumiller 1995).

Volunteers used paper sheets to log data on the location, size, species, and condition of 498,470 street trees in 1995 (Colangelo 2016). Ten years later, Central Forestry engaged an additional 900 volunteers using data logging software loaded on personal digital assistant (PDA) devices to count 592,131 street trees. Despite an advancement in data logging technology, the second census continued to rely on address-based protocols (rather than geo-coordinates) for recording individual street tree locations—a common practice in urban forestry that predates the advent of ubiquitous Global Positioning System technology in mobile phones and other handheld devices (Roman et al. 2013). Though volunteers can easily note the location of a tree relative to the nearest visible street address in the field, geographic information systems (GIS) and other map-making software cannot translate such address-based data into standard latitude and longitude coordinates. The result is a spatially incomplete street tree inventory that eludes multi-year comparisons between individual tree points and makes long-term tree monitoring of any individual tree a challenge for professional and volunteer urban forest managers (Roman et al. 2013).

I was one of 20 interns hired by Central Forestry during the summers of 2006 and 2007 to study the mortality of a random sample of 13,405 street trees scattered across New York City, using address-based location data from the 2005 census to find each tree and record data on its health and surrounding conditions. The other interns and I often struggled to match trees we found in the field to tree address-based tree locations logged by census volunteers one year prior. A research article based on the study found that twenty percent of the randomly sampled trees "were not present from their planted location" (Lu et al. 2011, p. 11) when sought in the field by an intern. Though the 1995 and 2005 censuses had been useful for developing a generalized understanding of New York City's urban forest, the address-based locational data used in both initiatives made fine-grain data analysis and management difficult.

In 2010 I co-founded TreeKIT, an initiative aimed at creating a precise and accurate street tree locating protocol that didn't rely on either street addresses or global positioning systems (thereby avoiding the "urban canyon effect" (Chang, Wang, and Chang 2009), or the tendency for inaccuracies in data derived by GPS in the presence of tall buildings that block satellite signals). The "TreeKIT Method" uses linear measures of distance from a start point with a known geo-coordinate to derive the precise locations of street trees lined up sequentially along a city block (see Silva, Barry, and Plitt (2013) for a detailed description of the linnear referencing protocol). TreeKIT worked with geospatial software experts to develop a data processing application that translated measurements taken in the field into points with geo-coordinates that could be plotted on a map by any cartographic software, including the popular GIS. Using a seed grant from the City Parks Foundation (the non-profit fundraising arm of NYC Parks), TreeKIT tested the protocol with volunteer mappers throughout the summers of 2011 and 2012, collecting location data for more than 10,000 trees across more than 500 blocks in the western Queens County, a borough of New York City. Volunteers worked alongside TreeKIT personnel to painstakingly measure the distance between trees, and TreeKIT personnel debriefed after every mapping session to discuss the volunteer experience, including challenges to using the TreeKIT method and minute innovations developed in the field that made the method easier to learn and use. For example, one volunteer in Western Queens discovered that rolling a measuring wheel along a sidewalk expansion joint provided a guide for measuring in straight lines (thereby reducing error). Instructions to follow expansion joints as a measuring guide became part of the method and all subsequent training.

In early 2012, the Executive Director of the Gowanus Canal Conservancy in Brooklyn emailed TreeKIT to express interest in mapping trees on city blocks surrounding the Gowanus Canal. The Conservancy and its network of volunteers were working to reduce the amount of raw sewage flowing into the canal from combined sewers on rainy days, and their efforts included mobilizing volunteers "stewards" to take care of street trees (see Chapter 2). Yet the Conservancy struggled to track the work done by volunteers on any individual tree and monitor changes in tree health that resulted from that work. One volunteer had, on his own initiative, started collecting data on the pounds of trash and weeds extracted from street tree beds during Conservancy volunteer events and the number of hours that volunteers spent in the field, reporting the results to a Conservancy staffer to include in grant applications and annual organization reports. This data, however, did not address the Executive Director's need to track the work done to any individual tree—a need that could only be met by precisely mapping all the trees in the area to create a spatially structured inventory.

The New York State Department of Environmental Conservation awarded the Conservancy an urban forest inventory grant in 2012, allowing the group to work with TreeKIT on training and mobilizing volunteers to map the precise locations of 1,000 trees on streets surrounding the canal throughout the summer of 2013. A year later, the Conservancy purchased a subscription to OpenTreeMap, an interactive web-based tree inventory management system originally created for urban foresters in San Francisco and subsequently developed as an open-source product by Azavea, a geospatial software firm based in Philadelphia. The system displays tree locations on a web-based map and connects each tree point to an underlying database designed to store information on tree species, local street conditions, and stewardship work history. The Conservancy uploaded its inventory of trees to OpenTreeMap in late 2014 and encouraged volunteer stewards to use the system to log every time they weeded, watered, pruned, mulched, or otherwise took care of any individual tree surrounding the canal.

TreeKIT simultaneously worked with Central Forestry to incorporate its mapping methods into the 2015 NYC street tree census, or "TreesCount!2015." The agency and its affiliates had financially supported a large portion of TreeKIT's research and development work since the initiative's founding in 2010, always with the aim of finding a more accurate approach to deriving the location of street trees in the upcoming census without relying on GPS technology. In 2014, Central Forestry contracted Azavea (see above) to develop a comprehensive web-based software product to manage every dimension of the upcoming census, from recruiting and organizing volunteer mappers to digitally logging tree location data derived in the field using TreeKIT's manual linear referencing methods. The system included a portion of open-source code developed by TreeKIT and its partners to translate measures of the distance between street trees into precise geo-coordinates for every tree mapped.

Central Forestry worked with neighborhood-based organizations throughout New York City to recruit and mobilize volunteer mappers in the lead-up to the census in the early summer of 2015. Gowanus Canal Conservancy signed on with the initiative, pledging to re-map the trees it had already inventoried with TreeKIT in 2013 and expanding outward to map a larger selection of city blocks surrounding the Gowanus Canal. "We knew how to do it already, so we felt confident taking on more work for the census," one volunteer recalled. The Conservancy sponsored a series of group mapping events throughout the summer, with Central Forestry staff on-site to help train new volunteers in collecting census data. The Conservancy recruited new volunteers to join its existing core group of street tree stewardship leaders in mapping more than 3,000 trees by the autumn of 2015.

The Conservancy continued to mobilize volunteers to take care of street trees during the census, asking them to use OpenTreeMap to log their efforts and create work histories for street trees surrounding the canal. To log data in OpenTreeMap on work performed by volunteers and staff in the preceding three years, the Conservancy hosted a "Data Party" in June of 2015, inviting core volunteers to eat pizza, drink beer, and sit around computers in the Conservancy office to collaboratively recall and record different instances of weeding, watering, pruning, mulching, and removing garbage from the beds of different trees in the area. One volunteer leader brought a binder of printed spreadsheets with his address-based records of work on different trees in the months leading up to the Data Party, and the small group of assembled staff and volunteers worked together to match his records to the tree points displayed on a large computer screen. Despite these efforts to standardize data collection using the data logging features in OpenTreeMap, volunteers and staff never picked up the habit of signing in to OpenTreeMap after working in the field to log a record of their work. One volunteer shared that the process felt too onerous after a day of physically demanding work while the value and purpose of logging data was unclear. Others expressed frustration with memorizing log-in names and passwords required to access the Conservancy's subscription to OpenTreeMap. Though the group had successfully adopted data collection methods and technologies developed by outsiders to map trees around the Gowanus Canal, its members struggled to use other technologies to track records of their work. However, the group *was* successful in using data collection methods and technologies to conduct two censuses of street trees surrounding the canal.

*Measuring the Outputs of a Community Garden in the Bronx*

The Design Trust for Public Space (Design Trust) is a New York City-based non-profit organization founded in 1995 to sponsor speculative design and research projects around local issues of public space and urban planning. In 2009, the organization launched its "Five Borough Farm" initiative aimed at understanding the various social, economic, and environmental benefits associated with community gardening and urban farming and developing policy recommendations for supporting and expanding horticultural initiatives in New York City. In its first report on the Five Borough, the Design Trust wrote:

> …while [the] benefits [of urban agriculture] have been well-documented in scholarly literature, they have not been measured systematically in New York City, making it

> difficult for policy makers, philanthropic organizations, and advocates to substantiate and quantify the impacts of urban agriculture citywide (Cohen, Reynolds, and Sanghvi 2012).

A team of Five Borough Farm project fellows spent nearly three years synthesizing academic research on urban farms and community gardens and producing a matrix of the social, economic, environmental, and health benefits resulting from nearly thirty different horticultural practices (Cohen, Reynolds, and Sanghvi 2012).

In late 2012, the Design Trust recruited a pair of new fellows to create a toolkit of easy-to-use data collection methods aimed at helping farmers and gardeners generate local data about the outcomes and impacts of their work. The Design Trust, along with colleagues in municipal government, hoped to tap into a stream of standardized data from more than 600 community gardens and other food production sites in New York City, using the data to weigh the relative costs and benefits of supporting gardens and farms over other land use priorities, such as housing (Altman et al. 2014).

I served on the small team of fellows tasked by the Design Trust with crafting a toolkit of simple data collection protocols for community gardeners and urban farmers engaged in the Five Borough Farm initiative. Our efforts began with a small focus group in the winter of 2013 comprised of leaders in New York City's urban horticulture community. The group expressed concerns about collecting data on the outcomes of their practices as a strategy for "proving" the value of *all* New York City farms and gardens to local policymakers and funders. "Who wants to know?" one gardener asked skeptically during the meeting. Instead the group asked for a kit of data collection protocols that could help practitioners track their progress toward achieving their objectives at their own farms and gardens, monitoring the efficacy of their local work without feeding into an aggregate citywide measure. Many participants in the focus group shared that they *already* collected data as part of their regular gardening and farming practice, but they were not eager to share it with city officials for fear that it could be used out of context to devalue their work.

We followed up on the focus group with a daylong workshop in May of 2013 that engaged thirty local farmers and gardeners in a process of identifying their own data collection needs and crafting their own strategies for surveillance and monitoring. Participants worked in small self-organized groups throughout the day, brainstorming, diagramming, and deliberating over different strategies for collecting data on a range of topics, from the number of pounds of compost they created to the number of children that developed a new taste for fresh vegetables after visiting local gardens and farms. The groups presented their work for feedback from other participants at the end of the session. We refined the products of their work and created a draft toolkit of fifteen protocols for collecting data on the social, environmental, and economic outcomes of community gardening and urban farming practices, including a protocol for tracking data on the pounds of food harvested by farmers and gardeners originally developed in 2009 by the New York City-based organization Farming Concrete.

We piloted the toolkit at multiple farms and gardens throughout the summer of 2013. One participant in Brooklyn observed that the toolkit helped his community garden determine how much compost it had produced throughout the summer. "To me, the only way you can do that is by showing some metric that says, 'This is what we managed to divert, to create, to grow. It goes past just counting for the sake of counting," he observed. "It becomes counting for the sake of asking, 'What's the next best thing we can do systemically to improve our given situation'" (Altman et al. 2014). Other gardeners shared that they enjoyed collecting data but didn't see any immediate use for it in their work. "It's the first time I've ever done anything like that," a gardener in Brooklyn shared. “I just like to grow stuff, eat it, and give it to people” (Altman et al. 2014).

