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Civic ecology practices: Participatory approaches to generating and measuring ecosystem services in cities ☆

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ABSTRACT

Civic ecology practices are community-based, environmental stewardship actions taken to enhance green infrastructure, ecosystem services, and human well-being in cities and other human-dominated landscapes. Examples include tree planting in post-Katrina New Orleans, oyster restoration in New York City, community gardening in Detroit, friends of parks groups in Seattle, and natural area restoration in Cape Flats, South Africa. Whereas civic ecology practices are growing in number and represent a participatory approach to management and knowledge production as called for by global sustainability initiatives, only rarely are their contributions to ecosystem services measured. In this paper, we draw on literature sources and our prior research in urban social-ecological systems to explore protocols for monitoring biodiversity, functional measures of ecosystem services, and ecosystem services valuation that can be adapted for use by practitioner-scientist partnerships in civic ecology settings. Engaging civic ecology stewards in collecting such measurements presents opportunities to gather data that can be used as feedback in an adaptive co-management process. Further, we suggest that civic ecology practices not only create green infrastructure that produces ecosystem services, but also constitute social-ecological processes that directly generate ecosystem services (e.g., recreation, education) and associated benefits to human well-being.

1. Introduction

Cities are critically important social-ecological systems globally (Grove, 2009). Although dominated by humans and the built environment, cities also have ecological structures and functions, which provide ecosystem services (Grimm et al., 2000; Pickett and Cadenasso, 2008). For example, parks, community gardens, and other green infrastructure serve as sites for microclimate regulation, pollination, food production, education, and recreation (Bolund and Hunhammar, 1999; Colding et al., 2006; Dearborn and Kark, 2009; Barthel et al., 2010; Ernstson et al., 2010a; Niemelä et al., 2011), and highly engineered systems in cities, such as those producing algal biofuels, use ecological principles to produce energy and reduce greenhouse gasses (Sassen and Dotan, 2011).

Civic ecology practices, defined as "local environmental stewardship actions taken to enhance the green infrastructure and community well-being of urban and other human-dominated systems" (Krasny and Tidball, 2012), may also contribute to ecosystem services. Examples of civic ecology practices include community tree planting in post-Katrina New Orleans (Tidball et al., 2010), natural area restoration in Cape Flats, South Africa (Ernstson et al., 2010b), and community gardening and oyster restoration in New York City (Kudryavtsev et al., 2012). A critical aspect of such practices is that they entail active, hands-on stewardship or restoration of nature by a group of individuals. Participants in stewardship may be exhibiting a type of biophilic attraction (Wilson, 1984; Kellert and Wilson, 1993; Tidball, 2012) and thus may experience the psychological, emotional, cognitive, and social benefits inherent to nature contact (Kuo et al., 1998; Branas et al., 2011; Okvat and Zautra, 2014; Wells, 2014), and to participation in environmental restoration (Miles et al., 1998; Austin and Kaplan, 2003). Further, civic ecology practices represent instances of local stewardship where knowledge is co-produced by practitioners and scientists, as called for in the Sustainability Science (Clark and Dickson, 2003), Future Earth (Quadrelli and Uhle, 2012), and Earth Stewardship (Chapin et al., 2011) research agendas.

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Although Ernstson et al. (2010b) claim that civic ecology practices are "urban innovations to sustain ecosystem services", research focusing on ecosystem services outcomes of civic ecology and other urban environmental stewardship practices is limited. Studies in Stockholm and New York City (NYC) have relied on indirect measurements such as observations, interviews with practitioners, and area in certain land uses (Barthel et al., 2005, 2010) or quantitative surveys of species diversity (Andersson et al., 2007); other research has investigated governance structures contributing to the production of ecosystem services in cities (Ernstson et al., 2010a; Connolly et al., 2013). To better understand the contributions of civic ecology and related urban stewardship initiatives (cf. Svendsen and Campbell, 2008; Wolf et al., 2011; Fisher et al., 2012), a need exists for additional assessments of their outcomes relative to ecosystem services. Further, to enhance learning about local social-ecological system dynamics and increase the likelihood of monitoring data being used to improve ongoing resource management, consideration should be given as to how volunteers engaged in civic ecology practices could themselves assess their contributions to ecosystem services (Olsson et al., 2004; Armitage et al., 2007). However, given that the individuals engaged in such practices often have limited science backgrounds, partnerships with scientists will be critical to assessing and monitoring their contributions to ecosystem services (cf. Chee, 2004; Pickett et al., 2004; Cowling et al., 2008; Díaz et al., 2011).

In this paper, we explore two questions: What protocols for measuring ecosystem services are appropriate for practitioner-scientist partnerships in civic ecology practices? What are the implications of civic ecology practices and their monitoring for urban ecosystem services more broadly? In answering the first question, we consider that measures suitable for civic ecology settings need to be accessible to those with limited formal understanding of science and research, and take into account diverse stakeholder values relative to ecosystem services (Wilson and Howarth, 2002; Kumar and Kumar, 2008; Díaz et al., 2011; Chan et al., 2012b). Additionally, we consider that participatory processes designed to engage stakeholders in monitoring ecosystem services (Chee, 2004; Lucas et al., 2010) may need to be adapted in cases where community-based organizations have initiated stewardship actions but have limited staff and volunteer time for participating in extended planning, monitoring, and data analysis. In answering the first and second questions, we focus on designing protocols to measure ecosystem services produced not only by green infrastructure or physical sites, but also ecosystem services generated by the participatory, social-ecological *practices or processes* that create such spaces. In other words, stewardship, as one form of interaction between people and the rest of the social-ecological system, may be understood as a practice or process that contributes to the production of ecosystem services in important and previously unexplored and under-theorized ways. Thus, our paper differs from other studies that focus only on the role of urban green infrastructure in providing ecosystem services (Tzoulas et al., 2007).

