Chapter 10

Disturbances in Urban Social-Ecological Systems: Niche Opportunities for Environmental Education

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The field of disturbance ecology has demonstrated the importance of both small- and large-scale perturbations in ecosystems for opening niches and creating opportunities for species and processes to become established and change the system over time (Pickett and White 1985; Tilman and Downing 1994; Parminter 1998). Here, we explore the ecological and educational corollary of disturbance ecology by looking at the effect of human-mediated and other disturbances in urban systems, and the potential they have for creating niches where new awareness and associated attitudes towards urban ecosystems can reside and therefore open unique opportunities for environmental educators. We do this by investigating two U.S. urban case studies, New York City and New Orleans, as social-ecological systems (SES) in which large-scale, but very different, disturbances occurred in 2001 and 2005, respectively. We examine how the social, ecological, and educational communities changed as a result of these disturbances. We specifically ask how attitudes towards urban nature may have changed, using an adaptive cycle framework that analyzes post-disaster citizen-driven initiatives. This analysis will examine tree planting as living memorials as an initial node in the post-disaster grieving process in New York City (Svendsen and Campbell 2010), the succession in the SES that led to the establishment

of a public-private partnership to plant a million trees in the city (McPhearson 2011), and how tree planting continues to expand through current reforestation and environmental education initiatives. In New Orleans, we examine how communities of practice emerged around restoring trees and the urban forest as a way to demonstrate the city's SES resistance to outside assessments that it had "failed" and was incapable of coming back, as well as to initiate resilient adaptive management to begin the process of rebirth. We also explore how social-ecological succession in an urban system affects environmental education by creating potential for educators to utilize the theory of ecological identity as a way to promote education about and for local environments.

We found the collaborative process of writing this chapter a relatively smooth exercise, given our overlapping interest in exploring environmental and educational issues from a system analysis perspective. The heuristic of the adaptive cycle in resilience theory provided a tool that created commonality between the case studies each of us contributed to the chapter. Though previous empirical fieldwork for each of us involved different lenses (one more social, the other more biophysical) for investigating the relationships between citizens engaged in their social-ecological urban environments, we found commonality in that citizens in both New Orleans and New York City, following significant disturbances, engaged in tree planting, a particular highly visible act, as a way of personally responding to crisis affecting their lives and their city. Ultimately, Keith's previous work examining post-disaster contexts of urban ecosystems and Timon's work as an urban ecologist examining ecosystem dynamics led to the formation of a novel hypothesis about how environmental education (which both authors have engaged in as practitioners and scholars) might be well situated to leverage in post-disturbance social-ecological systems. This is not to say that there were not difficulties and challenges to be solved along the way towards completing this chapter. Though both authors feel intuitively that the main hypothesis of the chapter resonates with our experience as researchers and citizens of complex urban systems, we felt it was imperative that we embed our discussion in empiricism. From one perspective, one might think it fortuitous (for this chapter) that we both work in cities that have recently suffered from major disasters, or that we both discovered civic engagement with nature to be a dominant response to these disasters. Instead, we suggest that it may not be fortune at all, but a kind of ephemeral biophilic response (Tidball 2012a) we should be looking for (and further engaging) as major

disturbances continue to affect cities, creating unique opportunities for environmental education. It may be rare that transboundary research falls into place as it did in our collaboration. However, we suggest that one starting point for finding commonality may be to begin with a systems approach to understanding any question, finding the linkages that overlap between various components of the system (in this case, social and ecological components embedded in a complex social-ecological system of a city), and using these linkages as a way to begin conversation about what new ideas may emerge from deeper exploration of these initial overlaps. We hope that our efforts have produced something novel, even provocative, that will stand up to new empirical examination of the hypotheses explored below.

Primary Questions

Do disturbances in urban social-ecological systems, such as weather, climate, or human-mediated technological disasters, create new opportunities for adaptation through environmental education? What can we learn by attempting to better understand these disturbances and environmental education as adaptive capacity, utilizing the heuristic approach suggested by the adaptive cycle in resilience theory? Additionally, how can an understanding of ecological identity be used to improve environmental education outcomes?