We drew on feedback from gardeners and farmers in the pilot to refine the toolkit during the winter of 2014. In May of that year the Design Trust published an updated version of the toolkit and launched a free data logging website developed and hosted by Farming Concrete (see above). The website gave gardeners and farmers an electronic database for storing the data they collected on paper worksheets in the field. The website also allowed users to generate stylized data reports and spreadsheets from the data they accumulated in their accounts. The Design Trust invited farmers and gardeners throughout New York City and nearby municipalities to attend a kickoff event in May where they learned to use the toolkit and its accompanying website.

The newly hired Coordinator of the Kelly Street Garden in the Bronx attended the kickoff event out of curiosity about the toolkit and on a hunch that data about the garden’s impacts might prove useful for future fundraising. “I thought we could collect the data to apply for grants and maybe to show Workforce Housing [the site landlord],” she recounted. She brought a physical copy of the toolkit back to the recently formed Garden Committee (see Chapter 2) and encouraged members of the fledgling initiative to collect data on their work. The gardeners used two relatively simple protocols from the Five Borough Farm toolkit during their inaugural summer, tracking the number of pounds of food they grew and the number of volunteer hours they invested in the garden. One member of the group became the self-appointed “manager” of a binder filled with volunteer time sheets, exhorting both visitors and regular gardeners to clock in and out upon entering and exiting the garden. The group also kept a small kitchen scale and binder filled with data sheets in a visible area near the garden entrance and participants fell into the habit of weighing and logging the vegetables they harvested. The Garden Coordinator collected the data sheets at the end of the season and handed them off to a staffer at Workforce Housing who tabulated the results in a spreadsheet: more than 350 pounds of fruits, vegetables, and herbs and 790 hours of volunteer work. Yet the gardeners themselves wouldn't learn the results until months after the season came to an end, after the data had been processed, tabulated, logged,

Despite their success in measuring pounds of produce harvested and hours of volunteer work expended in the garden, the group shared that they struggled to implement somewhat more complicated protocols for measuring changes in eating habits and emotional wellbeing experienced by people visiting and working in the garden. The "Good Moods in the Garden" protocol asks users to post two sheets of paper, each a different color, near the entrance to their garden. Each sheet of paper has "good" and "bad" mood words printed on pre-cut tear-away tabs that resemble flyers with tear-away telephone numbers used to advertise services on a community bulletin board. Gardeners and visitors are instructed to choose a "mood word" from one colored sheet of paper upon entering the garden and another word from the other sheet of paper upon exiting, tearing each word from the sheet and depositing the tab in a nearby waterproof envelope or mailbox. At the end of a week, users are instructed to count the number of positive and negative mood words deposited in the envelope to estimate improvements in emotional wellbeing experienced by people spending time in the garden. The gardeners at Kelly Street abandoned "Good Moods in the Garden" early in their first season. "It just wasn't working," the Garden Coordinator recounted, for reasons she couldn't specify.

***Tracking Invasive Plant Management on the Bronx River***

The Natural Resources Group (NRG) is a branch of the NYC Parks tasked with acquiring, managing, studying, and restoring approximately 10,000 acres of forests, meadows, and wetlands within the city (New York City Department of Parks and Recreation 2016), including large portions of the 500 acres of parkland lining the Bronx River. In 2012, NRG published a strategic plan for managing the proliferation of invasive plants in the string of parks, forests, and open spaces that make up the Bronx River Greenway. The plan included a plot-based monitoring protocol for recording instances of invasive plant removal by volunteers and staff at partnering organizations (including the Bronx River Alliance) and tracking the long-term efficacy of different removal strategies across multiple plots. The protocols required invasive plant managers to track their work by filling out forms printed on large sheets of paper and by noting work locations on plot-gridded paper maps. "It was too cumbersome," recalled a senior manager at the Bronx River Alliance, pointing out the challenges field crewmembers experienced in finding their locations on the paper maps. "The geospatial is the piece that's really missing."

To simplify the process, the Bronx River Alliance engaged Sound Science LLC, an environmental research and data firm, to reformat an existing data logging application to match data sheets previously developed by NRG. "Having a cool app that is kind of fun to use would really help—as opposed to filling out forms," a senior administrator at the organization shared. "Something that is a little sexy and interesting to have on your phone. We tend to want a lot of information." "I'm a big proponent of technology," the organization's Ecology Director shared. "I wish that everybody would adopt a compatible method of using technology so we could all share our data and really know what was going on." Sound Science LCC designed the data logger to operate on mobile phones and tablets using the GPS technology embedded in such devices to derive and attach geo-coordinates to submitted work records. Staff at Sound Science LLC met with members of the Bronx River Alliance field Conservation Crew to collect samples of paper data sheets and learn more about their day-to-day work practices and data collection needs. “[We wanted] an app that could just be used on anyone’s smart phone where you would record your location using the phone’s GPS… and you could just select from… a drop-down menu of what activities you’re doing,” the Bronx River Alliance Ecology Director said. “You’d have all that information stored up in the cloud… and then they would generate reports or give us back the data as needed.” Sound Science LLC completed the app by the start of the 2013 field season, making it available for the Bronx River Alliance to install on mobile phones and tablets owned by the organization.

That summer, Bronx River Alliance administrators tasked the organization’s Conservation Crew with using the data-logging app to keep geospatially referenced records of their daily work and monitor invasive plant conditions along the Bronx River at the start of every week. Yet two years after the tool was first developed, the crew had failed to incorporate digitized data collection into their daily practice. “I did pilot it and brought it out for a couple of months but I haven’t managed to get the data,” a senior crew leader noted. “I never saw how it looked like.” Both crew team leaders and administrators observed that recording casual field observations in a notebook or holding them in their memory seemed like less of a distraction from daily tasks than managing a digital data logger on a mobile phone. “Crew supervisors have been here for more than ten or eleven years and they’re used to doing it the way they do it,” a Bronx River Alliance administrator shared. “They really do have everything in their head. So, they know what’s going on out there and this is just an extra nuisance.”

An NRG staff member, reflecting on her experience working to coordinate with Bronx River Alliance Conservation Crew members, recalled the crew’s reliance on local place names to keep track of their work:

> They sort of still use their own naming conventions and their own sort of... yeah, they do their own thing even though this was created. One of my favorite ones, for example, is French Charlie. French Charlie is like... everyone knows where that is! It used to be a restaurant, a concession that is now a bathroom, so now whenever they go to that area they'll say they're going to French Charlie, even thought is really called, like, VF09 or VF07 or something like that.

Two years after the app was first developed, crew leaders continued to rely on personal memory and a notebook stored on the dashboard of a utility vehicle to track their work and its outcomes. Instead of site coordinates derived by (GPS), practitioners used colloquial place names and site markers to create mental maps of their work, waiting until they returned to the Alliance offices to log a more formal record in a shared spreadsheet.

The crew leaders themselves were hard pressed to pinpoint a reason for their reluctance to adopt more formal data collection practices using a mobile phone or tablet, despite recognizing the potential value of the data for researchers in city government. "I think the most important thing is locating exact spots—so that it's not like the next person came in after us and said, 'Ok 227$^{th}$ street by the bench.' Now it's a coordinate," one crew member reflected. "I don't know. It's hard to explain why not, but I guess the way we operate in the mornings, it's just, like, it never was the first thing to grab," the same crew leader observed, noting that both the tablet computer and mobile phone where the app had been installed were kept in a locked cabinet at the organization's main office. "There's a problem of signing out the phone and is it charged and being responsible for something that isn't theirs," an administrator observed.

**Table 2: Division of Labor in Data Collection Initiatives**

| | **Gowanus Street Tree Stewardship** | **Bronx River Invasive Plant Management** | **Kelly Street Community Gardening** |
|---|---|---|---|
| **Tools & Methods** | TreeKIT mapping method OpenTreeMap data logging map | Sound Science LLC data logging application | Five Borough Farm data collection toolkit |
| **Tool Patron** | NYC Parks Central Forestry | Bronx River Alliance administrators | Design Trust for Public Space |
| **Tool Maker** | TreeKIT Azavea | Sound Science LLC | Five Borough Farm Fellows |
| **Tool User** | Gowanus Canal Conservancy volunteers and staff | Bronx River Alliance Conservation Crew leaders | Kelly Street Garden community gardeners |

***Discussion***

This study aimed to shed light on the division of labor in developing and deploying data collection protocols for three grassroots environmental management initiatives variously labeled civic ecology practices (Krasny and Tidball 2015) or urban environmental stewardship (Svendsen and Campbell 2008). In all three cases we see: 1) Tool Patrons engaged in sponsoring the development of new data collection protocols for various kinds of surveys, surveillance, or monitoring initiatives related to environmental management; 2) Tool Makers tasked with creating and/or reconstructing data collection protocols within parameters set by Tool Patrons but with input from Tool Users; and, finally, 3) Tool Users who inherit protocols from Tool

Makers and data collection agendas from Tool Patrons and exhibit varying degrees of success in making data collection a sustained part of regular management practice (see Table 2).

The Design Trust, Central Forestry, and administrators at the Bronx River Alliance each acted as Patrons supporting independent Tool Makers in the development of new data collection protocols related to the civic ecology practices described in Chapter 2. All three Patrons supported data collection efforts aimed at creating baseline data about community gardens, invasive plants, and street trees. In contrast to Tool Users, all three Tool Patrons also aimed to monitor and evaluate the efforts of practitioners engaged in managing these resources, though with varying degrees of lag time between baseline data collection, evaluation, and adaptations in management practice. Tool Patrons in the invasive plant management case hoped for feedback on the efficacy of different plant eradication practices to adapt those practices as needed. Tool Patrons in the community gardening case were motivated by a desire to evaluate the relative costs and benefits of supporting urban horticulture versus other land use policy priorities. Finally, Tool Patrons in the urban forestry case aimed to create a precise and accurate inventory of street trees from which to build a more sustained monitoring and evaluation program.

While the Tool Patrons in all three cases were organizations or agencies with well-defined boundaries, the Tool Makers in all three cases found themselves working as nodes within a broader network of research and technological innovation (Ahrweiler and Keane 2013) in their respective areas of expertise. The data-logging app developed by Sound Science LLC for the Bronx River Alliance was itself based on protocols developed by the NYC Parks Natural Resources Group. The Five Borough Farm toolkit included harvest tracking protocols developed by the Farming Concrete initiative, while other protocols in the toolkit drew inspiration from community organizing and participatory action research traditions. The 2015 NYC street tree census incorporated technology and methods developed by TreeKIT and Azavea, while the OpenTreeMap application used by the Gowanus Canal Conservancy was built from the open source code of the pre-existing Urban Forest Map in San Francisco. Thus like most other forms of technological development, tool making related to data collection within civic ecology practices is opportunistically *combinatorial* (Barham 2013; Arthur 2009), drawing on previous tools, methods, and protocols to create something new and appropriate for a specific application.