In short, our intent in this paper is not to recommend one particular monitoring protocol or instrument, but rather to present options and challenges, and to stimulate thinking about possibilities for expanding conceptual and practice-based frameworks for collaborative ecosystem services monitoring in urban, self-organized stewardship settings. Below we present an overview of civic ecology practices and ecosystem services, practice and activity theory as conceptual frameworks for understanding these practices, and appropriate protocols for measuring ecosystem services. We close by considering the implications of civic ecology practices not only as practices that create and steward green infrastructure which in turn provides ecosystem services, but also as processes that in themselves directly generate cultural ecosystem services.

2. Civic ecology practice

In contrast to other volunteer environmental activities such as donating money or signing petitions, civic ecology practices refer to local, hands-on environmental stewardship actions taken to enhance both green infrastructure and community well-being in human-dominated systems. Environmental stewardship embodies "environmental virtue ethics" as theorized by Thoreau, Leopold and Carson (cf. Cafaro, 2001); well-being refers to social cohesion, the ability to help others, personal security, access to clean air and water, and opportunities to participate in valued activities (MEA, 2005). Examples of civic ecology practices include community gardening, shellfish reintroductions, tree planting, invasive species removal, and native habitat restoration, among other practices (Tidball and Krasny, 2007; Krasny and Tidball, 2012). Although urban agriculture and civic ecology practices overlap, civic ecology includes a broader suite of stewardship practices; those civic ecology practices that do focus on cultivation of plants generallly adhere to "organic" or "sustainable" agriculture principles such as composting, mulching, seed saving, and limited use of pesticides and synthetic fertilizers.

Civic ecology practices often are initiated by lay persons, generally as a community-based response to urban decline or sudden disturbances like hurricanes and war (Tidball and Krasny, 2014); forming partnerships with scientists, non-profits, and government helps to ensure larger impacts and longer-term sustainability of these community-driven efforts (Krasny and Tidball, 2012) and connects them to larger environmental governance and civic engagement initiatives (Sirianni and Friedland, 2001; Sirianni, 2009; Ostrom and Cox, 2010). In addition, because civic ecology practices reflect local environments and cultural traditions, they vary widely across different locations. For example, allotment gardeners in Stockholm plant raspberry hedges to attract bumblebee pollinators (Barthel et al., 2010); African Americans grow okra and other southern US crops in community gardens in Harlem (Shava et al., 2010); Seattle residents form friends of parks groups to replant native evergreen forests (EarthCorps, 2012); and residents of New Orleans replant and care for hurricane-damaged live oak trees (Tidball et al., 2010). These practices reflect social-ecological memories, or the "means by which knowledge, experience and practice about how to manage a local ecosystem and its services is retained in a community, and modified, revived and transmitted through time" (Barthel et al., 2010, p. 256), as well as social-ecological rituals and symbols that serve to reify and reconstitute these social-ecological memories (Tidball, 2014c). Further, civic ecology practices provide opportunities for learning among both adult practitioners and youth who engage in such practices through after-school and summer programs (Krasny and Tidball, 2009b; Kudryavtsev et al., 2012).

Several studies and media reports suggest the prevalence of civic ecology practices in US cities. For example, Svendsen and Campbell (2008) compiled a database of over 2000 stewardship groups in NYC alone, including 1000 active park-based volunteer groups and over 900 community gardens, and Wolf et al. (2011) identified 588 stewardship organizations in the greater Seattle/Tacoma area. Additional evidence of the prevalence of civic ecology practices comes from recent media reports focusing on community gardening in Detroit (Long, 2011) and Cleveland (Tortorello, 2011), and the burgeoning rain garden movement in Seattle (Moulton and Burger, 2011), among others.

Because civic ecology practices are often small-scale and scattered throughout a city, and may have a history of adversarial relations with government and business, in the past government agencies have often overlooked or did not value their contributions to green infrastructure and ecosystem services. More recently, city governments, strapped for cash, have recognized the potential benefits of these efforts (NYC Department of Parks & Recreation, 2011; Wolf et al., 2011), and have “outsourced to non-profit organizations the implementation of ecosystem-services infrastructure programs such as tree planting, stream daylighting (bringing underground stream diversions to the surface), and construction of biofiltration projects” (Pataki et al., 2011, p. 33). While warning that we lack studies to document the effectiveness of such decentralized approaches, Pataki et al. (2011) suggest that creating green infrastructure should be viewed as part of a suite of approaches that can reduce costs of built infrastructure, and that have potential co-benefits such as habitat restoration and generating cultural ecosystem services.

