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Applying a resilience systems framework to urban environmental education

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A growing body of literature on community gardening, watershed restoration, and similar 'civic ecology' practices suggests avenues for integrating social and ecological outcomes in urban natural resources management. In this paper, we argue that an environmental education programme in which learning is situated in civic ecology practices also has the potential to address both community and environmental goals. Further, we suggest that civic ecology practices and related environmental education programmes may foster resilience in urban social-ecological systems, through enhancing biological diversity and ecosystem services, and through incorporating diverse forms of knowledge and participatory processes in resource management. By proposing interrelationships among natural resources management, environmental education, and social-ecological systems, we hope to open up discussion of a research agenda focusing on the role of environmental education in systems processes and resilience.

Keywords: resilience; systems; urban; diversity; participation; natural resources management; civic ecology

Introduction

Incorporating social and ecological perspectives in environmental education is particularly important in cities, where the human imprint is most obvious and where over 50% of the world's population lives (UNFPA 2007). Environmental education that includes an action component, such as action competence that focuses on issue identification, analysis and in some cases advocacy, is one model for integrating social and ecological concerns (Jensen and Schnack 1997). In an analysis of multiple environmental action programmes across the US, Schusler and Krasny (forthcoming) suggest that in addition to public issue analysis and advocacy for policy change, such programmes may involve participants in community development and in hands-on activities to enhance the natural and built environment.

Parallel to environmental education approaches that 'couple' social and ecological outcomes, a new type of environmentalism is emerging in North American cities, which in contrast to the traditional environmental movement's focus on preserving pristine landscapes, integrates community and ecological values. Variously labeled as civic environmentalism (Light 2003), urban ecological stewardship (Svendsen and Campbell 2008), urban restoration (Stevens 1995), ecological restoration (Palamar 2008) or civic ecology (Tidball and Krasny 2007), this movement involves citizens,

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non-profit groups and government in restoring nature in cities through such activities as planting trees along river corridors, community gardening and recreating native wildlife habitat. Although in some cases these activities involve advocacy (e.g., demonstrations in favour of managing land for community and environmental rather than economic values), the emphasis is on restoration or stewardship practices. Residents who take on the stewardship of plots of land or sections of streams that have fallen into neglect not only enhance local ecosystems, but also may build social networks and otherwise contribute to community well-being (Light 2003; Palamar 2008; Svendsen and Campbell 2008).

We have proposed the term 'civic ecology' to refer not only to these urban restoration and stewardship practices, but also to a theoretical framework for studying the role such practices play in the larger social–ecological system (Tidball and Krasny 2008). A number of bodies of literature focus on the integration of the social and ecological sciences, including: *human ecology*, which encompasses a broad and diverse set of ideas about human–environment interactions (Borden 2008); *social ecology*, which variously refers to a radical stance arguing against political domination, hierarchy and capitalism as causes of environmental degradation (Bookchin 1993), the nested arrangement of the family, school, neighborhood and community contexts in which children grow up (Earls and Carlson 2001), and an integrated or biosocial approach to the study of human ecological systems (Burch and Grove 1999); *environmental justice*, which emphasizes advocacy, rights to a clean environment and organizational networking (Faber and McCarthy 2001; Palamar 2008); and *collaborative approaches to natural resources planning and management*, in which public and private stakeholders engage in conservation planning (Schlosberg and Dryzek 2002; Schusler, Decker, and Pfeffer 2003). Civic ecology more specifically examines stewardship practices that integrate social and environmental values within a social–ecological systems framework. In so doing, civic ecology differs from the above approaches in two ways: (1) it shifts the focus from power, individual rights, advocacy and planning to people acting as stewards of their environment through such practices as community gardening, community forestry and watershed restoration. Such practices create opportunities for individuals, including those in cities, to experience the health and restorative benefits of gardening, habitat restoration and other forms of stewardship. Civic ecology practices also allow individuals to learn through observing and experiencing how their actions impact the biological (including plants, humans and other animals) and physical environment, as well as the feedbacks and other interactions among their actions and other ecosystem components. (2) Civic ecology applies a specific social–ecological systems framework, i.e., resilience (Resilience Alliance 2008), to examine the interactions of humans with other forms of life and with the physical environment, as well as the outcomes of stewardship (or civic ecology) practices.

Civic ecology's focus on active engagement with nature draws from notions of 'biophilia' (Wilson 1984) and 'nature deficit disorder' (Louv 2006), and suggests that restoring nature may contribute to individual well-being (Miles, Sullivan, and Kuo 1998). Moving from the individual to community level, civic ecology practices are closely tied to civic engagement, and thus may foster such community-level attributes as social trust, social connectedness, associational involvement and other aspects of social capital (Palamar 2008; Putnam 1995). Finally, civic ecology poses questions about the role of stewardship practices *and* of environmental education programmes situated in these practices, in fostering desirable properties of social–ecological systems,

including resilience or the capacity of a social–ecological system to buffer perturbances and to renew and reorganize in response to change (Folke et al. 2002). Thus, civic ecology suggests a role for environmental stewardship practice and environmental education at the level of the individual, community and social–ecological system.