Bosch et al. (1996) argue that data collection can fail to take root within management practices because protocols are rarely designed to help day-to-day practitioners navigate day-to-day decisions in their work. Yet the Tool Makers in all three cases diligently consulted with Tool Users for insights into their practices and for feedback on iterative improvements to the design of data collection tools and protocols. These interactions suggest a new dimension to inclusionary forms of environmental data collection, research, and knowledge production. Where earlier studies have focused on varying degrees of inclusion and participation by non-scientists in environmental research programs (Bonney et al. 2009; Shirk et al. 2012; Conrad and Hilchey 2011), this study takes a step back to reveal co-creation of the very tools and protocols used for collecting data toward environmental surveys, surveillance, and monitoring within management practices, adding a new set of cases to literature on the social construction of technology (Pinch and Bijker 1984). Future research may surface gradations of inclusion and engagement by users in the tool making process, much as Bonney et al. (2009) and, later, Shirk et al. (2012) have defined gradations of public participation in scientific research.

Even though Tool Makers included Tool Users in designing, testing, and refining data collection protocols, Tool Users in all three cases described challenges to fully incorporating some forms of data collection into their management practices. The field crew on the Bronx

River and volunteer tree stewards working in the Gowanus Canal watershed reverted to memory and paper-based record keeping despite having access to technologically robust data logging tools for tracking their work. Community gardeners in the South Bronx needed help executing data collection protocols that went beyond simple weights and time logs and eventually abandoned efforts to measure indicators of emotional wellbeing associated with time spent in their garden. Tool Users in all three cases were unable to pinpoint the precise reasons for their difficulty in adopting or refining data collection habits in their practices. Given the steps taken by the Tool Makers to include Tool Users in their work, the problem may have to do with a disconnect between the data collection motivations of the Tool Patrons and the day-to-day needs of the Tool Users. "[Adaptive co-management] is not just some strategy that one can impose externally on any group of innocent bystanders," Ruitenbeek and Cartier (2001, p. 37) write. "ACM is potentially something that emerges naturally from a complex bio-economic system." The same may be true of the data collection strategies used to support environmental management practices, including those that create the informational feedback loops that typify an adaptive co-management approach. Thus, the desire to collect data using certain tools, methods, and technologies may need to emerge *from* practice if there is to be any hope of sustaining data collection *within* practice—for adaptation or for any other purpose.

Another challenge to incorporating data collection protocols into daily practice may have to do with the tacit dimensions of the knowledge involved in adopting, adapting, and applying research tools developed outside of a specific community of practice. Harry Collins (1985), in his ethnography of British research scientists working to replicate the construction of lasers across multiple laboratories, demonstrated the limits of algorithmic instructions in transmitting the know-how needed to build a complex piece of research technology. "No scientist succeeded in building a laser by using only information found in published or other written sources," Collins wrote. "Every scientist who managed to copy the laser obtained a crucial component of the requisite knowledge from personal contact and discussion" (p 55). *Tacit* knowledge, or the concept that "we can know more than we can tell" (Polanyi 2009, p. 4), may play a critical role in learning to duplicate the creation and use of complex research tools, protocols, and technologies in new settings. Acquiring tacit knowledge is closer in nature to socialization into a community of practitioners (Wenger 1998; Brown and Duguid 2000; Nonaka, Ikujirō, Konno, and Toyama 2001) than simply reading and applying knowledge codified in explicit best-practices, technical guides, or instruction manuals. In the case of gardeners at Kelly Street, reading a step-by-step guide for collecting proxy measures of emotional wellbeing associated with time spent in a garden may not have been instruction enough to ensure the protocol was successfully applied, while reading instructions for simply weighing vegetables and logging volunteer hours resulted in an effective data collection regimen. The protocols for mapping trees in the Gowanus Canal watershed were also technically intricate, but a core group of tree stewards benefited from sustained contact with the Tool Maker during a lengthy testing period leading up to the 2015 street tree census, and volunteers who came on board during the census benefited from a hands-on, field-based training alongside those volunteers.

While Krasny and Tidball (2012; 2015) hypothesized that civic ecology practitioners monitor the outcomes of their work and adapt their practices based on what they discover, Silva and Krasny (2014) found that monitoring is an elusive activity in most cases. Of the three cases presented here, only the community gardeners at Kelly Street set explicit and measurable objectives for their work at the start of their second season, though they focused exclusively on the number of pounds of vegetables they aimed to harvest and the number of volunteer and visitor hours they generated on site. Objectives for other outcomes remained undefined. Street tree stewards along the Gowanus Canal mainly aimed to create a baseline digital inventory of the trees under their care. Even when the group aimed to collect data on day-to-day stewardship activities associated with particular trees in their inventory, they did not establish measurable objectives for either their work or the impact of their work on local tree health. Invasive plant managers along the Bronx River also aimed to collect data on their practices without specific outcomes in mind. Although practitioners in all three cases repeatedly expressed broad goals related to environmental sustainability, ecological resilience, and social cohesion, their reasons for collecting data related to their practice had neither to do with measuring "compliance with a predetermined standard" or a "deviation from the expected norm" (Hellawell 1991, p. 2). These cases suggest that that civic ecology and stewardship practitioners may collect data to create useful knowledge within their management practices, but true *monitoring* in the recursively adaptive sense remains elusive.

***Conclusion***

This exploratory study extends our knowledge of data collection initiatives within civic ecology practices, building on the proposition put forward by Krasny and Tidball (2012) that such practices have the capacity to monitor the outcomes of their work and adapt over time. Three cases of civic ecology practice underway in New York City demonstrate a division of labor in data collection efforts, with Tool Patrons, Tool Makers, and Tool Users each playing different roles in the development and application of new research protocols and technologies. This division of labor may result in challenges to sustaining data collection as a regular feature of civic ecology practice. Moreover, not all data collection efforts attached to civic ecology practices necessarily result in *monitoring,* particularly for adaptations in practice, though surveys and more sustained surveillance may nonetheless be useful for management purposes.

The insights offered here may help philanthropic funders, researchers, and practitioners collaboratively design and execute more effective data collection initiatives. For example, funders (or other potential patrons) may work with practitioners to define data collection priorities directly relevant to practice before initiating a tool development process. Practitioners may also take steps to clarify and establish measurable objectives for their work, thus creating a meaningful need to monitor progress over time and establish data collection as a feature of daily practice. Given the possibility that tacit knowledge is at play in the application of more complex data collection protocols and tools, funders and other patrons may also experiment with experiential training and other forms of hands-on learning (Kolb 2014) as a supplement to step-by-step instructional guides to data collection in practice.

Finally, this study presents a variety of data collection activities aimed at producing knowledge for grassroots environmental management without recourse to scientific research. Thus, civic ecology practitioners engaged in collecting, analyzing, and using data associated with their practices offer examples of *inclusionary production of environmental knowledge* (I.P.E.K) for management (see Chapter 3), rather than for the strict advancement of scientific knowledge for its own sake. Future research in this area may shed light on the relationship between formal data collection and other forms of knowledge production within practice, including the construction of tacit knowledge between practitioners as they go about their work together.

CHAPTER 5
CONSTRUCTING ORDINARY KNOWLEDGE IN COMMUNITIES OF URBAN ENVIRONMENTAL MANAGEMENT PRACTICE

### *Introduction*

Knowledge has always been integral to human efforts at exploiting, conserving, or otherwise managing whole ecosystems and individual organisms. Prior to the advent of formal scientific inquiry, humans relied on "traditional" forms of environmental knowledge, accumulated and adapted through casual observation over multiple generations and tacitly encoded in myth, story, ritual, and daily practice (Radkau 2008; Berkes, Colding, and Folke 2003). Efforts to rationalize and explicitly codify the knowledge required for environmental management emerged alongside natural philosophy (and, its successor, modern science), beginning in the mid-eighteenth century with the development of "scientific forestry" in Germany (Scott 1998). The late nineteenth century saw the emergence of "agri-science" in the United States with the passage of the Hatch Act and the establishment of "land grant" colleges focused on the production and dissemination of new agricultural knowledge (Hillison 1996). In the late twentieth century, governments around the world turned once more to science for the knowledge required for preventing pollution and conserving or restoring environmental systems negatively impacted by industrialization (Vig and Kraft 2005).

Yet generalized scientific knowledge, valued for the parsimony of its explanations and its ability to transcend the particularities of local history and geography, was unequal to the task of understanding and addressing complex, historically-contingent, and spatially-limited environmental issues (Holling 1978). A new approach to generating useful knowledge was needed—one that mimicked the incrementally adaptive, practice-embedded, and spatiotemporally specific features of traditional environmental knowledge while maintaining the rigor, objectivity, and rationality of modern science (Stankey et al. 2005). Venturing outside the controlled environment of a laboratory, this new "adaptive management" approach treated management interventions as "large scale" (Walters and Holling 1990) or "natural" (Layzer 2008) experiments, and scientists worked with managers to iteratively monitor and measure the results of new and incrementally modified interventions over time.

Adaptive management initiatives that included a broader community of stakeholders in designing and deliberating over different intervention choices earned the extended label of "adaptive collaborative management (co-management)" (Armitage et al. 2008). Armitage et al. (2008) describe adaptive management as "learning-by-doing in a scientific way to deal with uncertainty" (p. 1), while adaptive *co*-management strives to take alternative "knowledge systems," including traditional environmental knowledge, into account (Olsson, Folke, and Berkes 2004). Some scholars question the commensurability and interchangeability of alternative knowledge systems and what Kuhn (1996) describes as "normal" science (Gadgil et al. 2002). Others believe traditional environmental knowledge deserves to be considered a form of science in its own right (Dunbar 1996). This focus on the validity and rigor of alternative knowledge systems as compared to science has led scholars to ignore the quotidian production of environmental knowledge within contemporary environmental management practices, through hands-on engagement with the puzzles and problems that emerge in sustained ecosystem or natural resource management.

Environmental management is a *practice,* and much like the practices of hunting, gathering, and subsistence farming that produce "traditional" forms of environmental knowledge, contemporary environmental managers likely construct and share new knowledge *about* their work (and the objects of their work) *through* their daily work together—with or without recourse to more scientific methods of experimentally deriving knowledge from practice associated with adaptive (co-) management. To that end, environmental management practices can resemble "communities of practice" (Lave and Wenger 1991; Wenger 1998)—social units comprised of individuals constructing personal identities and a shared sense of belonging through meaningful work together. While Etienne Wenger and Jean Lave focus their research on *learning* as an individual's process of becoming enmeshed in a community of practice with a relatively stable and unchanging knowledge base, John Seely Brown and Paul Duguid (1991) emphasize innovative and disruptive *knowledge creation* within more dynamic communities of practice (Cox 2005). Efforts to make conceptual links between the community of practice literature and adaptive co-management have focused on collective *learning* and mostly ignored *knowledge making* as a process that can stand apart from scientific data collection, monitoring, and research interwoven with practice.