Environmental Literacy in Crisis

In the next few years it is clear that human demands of rising population, expanding global economy, climate change, and overdependence on fossil fuels will have to be recalibrated to match ecological capacities (Orr 2004; Rockström et al. 2009). The exploitation of natural capital will be forced to give way to a global economy that better preserves biodiversity and focuses on resilience and environmental sustainability (McPhearson et al., in press). Some have argued that these issues will result in both more conflicts among competing natural resource users and more weather-related or climate-induced disasters. Given the above, the role of environmental education (EE) can be seen as critical to improving the public's environmental knowledge and understanding and engaging citizens in a closer, more nuanced, and adaptive relationship with the environment they depend on (McPhearson et al. 2008). However, significant problems stand in the way of successful EE

and sustainability (Potter 2010; Navarro and Tidball, 2012), not the least of which are the diverse and sometimes contradictory pedagogical approaches to EE, or even how we conceptualize EE.

In this chapter, we build on previous work on systems thinking as a component of ecological literacy, and echo calls for EE to look beyond a focus on solely changing individual behaviors to suggest conceptual models for EE and learning that place the behaviors and interactions of individuals within larger SESs. We draw from the SES and disturbance ecology literatures, and attempt to integrate EE into novel conceptual models. Further, we point to recent work on an "ecology of environmental education" that draws on sociocultural learning theories, and attempt to add to proposals that not only EE but also environmental learning among individuals participating in an educational program can be viewed from an ecological perspective. We maintain that learning systems can be thought of as "composed of individuals interacting with each other and with their biophysical environment as embedded in the larger system of an environmental education program, which in turn interacts with natural resources management practices, environmental policies, and other elements of a local social-ecological system" (Tidball and Krasny 2011).

In 2003, the National Science Foundation released a report of its Advisory Committee for Environmental Research and Education (Pfirman and AC-ERE 2003) finding that "in the coming decades, the public will more frequently be called upon to understand complex environmental issues, assess risk, evaluate proposed environmental plans and understand how individual decisions affect the environment at local and global scales" (2003, 41). The committee called for the creation of a scientifically informed citizenry, and pointed out that this will require a "concerted and systematic approach to environmental education grounded in a broad and deep research base that offers a compelling invitation to lifelong learning" (2003, 41).

At a time when Americans are confronted with increasingly challenging environmental choices, some argue that our citizenry is by and large both uninformed and misinformed, and also believe they know much more about the environment than they actually do (Coyle 2005). In 2005 the National Environmental Education and Training Foundation (NEETF) released, in collaboration with Roper Reports, a sobering assessment of environmental literacy in America. The NEETF/Roper study found that 45 million Americans think the ocean is a direct source of fresh water; 120 million think the average spray can still has CFCs in it, even though CFCs were banned in

1978; 120 million people think disposable diapers are the leading problem with landfills, when they actually represent about 1% of the problem; and 130 million believe that hydropower is the United States' top energy source, when it accounts for just 10% of the total (Coyle 2005).

Though low levels of environmental literacy are disturbing, a more recent phenomenon appears to be growing that warrants careful attention, and also a targeted education strategy to correct. This phenomenon is described as a widespread "nature-deficit disorder" (Louv 2005). A growing number of scientists have documented unprecedented pattern changes in how young people relate to nature and the outdoors (see also Green Cities: Good Health 2012). The nature-deficit disorder argument hypothesizes that as children become more "wired" than ever before, they are drawn away from healthful, outdoor play and are therefore less directly connected to nature than previous generations (Coyle 2005). The disconnect between humans and natural ecosystems is a potential driver of unsustainability as children grow up without observing the impact of modern lifestyles on ecosystems (Berry 1977). Additionally, contact with nature, sometimes absent or infrequent in urban areas, helps children to develop cognitive, emotional, and behavioral connections to nearby social and biophysical environments (Heerwagen and Orians 2002; Isenberg and Quisenberry 2002; Kahn and Kellert 2002). As rapid urbanization continues (United Nations Population Fund 2007), the average human condition could become one of decreasing connection to natural areas and, by corollary, a decreased ecological identity (more on this below). Given that many cities globally are located in areas susceptible to natural disasters that can severely disrupt the SES (as explored in the urban case studies below), we are interested in exploring how disasters and other significant disturbances may facilitate or hinder human connections to local ecosystems.