While recognizing the existence of other natural resources management frameworks that have been applied to stewardship practices (e.g., the Human Ecosystem Framework, Machlis et al. 1997; Svendsen and Campbell 2008), we have chosen a social–ecological systems resilience framework for examining civic ecology practices and related environmental education programmes for the following reasons. First, the resilience framework is attentive to complexity, non-linearity, unpredictability and other factors that impact the outcomes of environmental education; thus, it challenges environmental educators to look beyond behavioural and other individual-level outcomes and consider the role of environmental education in fostering the wellbeing of larger social–ecological systems (Sterling 2003). Second, resilience theory incorporates response to change; because all social–ecological systems face disturbance or change (including catastrophes such as hurricanes, earthquakes and ethnic conflict, as well as more gradual change such as increasing crime or shifting demographics), a focus on system response to change adds an important dimension to considerations of sustainable development and education for sustainable development (ESD). Third, a resilience framework has been used for examining the role of civic ecology practices in helping communities respond to change, including community forestry as a means for neighbourhoods to rebuild social and natural capital following Hurricane Katrina (Tidball and Krasny 2008) and community gardening as a response to change brought about by industrial agriculture (King 2008). Such civic ecology practices provide opportunities for situating learning in real-life resource management efforts in cities; examining such learning using a resilience framework can contribute to our understanding of the role of environmental education in broader community and environmental sustainability. In short, a resilience framework challenges us to consider the role of environmental education within a broader social–ecological system, can be readily linked to and builds on notions of sustainability, and suggests ways to situate learning in natural resources management practices in cities and in the other 'peopled landscapes' or anthropogenic biomes, which increasingly dominate the earth (Crouch 1992; Ellis and Ramankutty 2008). Further, through incorporating notions of feedback loops and nested systems (Gunderson and Hollings 2001), a resilience framework allows us to pose questions about how stewardship practices, environmental education, and ecological and social system health might reinforce each other, and thus suggests an 'ecology of environmental education' (Tidball and Krasny 2009).

In the remaining sections of this paper, we first provide a brief overview of the resilience framework. We next describe an example civic ecology practice (community gardening) and an environmental education programme situated within this practice ('Garden Mosaics'), following which we apply the resilience framework to examine the potential impacts of community gardening and other civic ecology practices and of environmental education situated in such practices. By applying the resilience framework to environmental education situated in ongoing civic ecology practice, we extend the application of resilience principles from natural resource management to stewardship and education. By applying resilience thinking in cities, we are able to focus on systems that are increasingly important globally (Brunn 2003; Parlange 1998; UNFPA 2007) and to highlight cases of integrated social–ecological practice in resource stewardship (Light 2003).

Thus, the major contributions of this paper to the environmental education literature are twofold. First, by addressing the implications of a growing urban environmental stewardship movement for environmental education, we present new ideas about the crossover between natural resources management and environmental education. Second, by adding a resilience perspective, we elaborate on systems thinking in environmental education (see also Sterling 2003) and focus the debate on the importance of environmental education to the overall social–ecological system. Whereas Sterling (2003) presents a thorough theoretical discussion of the role of systems thinking in environmental education, we focus more specifically on exploring the application of resilience systems thinking to practical examples of education programmes, particularly in urban areas. Other authors have focused on teaching systems thinking (see Jacobson and Wilensky 2006), or have used the term socio-ecological to refer to environmental learning within real-life situations such as family households and sports grounds, including the people involved and issues that arise in these contexts (Kyburz-Graber, Hofer, and Wolfensberger 2006). Building on these important approaches, we suggest that: (1) environmental education can be situated in civic ecology practices that foster social–ecological systems resilience; and (2) the environmental education programmes themselves can be examined in terms of their role in larger social–ecological systems.

While suggesting potential resilience outcomes of environmental education situated within civic ecology practice, we recognize that it is too early to make definitive claims about this approach. Thus, the goal of this paper is to open up a discussion of applying resilience systems thinking to environmental education. In so doing, we hope to stimulate potential new lines of research, including questions focusing on outcomes of environmental education related to attributes of resilient social–ecological systems (e.g., social capital, biological and cultural diversity, ecosystem services, see also Walker and Salt, 2006). Applying resilience systems thinking to environmental education also suggests research questions related to the feedbacks among environmental education, stewardship practices, and the physical, biological and social components of a system, or what Tidball and Krasny (2009) have referred to as an ‘ecology of environmental education’.