This paper is a first foray into understanding environmental management practices in terms of *communities* of practice that produce new and useful knowledge *outside of* or *in parallel to* a scientific adaptive co-management approach. I draw on cases of urban environmental stewardship (Svendsen and Campbell 2008) or civic ecology practice (Krasny and Tidball 2012; 2015) in New York City (see Chapter 2) to develop these new insights through qualitative fieldwork and interpretive data analysis. Urban environmental stewardship is a label applied to a broad diversity of practices undertaken by non-governmental organizations and government agencies of various sizes and structures (Fisher, Campbell, and Svendsen 2012). It may involve paid staff, volunteers, or a collaborative mix of the two, and stewardship practices tend to emphasize hands-on resource or ecosystem management in addition to "elements of direct action, self-help, and often education and community capacity building" (Svendsen and

Campbell 2008, p.1). Civic ecology practices are a sub-category of environmental stewardship practice that feature self-organized groups of volunteers, often working in partnership with NGOs and government agencies, to create “positive outcomes for individuals, communities, and local ecosystems” (Krasny and Tidball 2012 p.1) through direct resource or ecosystem management.

Various studies of urban environmental stewardship and civic ecology practices seek to understand the motivations that drive individuals to get involved—and stay involved—in grassroots environmental initiatives. Fisher et al. (2015), in their study of volunteer stewards of New York City’s urban forest, note that “levels of participation in environmental stewardship… run the gamut” from those with “fleeting involvement” to those who “regularly volunteer over a substantial portion of their lives” (p. 67). Citing Dresbach (1992), Donald (1997), and Ryan et al. (2001), they emphasize the importance of meaningful social interactions between volunteers as the driver of deeper and more sustained engagement:

> This literature generally finds that people first get involved because their personal belief system fuels a desire to care for the environment and then they become committed to programs because they enjoy being members of a group—a community of stewards (Fisher, Svendsen, and Connolly 2015, p. 68)

Ryan et al. (2001) note that individuals are initially drawn to join volunteer initiatives by the promise of learning new skills and concepts, yet the literature is mostly silent on the relationship between knowledge making and different levels of investment in practice.

Research on knowledge production as a dimension of urban stewardship and civic ecology has focused on collaborative relationships between professional research scientists and field-based managers with varying levels of training and expertise. Campbell et al. (2016) review knowledge co-production efforts within three cases of urban forest management in the United States and apply the “community of practice” label to a group comprised of research scientists and professional foresters working to improve communication and knowledge-sharing between these two constituencies. Silva and Krasny (2014) review seven cases of data collection within civic ecology practice in New York City and assign each practice to categories of "public participation in scientific research" developed by researchers at the Cornell Lab of Ornithology (Bonney et al. 2009; Shirk et al. 2012). Their findings suggest that data collection efforts within civic ecology practices occur with little or no involvement on the part of research scientists, though some practices may rely on data collection protocols developed by researchers for use by managers. Neither study examines knowledge production as a feature of daily practice separate from formal data collection or knowledge exchange with research scientists.

This paper refocuses on knowledge production as a fluid and mostly tacit dimension of daily civic ecology or stewardship practice, drawing on a view of communities of practice as a source of innovative and new knowledge (Brown and Duguid 1991). The research presented here began with my efforts to intervene in three grassroots urban environmental management practices to instigate the iterative data collection, monitoring, and adaptation cycles associated with adaptive co-management. Inspired by the tradition of participatory action research (Chevalier and Buckles 2013) that pairs scholars with practitioners to create new and useful insights into intractable social problems, I set out to introduce the rigors of scientific adaptive co-management to urban environmental managers. Yet during my fieldwork with these three practices, I became increasingly aware of the knowledge producing quality of the daily work undertaken by paid staff and volunteers and witnessed efforts to create and manage knowledge that stood apart from any explicit data collection, analysis, and adaptation processes.

I initially strove to compartmentalize and set aside these parallel aspects of knowledge-in-practice while collecting interview, focus group, and observational data in the field, focusing instead on formal data collection, outcomes monitoring, and adaptation as the main objects of my research. I was eventually forced to confront data I had pushed into my peripheral vision while comparatively analyzing transcripts and notes collected in the field. Urban environmental stewardship and civic ecology practices are shot through with issues of knowledge making intertwined with management, regardless of whether practitioners engage in more scientific processes of adaptive co-management. Efforts to understand how such practices adapt over time must consider the production (or construction) of "ordinary knowledge"[2] in practice, much as scholars of rural environmental management have come to appreciate and recognize the value of "traditional environmental knowledge" and the worth of studying alternative environmental knowledge systems in their own right.

How, then, can we begin to surface and expose the knowledge making dimensions of environmental stewardship practices? What *are* the knowledge making dimensions of these practices? How are practitioners constructing knowledge within practice and what challenges do they face in dealing with knowledge in their work together? To answer these questions, I begin by introducing a set of conceptual lenses that helped me focus my gaze on the production of ordinary knowledge in cases of hands-on stewardship and civic ecology practice, drawing from literature on organizational knowledge management and the interplay between tacit and explicit forms of practice-based knowledge. I then introduce three thematic insights that emerged from a comparative interpretive analysis of ordinary knowledge making across the three cases described in Chapter 2. I conclude by reviewing the implications of this research for both scholars and practitioners and suggest pathways for future research and conceptual development.

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[2] Lindblom and Cohen (1979), writing in the social sciences, define ordinary knowledge as "knowledge that does not owe its origin, testing, degree of verification, truth status, or currency to distinctive… professional techniques but rather to common sense, casual empiricism, or thoughtful speculation and analysis" (p. 12)

### *Conceptual Lenses*

Peter Drucker is widely cited as one of the earliest scholars of what is generally referred to as ‘knowledge work” and “knowledge workers,” beginning with *The Age of Discontinuity* (1969), his treatise on shifting trends in labor and economic productivity in the United States during the second half of the twentieth century. Drucker differentiated between knowledge created through work practices for applied use and knowledge created through scientific research exclusively for the advancement of knowledge itself. “What matters in the knowledge economy is whether knowledge, old or new, is applicable,” Drucker wrote. “What matters is the imagination or skill of whoever applies it, rather than the sophistication or newness of the information” (p. 269). Drucker’s early work marked a turn away from efficiency-driven and process-focused “scientific management” popularized by Frederick W. Taylor in the early years of the twentieth century (Maier 1970) and a turn toward seeing knowledge production in organizational settings as inextricable from work practice. Knowledge, according to Drucker, had “become productive” (1969, p. 266).

Starbuck (1992) loosely defines a knowledge-intensive organization as one in which knowledge is a leading factor in determining productivity and efficacy. The knowledge constructed, applied, and refined within the practices of knowledge-intensive organizations needn’t result from formal scientific research processes (Gibbons et al. 1994). Indeed, knowledge in such organizations typically emerges from sustained practice—or, more precisely, from the workings of a community of practice grappling with emergent puzzles or problems (Brown and Duguid 2000). Research on environmental knowledge systems in traditional communities sanctions the perspective that reliable environmental knowledge can emerge from daily practice (Gadgil et al. 2002; Kendrick 2002), yet research into more contemporary environmental management practices has prioritized *scientific* knowledge-making over other knowledge systems in practice. This exploratory paper aims to extend our understanding of civic ecology and urban environmental stewardship practices as knowledge-intensive and knowledge producing in their own right, regardless of the presence or absence of partnerships with research scientists or any formal data collection, monitoring, or scientific adaptive management processes.

The study and practice of *knowledge management* focuses on fostering and harnessing the productivity of knowledge for organizational innovation and adaptation (Dalkir 2005). Scholars of knowledge management have variously emphasized individual learning, group learning, knowledge creation, knowledge acquisition, information storage, and technology in their research (Reed et al. 2011; Hammer, Leonard, and Davenport 2004; Baskerville and Dulipovici 2006), making knowledge management a wide-ranging and eclectic field of both inquiry and practice. Although early knowledge management scholars differentiated "knowledge work" from other types of labor, more recent scholars argue that *most* workers are capable of constructing knowledge about what they do and how they do it together (Hammer, Leonard, and Davenport 2004; Dalkir 2005). Drucker himself came to define a knowledge worker as "someone who knows more about his or her job than anyone else in the organization" (Hammer, Leonard, and Davenport 2004, p. 15). John Seely Brown and Paul Duguid, both influential in the field of knowledge management, have gone so far as to argue that "all firms are in essence knowledge organizations" (Brown and Duguid 1998, p. 91). Thus, we see knowledge management as a component of multiple kinds of work across various types of social arrangements, from large private firms to small non-governmental organizations.

Knowledge management scholars generally treat knowledge "as something that is actively constructed in a social setting" (Dalkir 2005, p. 114) and, as constructivists, they strive to understand the social dynamics that create, translate, repurpose, assess, and share knowledge as a dimension of practice. Wenger (1998) and Lave (2011), in their individual and joint research, explore how newcomers grow to become members of a specialized community of practice through the gradual apprenticeship-like experience of what they name "legitimate peripheral participation" in routine work (Lave and Wenger 1991). Their research focuses on knowledge sharing as a process of enculturation and identity formation through *legitimate* day-to-day work with fully-fledged practitioners, moving from a *periphery* of partial practice to gradually more complex and totally immersive participation. From this perspective, the process of gaining and retaining knowledge constructs within a community of practice has more to do with "learning to become" like other practitioners than "learning about" the work abstractly, to paraphrase constructivist education theorist Jerome Bruner (1996). Thus, shared identity and a sense of belonging are inextricably linked to practice and the construction of knowledge within practice (Wenger's 1998, p. 5).

While Wenger and Lave focus on individuals learning to become enmeshed in communities of practice with relatively unchanging banks of knowledge, Brown and Duguid (1998; 2001; 1991; 2000) explore the dynamic construction of new and sometimes iconoclastic knowledge within practices that deal with complex and emergent puzzles. Throughout their work, the pair emphasize the use of narrative and metaphor in the social construction of knowledge-in-practice, drawing on an extensive ethnography by Julian Orr (1996) of photocopy machine repair technicians and the tactics they develop to solve problems that fall outside standard repair protocols and instructions. "While eating, playing cribbage, and engaging in what might seem like idle gossip, the reps talked work, and talked it continuously," Brown and Duguid observe (2000, p. 102).

Both the static knowledge embedded in routine practices and the innovative knowledge created in more dynamic practices typically exist in *tacit* rather than *explicit* forms. Surfacing, capturing, and disseminating the unspoken tacit knowledge that exists in practice has become a central concern for organizations that rely on knowledge to stay competitive and manage complex problems (Leonard 1995). Yet tacit knowledge, by its very nature, is difficult to translate into explicitly codified knowledge, and members of a community of practice are often unaware of the tacit dimensions of what they know and how they know it (Polanyi 2009; Nonaka 1994; Nonaka and Takeuchi 1995; Leonard and Sensiper 1998). Polanyi (2009) argues that tacit knowledge and explicit knowledge are two incommensurable *dimensions* of knowledge and that any effort to translate one into the other is misguided and likely to fail. Nonaka (1994; 2001) argues that knowledge *can* be made explicit, though only obliquely and through indirect storytelling and metaphor shared within practice as a means of "understanding and experiencing one kind of thing in terms of another" (Lakoff and Johnson 1980, p. 5). To that end, acquiring tacit knowledge from a particular practice depends upon an individual's capacity to become a fully-fledged member of the community that sustains the practice, engaging in the storytelling, myth-making, and metaphoric communication unique to that practice (Ryle 1988; Wenger 1998; Lave and Wenger 1991).