In urban systems, disturbance can dramatically affect the built and social environment in addition to the biophysical environment (Pickett et al. 2001). Earthquakes can cause sudden damage to natural and technological systems. Storm floods can cut away banks, change the courses of streams and rivers, redeposit sediments, and carry away aquatic organisms, but also damage buildings, flood roads, move debris, and further destabilize built infrastructure. High winds, tides, and tsunamis break down barrier dunes and allow seawater to invade the shoreline where many cities are located, changing the geomorphology of barrier islands and affecting groundwater, a source of drinking water in many urban areas. Hurricanes can result in

devastating impacts on rural and urban ecosystems, as evidenced by the severe damage that Hurricane Katrina caused in New Orleans and surrounding areas in 2005. Disturbances in urban ecosystems can also affect the social component by altering travel pathways, disrupting social networks, and altering perceptions of the system. By drawing attention to deficiencies or missed opportunities in the changes that can occur in the social component of SESs experiencing disturbance, it should be possible to uncover missed opportunities for EE.

An urgent need for EE is further evidenced by the United Nations's declarations of the International Decade on Biodiversity (2011–2020) and the Decade of Education for Sustainable Development (2005–2014). These declarations come amid growing concerns about habitat fragmentation, decline of ecosystems and species, increased urbanization, and possible dangerous effects of climate change, some of which are already being felt. Further, this pressing need is exacerbated by revelations such as were revealed in the speech that launched the International Year of Biodiversity at the American Museum of Natural History, where the executive secretary general of the Convention on Biological Diversity (CBD), Ahmed Djoghlaf, announced that the 2010 biodiversity target set in 2002 by the 110 heads of state during the Johannesburg World Summit on Sustainable Development had not been met. In fact, none of the national reports submitted by the affiliated parties to the CBD were able to show that their targets had been achieved. Rather, they confirmed that biodiversity loss continues at an unprecedented rate (Djoghlaf 2010) due, in part, arguably, to miscalculations regarding public awareness of the importance of biodiversity and EE targeted specifically toward biodiversity issues.

We suggest that improving environmental literacy and creating more opportunities for urban citizens to connect directly with natural areas are critical to improving the state of the environment. Thus, there is a need for broader, deeper, more diverse, place-based, and socially engaged EE. To advance these EE goals, we need to identify new opportunities for EE to increase public environmental awareness and foster greater interaction with local natural systems. How can EE best deal with its inherent complexities, and address the urgent need for protection, conservation, restoration, social engagement, and greater connectedness between humans and the ecosystems they currently dominate? We use the opportunity afforded by the editors of and contributors to this volume to suggest a novel hypothesis that *crises such as large-scale natural disasters or human-caused disruptions in densely*

populated urban centers may serve to create new, critical opportunities for expansive EE. In particular, an understanding of human relationships to nature as viewed through disturbance ecology, resilience theory, and an appreciation of the ecological identity may help EE practitioners to be more successful. We will begin by introducing these concepts, followed by two case studies to illustrate linkages between the concepts and their potential application to EE.

An Ecological Identity

Discussions of SES resilience in urban contexts often revolve around attempts to better understand, quantify, and most importantly, appreciate ecosystem services provided to human communities within urban SESs. Not inappropriately, a great deal of attention is given to the mostly negative effects of anthropogenic change in urban and other SESs. These negative effects may transfer to negative perceptions of ourselves as a species. Stephen Kellert muses in his book *Building for Life* that "a pervasive loneliness and self-hatred sometimes seem to have afflicted humanity like a virus that imperils our species" (2005, 217). This phenomenon may be due in part to the fact that we are sometimes a self-castigating and self-loathing species when it comes to contemplating our place in the environment. We seem to have lost our ecological selves. According to Rees (2003), modern humans are unaccustomed to conceiving of themselves as ecological or biological entities. It is as if we as individuals—and indeed, entire societies—have forgotten our ecological identities and are enduring a self-imposed humanity-nature apartheid (Hettinger 1996), a legacy of the Enlightenment in western culture's reductionist mindset that sees the human enterprise as somehow separate from and above the natural world (Hayward 1994). This can seem especially obvious in urban contexts. However, often overshadowed by this problem of negativity regarding humans and nature are the positive actions humans sometimes take in the systems within which they live that contribute to virtuous cycles that produce, or significantly enhance production of, ecosystem services, among other positive social and ecological outcomes (Tidball and Stedman, 2013).