Resilience in social–ecological systems

Folke et al. (2002) have pointed out that in managing ecosystems for stability and productivity, and in decoupling human and natural systems, we inadvertently reduce the ability of social–ecological systems to respond to change. So, for example, to increase forest productivity, we plant mono-specific, even-aged stands that may be unsustainable in the face of perturbations (e.g., insect infestations, climate change), and that may not support local people who depend on multiple ecosystem services provided by forests, such as food, fibre, fresh water, flood regulation and opportunities for cultural expression (see MEA 2005). In contrast, systems that incorporate ecological diversity, as well as diverse forms of knowledge, multiple levels of organization including those based in community participation, and adaptive learning, are likely to be more resilient in the face of small-scale change and larger disasters. Because change is inherent to all systems, resilience is an integral component of sustainability (Folke et al. 2002). The relationship of resilience to sustainability is further spelled out in the following quote:

> Managing complex, coevolving social–ecological systems for sustainability requires the ability to cope with, adapt to and shape change without losing options for future development. It requires resilience – the capacity to buffer perturbations, self-organize, learn and adapt. When massive transformation occurs, resilient systems contain the experience and the diversity of options needed for renewal and development. Sustainable systems need to be resilient. (Folke et al. 2002, 51)

The resilience framework has roots in systems dynamics thinking, which includes an emphasis on feedback loops rather than linear causality. System dynamics entails making three fundamental shifts of mind relative to traditional ways of thinking: (1) from linear, laundry list thinking to a circular, closed-loop view of causality; (2) from an external to an internal focus on performance, emphasizing how we, not others, are responsible for results; and (3) a focus on an operational view of how things work in contrast to analysis methods based on statistical correlation of past trends (Walkers 1997). According to Richardson (1997):

> Systems dynamics thinking gets a lot of its power from a 'feedback' perspective – the realization that tough dynamic problems arise in situations with lots of pressures and perceptions that interact to form loops of circular causality, rather than simple one-way causal chains.

Resilience thinking also draws from the adaptive cycle as a metaphor for how change occurs, with periods of rapid growth and stability alternating with decline followed by reorganization. Managing for change, rather than toward a stable state endpoint, is inherent to resilience thinking (Resilience Alliance 2008).

Systems scholars have cited three attributes as being fundamental to the ability of a social–ecological system, or of a community nested within that system, to respond to rapid changes and uncertainty, including: (1) the amount of change the system can undergo and still retain the same controls on function and structure; (2) the degree to which the system is capable of self-organization; and (3) the ability to build and increase the capacity for learning and adaptation (Folke et al. 2002). In an account aimed to make resilience thinking more accessible to non-researcher audiences, Walker and Salt (2006) list nine rather than three attributes that characterize resilient social–ecological systems, including diversity, ecological variability, modularity, slow variables, tight feedbacks, social capital, innovation, overlap in governance and ecosystem services. For this brief introduction, we focus our discussion on Folke et al.'s (2002) more limited set of factors, while recognizing that Walker and Salt's (2006) expanded list provides greater opportunity for posing questions about the potential for environmental education to contribute to multiple attributes of resilient social–ecological systems. (A subsequent special issue of *Environmental Education Research* will describe in more depth systems resilience thinking.)

According to resilience scholars, *diversity* is fundamental to retaining functional and structural controls in the face of disturbance and thus to buffering the impact of catastrophic and more gradual change (Folke et al. 2002; Perrings 2006; Walker et al. 2006). Levin (2005) describes how biological diversity can provide functional redundancy, so that if one species declines other species providing the same ecosystem services may continue to function. For example, if a plant community has several species capable of fixing nitrogen, the decline of one of those species may have limited impact given that other species continue to add nitrogen to the system. However, in a review article, Thompson and Starzomski (2007) caution that although biodiversity

may be positively associated with the ability of systems to respond to change, not all systems with higher biodiversity will be more stable under changing conditions.

Resilience scholars also claim that when diverse groups of stakeholders, such as scientists, community members with local knowledge, NGOs and government officials, share the management of a resource, decision-making may be better informed, stakeholders may be more invested in and supportive of the decisions, and more options exist for testing and evaluating policies (Olsson, Folke, and Berkes 2004). Thus, diverse forms of knowledge, including traditional ecological and scientific knowledge, may be critical in managing social–ecological systems (Berkes 1998; Berkes, Colding, and Folke 2000).