3. Ecosystem services

In the 1980s, alarmed that the public and policy makers were failing to grasp the gravity of species extinctions and environmental degradation, scientists began to promote the idea of services offered to humans by biodiversity and natural systems in hopes of spurring support for conservation (Ehrlich and Mooney, 1983; Daily, 1997; Peterson et al., 2009; Gómez-Baggethun et al., 2010). In a highly influential paper in the late 1990s, Costanza et al. (1997) calculated a dollar figure for the total global economic worth of 17 ecosystem services. In spite of the controversy generated by its assumptions and valuation methods (Norgaard et al., 1998), this study changed the debate from a consideration of ecosystem services as a tool for conservation education to one focused on economic (both monetary and non-monetary) means of valuing services provided by nature (Peterson et al., 2009). Several years later, the Millennium Ecosystem Assessment (MEA, 2005), which outlined the importance of ecosystem services to human health and well-being and documented the speed at which most services were being lost, catapulted ecosystem services into global policy and public deliberations (Gómez-Baggethun et al., 2010).

However, scholars have critiqued several aspects of ecosystem services, in particular the notion of ecosystem service valuation focused on monetary values, arguing that incentives rather than knowledge about monetary values motivate conservation behaviors (Heal, 2000). In addition, scientists argue that a focus on monetary valuation may obscure understanding of the importance of biodiversity (e.g., monocultures may be promoted to sequester carbon, Peterson et al., 2009), inhibit important social interactions, foster social inequality, ignore non-economic cultural values (Wilson and Howarth, 2002; Kumar and Kumar, 2008; Chan et al., 2012a; Chan et al., 2012b), and pay insufficient attention to uncertainty and irreversibility in resource management decisions (Chee, 2004). Further, in that cultural ecosystem services reflect worldviews, Gómez-Baggethun et al. (2010) conclude that whereas the focus on monetary valuation has played a role in mainstreaming ecosystem services science and garnering political support for conservation, uncertainties remain as to potential unanticipated consequences of utilitarian market-based rationales for conservation, including the possibility of fostering damaging motivations for conservation and promulgating particular worldviews of human-nature relations. Finally, Reyers et al. (2013) argue that measurements used to date have been unable to account for the dynamic linkages between social and ecological elements in the production of ecosystem services and human well-being, and that ecosystem services are produced by complex social-ecological systems and not by biophysical systems alone.

Whereas earlier writers focused on understanding of ecosystem services as a tool to motivate policies favoring conservation of biodiversity, in this paper we address situations where people in cities and other human-dominated landscapes are already engaged in stewardship practices that may generate ecosystem services. Thus, the importance of ecosystem services and their monitoring in our context is to: (1) provide civic ecology participants with a means to understand, articulate, and communicate the value of their work (cf. Chan et al., 2012a), and (2) enable them to better reach their stewardship goals through feedback based on information about outcomes (cf. Pahl-Wostl et al., 2007; Armitage et al., 2008).

4. Civic ecology practice and ecosystem services

Through creating green infrastructure and through engaging lay persons in meaningful stewardship activities, civic ecology practices would be expected to produce provisioning, regulating, and cultural ecosystem services. In fact, studies have described the value of civic ecology practices relative to food production (Lawson, 2005), pollinators (Strauss, 2009), education (Fusco, 2001; Krasny and Tidball, 2009b), as well as social connectivity and other aspects of community and individual well-being tied to ecosystem services (Schmelzkopf, 1995; Miles et al., 1998; Austin and Kaplan, 2003; Saldivar and Krasny, 2004; Kaplan and Kaplan, 2005; MEA, 2005; Ryan and Grese, 2005; King, 2008; Tidball et al., 2009, Okvat and Zautra, 2014). Research comparing allotment gardens managed informally by lay persons to professionally-managed cemeteries and city parks in Stockholm revealed that the allotment gardens had greater abundance of bumblebees as a result of gardeners' cultivation of flowering plants and active protection of bumblebee nests; additional practices linked to biodiversity and ecosystem services performed by allotment gardeners included composting, enhancing bird habitat, prolonging flowering season, and active protection of natural enemies of pests (Andersson et al., 2007). Youth engaged in civic ecology practices in the Bronx, NYC, conduct multiple stewardship activities that could enhance provisioning, regulating, supporting, and cultural ecosystem services (Kudryavtsev et al., 2012, see Table 1).

Whereas civic ecology practitioners often make claims about the positive impacts of their work in terms that reflect an implicit understanding of ecosystem services, such as tree planters claiming cooling benefits (Tidball, 2014a) and oyster gardeners talking about the ability of oysters to filter water and thereby cleanse estuaries (Crestol, unpub data), relatively few civic ecology practitioners actually monitor their outcomes on green infrastructure (e.g., number of surviving trees) or ecosystem services (Wolf et al., 2011; Silva and Krasny, 2013). This is not surprising given the limited resources and scientific expertise of most civic ecology practitioners coupled with the difficulty of measuring ecosystem services (Kremen and Ostfeld, 2005) and other potential outcomes. In contrast, hundreds of thousands of amateur naturalists and youth participate in citizen science projects, in which volunteers collect data on bird, insect, and other forms of biodiversity using protocols developed by scientists (Dickinson et al., 2010); such measures of biodiversity can be used as indicators of ecosystem services given certain caveats (Kremen and Ostfeld, 2005; Chan et al., 2006; Díaz et al., 2011). Another alternative to measuring ecosystem services directly is to engage participants in determining their economic and social values (De Groot et al., 2002; Chee, 2004; TEEB, 2010b), and in some cases lay stewards have adapted measurement methods used by economists and ecologists as we describe below.