Transferring knowledge from one practice to another is also challenging, resource intensive, and liable to fail (Leonard 1995). Nonaka et al. (2001) describe a process of *internalizing* explicit knowledge from outside a practice through repeated exercise in context, with outside knowledge effectively reconstructed to fit local problems and make sense in terms—both tacit and explicit—that are familiar to the members of a community of practice. "Learning" knowledge from outside of a practice "is not simply a matter of search and retrieval," Brown and Duguid argue (2002, p. 124). Learning, from this perspective, is itself a process of knowledge transformation, a view commonly held in constructivist traditions of educational theory (Fosnot 2005). Successfully transferring and reconstructing knowledge from outside a practice is contingent upon the existence of a direct need for new concepts and skills to address novel problems emergent in practice. "People learn in response to need," write Brown and Duguid (2002, p. 136), echoing the proposal by adult education theorist Malcolm Knowles (2990) that "adults need to know why they need to learn something before undertaking to learn it" (p. 64) and the assertion by adult learning specialist Jane Vella (2002) that "adult learners need to see the immediate usefulness of new learning" (p. 19). Efforts to transfer and internalize knowledge from outside a practice when no need for new knowledge is present are, therefore, unlikely to succeed (Leonard 1995), and training practitioners in new skills and concepts out of the context of practice can result in wasted time and resources (Wenger 1998).

These insights into managing and making knowledge in communities of practice serve as useful lenses for bringing previously unexplored aspects of civic ecology into focus—in particular, the inclusionary production of environmental knowledge (I.P.E.K.) for resource or ecosystem management (see Chapter 3). Research into the knowledge-making dimensions of various practices gathered under the headings of "urban environmental stewardship" and "civic ecology practice" is in its early stages. Existing studies focus on *knowledge making* as an outcome of scientific or quasi-scientific data collection, outcomes monitoring, and adaptive management or *learning* as a form of purposively designed environmental education (Krasny and Tidball 2009). The conceptual lenses outlined in this section help us train our gaze on aspects of knowledge making and constructivist learning (itself a form of knowledge making) within environmental management practices that create of “ordinary knowledge” aimed at solving management problems.

### ***Knowledge in Civic Ecology and Urban Stewardship Practices***

The following section analyzes and interprets the urban environmental stewardship and civic ecology practices described in Chapter 2 through the conceptual lenses described in the previous section. Three general themes, explored in depth below, emerge from such an interpretive analysis. First, practitioners are, indeed, constructing innovative and useful knowledge *about* their practices *through* their work together. Second, practices that rely on transient forms of labor from volunteers or seasonal workers to achieve their goals are liable to miss collaborative opportunities for making new knowledge and retain it for ongoing application and adaptation in practice. Third, practitioners who look to other practices for new and useful knowledge may find it challenging to reconstruct explicitly codified “best practices” from other sites and encode them as tacit knowledge in their own daily work.

#### *Knowledge in Practice*

Urban environmental stewardship and civic ecology practitioners seem to construct tacit knowledge *about* their practices and the resources they manage *through* their ongoing work together. The following paragraphs aim to shed light on knowledge making as a dimension of the three practices outlined in Chapter 2, focusing on three points: First, practitioners in all three cases are engaged in knowledge construction in response to dynamic and emergent social-ecological systems; Second, practitioners are all engaged in collecting qualitative observations about the objects of their work and reflecting on the relationship between work practices and their outcomes; Third, in keeping with Wenger’s holistic model of the components of a community of practice, the three cases all demonstrate an inextricable connection between issues of social belonging, identity, knowledge production, and work.

Tacit knowledge constructed in practice is, by definition, difficult to "see" in the same way as explicit knowledge encoded in text. One cannot point to a library shelf or computer hard drive filled with tacit knowledge to substantiate its existence. Nor can one simply ask individuals to qualitatively describe their tacit knowledge and hope to arrive at a thorough accounting of what they keep "in their heads." As Polanyi (2009) argued, "We can know more than we can tell." The elusive nature of tacit knowledge thus presents methodological challenges for any study of knowledge making in practice. Indigenous communities have been shown to encode tacit environmental knowledge in explicitly recounted stories and myths (Berkes and Folke 2002), and organizational scholars have noted the importance of storytelling in surfacing and sharing tacit knowledge.

All three practices described in Chapter 2 actively manage (plant, cultivate, remove, or harvest) flora growing in complex urban social-ecological systems, and practitioners find themselves constructing knowledge in response to ever-changing circumstances. Unlike the cases of relatively static communities of practice developed by Wenger and Lave, these stewardship and civic ecology practices find themselves grappling with constant change, uncertainty, and surprise. "There's always a new invasive plant coming out," observed one of the senior members of the Bronx River Alliance Conservation Crew, pointing to the rapid spread of Corydalis (*Corydalis incisa)* along the Bronx River Greenway since the plant was first spotted in the area in 2005 (Atha and Tobing 2014). While scientists at the nearby New York Botanic Garden work with staff from the New York City Department of Parks and Recreation to test and identify reliable removal strategies for Corydalis, field crews and the volunteers they oversee continue to remove the plant manually as it emerges in patches on the Bronx River floodplain, looking for tweaks in daily practice to make the work more effective and efficient, much as they did with Japanese knotweed. These tweaks in practice were small, incremental, and barely observable in real time. I worked alongside volunteers removing Corydalis on a patch of land regularly flooded by the Bronx River and observed participants adapting from plucking individual plants by their stalks to rolling up sheets of Corydalis from its roots in large tangled clumps of soil. Participants verbally compared strategies all throughout the work session. In the Gowanus Canal Watershed, shifting land use patterns, changing neighborhood demographics, and even periodic disturbances caused by extreme weather (such as Hurricane Sandy in the autumn of 2012) create unpredictable social and ecological conditions that force subtle adaptations in street tree stewardship practices. At Kelly Street Garden, where gardeners had only worked through one full growing season at the start of this study, community gardening was so new to most participants that many of their experiences demanded innovative approaches to problem solving in practice. Moreover, urban gardeners often deal with novel puzzles related to soil quality, irrigation, pests, diseases, and microclimates unique to urban settings. Thus, all three practices were situated within dynamic social-ecological systems and all three worked with conditions that confound one-size-fits-all solutions derived from scientific research on invasive plants, street trees, or garden crops. They are, then, communities of practice ripe for knowledge construction on-the-job.

Berkes and Folke (2002) observe that traditional communities in rural and wilderness settings create ecological knowledge through regular observations of qualitative data in daily practice. The practices reviewed in this paper all seem capable of producing knowledge in similar ways. “I guess it really falls back to being so entrenched in Gowanus and being here daily," one street tree stewardship practitioner noted. "I talk to a lot of people and volunteers and neighbors and I keep walking around and I get a feel physically of the urban forest in Gowanus. Just by talking to people I understand the urban forest more." Human activity is *the* primary factor influencing the structure and function of urban forests (McPherson 1993), and casual observations of human activity *in* an urban forest can legitimately form the basis of logical inductions *about* an urban forest. Another street tree stewardship practitioner noted that while informal observations made in practice didn't contradict what she learned in workshops or from books and websites on urban forestry, they "added detail" and made abstract concepts more intuitively knowable. All the street tree stewards I worked with engaged in casual assessments of tree health. They linked evidence of tree health to different stewardship actions and practices, inferring that the work they did to mulch, prune, and water the trees on an industrial avenue adjacent to the canal led those trees to survive harsh conditions in their local environment. Alternately, they struggled to understand how dead trees and trees that appeared unhealthy failed to thrive despite sustained care. A pair of trees planted at the intersection of an industrial block and a high-density residential block along a high-traffic street died despite receiving the same type and intensity of stewardship as other nearby trees that flourished during the same period. In the absence of scientific research into the multiple variables beyond stewardship that could cause poor street tree health, practitioners drew on qualitative observations to craft meaningful stories about the likely causes of mortality. In conversation with each other, they hypothesized about the role of underground infrastructure, wind patterns, or salt intrusion from periodic canal flooding as factors beyond their control as stewards. Participants also constructed knowledge about the dynamics of their work, observing and reflecting on minute changes in practice that helped them make the most of limited time and human resources. "It's kind of like a puzzle of logistics," one participant observed as he described a creative process of planning volunteer stewardship events around variables such as weather, daylight, the number of one-time volunteers present, and knowledge of the health of trees in a given area.

In all three cases, storytelling allowed practitioners to work through uncertainties in practice, encoding knowledge about possible causes of failure and success to inform future adaptations. Drawing on Orr (1996), Brown and Duguid (2000) propose that members of a community of practice:

> … tell stories about unsolved problems in an attempt to generate a coherent account of what the problem is and how to solve it. … Stories are good at presenting things sequentially (this happened, then that). They are also good for presenting them causally (this happened because of that). Thus stories are a powerful means to understand what happened (the sequence of events) and why (the causes and effects of those events (p. 106)).

Like Orr's photocopy machine repair technicians, street tree stewards in the Gowanus watershed and invasive plant managers on the Bronx River seemed to rely on stories to make sense of their work, particularly in cases where documented "best practices" failed to result in expected outcomes. Street trees can die despite careful watering, pruning, and mulching (Lu et al. 2011). Japanese Knotweed (*Fallopia japonica*), Corydalis, and other invasive plants can grow back despite efforts to mow, cut, pull, dig, or cover the plants manually (Soll 2004). Practitioners find that variables outside their control—even outside their field of vision—can result in unexpected and undesired outcomes in their work. "Every year is different," one of the more experienced gardeners at Kelly Street observed. "One year it might rain a lot. One year it might not. Different things grow, so it depends on the season, it depends on the year, it depends on what was planted." One mid-autumn morning I worked with gardeners to harvest bushels of basil and glean any vegetables still growing in the garden's raised beds before turning them over to late season "greens" and cover crops. The gardener working closest to me in the rows of raised beds told me stories of her childhood being put to work in her grandparents' rural garden, alternating back and forth between tales of her past and causal hypotheses about the success and failure of different crops at Kelly Street that season: "This here needed more sun… We shouldn't have planted these so close together… I moved this at one point because it was crowding out something else… You wouldn't believe how much of this we harvested!"

I spent a summer morning in 2015 riding in a pickup truck with two senior members of the Bronx River Alliance Conservation Crew, listening as they told stories about their years of experience working to remove invasive plants in the many parks that make up the Bronx River Greenway—stories laden with informal assessments of a gradually changing repertoire of plant eradication practices. Reflecting on multi-year efforts to remove Japanese Knotweed from the riparian corridor, one of the crew leaders recounted, "We tried cutting it, we tried digging it out. We tried bending it, we tried bending it at the second stalk, at the third stalk…" The pair laughed as they recalled laying thick geotextile over swaths of Knotweed and rolling their bodies over the matting. "We would just get on the floor and roll. We tried anything." Later that same morning we drove up next to a small group of seasonal field staff working together at scything thickets of Knotweed with homespun machetes made of fallen tree branches found on the ground nearby. Swinging their makeshift tools in wide arcs parallel to the ground, thy manually knocked down stalks of the invasive plant—a stopgap measure intended to curb the plant's grown before a planned application of herbicide later in the season. Most of the workers were new to the job and still learning to correctly identify plants in the field. They mixed casual botanizing with jokes and teased each other about the quality of their work, correcting each other and turning to a field supervisor for guidance from time to time. Standing to one side while observing the crew, one of my guides for the day recounted her own early efforts to weed out a similarly sized patch of

Knotweed on the banks of the Bronx River in an area known as Shoelace Park. "That's years and years of fighting knotweed there. Years and years of maintenance [to] that canopy and, like, kind of eliminated the knotweed in that area." She recalled developing her own approach to manually removing invasive plants and told of the many times she returned to the site during her days off to keep weeding and making space for native sapling trees to grow and eventually crowd out their competitors. Few other people are likely to be as intimately knowledgeable about that patch of Shoelace Park as she became over the course of more than a decade of focused work, and other staffers in the organization collegially refer to the spot as "[her] garden."