Self-organization refers to the emergence of macro-scale patterns or properties from smaller-scale rules, such as the emergence of ecosystem patterns related to nutrient cycling or plant size distributions as a result of evolution acting at the species level (Levin 2005). Olsson, Folke and Berkes (2004) apply the concept of self-organization to humans managing social–ecological systems, claiming that when private landowners, scientists and professional land managers work together to design and learn from management practices, adaptive co-management is the resultant emergent property. The authors describe two rural examples of adaptive co-management, one involving fishermen and lakeshore owners who responded to an acid rain threat in Sweden, and the other involving indigenous peoples whose way of life was threatened by hydropower development.

The capacity for *social and adaptive learning* is a third attribute of resilient social–ecological systems (Plummer and FitzGibbon 2008). Pahl-Wostl et al. (2007) suggest that learning among groups restoring a watershed results from an interplay among three elements: context formed by institutions and physical system, process formed by management practices, and outcomes that change the original context. The story of volunteer efforts to restore degraded prairie and savannah habitats in Chicago provides a case study of how, through a series of informal planting and land management experiments (e.g., controlled burns to suppress invasive species), lay people and scientists learned adaptively how to enhance the ecosystem services provided by urban open space (Stevens 1995).

In short, according to the resilience framework, diversity (including biological diversity and diverse types of knowledge), self-organization and adaptive learning are three attributes of social–ecological systems that are able to adapt to disturbance and change, although other factors also play a role. Currently, social and ecological scientists are applying this framework to forest, aquatic, marine, agricultural and urban social–ecological systems using case study and other methodologies (Alberti and Marzluff 2004; Anderies, Janssen, and Walker 2002; Baskerville 1995; Carpenter and Cottingham 1997; King 2008; Resilience Alliance 2008; Tidball and Krasny 2007).

Below we add to the existing literature by describing how the attributes of resilient systems are embodied in one type of civic ecology practice in cities, i.e., community gardening. We then present an example of an environmental education programme, 'Garden Mosaics', which is situated within this civic ecology practice, and discuss the potential of this and similar educational programmes to contribute to social–ecological system resilience. In suggesting that a specific educational intervention has the potential to enhance a system's resilience, we depart from the existing literature, which has focused primarily on applying the resilience framework to understanding the functioning of social–ecological systems. Whereas the 'Garden Mosaics' environmental education programme was not originally designed with resilience principles in mind,

we have found the framework useful in posing questions about the programme's potential impacts, and about its relationship to community gardening practice and to the larger system in which it is situated.

Urban community gardening practice and education

In the US and Canada, urban community gardeners often are new immigrants from developing countries, as well as African-Americans who have migrated to cities from the rural southern states. These individuals bring with them a form of experience-based, practical, or 'traditional ecological' knowledge of plants and planting practices, which they adapt to the new urban sites where they have relocated. As a result of the gardeners' efforts, community gardens provide important ecosystem services (MEA 2005) to people with limited access to other more natural areas. These services include opportunities to enjoy nature, learn about biological and cultural diversity, obtain fresh produce, get exercise, form social networks and escape from the noise and stress of urban living (Armstrong 2000; King 2008; Patel 1991; Saldivar-Tanaka and Krasny 2004; Westphal 2003). Further, through integrating biological and cultural diversity, diverse forms of knowledge (e.g., knowledge of immigrant gardeners and of scientists conducting research at these sites), participatory action, flexible social institutions and adaptive learning, community gardens may be contributing to social–ecological system resilience in cities (King 2008; Tidball and Krasny 2007).

Rogoff et al. (2003) and other sociocultural theorists speak to the importance of situating learning in authentic practice. Because urban community gardening is an example of resource management that integrates social and ecological values, it provides an opportunity for environmental learning situated within local practice. Further, if in fact community gardening contributes to resilience in urban social–ecological systems, embedding an environmental education programme within community gardening also may enhance resilience in cities.

Fusco (2001) describes a case of a youth science inquiry programme situated within a community garden in New York City (NYC). Similarly, 'Garden Mosaics' is an environmental education programme that takes place in community gardens in North America and elsewhere, and integrates science and environmental learning, civic action and multicultural and intergenerational understanding. Youth learn alongside adult community gardeners, who share their knowledge of plants and how plants connect to the gardeners' cultures and traditions. In addition to their experiences gardening alongside experienced practitioners within a community context, youth in 'Garden Mosaics' learn about ecology and agriculture through short-term inquiry activities, conduct investigations in which they explore questions about social and ecological components of the garden and neighbourhood, and conduct action projects to enhance the garden and neighbourhood (Texts 1 and 2):

Text 1. Garden Mosaics learning activities

Youth activities, including *i·m·science investigations*, Action Projects, and other shorter-term learning exercises, build on scientific and traditional knowledge, and civic values in community gardens. For example, in the Gardener Story *i·m·science investigation*, youth interview immigrant and African-American gardeners about their knowledge of plants, planting practices, and the connection of plants to their cultural traditions. Names of plants and planting practices from the gardeners' stories are linked to Science Pages,

which include science-based content and protocols for short-term learning activities. Youth also use problems or needs related by gardeners to develop garden and community Action Projects. Youth submit the results of their *i·m·science investigations* and Action Projects online, where others can view their findings.