Table 1
Examples of ecosystem services-related activities of youth programs in the Bronx River watershed in New York City, as reported by adult program leaders in 2010 (citations refer to videos of educators and youth explaining program activities).

Organizations	Social-ecological system and stewardship activities	Possible ecosystem services outcomes
Phipps Community Development Corporation	*Community garden* Planting common vegetables, exotic edible plants from other continents, native vegetation and flowers; mulching and watering; managing urban forest in community garden; organizing garden art projects and community events; supplying vegetables for a local farmers market; designing water harvesting system, composting system, handicap accessible garden beds, and butterfly garden (Kudryavtsev, 2011a).	• *Provisioning*: fresh food for community residents; ornamental plants. • *Regulating*: pollination. • *Cultural:* supporting diverse gardening knowledge systems; educational, spiritual, esthetic and inspirational use of the community garden by community members of all ages including recent immigrants; enhancing trust, social capital, sense of place, and appreciation of nature; providing space for art projects. • *Supporting*: creating compost for soil enhancement.
Rocking the Boat	*Bronx River* Restoring salt marsh; restoring and monitoring oyster reef at mouth of river; conducting community tours of river in rowboats and canoes (Kudryavtsev, 2011b).	• *Regulating*: water filtration by riparian vegetation and oysters. • *Cultural*: recreation on the Bronx River, connecting residents with the Bronx River, educating students about the urban environment; fostering ecologically-based sense of place; youth development.
Youth Ministries for Peace and Justice	*Green roof and rain garden* Maintaining a green roof by planting vegetables and native plants, watering and weeding; maintaining a rain garden; designing a water harvesting system (Kudryavtsev, 2011c).	• *Regulating*: stormwater retention on the green roof and rain gardens; green roof heat buffer, energy saving. • *Cultural*: educating youth and community about green infrastructure and environmental justice; physical exercise and connection to nature; youth development. • *Supporting*: soil formation on the green roof.

5. Theoretical underpinnings

Systems thinking, as articulated by social-ecological systems resilience scholars (Folke et al., 2002), and related applied work in adaptive co-management (Armitage et al., 2007), informs civic ecology scholarship. Social-ecological systems resilience is rooted in ecosystems theory, drawing from such concepts as the adaptive cycle (Holling et al., 1998) and self-organization (Levin, 2005), and focuses on how systems respond to change through adaptation and transformation (Gunderson and Holling, 2002; Folke et al., 2010). Adaptive co-management is a participatory process of building social capital and social learning leading to collective action (Plummer and Armitage, 2007; Plummer and FitzGibbon, 2007), and draws heavily from Habermas' (1984) theory of communicative action and from the empirical work of Elinor Ostrom and colleagues on collective action (Ahn and Ostrom, 2008).

Central to both systems thinking and adaptive co-management are notions of feedback, or information about the outcomes of management actions, which is used to better understand system behavior and thus to inform, adapt, and transform practice (Fisher et al., 2007; Armitage et al., 2008; Tidball et al., 2013). Fisher et al. (2007) argue for a collaborative monitoring approach in adaptive co-management, using indicators that are developed and tested jointly by multiple resource stakeholders, thus helping to ensure that collective action incorporates diverse perspectives and expertise. Critical to this process is reflection and multiple loop learning that extends beyond the technical aspects of the practice to a consideration of change in policies and norms (Armitage et al., 2008).

Social-ecological systems resilience thinking has been critiqued for its application of biophysical systems concepts to human social systems, which some argue deemphasizes the role of human agency and related processes such as power (Nadasdy, 2007; Davidson, 2010). One response to such a critique claims that an adjustment is required in the ascendant and dominant position of human agency and its role in exacerbating anthropocentric world views that are linked to loss of ecological identity (Tidball and Stedman, 2013). However, in the context of management practices such as civic ecology or adaptive co-management more broadly, one might better address this critique by drawing from theoretical work in practice and activity theory. Practice theory is a form of cultural theory that offers a middle ground between a focus on individual agency or behavior and on social or institutional structures, and in which the practice itself becomes the core unit of analysis (Reckwitz, 2002; Hargreaves, 2011). Thus, in order to create more sustainable behaviors, "The focus is no longer on individuals' attitudes, behaviors and choices, but instead on how practices form, how they are reproduced, maintained, stabilized, challenged and ultimately killed-off; on how practices recruit practitioners to maintain and strengthen them through continued performance, and on how such practitioners may be encouraged to defect to more sustainable practices" (Hargreaves, 2011, p. 84). Such a focus on practice rather than attitudes and behaviors is consistent with previous work on civic ecology practices as contexts for meaningful engagement and learning (Krasny and Tidball, 2009a; Krasny and Tidball, 2013). Also important in practice theory is the role of technology and the relationship between different practices (Gram-Hanssen, 2011). This would suggest that examining technologies, including monitoring technologies accessible to lay persons, as well as the relationship between civic ecology stewardship and monitoring practices, would help shed light on how these practices evolve.