Constructing and encoding tacit knowledge in practice through casual observation and storytelling depends upon the actual existence of *community* amongst practitioners—a sense of belonging to a joint enterprise of individuals exercising similar traits and competencies that amount to a shared identity rooted in practice (Wenger 1998). Reflecting on the relationship between identity and knowledge in communities of practice, Lave and Wenger (1991) write:

> …Participation in social practice… suggests a very explicit focus on the person, but as person-in-the-world, as member of a sociocultural community. This focus in turn promotes a view of knowing as activity by specific people in specific circumstances (p. 52).

In all three cases reviewed in this paper, a core group of leaders linked their identities as practitioners to the insights they gained working together to care for street trees, cultivate a garden, or eradicate invasive plants. "People ask—family and friends—they say, 'What do you do?' and I say, 'Ecological restoration,' and they're, like, 'What's that?'" recounted one of the leaders of the Bronx River crew. The two senior members of the crew recalled more than a decade of work together on the Bronx River with a rotating cast of colleagues within and outside the Bronx River Alliance. As members of a small community of practice, the label "ecological restoration" seemed to double as a way of *being* in the world (as an identity) and a way of *seeing* the world (as a way of interpreting and puzzling through the interacting variables that bear on their work).

By the end of the second year of operation at Kelly Street Garden, participants reported feeling more grounded in their identities as gardeners because of the work they had done together. For at least one participant, the garden offered a new opportunity to bring an aspect of her pre-existing identity in line with a regular practice:

> "I do like eating kale and different things and being very organic but it's not very affordable at times here, so it is very difficult to maintain that lifestyle and live here. So when this garden came up, I was, like, 'This is great—this is the perfect opportunity to be able to grow my own food and have this addition to my life.'"

For other gardeners, the work—and the shared identity that grew out of the work—was entirely new. "I learned that it takes a lot of patience. We are women, and we are women who have seen a lot in life," one participant shared. "We are like a force, and at the end of the day we get it done." Another participant observed, "We were little babies, and now we're starting to walk! We need a walker now!" A third participant asserted, "We still have a long… we have much more we need to figure out." Working together, the women at Kelly Street Garden seemed to gradually construct new identities as gardeners while simultaneously constructing knowledge about their gardening practices. Even though they felt they still had "much more to figure out"—about horticulture, community organizing, fundraising, and event planning in the garden—their habits for "figuring it out" together had started to take form.

Shared identity also played a role in the community of street tree stewardship practices along the Gowanus Canal. One of the leaders of the initiative observed, "It was very gradual, [my] taking on a leadership role. It was gradual because there was no structure [to the initiative], there was no street tree stewardship existing, so we built it together." For this participant, getting involved in creating street tree stewardship initiatives around the Gowanus Canal was directly tied to feeling more at home in the neighborhood—of feeling like someone who shared an identity with others and, consequentially, belonged. Recalling the early months of her involvement in the initiative, she said, "It felt like a community. It definitely felt like a community in a place that I didn't … I was pretty new, I had lived in Gowanus for six months, and I didn't know much about it." Thus, belonging and identity were linked to thoughtful practice around street tree stewardship, much as belonging and identity formed a component of practice at Kelly Street and along the Bronx River.

The three cases reviewed here all demonstrate the core components of communities of practice, with evidence of constructivist learning (itself a form of knowledge creation) and innovative knowledge making tied to experiences of community, identity, meaning making, and work. Constructing tacit knowledge *in* and *through* practice "requires sharing the same experience through joint activities such as being together, spending time, or living in the same environment" (Nonaka, Konno, and Toyama 2001, p. 15-16), while externalizing tacit knowledge depends upon the creation and narration stories and myths shared in dialogue between practitioners (Brown and Duguid 2000). We find a core group of leaders engaged in practice together over prolonged periods in each of these cases, yet all three practices also rely on a transient supply of labor provided by seasonal staff and occasional volunteers, creating a unique set of challenges for knowledge production and retention in practice.

*Transient Labor and Knowledge in Practice*—While leaders in all three cases form core communities of practice constructing knowledge *about* their work *through* their work together, a larger and more diffuse collection of transient workers also drift in and out of these practices over time. The work of recruiting, training, and retaining these casual volunteers and seasonal staff has become a central concern for the consistent members of each practice. Indeed, this volunteer management work has become a *part* of each practice, woven together with core tasks related to gardening, tree care, and invasive plant removal.

A core group of three to five street tree stewards working in the Gowanus Canal watershed rely on a steady stream of one-time volunteers to help them extend the reach of their work. Most volunteers arrive as members of school, business, civic, or religious groups attending weekend "Clean and Green" events organized by the Gowanus Canal Conservancy. A volunteer coordinator typically divides visiting groups into smaller teams once they arrive at a central meeting place in the watershed, with each team working on different environmental restoration tasks that include street tree stewardship. The coordinator briefly coaches visiting tree stewards through the rudiments of weeding, mulching, and watering street tree beds before leading them out into the field for two to three hours of work. "Volunteers catch on very quickly," A Conservancy staffer admitted, "But we've found that there's kind of a maximum amount of time that volunteers will engage in maintenance… it's pretty exhausting, monotonous work, so keeping that excitement level, that's a challenge." Most volunteers don't return. The same staffer observed:

> A lot of volunteers have told me that they want to be more involved but they have limited capacity to do it at the level that [volunteer coordinators] do. It's difficult to strategically think about how to cultivate that leadership. I think it requires a lot of structure and training that staff doesn't have.

At one point the Conservancy sponsored volunteers enrolling in a short "Citizen Pruner" course taught by another New York City-based environmental organization. In exchange for earning a license to prune street trees and learning to identify common street tree species through the course, students pledge to stay involved in caring for trees in the Gowanus Watershed. Yet few followed through with their promise once the course was over. "I don't know why they don't come back," one of the volunteer coordinators—a volunteer herself—said. "If they come back, it means that they already know and they'll probably do a better job and then they can motivate other people who are new at that event. I think it would be wonderful." Another leader described a thorough process of explaining to volunteers the impacts of their work in order to help them quickly find meaning in the mundane tasks of pulling weeds and picking trash out of tree beds. Although transient volunteers have expressed gratitude for the opportunity to see their work as contributing to broader environmental goals, the extra effort to help them find meaning in their work has not resulted in higher retention rates.

The Garden Committee at Kelly Street faced similar challenges in recruiting new gardeners from the neighborhood. "I would love to have more people come to enjoy what we have down here and go get something out of it," one gardener noted. "I've tried to get people in my building to participate… and I think there's a sigma around working with each other in the sense that they may feel like we aren't inclusive." With fewer than ten core Garden Committee members working with a part-time Garden Coordinator to cultivate 1,150 square feet of growing space, the committee looked beyond local volunteers for help during the garden's second season. A local summer youth employment program paid a small group of young people to work in the garden throughout July and August of 2015, but the results of their work were mixed. While one Garden Committee member felt the youth "lessened the burden on regular gardeners" and "helped us keep up with our production," others worried that the program did more harm than good. "There were some kids that were really interested in the gardening aspect of it… but there were some kids that were just coming here for the check," one gardener said.

Young volunteers also helped with invasive plant removal and environmental restoration along the Bronx River, though unlike the summer youth employed at Kelly Street Garden, they came with classroom teachers and mentors from local youth programs. A senior member of the Bronx River Conservation Crew noted:

> Yesterday we had twenty-five kids from [a local high school] come out and when we were about to do the planting demonstration the kids were, like, "Oh, we were here before, we planted already." So, I was, like, "Oh, good, let's just do this let's come on." The teacher was, like, 'Is there P.I.?" which means Poison Ivy—so he knew those codes.

"Knowing the codes" because of sustained practice can make the difference between efficiency and ineffectiveness in a volunteer event. Despite the example proffered above, few volunteers assigned to work with the Bronx River crew seemed to have accumulated enough field experience to get straight to work. A crew leader noted:

> Sometimes it's just a big waste of time getting everything together and getting everything prepared and getting the tools and getting the gloves and the waders and by the time they sign up and get in the field it's time for them to go because their bus is coming or they have to take lunch… and you've got to train them, too.

In addition to relying on volunteer labor, the Bronx River Alliance hires a small cohort of seasonal staff every year to supplement their full-time year-round Conservation Crew team. They, too, go through a lengthy process of learning "the codes" and becoming fully-fledged members of their new community of practice. "Now we're constantly training," one senior crew leader said. "By the time people get to know, then they're gone." The pair of crew leaders described an intensive process of teaching seasonal staff new skills and conceptual knowledge while working with them in the field. "I have to bust something out and ask, 'Do you know what this is you just removed? No? Ok, so why are you removing it if you don't know? Come out here and learn something." Both senior crew leaders shared that most of the people who pass in and out of the crew over the years never gain the deep experience needed to take initiative and make knowledgeable minute-by-minute decisions in practice, noting: "They don't have the confidence in themselves or the confidence to lead."

Gowanus Canal Conservancy also relies on temporary employees in the form of Civic Corps staffers (a New York City-based version of the national service program Americorps) serving ten-month-long full-time rotations at the organization each year. In addition to other programmatic responsibilities, Civic Corps staff help lead the organization's street tree stewardship initiatives. Yet not all the Civic Corps assigned to work in the Gowanus have shown the same level of enthusiasm for street tree care, and those that do rarely stay on site for longer than their ten-month posting. "We've had three or four cycles of Civic Corps and… it is difficult to retrain a staff member to do things like take volunteer metrics and teach them how to train other volunteers," a full-time Conservancy staffer noted.

*Importing Knowledge from Outside of Practice*—Practitioners in all three cases rely on outside sources of knowledge to supplement the insights they construct together in their work. Explicit knowledge imported from outside of a practice may be encoded and recorded in books, websites, pamphlets, tip-sheets, and audio/video media or in presentations at workshops, training sessions, and through other interactive learning experiences. Accessing knowledge from outside of practice can be challenging for practitioners and may depend on the availability of funding for professional development or proximity to technical assistance providers offering free resources. Internalizing knowledge from outside of practice can also be challenging if opportunities to immediately apply and exercise new knowledge are not available in actual practice (Nonaka 1994).

For the two senior Conservation Crew leaders on the Bronx River, the process of learning to do their day-to-day work began nearly a decade ago in an experiential field-based "green jobs" training program hosted by another organization in the Bronx. Both leaders were in the program at roughly the same time, one having learned about it from the other. One of the leaders reflected on the immediacy of the program and its lessons:

> So, I applied myself and I couldn't turn back from it. It was just—I like this, you know? It serves a big purpose… I just fell in love with it. Like, she's jumping in the river with no waders on, me climbing trees pruning dead limbs without equipment. It was just, like, the thrill of it—you're getting paid for something like this that you *care* about.