i·m·science investigations
- *Neighbourhood Exploration*, in which youth explore the assets of their community using spatial imagery, and observations and interviews conducted while walking around their neighbourhood.
- *Gardener Story*, which entails interviewing a gardener about the connections between planting practices and cultural traditions.
- *Community Garden Inventory*, in which participants list the activities and other services community gardens provide for their neighbourhood.
- *Weed Watch*, designed to collect data about weed problems and control methods in urban gardens.

Action projects, in which youth apply what they have learned in their *i·m·science investigations* to enhancing their neighbourhood or community gardens. Example Action Projects include youth building a handicap-accessible raised bed, conducting a neighbourhood garden festival, donating produce to food kitchens, creating a plant sculpture in a garden, and sharing what they have learned with younger children.

Short-term inquiry and other learning activities ranging from jeopardy games focused on food crops to blog exchanges with youth overseas. (Krasny et al. 2005; Krasny, Tidball, and Najarian 2006)

Text 2. Example Garden Mosaics youth programmes

Sacramento, California
In Sacramento, youth interviewed Hmong, refugee community gardeners about what they were growing and the cultural relevance of their plants. The youth compiled a list of insects in the gardens with both the English and Hmong names. They also learned that there was a long waiting list for plots at the community garden, so they designed a new community garden for elders and youth next to their high school.

Bronx, New York City
In the Bronx, Abraham House provides an alternative to incarceration for first time offenders and support services for their families. The youth in their summer programme conducted an interview of an elderly Mexican gardener at the nearby Bronx Cultural and Community Garden, and posted what they learned on the Gardener Story database. Abraham House staff and a Cornell graduate student worked together to guide the youth in inventorying weed problems, and entering their data on the Weed Watch database. The youth created a poster of their Weed Watch activities, which they presented at the annual meetings of the Weed Science Society of America. Later the youth used a blog to share their garden and neighbourhood activities with youth conducting *Garden Mosaics* activities in Tomsk, Siberia.

Applying the resilience framework to community gardening and environmental education

Below we apply two attributes of resilient systems to an analysis of urban community gardening and the 'Garden Mosaics' environmental education programme. In particular, we focus on two attributes that are directly addressed through community gardening and the 'Garden Mosaics' programme: diversity and self-organization. In future papers, including a forthcoming special issue of *Environmental Education*

Research, we will expand our discussion of resilience and environmental education to include additional attributes of resilient systems including adaptive learning (Armitage, Marschke, and Plummer 2008) and social capital (Adger 2003); a more thorough discussion of resilience concepts (e.g., adaptive cycle, feedback loops and panarchy; Resilience Alliance 2008); and a wider array of environmental education programmes focusing on watersheds, community forestry and wildlife habitat restoration in community, formal and higher education settings.

Diversity

Community gardens often include a rich diversity of vegetables, herbs, trees and flowering plants, albeit many of the species are non-native. In cities where community gardens are common, they contribute significantly to overall green space and biodiversity (e.g., provide sites for migrating birds, Tidball 2007; Gutierrez and Vargo 2007), as well as to landscape heterogeneity (an attribute of resilient systems, Walker and Salt 2006). Community gardens may provide the only opportunity for residents in some urban neighbourhoods to experience biodiversity or nature, and as such they may foster psychological and physical health (Louv 2006) and provide opportunities for learning (King 2008). For these reasons, community gardens may contribute to the resilience of urban social–ecological systems, or of communities or neighbourhoods nested within larger urban systems, in the face of such perturbances as demographic shifts, food insecurity, ethnic conflict, or floods and other catastrophes (Tidball and Krasny 2007).

Urban community gardens also represent sites where individuals holding diverse practical and scientific knowledge come together, including community gardeners and staff of non-profit organizations, government agencies and universities. Whereas most literature on traditional knowledge and natural resources management focuses on indigenous or rural communities in which there is a long history of *in situ* adaptive learning and traditions (see Berkes 1998), Shava et al. (forthcoming) describe how farm communities in Zimbabwe that have been resettled turn to traditional knowledge and crops as a resilience strategy in the face of severe economic and environmental hardship. Similarly, in the case of immigrant and internal migrant urban community gardeners in North America, agricultural knowledge acquired in rural settings has been adapted to new environments. Given that even remote 'indigenous' communities are linked into the global economy through migration and international markets (e.g., yak herders in remote villages of Bhutan collect medicinal products and sell them on the global market; M. Krasny, pers. obs.), it may be that rural as well as urban farmers develop a constantly changing 'hybrid' form of local knowledge (Briggs 2005).