Although the work of Gram-Hanssen (2011), Warde (2005), and others encompasses how practices evolve, Miettinen et al. (2012) claim that practice theory emphasizes habituality of practice or "pre-reflective embodied actions in contrast of individual rationality and conscious reflection" (p. 346). This suggests a need for a theory that is useful in considering how feedback processes, such as those between the results of monitoring and management actions, change practice. Similar to practice theory in its focus on practices, cultural historical activity theory (activity theory) emerged from the work of Vygotsky and others in developmental psychology and educational studies (Roth and Lee, 2007; Daniels, 2008), and thus offers insights into the relationship of individual learning and reflection to change in practice (Miettinen et al., 2012). The unit of analysis in activity theory is a "collective, artifact-mediated and object-oriented activity system, seen in its network relations to other activity systems" (Engeström, 2001, p. 136). Importantly, activity systems are characterized by contradictions that "generate disturbances and conflicts, but also

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innovative attempts to change the activity" (p. 137). In a statement that echoes notions of transformation from the social-ecological systems resilience literature (Gunderson and Holling, 2002), Engeström (2001, p. 137) states:

> "Activity systems move through relatively long cycles of qualitative transformations. As the contradictions of an activity system are aggravated, some individual participants begin to question and deviate from its established norms. In some cases, this escalates into collaborative envisioning and a deliberate collective change effort. An expansive transformation is accomplished when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity."

Applied to civic ecology, activity theory would suggest that a community engaged in stewardship practices might experience contradictions, perhaps as a result of reflection on the part of practitioners or of outsiders questioning the practitioners' effectiveness in achieving what they claim as environmental and community outcomes (Krasny and Roth, 2010). Such a stewardship activity might then expand to incorporate monitoring, reflection, and possible adaptation of the original stewardship practice. This process is consistent with the notions of feedback from the social-ecological systems resilience literature (Walker et al., 2004) and with Engeström's (2001) expanded cycle of learning.

6. Measuring ecosystem services in civic ecology practices

Several considerations arise in measuring the impact of stewardship practices intended to restore social-ecological values in highly disturbed urban systems, as opposed to measuring the negative impact of humans on ecosystem services relative to a pre-settlement or pre-industrialization benchmark condition. First, appropriate historical reference conditions may not be self-evident in sites such as vacant lots, although no-treatment controls would be possible and as more data are collected on urban systems, appropriate reference conditions may be developed. Second, in that we are interested not only in the contribution of green infrastructure but also of stewardship practices per se, paying particular attention to cultural services is warranted (e.g., community gardening and other forms of stewardship could be envisioned as a form of recreation or education).

Below we review three approaches to measuring ecosystem services – citizen science protocols to measure biodiversity, functional measures of ecosystem services, and ecosystem services valuation – in an attempt to explore assessment protocols suitable for civic ecology practices.

6.1. Citizen science measures of biodiversity

Although measures of species presence and abundance can be used as indicators of ecosystem services, caution is warranted in that the relationship of different species or functional groups to ecosystem services is non-linear and complex (Elmqvist et al., 2003; Kremen and Ostfeld, 2005; Elmqvist and Maltby, 2010; Jansson and Polasky, 2010, Díaz et al., 2011). Further, response diversity, i.e., the range of reactions to environmental change among species contributing to the same ecosystem function, may be a better measure of the potential to produce ecosystem services than species diversity per se (Elmqvist et al., 2003). However, species diversity may be easier for lay persons to measure, in particular given that well-established citizen science protocols for non-experts to measure the diversity of birds, insects, plants, and other organisms are readily available (Bonney et al., 2009, Dickinson et al., 2010). Whereas citizen science generally does not focus on ecosystem services per se, several projects collect data on bees, which provide the regulating service pollination (e.g., Great Pollinator Project, AMNH, 2012), or ladybird beetles, which help control pests (Lost Ladybug Project, Anon., 2011).

Citizen science projects are designed by scientists as a means to collect data that would otherwise be prohibitively expensive to obtain (e.g., global species distributions), but also include opportunities for participants to learn about scientific inquiry and biodiversity (Dickinson and Bonney, 2012). Given attention to volunteer training and data filtering procedures, data collected by citizen science volunteers often are of sufficient quality to allow inclusion in scientific studies, although issues of observer error and sampling bias need to be addressed on an ongoing basis (Dickinson et al., 2010; Kremen et al., 2011). Recently, more attention is being paid to conservation outcomes of citizen science (McEver et al., 2011) and a growing number of citizen science projects incorporate stewardship (e.g., Project FeederWatch, Anon., 2010). The potential exists to adapt citizen science monitoring protocols to include collecting information on changes in species composition as a result of civic ecology practices, including in disaster settings (Tidball and Krasny, 2012).

The City Biodiversity Index is another example of a tool using relatively simple measures that might be adapted for use in civic ecology practices. This index measures urban biodiversity, ecosystem services, and related governance and management capacity, and is receiving widespread global attention as a means to support international agreements reached by the Convention on Biological Diversity (CBD, 2012). Other participatory biodiversity monitoring protocols that could be adapted for civic ecology settings include those used in developing countries, where experienced, resource-dependent villagers collect data on species, populations, habitat conditions, and human resource use in collaboration with scientists and protected area staff (Danielsen et al., 2007, 2009).

6.2. Functional measures of ecosystem services

Functional measures are designed specifically to assess provisioning, regulating, supporting, and cultural ecosystem services (MEA, 2005), and include protocols based on area in certain land uses (e.g., restored wetland), presence of particular practices (e.g., composting), or measures of outputs (e.g., produce, water runoff). In contrast to the well-developed field of citizen science for biodiversity data collection, fewer protocols are available for engaging lay people in directly measuring ecosystem services.