To fully appreciate these human-initiated virtuous cycles requires an explicitly comprehensive perspective, viewing humans as part of ecosystems, and then viewing their activities and social behaviors such as EE, much like we are accustomed to doing for other terrestrial life—as merely parts of a

larger whole rather than as distinctly separate, and therefore unlinked or decoupled, systems. This contribution ventures into this contested territory for a utilitarian purpose. The authors speculate that purely deficit-based perspectives regarding urban SES and the human populations within them represent barriers to these systems' ability to move from undesirable states into more desirable ones. In other words, so long as humans view themselves *solely* as distinct, or worse, distinctly *negative,* within their SES, they are considerably hampered in their efforts to visualize and then actualize the transformation called for in both the sustainability and resilience discourses. It is our view that EE that reinforces this negative view is therefore ineffective at best, and perhaps even harmful when propagating human exemptionalism.

Human exemptionalism separates the human from natural worlds by privileging human consciousness and the societies that it produces as unique and distinct, a tendency of humans for centuries. To provide historical perspective, over 30 years ago, in his review of "unecological" traditions and perspectives in modern social science, Dunlap (1980) pointed out that social scientists tended to look at values, economic organization, culture, or technology, but *not* at the relationship between a society and its biophysical environment. He went on to describe how different social sciences manifested human exemptionalism. Within sociology, Dunlap argued, social organization and technology are assumed to maintain a human population within the carrying capacity of its environment, thus ensuring successful adaptation. For the field of anthropology, Dunlap argues, "culture" will ensure that a population adapts well to its environment; for political science, it is the political system or "polity" that regulates human societies to ensure their successful adaption; for economics, which is not generally concerned with broad adaptation, the focus is upon ensuring an adequate resource base for continued growth. Therefore, in the sphere of economics, technology and the institution of the market will produce an infinite supply of substitutable resources, making resource scarcity all but impossible (Dunlap 1980). All of the above treatments by social science, argues Dunlap, tend to assume that human mechanisms—social institutions, culture, technology, and so on—will insure that humans will adapt successfully to their environment. Importantly, Dunlap clearly articulates how this amounts to denial of the possibility that humans could *fail* in their efforts to adapt to changing environmental conditions, including changes brought about by humans

themselves, and how this denial involves the assumption that, unlike other species, humans are exempt from ecological constraints.

In the twenty-first century, we have, in important ways, begun to escape the human exemptionalist paradigm in favor of a new environmental or ecological paradigm. However, even today, many scientists seem to be of two minds about this debate. As Williams (2007) explains it, on one hand, scholars point out that the market, a social institution, causes significant amounts of environmental disorder, yet on the other hand, some of these scholars suggest that choice and rationality can fix these problems. We see this because, as Murphy (1995) recognized, a strong bias persists in the social sciences for perspectives that prioritize agency and the power of social actors. But, Williams counters, even in the predominately secular thinking of sociology, "agency has a mythic grasp. . . . To question our ability to choose and to choose rationally is to question the exemptionalism of our consciousness; it is to question our humanity and the self conception of ourselves as special and unique creatures of evolutionary history" (2007, 138). Williams (2007) states emphatically that mythical ideas have no place in a nonexemptionalist and scientific view of social and environmental interaction. As Dunlap and Catton (1994, 24) have asserted, "the welfare of human beings is inextricably interrelated with the condition of our earthly habitat, and . . . the increasingly problematic nature of this interrelationship cannot simply be deconstructed."

Yet, we find human exemptionalism creeping in in other ways. Where our species was once thought to transcend "nature," we find some now arguing that we humans are anathema to nature (cf. Cole and Landres 1996). This argument is seen in assertions that humans are somehow to be excluded from real nature, from pristine nature, from wilderness. These arguments and assumptions are subtler, but, in the end, continue to place humans outside the environment, contributing to de-linking, de-coupling, and alienating humanity from its ecological home.