In addition to possessing knowledge of plants, through gardening in a shared public space community gardeners acquire knowledge of urban infrastructure (e.g., water lines), urban natural resources (e.g., sources of uncontaminated soil, sources of fresh food) and local advocacy and politics (related to protecting garden sites from commercial or other development). Further, refugee and other gardeners who use gardening as a form of personal psychological resilience to trauma and hardship (Helphand 2006; Slater 2001; Stuart 2005) may possess a form of experience-based knowledge about plants and emotional well-being. Consistent with the horticultural therapy literature detailing the psychological benefits of plant–people interactions, the Healing Through Community Gardening project in Bosnia-Herzegovina, where people from ethnic groups formerly in conflict work side-by-side to grow food for themselves and their families (American Friends Service Committee 2008), provides

an example of using the experiential knowledge of individuals (i.e., of how gardening with others can help in reconciliation) for the purposes of community resilience following conflict. Similarly, our observations of Afghani, Laotian and Liberian refugees, elderly Korean and war-injured Ethiopian community gardeners in North American cities support the notion that people use community gardening to help in resilience at the individual level (see also Luthans, Vogelgesang, and Lester 2006), while also building more resilient communities. As an example of how this individual and community resilience may serve to buffer the impacts of a disturbance, a number of US cities responded to the 9/11 terrorist attacks by transforming community gardens into 'Living Memorial' gardens (Svendsen and Campbell 2005). Through the lens of resilience thinking, neighbourhoods in which residents have diverse forms of knowledge (e.g., of plants, urban infrastructure and strategies for personal resilience) may have a higher degree of community resilience, which they tap into to help sustain their communities in the face of a disturbance such as a terrorist attack.

Briggs (2005) and Henkel and Stirrat (2001) point out the dangers of romanticizing traditional knowledge, and Reid, Teamey and Dillon (2002, 2004) describe the contested nature of traditional ecological knowledge and caution about its inappropriate uses in education (e.g., use out of context, 'value-through-utility', romanticizing). Despite these cautions, a number of education scholars and practitioners use traditional knowledge in school science learning, claiming that it is an effective means to engage youth who otherwise feel alienated. Further, when children learn traditional knowledge alongside community members, both the youth and adults may experience enhanced agency and a sense of renewed respect for and pride in the value of their cultural heritage (Aikenhead 1996; Fakudze 2004; Jegede and Aikenhead 1999; Masuku van Damme and Neluvhalani 2004; O'Donoghue et al. 2007), outcomes which are consistent with ESD (UNESCO 2005) and which may contribute to resilience at the individual level (Clauss-Ehlers and Weist 2004). Share Net in South Africa provides an example of integrating traditional knowledge learned from elders into standard life sciences, chemistry and physics curricula, including lessons on wild edible greens (*imifino*), cholera and fermented foods (O'Donoghue et al. 2007; O'Donoghue and Russo 2004). Similarly, in the case of 'Garden Mosaics', we use local, practical knowledge of gardeners to engage youth and elder gardeners in learning together.

If, as suggested by resilience scholars, diverse forms of knowledge foster resilience in a social–ecological system, environmental education programmes that incorporate and foster such knowledge also might contribute to resilience of the surrounding community. Further, environmental education programmes that directly contribute to biological diversity and landscape heterogeneity through engaging participants in planting diverse species and creating new gardens and other green spaces may help confer resilience in local communities.

Self-organization

Self-organization, or the emergence of larger-scale patterns from independent smaller-scale processes, may occur when the density of community gardens is high, or when community gardens together with parks, recreation corridors along train tracks and other types of green spaces contribute to the total green area in a city. In both cases, one can envision a diversity of green spaces, each one initiated and managed somewhat independently, contributing to a larger landscape that provides ecosystem

services for city residents (e.g., wildlife habitat, water quality, carbon sequestration). Thus, from an ecological perspective, the organismal processes in a single community garden, such as fruit production, rainwater retention and photosynthesis, can be viewed as small-scale processes contributing to larger-scale patterns of ecosystem services (MEA 2005).

The actions of city residents who reach a critical mass of shared frustration with the status quo, and then organize themselves to remove rubble and replace it with soil to grow crops and trees, embody a form of community-based self-organization that presents an alternative to dependence on formal institutions (see also Folke et al. 2002). A system of adaptive co-management of informal green spaces in cities may emerge from the collaborations and social learning among local stakeholders (see also, Armitage, Marschke, and Plummer 2008; Plummer and FitzGibbon 2007).