In one example of a relatively simple and participatory functional measure of ecosystem services, knowledgeable lay persons work in collaboration with city foresters to collect data on tree species, diameter, and location, which when entered into the i-Tree software, generate information on the type and monetary value of ecosystem services provided by trees (US Forest Service, n.d.). The online National Tree Benefit Calculator is a simpler adaptation of i-Tree, which generates quick results and may be useful for educational purposes; however, its simplification masks the complexities in measuring ecosystem services and thus it has limited potential for use in adaptive management. In contrast, i-Tree used in conjunction with comprehensive tree surveys may suggest areas where tree planting schemes could be adapted to more effectively provide ecosystem services. New forms of amateur cartography enabled by services like Google Earth also offer possibilities for lay persons to collect information on ecosystem services (Grove, 2009).

Whereas citizen science biodiversity protocols are designed so that thousands of lay people can collect data with no or minimal direct contact with scientists, taking more direct measurements of ecosystem services outcomes of civic ecology practices will necessarily entail close collaboration between practitioners and

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researchers. Examples of such collaboration come from the community-based organization Rocking the Boat in the Bronx, which engages youth in civic ecology practices and collecting relevant data in partnership with adult community members and scientists. In one such project, youth collected data that were used to help determine that the Bronx River water quality was suitable for alewife reintroduction, and then helped university and city parks department scientists release adult fish, and monitor survival, spawning rate, and egg production (Goncalves, 2009; Kudryavtsev, 2013). In another partnership, youth worked with scientists to grow mussels and seaweed on rafts designed to filter nitrates from stormwater releases from a wastewater treatment plant, and to monitor seaweed growth and health, the nitrate content of the mussels, and water quality around the raft as indicators of pollution filtration services. Students from Rocking the Boat also partnered with the NYC Department of Parks & Recreation and non-profit NY/NJ Baykeeper to monitor the growth and mortality of oysters in cages they installed in the Bronx River (RTB, 2012).

Measures of cultural ecosystem services include such data as number, quality and accessibility of recreation areas, or number of people participating in an outdoor activity (Fitzsimons and Cherry, 2008). Daniel et al. (2012) demonstrate how methods used in studies of landscape esthetics, cultural heritage, outdoor recreation, and spiritual significance provide opportunities for operationally defining cultural services, which could lead to better assessment methods. A civic ecology perspective suggests the need not only for measures of more *passive recreational use* of parks and other natural areas but also of actual *participation* in environmental stewardship. For example, Rocking the Boat counts number of people coming to their community rowing events (recreational service), whereas Friends of the Los Angeles River recorded pounds of trash collected during volunteer clean-ups (indicator of esthetic values, Tyack, 2011). Other community environmental organizations have developed means for valuation of cultural services (see below).

6.3. Ecosystem services valuation measures

Ecosystem services valuation variously measures direct use values derived from resource extraction (e.g., timber production) or recreation; indirect use values that support economic activity (e.g., water quality supporting agricultural production); option use values that may be valuable in the future (e.g., genetic diversity that creates options for future medicines); and non-use values referring to conservation for its own sake (TEEB, 2010b). Valuation can be based on observed market prices, costs of market alternatives (e.g., technological alternatives to ecosystem services); travel costs of visiting a site for recreational cultural services; and hedonic price and stated preferences methods indicating how much an individual is willing to pay for ecosystem services. In addition, participatory valuation is used in cases where stakeholders voice concern or lack of understanding over valuation methods that attempt to elicit monetary values, and instead focuses on stakeholder perceptions, needs, and priorities. Examples include forest-dependent villagers using pebbles to rank the value of products extracted from the forest (TEEB, 2010b), citizens' juries (Proctor and Drechsler, 2003), scenario planning (Carpenter et al., 2006), dynamic modeling as a tool for consensus building (Constanza and Ruth, 1998), participatory mapping coupled with interviews (Klain and Chan, 2012), narratives (Chan et al., 2012b), and discourse-based valuation (Wilson and Howarth, 2002; Chee, 2004; Kumar and Kumar, 2008).

Leaders of youth programs and community gardens have devised protocols resembling ecosystem services valuation for educational and program assessments. For example, students in the summer EcoLeaders program at Satellite Academy High School conducted interviews to gather information on how users of the High Line park in Manhattan valued their nature-based experience. Through asking visitors to High Line park questions such as “Would you be willing to pay (a very small amount) for more green spaces to be easily available to all persons in the city? Why?”, students appeared to gain an understanding of the benefits of urban nature. In another example of valuation measures developed by civic ecology practitioners, the leader of the Peterson Community Garden in Chicago designed a survey to assess how gardeners value different aspects of their experience (Joy and Ginther, 2011). The Likert scale questions reflect the production and valuing of provisioning services (e.g., gardening has given me a “cost effective way to eat fresh and organically”; “How frequently were you able to add your fresh grown produce to your meals?”) and cultural ecosystem services (e.g., gardening has given me “greater opportunity for exercise and fresh air”). Questions also were included that measured how participants value the time spent volunteering in the community garden, and thus reflect the unique value of stewardship practices rather than simply the produce or other more tangible outcomes (e.g., “Would you like to volunteer for the 2011 garden season in some capacity?; If so, how many hours per month would you be willing to dedicate?”).