Given the hands-on and immersive nature of the training program, there were few (if any) gaps between learning a new skill or concept outside of practice and having to promptly apply it in an actual work practice.

The core group of gardeners at Kelly Street described a more abstract process of trying to import knowledge from outside their practice, particularly during the garden's first growing season in 2014. Some of the gardeners attended a series of free horticultural workshops provided by an outreach program at the nearby New York Botanic Garden (located on a 250-acre site in the center of the Bronx), while others attended workshops and community organizing and fundraising for small non-profits hosted by a technical assistance provider in the neighboring borough of Manhattan. "It was a lot to comprehend. A lot of information," one gardener recalled. "So I had to save every last piece of literature in order to bring it back to the group and share it with them." The gardeners collected the literature they received at various workshops in a bulging three-ring binder, creating a library of free information that was only partially applied and exercised in practice during their first two years of work. One notable exception had to do with companion planting, a horticultural practice some of the gardeners learned about in workshops at New York Botanic Garden. "There was no thought behind it," one gardener said, reflecting on the earlier rush to get crops in the ground when the garden opened in June of 2014. "It was just 'get it into the ground.' So, it wasn't much good. Now we're being a lot more careful and putting a lot more thought behind it." Thus the gardeners seemed to experience a sense of immediacy in wanting to apply what they learned about companion planting, and their "need to know" (Knowles, Holton, and Swanson 2015) led them to more easily internalize the skills and knowledge associated with the practice. "With that information we can bring it here and implement it," one gardener affirmed.

Street tree stewards in the Gowanus watershed also imported knowledge from outside sources, mainly through the "Citizen Pruner" course described above. Both street tree stewardship volunteer coordinators (themselves volunteers) working with the Gowanus Canal Conservancy came to their work having already earned their Citizen Pruner licenses on their own. The course is partially field-based, with students immediately applying tree species identification knowledge and basic pruning skills in field clinics. A paid staffer at the Conservancy who works closely with volunteers on street tree stewardship initiatives also earned a Citizen Pruner license early in her employment at the organization. "Doing the work and having to teach others to do it helped me gain that confidence—but also reaffirmed what I had learned in class," she recounted. Thus, the lag between learning in a Citizen Pruner workshop and incorporating new skills and concepts in practice seems to have been minimal.

***Discussion***

Despite the widespread absence of formal adaptive management or research partnerships between practitioners and professional scientists, the cases reviewed in this paper suggest that civic ecology and urban environmental stewardship practices can, nonetheless, be knowledge-intensive (Kärreman 2008; Starbuck 1992) endeavors. Three broad themes related to knowledge making and knowledge management emerge from an interpretive analysis of the cases presented here: 1) Practitioners create knowledge-in-practice apart from science; 2) Reliance on transient volunteers and seasonal staff has a negative impact on knowledge-making and knowledge management in practice; and 3) Knowledge imported from outside a practice must find immediate application *in* practice or risk being lost for lack of use.

Civic ecology and urban environmental stewardship practitioners do, indeed, seem to be engaged in constructing knowledge *about* their work *through* their work together. Becoming a fully-fledged member of a community of environmental management practitioners isn't solely a matter of internalizing the pre-existing customs, skills, and conceptual forms of knowledge that typify the community. Instead, a more constructivist (Fosnot 2005) view of learning-as-knowledge-making seems appropriate for interpreting the relationship between knowing and doing in these practices. "Learning," in this sense, has to do with discovery and problem solving in the face of the unknown or in contexts of uncertainty. Previous studies view environmental management and civic ecology practices as communities of practice (Armitage, Marschke, and Plummer 2008; Krasny and Tidball 2015), but focus on surfacing the "social knowledge" about self-organization constructed within these communities, such as "managing social cohesion, division of labor, collective responsibilities, decision structures, involvement of new members, and engaging with the public" (Bendt, Barthel, and Colding 2013, p. 26). This paper finds civic ecology and environmental stewardship practitioners constructing knowledge about both the resources they manage and the interplay between habitual management practices and outcomes related to growing vegetables, eradicating invasive plants, or caring for street trees. To that end, this paper opens new territory for research into knowledge as a dimension of practice, shedding light on knowledge constructed through practice alone and with no recourse to formal data collection, monitoring, scientific adaptive management, or even research partnerships with professional scientists.

Practitioners construct knowledge together through their work. The paths they take to construct knowledge may not conform to accepted scientific norms, nor will the knowledge they produce help to advance scientific understanding of a topic. The knowledge created in practice may not even be *original* in the scientific sense, duplicating insights and discoveries that have already emerged in other practices across space and time. Instead of novelty or the advancement of scholarship, the value of knowledge constructed in practice is measured in terms of usability (Greenwood 1998) and applicability (Drucker 1969). Thus to research and understand knowledge as a factor in civic ecology and urban environmental stewardship practices—and, perhaps, in all forms of environmental management—one may find it conceptually fruitful to decouple knowledge produced in practice from knowledge produced according to scientific norms—a challenge, according to Gibbons et al. (1994), in Western societies that equate all valid knowledge with *scientific* knowledge by default. Yet much as the literature on traditional environmental knowledge has argued that knowledge constructed in the daily practices of subsistence cultures is, on the whole, valid and reliable in its own context (Berkes, Colding, and Folke 2000), one can draw on the cases presented here to make a similar argument in favor of studying the knowledge that emerges from more contemporary and urban practices of environmental management. To that end, this paper extends the study of the inclusionary production of environmental knowledge for management (see Chapter 3) to include contemporary urban environmental management practices that operate in parallel to or outside of any formal scientific frame, including scientific adaptive (co-) management or public participation in scientific research.

Fisher et al. (2015) describe a spectrum of deepening volunteer participation in urban environmental stewardship practice, and others (Ryan, Kaplan, and Grese 2001; Donald 1997;

Dresbach 1992; Krasny et al. 2014) seek to understand the motivational drivers behind varying degrees of volunteer engagement in different settings. This study adds to the literature by examining the relationship between knowledge management and the existence of multiple tiers of volunteer engagement in stewardship and civic ecology practices. As with cases found in the literature, the three cases reviewed here featured a core group of leaders with sustained engagement in practice and a peripheral stream of volunteers and seasonal staff with limited engagement in day-to-day practice. Training and retaining these volunteers and seasonal staff can create knowledge management costs for the fully-fledged members of a practice, with costs likely higher in practices that demand greater degrees of creative problem solving in day-to-day work. Volunteers and seasonal staff who fail to stay engaged in practice long enough to experience successive stages of legitimate peripheral participation (Lave and Wenger 1991) may never grow to make meaningful contributions to the skills and knowledge woven into practice. Nor can they make the shift from *apprentices* learning to master habitual skills and tacit knowledge held by long-time practitioners—those capable of constructing innovative insights into practice through sustained engagement over time. They leave before achieving their full potential, forcing core members of the community to train a new cohort of transient workers to replace them. More challenging, perhaps, are those instances when transient workers *do* achieve mastery, only to take it with them when budgets for seasonal staff run dry or interest in volunteering fades. To that end, civic ecology and urban environmental stewardship practices that rely on transient help may experience the same knowledge management challenges related to staff turnover in private firms (Fidalgo, Gouveia, et al. 2012; Beazley, Boenisch, and Harden 2002).

Decoupling the physical labor of practice from its knowledge-making dimensions may exacerbate the problem of transience in volunteers. Hands-on environmental stewardship can be physically challenging work, as one gardener at Kelly Street observed:

> Gardening, I watched my grandparents do it. I didn't enjoy it. I didn't like it. Still don't. It's work. It looks so nice on the video when you see us smiling together and shucking corn and picking seeds, but it's backbreaking work.

Indeed, the need for supplemental physical labor seems to drive the reliance on transient help from volunteers and seasonal staff in civic ecology and urban environmental stewardship practices. The three cases reviewed here seemed to face a paradox between fostering deeper volunteer engagement and quickly accomplishing physically demanding tasks. Management theorist Michael Hammer notes that even rote manual can be "knowledge work" if it involves creative problem solving in a meaningful context:

> ...the manufacturing worker who diagnoses and solves production problems, the utility linesman who schedules his own day and the warehouse worker who evaluates vendor performance all perform knowledge work and must be considered at least in part to be knowledge workers (Hammer, Leonard, and Davenport 2004, p. 14).

Yet volunteer work in civic ecology practices and urban environmental stewardship is often stripped of its knowledge making context to create a collection of routinized processes readily accessible to a volunteer showing up for just a few hours of work. Routinization "de-skills" work (Braverman 1998) and typically shifts power over minute-by-minute decision making from a laborer to a manager (Leidner 1993), thereby removing the need for creative problem solving in practice. In the context of volunteer work, Ilsley (1990) notes that "the duration of service in a volunteer organization is linked to the amount, kind, and quality of learning that volunteers experience" (p. 69), with "learning" defined as both instrumental knowledge transfer and constructivist forms of learning as creative knowledge-making.

Routinization, then, may prevent volunteers from finding entry into communities of civic ecology or stewardship practice that include knowledge making as a dimension of practice (such as the cases reviewed here). Further, routinization may remove opportunities for meaningful learning in volunteer experiences, giving volunteers little reason to stay engaged over time. However, the paradox between engagement and rapid labor deployment in volunteer-based civic ecology and stewardship practices may not be insurmountable. One of the core leaders of the street tree stewardship initiatives around the Gowanus Canal shared that his skill at simple but physically laborious tasks such as weeding and soil cultivation probably hadn't improved much in his seven or eight years of practice, while his skills at more technically complex tasks (such as structural branch pruning) and his abilities to diagnose problems, strategize work routes, and streamline work processes had improved over time. Thus, even when the main work of a practice is, by its nature, simple and rote, the larger context of organizing, executing, and evaluating the work may provide opportunities for ongoing innovations in practice.

Civic ecology and stewardship practices offer opportunities for learning about a range of environmental topics, making them vehicles for environmental education amongst various populations of participants (Krasny and Tidball 2009; Tidball and Krasny 2011). Civic ecology and urban environmental stewardship practitioners seem to draw on knowledge from outside sources to extend or enhance the knowledge they construct in practice. However, the extent to which practitioners can successfully learn, internalize, and incorporate knowledge developed outside practice may be related to its immediate applicability in dealing with problems or puzzles found within practice. Brown and Duguid (2000) make three general distinctions between the type of information gardeners stored in a binder at Kelly Street and the more tacit and fluid knowledge that resides in practice: "First, knowledge usually entails a knower" (p. 119), while information typically exists in a codified and physical form. Second, knowledge tends to be more difficult to detach from context and “pick up, possess, pass around, put in a database, lose, find, write down, accumulate, count, compare, and so forth” (p. 120). Third, it can take more effort to assimilate and understand knowledge than raw information because “knowledge is something we digest rather than merely hold” (p. 120). Assimilating knowledge from outside sources and applying it in practice is, therefore, not a linear process of learning as information retrieval resulting in observable behavior changes (Skinner 1976) but of learning as the reconstruction of knowledge to make it “fit” existing constructs and contexts in practice (Ally 2004).