Because self-organization is tightly linked to citizen participation, it is useful to consider the existing literature on participation in natural resources management and environmental education. In the introduction to their edited volume, *Participation: from tyranny to transformation*, Hickey and Mohan (2004) argue for moving beyond the debate about whether participation is exploitative in offering solely technical solutions and ignoring power relations, to considering in more depth the outcomes of various forms of participation, including participatory spaces. In the context of civic ecology, participation sometimes occurs in what Gaventa (2004) refers to as 'claimed or created spaces', in which less powerful actors with a common set of concerns or identities claim spaces from more powerful players. An example of this type of participation is the community gardening movement in the late 1970s in NYC, where residents seized control of blighted vacant lots and converted them to community open space. As the city increasingly recognized the value of the gardens, they began to support them through granting permanent land tenure; helping with water systems, soil remediation and procuring seeds; technical advice; and competitive grants programmes. It is at this point, when the balance shifts from local control and entrepreneurship to greater dependence on municipalities or other bodies, that community gardens become less 'claimed spaces' and take on aspects of 'invited spaces' (Gaventa 2004). Whereas much of the participatory development and collaborative natural resources management literature focuses on invited spaces, or situations where government or more powerful NGOs invite local stakeholders to participate in management decisions (see Schusler, Decker, and Pfeffer 2003), civic ecology practices often begin as claimed participation and may later include elements of invited participation. Such claimed participation bears resemblance to emergent or self-organized forms of natural resources management (Ruitenbeek and Cartier 2000).

In a parallel to the distinctions between environmental activism and stewardship practice discussed earlier, Reid and Nikel (2008) review the literature on participation in environmental education, defined as opportunities to be actively involved in all aspects of solving environmental problems, and on participatory learning, which suggests that learning occurs through engagement in behaviours and practices, generally in cooperation with more experienced others. 'Garden Mosaics' includes an environmental activism component through the youth Action Projects (see Text 1), as well as a focus on participation as learning situated in practice. Learning in 'Garden Mosaics' occurs within the context of an ongoing natural resources stewardship practice; youth participants can be viewed as moving from peripheral to full participation in a community gardening community of practice (Rogoff et al. 2003). Similar environmental education and science education programmes in which youth become

engaged in stewardship communities of practice focused on enhancing local wetland habitats are described by Roth and Lee (2004).

In order for the participatory learning that occurs through 'Garden Mosaics' to represent the self-organization attribute described by resilience systems scholars, we should be able to identify a social–ecological system level property emerging from the individual inquiry, stewardship and civic activities. We have initial evidence from participant surveys and informal observations that elders who were interviewed by 'Garden Mosaics' youth developed more positive ways of viewing youth in their community, and felt recognized by youth's interest in their expertise (Krasny 2007). Greater connectedness among youth and adults can be viewed as a community-level property emerging from the interviewing, gardening and other individual-level activities. Such social connectedness may lead to a number of outcomes that contribute to social–ecological system resilience, such as broadening the range of perspectives included in managing local resources, and the development of social networks that may mobilize knowledge for ecosystem management (see also Olsson, Folke, and Berkes 2004).

Thus, while 'Garden Mosaics' itself does not represent a self-organized environmental education programme, it is situated in civic ecology practices that are largely self-organized. Further, through focusing on how interactions among participants may lead not only to individual learning, but also to community or system-level properties, such as social capital, and to enhanced ecosystem services, we may identify elements of self-organization in 'Garden Mosaics' and other environmental education programmes.

Conclusion: towards a social–ecological systems resilience environmental education research agenda

In this paper, we describe how civic ecology and related environmental education practices may contribute to two attributes of resilient social–ecological systems: diversity (biological and forms of knowledge) and self-organization (plantings leading to ecosystem services and participation leading to social connectedness). Although not within the scope of this paper, environmental education may also contribute to additional resilience attributes, and thus one outcome of environmental education could be fostering resilience in urban social–ecological systems (Figure 1). Having proposed such an approach, we recognize two caveats. First, even though civic ecology and environmental education situated within civic ecology practice seem to have promise for integrating social and ecological outcomes in urban and other populated areas, they represent only one of many approaches to environmental education linked to natural resources management. Second, assumptions inherent to the resilience framework need to be critically examined rather than accepted at face value. For example, ethnic diversity is inversely correlated with measures of social capital in the US (Putnam 2007), yet both diversity and social capital are proposed as attributes of resilient social–ecological systems (Walker and Salt 2006). Similarly, Thompson and Starzomski (2007) have questioned commonly accepted notions about the role of biological diversity in ecosystem functioning. The fact that concepts such as diversity and self-organization developed within the ecological sciences have been broadly applied to the social sciences also creates confusion within the resilience literature. Thus, a critical discussion of the role of diversity and self-organization in fostering resilience must address multiple issues having to do with vague definitions