7. Considerations in developing participatory monitoring protocols

In developing and implementing protocols for monitoring ecosystem services outcomes of civic ecology practices, attention should be paid to the participants, scale, type of practice, and values embedded in practices, as well as to practitioner-scientist partnerships. Relative to participants, measures would need to be easily understood by lay audiences, use simple and inexpensive data collection, and pay attention to stakeholder values, perspectives, knowledge, and time constraints. Relative to scale, measures should be suitable for detecting changes in small-scale, urban social-ecological systems. Although protocols will necessarily vary according to type of civic ecology practice (e.g., park clean-up, tree planting), current attempts by a group in NYC to develop generic outcome measures for community gardening suggest that protocols could be used across multiple locations (Silva and Barry, 2013). Relative to the values embodied in civic ecology practices, measures would pay particular attention to cultural services and human health and well-being outcomes of stewardship participation, and would facilitate social learning that leads to adaptive co-management (Anderson, 1991; World Bank, 1995; Wilson and Howarth, 2002, Shear et al., 2003; Blundell, 2004; Chee, 2004; Olsson et al., 2004, Blackmore et al., 2007; Kumar and Kumar, 2008; Cundill and Fabricius, 2009; Díaz et al., 2011). Places to start in developing and implementing monitoring protocols include adapting instruments created by scientists such as i-Tree, as well as identifying “monitoring innovations” created by civic ecology practitioners themselves, such as those devised by Rocking the Boat, Satellite Academy High School, and Peterson Community Garden, and then working with practitioners to enhance the rigor and effectiveness of such efforts. Development and implementation of protocols also will require ongoing practitioner-scientist partnerships in the implementation stage, which we discuss further below.

7.1. Practitioner–scientist partnerships in civic ecology contexts

Arguments for engaging stakeholders in monitoring and resource management include the need for more data on biodiversity than the

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scientific community is able to collect on its own (Dickinson et al., 2010); educational outcomes for participants (Krasny and Bonney, 2005; Krasny and Tidball, 2009b); concerns about equity and that all stakeholder values and world views are represented (Chee, 2004; Díaz et al., 2011; Chan et al., 2012b); the critical value of local knowledge in addressing the sustainability crisis (Clark and Dickson, 2003; Chapin et al., 2011; Daniel et al., 2012), in achieving relevance, credibility, and legitimacy (Lucas et al., 2010), and in fostering social-ecological systems resilience (Berkes and Folke, 2002; Olsson et al., 2004; Pickett et al., 2004; Cowling et al., 2008); and the emotional and cognitive benefits of engagement with nature (Okvat and Zautra, 2014; Wells, 2014). Several authors have outlined participatory strategies for engaging stakeholders in assessing and valuing ecosystem services, and in planning and implementing policies that foster provision of these services (Chee, 2004; Cowling et al., 2008; Lucas et al., 2010; Díaz et al., 2011; Chan et al., 2012b). However, these approaches assume considerable involvement and time commitment on the part of participants, as in this statement: "Such approaches should include mechanisms for: (a) articulating visions about what sort of ecosystem services people want; (b) learning about the decision problem; (c) exploring system dynamics and potential outcomes associated with decision options; (d) risk assessment and analysis of uncertainty; (e) facilitating discussion, deliberation and negotiation about trade-offs; and (f) evaluating options in the search for compromise solutions" (Chee, 2004, p. 559).

In applying participatory monitoring strategies to civic ecology practices, the motivations and interests of participants and leaders in these practices need to be taken into account. We have found that often civic ecology participants may demonstrate little interest in becoming volunteer co-researchers (Saldivar and Krasny, 2004). However, leaders of such practices sometimes are eager for partnerships that enable them to achieve their larger vision, with the caveat that in many organizations staff or volunteer time necessary to engage in such partnerships needs to be compensated. These leaders may seek long-term partnerships with scientists who provide educational opportunities for participants, assist with planning and assessing their stewardship efforts, and help produce data that can be used to support claims they make about impacts of their programs. Among the most successful strategies for research and monitoring partnerships are those devised by the community organization Rocking the Boat, whose access to the Bronx River, fleet of rowboats, and youth science education and river stewardship programs are seen as assets by estuary scientists who seek cost-effective ways to collect data and means to engage diverse audiences as required by funding agencies. The director of this community organization sees the benefit of and initiates partnerships with scientists because of the opportunities to hire youth to implement and collect data on stewardship practices. In other examples, community activists who envision converting an elevated railroad in Queens NYC to a greenway similar to the Manhattan High Line are beginning conversations about baseline monitoring with scientists, and the Gowanus Canal Conservancy is working with a member of our lab to collectively implement monitoring protocols, including those using low-cost, "do-it-yourself" (DIY) technologies (Silva and Krasny, 2013).