Practitioners of invasive plant removal and street tree stewardship in the Bronx and Brooklyn seemed to experience a seamless connection between acquiring new skills and knowledge in training and applying what they learned in the field. Gardeners at Kelly Street, however, seemed to experience an information overload, receiving much more codified *explicit* knowledge in the form of workshops and printed literature than they could readily apply, internalize, and make tacit in their practices. The “overflow” accumulated as raw information in a bulging three-ring binder, waiting to be translated into practice. To paraphrase Brown and Duguid (2000), the gardeners “held” the information but had yet to “digest” it. These findings suggest a new avenue for research into instrumental forms of learning and environmental education as a feature of civic ecology and stewardship practices, extending work by Krasny and Tidball to include a constructivist approach to understanding learning in practice.

**Conclusion**

This paper has implications for research into citizen science (Cooper 2016) and other forms of public participation in scientific research (Bonney et al. 2009; Shirk et al. 2012), framing knowledge constructed in practice as an alternative form of inclusionary production of environmental knowledge (I.P.E.K.) for management (see Chapter 3). A comparative analysis of three qualitative case studies suggests that civic ecology and urban environmental stewardship practitioners construct knowledge about their work and the resources they manage while dealing with issues of knowledge transfer and loss amongst more transient volunteers and staff. They also deal with issues related to internalizing knowledge imported from outside sources, with successful knowledge assimilation tied to the direct applicability and relevance of new knowledge in practice. Using conceptual lenses borrowed from the organizational management literature, we begin to see knowledge making *in* and *through* practice and distinct from more scientific forms of knowledge found in formal adaptive management and/or citizen science initiatives. This paper proffers a new set of conceptual lenses for a growing body of research into civic ecology and urban environmental stewardship practices and models an approach to researching knowledge issues in environmental management initiatives.

This paper also has direct implications for civic ecology practitioners who rely on volunteers to extend the reach of their work but also struggle to keep new volunteers engaged. Just as Peter Drucker foresaw the rise of the knowledge worker in a knowledge economy, the research presented here suggests the rise of "knowledge volunteers" in knowledge intensive grassroots environmental management practices. Overcoming the paradox between accessibility and sustained engagement in the tasks assigned to new volunteers may depend upon the availability of opportunities for volunteers to participate in meaningful decision-making, puzzle solving, and knowledge construction in their earliest exposures to a practice. Volunteer coordinators—usually core members of a practice themselves—may find useful strategies for addressing this paradox in the constructivist tradition of adult education, with emphases on open-ended problem solving and meaning-making through hands-on learning experiences (Knowles, Holton, and Swanson 2015; Kolb 2014; Vella 2002; Freire 2000; Wilson 1996). Future research may aid practitioners in designing and assessing the outcomes of constructivist interventions.

Finally, the findings presented here have implications for philanthropic foundations concerned with program evaluation and capacity building amongst the organizations and initiatives they fund (De Vita, Fleming, and Twombly 2001), particularly those that play host to civic ecology and stewardship practices. Transient volunteers and seasonal staff may walk away from a short engagement in a civic ecology practice with new skills, conceptual knowledge, and positive attitudes about environmental issues, and grant writers may point to these outcomes to make a case for philanthropic funding. However, this paper sheds light on the costs resulting from cycles of knowledge loss and ongoing training that arise from a reliance on transient labor.

# CHAPTER 6
# CONCLUSION

Civic ecology and urban environmental stewardship practices are knowledge intensive. Practitioners must puzzle through emergent problems to effectively manage green infrastructures embedded in complex social-ecological systems. While discoveries from applied scientific research can inform adaptations in practice, scientific knowledge production processes are deliberately slow—and, consequentially, incapable of responding to novel challenges at the pace demanded by day-to-day management. Moreover, the culture of science values knowledge that is parsimonious, generalizable, and reliably predictive, whereas environmental managers often deal with issues that are spatiotemporally unique and contingent upon local system dynamics. Where, then, do civic ecology and urban environmental stewardship practitioners turn for the knowledge that drives their work?

In this exploratory study I sought to gain a clearer understanding of the knowledge making dimensions of environmental management practices that take the form of civic ecology and urban stewardship, drawing on data from three cases underway in New York City. I also sought to conceptually reframe knowledge making within management practice as a social phenomenon distinct from inclusionary forms of knowledge production for environmental science or regulation. My overarching purpose was threefold: First, to extend our overall knowledge of stewardship and civic ecology practices as social phenomena; second, to carve out a new conceptual space for scholarly research into knowledge making as a dimension of environmental management practice; and third, to provide practitioners and their patrons with insights that could prove useful for improving and adapting practices over time.

Citizen science initiatives have opened the processes and practices of environmental science to people who do not identify as professional research scientists. Yet many forms of inclusionary knowledge production labeled citizen science do not conform to the prevailing standards or objectives of scientific research. The conceptual reframing undertaken in Chapter 3 posits three new categorical approaches to thinking about the inclusionary production of environmental knowledge, or I.P.E.K. In cases of I.P.E.K. for science (typically labeled "citizen science" or "public participation in scientific research") we see members of the public working with formally trained research scientists to advance scientific knowledge *for its own sake.* While the knowledge derived from such practices can go on to inform environmental policy, regulation, and management once it has been vetted and codified, its *primary* purpose is, above all else, the advancement of knowledge. In cases of I.P.E.K. for regulation, we again see individuals with little formal background in scientific research constructing knowledge about environmental issues. While they may generate original scholarship through their work, their *primary* purpose involves enhancing, extending, or enforcing environmental regulations. Finally, in cases of I.P.E.K for management, we see a bifurcation of inclusionary knowledge making practices.

In some cases of I.P.E.K. for management, practitioners and other stakeholders work with research scientists to collect data and construct new and useful knowledge through an adaptive management framework, rigorously following the protocols of iterative "natural" experiments (rather than controlled experiments) to arrive at new knowledge. Yet as some scholars of environmental management (and, in its more inclusionary form, adaptive co-management) point out, there are few successful examples of scientifically rigorous adaptive management to be found, for reasons that mostly have to do with competing goals between scholarship and management. In Chapter 4 I set out to gain a clearer understanding of structured data collection as a facet of knowledge production within civic ecology and stewardship practices. The three cases I explored all featured a three-part division of labor in the development and execution of data collection initiatives: Tool Patrons who identified a need for data related to a practice and sponsored the creation of new protocols, tools, and technologies for data collection; Tool Makers who were engaged by Tool Patrons; and Tool Users, or practitioners "in the field" tasked with employing data collection tools as part of their work. While this division of labor has been effective in spearheading new data collection efforts in civic ecology and stewardship practices, the gaps between Tool Patrons, Makers, and Users may create challenges for sustaining data collection amongst practitioners. Tool Users may not share the same data collection motivations as Tool Patrons, and deploying a data collection tool in practice may itself rely on tacit forms of knowledge that cannot be explicated in how-to guides or instruction manuals.

Although more research is needed to further clarify the role of tacit knowledge in the "uptake" of data collection tools as a feature of daily practice, this study suggests some preliminary insights of value to practitioners and their patrons. First, consulting with Tool Users for their input in the creation of data collection protocols and technologies may not be enough to guarantee that tools are easily used in practice. Second, the need for data as a feature of practice may need to emerge out of the practice itself, with practitioners asking for protocols and procedures that can shed light on the efficacy and outcomes of their work together.

Looking beyond scientific adaptive management as a frame for inclusionary knowledge production in the service of environmental management, one finds a rich collection of case studies on what has variously been called traditional environmental knowledge or indigenous knowledge. While these studies confirm the validity of knowledge making as a tacit dimension of daily management practice, they tend to draw from cases of subsistence hunting, gathering, and farming in rural settings. Thus, the study of knowledge making as process woven into daily practice in contemporary and urban settings is ripe for new exploration. Chapter 5 documents the insights into knowledge making as a tacit dimension of practice that became apparent while researching the more formal attempts at knowledge making through data collection described in Chapter 4. Civic ecology and stewardship practices can arguably be viewed as *communities* of practice—a perspective that emphasizes the role of knowledge transmission and construction in issues of collective meaning making, identity, and work. Much like the subsistence cultures that make up the preponderance of cases in the traditional environmental knowledge literature, civic ecology and stewardship groups seem capable of constructing tacit knowledge about their practices and the biophysical subjects of their practices through their daily work together. Borrowing theoretical lenses from organizational studies literature to interpret knowledge making in my three cases, I propose the following preliminary insights: First, practitioners actively construct knowledge together in response to novel challenges they encounter in their work, and *knowing* is inextricably tied up in *doing*. Second, though practitioners may look outside their work to import knowledge from other sites and sources, the immediate applicability of new knowledge to timely problems may determine the "stickiness" of the solutions. Further, knowledge imported in explicitly codified forms may not translate into implicit knowledge used in practice if no opportunities exist to immediately exercise it. Finally, the reliance on transient forms of volunteer and seasonal staff labor in civic ecology and stewardship practices may hamper efforts to create and retain useful knowledge in these practices. Transient workers may never find meaningful entry into the community of practice or, if they do, their eventual disappearance may also result in a loss of useful knowledge derived from sustained practice.

These insights into the tacit dimensions of knowledge making in civic ecology and stewardship practices emerged unexpectedly from my efforts to study data collection and adaptive management in my three cases. Thus, the findings presented here are preliminary and welcome further ethnographic research focused exclusively on the presence of tacit knowledge making in environmental management practices. Despite these limitations, this study suggests a new way of conceptualizing civic ecology and stewardship practices as inherently knowledge intensive, much the same way organizational research has reframed many private sector firms as centered around knowledge making and knowledge managing concerns. To that end, practitioners and their supporters may find useful insights in the organizational literature on knowledge intensive firms for managing their civic ecology and stewardship initiatives. For example, Wenger (1998) originally argued that communities of practice emerge and develop organically as social phenomena and could not be induced to form by exogenous forces. Yet later work by Wenger and others (2002) suggests strategies that can be taken to foster and sustain communities of practice as knowledge-rich endeavors. The work of recruiting and retaining volunteers and other transient laborers in these communities of environmental management practice may require looking beyond their capacity to provide affordable or free physical labor and activating their capacity to engage in knowledgeable work.

The research presented in the preceding chapters started as an effort to engage civic ecology and stewardship practitioners in action research, working with them to use data collection for monitoring toward useful adaptations in practice over time. Yet action research dissertations are notoriously fraught with pitfalls (Herr and Anderson 2005), and my initial efforts were no exception. Even though I actively participated, to greater and lesser degrees, in all three practices, my research gradually took the shape of a time-bound comparative study of three cases while my engagement in the practices shifted to the periphery of my inquiry process. As with any descriptive qualitative research project, my findings are primarily exploratory rather than explanatory, revealing new processes and variables in social phenomena that have, up to now, been mostly overlooked. Future research may pick up where this work leaves off, shedding new light on causal connections between Tool Patrons, Makers, and Users or revealing, in more concrete terms, the production of tacit knowledge in practice. For now, I believe this study successfully differentiates knowledge production in environmental management practices from other forms of inclusionary knowledge making and charts a path forward for future research.

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