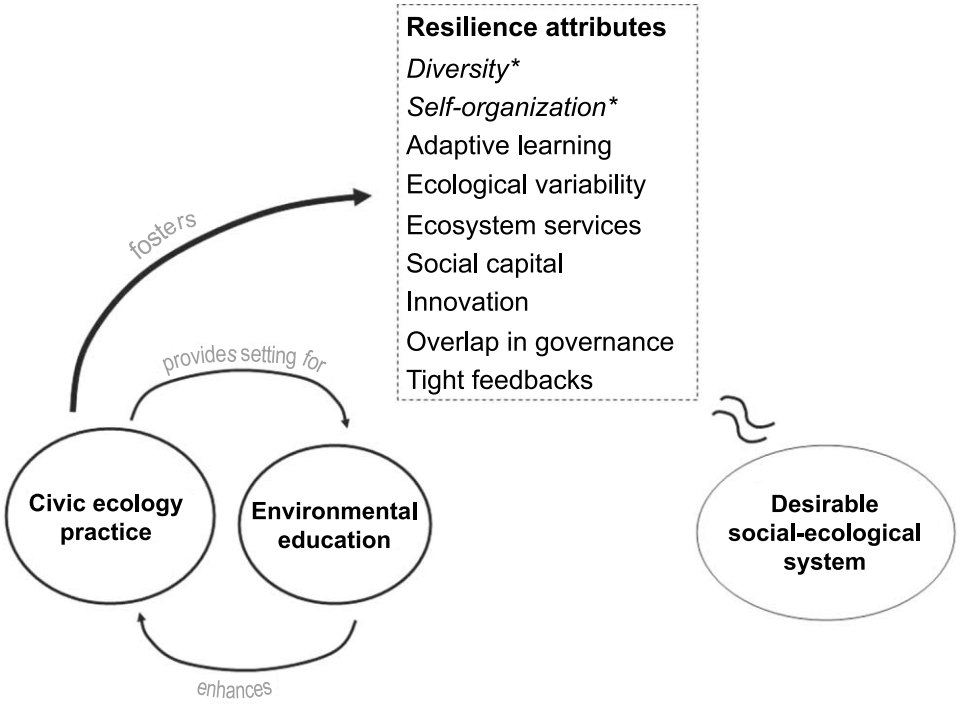

Figure 1. Hypothesized relationships of civic ecology practice, environmental education, and resilience of a desirable social–ecological system. Civic ecology practices, such as community gardening, community forestry and watershed restoration, foster multiple attributes of resilient social–ecological systems (see also Folke et al. 2002; Walker and Salt, 2006). Civic Ecology practices also provide a setting for environmental education programmes. environmental education programmes situated in civic ecology practices enhance those practices and thus further foster the resilience attributes characterizing desirable social–ecological systems.
Note: *Two resilience attributes that are discussed in this paper; additional ecological and social attributes of resilient social–ecological systems also may be fostered by civic ecology practice and environmental education, and are the subject of forthcoming papers.

of terms as well as contested uses of various forms of knowledge and of participatory approaches to development, natural resources management and education.

In addition to more critically examining the diversity and self-organization attributes discussed in this paper, a resilience environmental education research programme would expand its analysis to include such attributes as adaptive learning, innovation, social capital and ecosystem services (Walker and Salt 2006). Some such research projects are currently underway. For example, Duffin, Murphy and Johnson (2007) examined the impact of environmental education programmes in the US on improving air quality, an important ecosystem service (e.g., when youth advocate for a new school bus idling policy). Our research group at Cornell is conducting research to determine changes in social capital among youth from military communities engaged in environmental education, and Kudryavtsev (2009) is investigating individual and ecosystem outcomes of environmental education programmes that engage youth in habitat restoration along the Bronx River in NYC.

In addition to a focus on more 'linear' research approaches designed to determine the impact of civic ecology education and other forms of environmental education on

resilience attributes, a systems perspective suggests questions about feedbacks among environmental education and other components of a social–ecological system. For example, a series of positive feedback loops may transpire as people engaged in civic ecology practice realize individual outcomes (e.g., sense of agency, feeling of connectedness to people and to nature) and become more active in such practices, thus contributing to greater social–ecological system resilience. Feedbacks also may occur between an environmental education programme and civic ecology practice, as youth learn from adults and then contribute to the adults' work in restoring local habitats. By positing educational programmes, civic ecology practices and system level changes as a series of nested feedback loops, the resilience framework also suggests questions about how educational outcomes for individuals might be linked to outcomes for surrounding communities (e.g., social capital, ecosystem services, biodiversity; see Krasny et al. in review). A research programme that examines a broader 'ecology of environmental education' (Tidball and Krasny 2009) would address these and similar questions about interrelationships among different system components.

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