These examples suggest that practitioner-scientist partnerships to measure ecosystem services will demand closer collaboration than that required in citizen science projects, but that such partnerships may enable scientists to conduct research on urban resource management practices that would not otherwise be possible, as well as enable conservation action and policy change (cf., Jones et al., 2006; Danielsen et al., 2007, 2009) and document impacts for use by funding agencies and international biodiversity certification programs (Alfsen et al., 2010; ICLEI, 2012). Further, monitoring partnerships can foster learning and provide information about the effectiveness of stewardship actions, thus strengthening civic ecology practices through a social learning and information feedback process consistent with adaptive co-management (cf., Armitage et al., 2007; Pahl-Wostl et al., 2007, 2008). In some instances, data from other sources may augment data collected through practitioner-scientist partnerships. For example, GIS and planting records could be used along with growth and survival data collected through monitoring partnerships to shed light on the ecosystem services restored through community forestry.

8. Implications of civic ecology practices for ecosystem services

In addition to starting a conversation about participatory means of monitoring ecosystem services in urban stewardship practices, our work in civic ecology has two broader implications for the consideration of ecosystem services in cities. These include the positive role of humans in producing ecosystem services and the potential of environmental stewardship as a process that provides ecosystem services.

8.1. Positive role of humans in cities

Much media and other communication about ecosystems focuses on the negative impacts of humans, which may create feelings of fear and vulnerability that spur anti-environmental rather than the intended pro-environmental behaviors (Dickinson, 2009). The possibility that humans, through "care/cultivation" resource management practices (Agrawal, 2010) such as civic ecology, may become positive drivers of ecosystem change is often absent from the discussion. This view of humans as positive drivers is particularly important in urban systems, where paradigms assuming that humans act exclusively to negatively alter systems from their original or more productive state may not be useful in systems already far removed from any historical conditions (MEA, 2005; Elmqvist et al., 2013). While recognizing the negative impacts of humans, we contend that humans also can be looked to as sources of social-ecological and technological innovation that restore the capacity of cities to harbor biodiversity and provide ecosystem services (Barthel et al., 2010; Sassen and Dotan, 2011; Tidball and Stedman, 2013).

8.2. Stewardship as a process that produces cultural ecosystem services

Carpenter et al. (2009) have critiqued causal pathways such as those describing the relationships among drivers, ecosystems, ecosystem services, and human outcomes, arguing that they fail to capture complex linkages and feedbacks. In the context of this paper, the engagement of social actors in hands-on restoration and stewardship, i.e., in civic ecology practice, not only leads to creation of new green infrastructure which in turn provides ecosystem services that sustain human health (Tzoulas et al., 2007; TEEB, 2010a). Another possible pathway is that civic ecology practices, as well as monitoring their outcomes, directly contribute to the provision of cultural ecosystem services and related benefits, including recreation (e.g., gardening), esthetic/spiritual (e.g., through the act of planting village groves that hold cultural meanings, Lee, 2014), education and learning (Krasny et al., 2009; Krasny and Roth, 2010), social relations (Krasny et al., in press), and sense of place (Kudryavtsev et al., 2012; Tidball, 2014b). From an integrated social-ecological systems perspective, one could consider stewardship practices as processes or functions within such a system, which, not unlike other functions such as decomposition that produces the ecosystem service of nutrient recycling, directly produce cultural ecosystem services such as recreation and education. This suggests expanding existing conceptual frameworks (MEA, 2005; LTER, 2007) to incorporate human behaviors as social-ecological system processes or functions that both produce ecosystem services indirectly through creating green infrastructure and directly through the actual stewardship behaviors. Further, given that a social-ecological practice can directly produce ecosystem services, frameworks that separate ecological and human processes – i.e., view ecosystems as producers of services for humans but ignore the potential for humans also to play a role in ecosystem services provision – may need to be re-examined to determine ways in which humans acting in concert with desired ecosystem functions may be better incorporated into explanatory models (Reyers et al., 2013).

9. Conclusion

Carpenter et al. (2009, p. 1310) give an accurate portrayal of the current state of civic ecology practice when they state: “Conservation organizations, global institutions, and governments are increasingly engaged in projects intended to improve human well-being in concert with ecosystem services. In view of the current state of knowledge, such projects must be regarded as hopeful hypotheses to be tested rather than guaranteed prescriptions for success. Yet, only rarely is the success of these projects evaluated by using appropriate data and indicators.” This paper is a first attempt at suggesting strategies for addressing the paucity of data on the impacts of self-organized stewardship initiatives in cities, and presents several measures that have been developed by civic ecology practitioners to evaluate their efforts. Further, this paper has broader implications for ecosystem services in suggesting that not only does green infrastructure produce ecosystem services in cities, but also the stewardship practices of humans may be seen as processes that produce ecosystem services (see also, Reyers et al., 2013).

The focus in practice and activity theory on the role of technologies and contradictions in changing practice (Engeström, 2001; Gram-Hanssen, 2011) provides a perspective on how civic ecology practices may evolve to incorporate monitoring. First, the growth of do-it-yourself and other inexpensive surveillance and measurement technologies is making monitoring more accessible to lay persons. For example, civil society groups such as the Public Laboratory for Open Technology and Science, are using inexpensive infrared cameras suspended from hot air balloons and kites to detect sources of pollution, plant health, and land use patterns (PLOTS, 2013). Second, as governments and NGOs increasingly see the opportunity for civil society groups to contribute to green infrastructure (Pataki et al., 2011) but also demand accountability, civic ecology practitioners may see contradictions (cf. Engeström, 2001) between their current practice and their ability to reach their goals and sustain themselves. One possibility for addressing such contradictions would be partnering with scientists to expand their practices to incorporate monitoring of ecosystem services outcomes.

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