In light of this, EE as a whole would do well to overtly drop human exemptionalism references and instead reinforce the view of humans as integral, natural components of SESs. When environmental educators are better able to understand the fundamental integration of humans and the rest of the environment, we argue that the field will find greater success and be better able to recognize opportunities for expanding EE. Urban areas have a special role to play because they are places where humans are most densely

concentrated and where, therefore, humans as components of ecosystem can be most easily demonstrated.

The Urban System

Because SESs comprise the complex sets of interactions among humans and nature at multiple scales (Holling 2001), and cities are dynamic and notoriously heterogeneous, they are perfect examples of complex SESs (Batty et al. 2004) and provide exceptional opportunity for exploring the relationship between human and nonhuman nature (Bettencourt et al. 2007). We also focus our discussion on urban systems because half of the world's population already lives in cities, suggesting urgency for increasing our understanding of SES dynamics. Further, urbanization is expanding, with urban dwellers predicted to rise to nearly 60% of humanity, or roughly 5 billion people, by 2030 (United Nations Population Fund 2007). In the United States, it is estimated that approximately 80% of Americans live in urban areas, and more people are moving to cities each year. Additionally, because the majority of the human population lives in cities, EE should be concerned with the fact that the dominant human view of nature is the nature found and experienced in cities (Miller 2005; Pickett et al. 2008). If EE is to impact the widest group of citizens, then the practice of EE should be focused on urban EE.

With more people living in urban areas, more cities will have to be built, potentially doubling the size of the built environment by 2050 (Nelson 2006) This fact offers tremendous opportunities for designing cities to be more resilient and sustainable than traditional cities, most of which were built in the last 200 years. However, our understanding of how urban ecosystems function and how to design them to be resilient to frequent mild and less frequent major disturbances is still at early stages. Yet, we already know that despite occupying less than 2% of the Earth's surface, urban areas have large ecological footprints, producing 78% of the global greenhouse gases and inextricably altering biogeochemical cycles (Grimm et al. 2008). If humans are to come into a more sustainable relationship with the natural world, we will need to decrease the ecological footprint of cities and better manage and build resilient urban SESs. This approach requires a massive effort on the part of urban residents, and EE will be critical to this potential transformation. We suggest that the hard work of building and transforming cities to be more resilient to disturbances and potential disasters requires an

aggressive EE campaign in urban centers that is informed by a resilience perspective and SES research.

Disturbances in Complex Social-Ecological Systems

More than 80% of terrestrial ecosystems have been influenced by natural disasters, human activities, and the combination of both natural and human disturbances (Zhu and Liu 2004). The role of disturbance in molding the structure and function of ecosystems has been well studied, and is a major paradigm in ecology (Sousa 1984; Pickett and White 1985). Less well understood is the response of urban SESs to disturbance regimes, especially intense disturbances such as natural disasters and acts of war or terrorism. Cities are not static entities, but dynamic and subject to disturbances of varying magnitude and frequency (Batty et al. 2004). Understanding how disturbance affects urban SESs is important for considering how EE may better capitalize on potential opportunities created when disturbances change the system. Indeed, as the human population continues to grow and concentrate more heavily in urban areas, with coincident expansion of agricultural and industrial enterprises, the future of ecology may depend on understanding the ways in which disturbance modifies the structure of communities, as well as the way component species, including humans, affect biodiversity (Christensen et al. 1989), energy flow, and nutrient cycling of disturbed ecosystems (Willig and Walker 1999; Walker and Willig 1999). The expanding field of urban ecology has already begun to address the need for greater understanding of urban cycles and flows and the influence of disturbance on complex SES dynamics in a handful of cities (see Grimm et al. 2000; Pickett et al. 2001; Pickett et al. 2011).

Here we suggest that understanding the role of disturbances in complex systems is important to conceiving how EE can be more effective because disturbances may create unrealized, or even unrecognized, niche opportunities for expanded EE. From an ecological perspective, a disturbance can be viewed as a temporary change from previously stable environmental conditions that causes pronounced changes in an ecosystem, though ecologists have noted the difficulty in defining disturbance generally (Rykiel 1985; Pickett et al. 1989). However, it is clear that ecological disturbances include fires, flooding, windstorms, and insect outbreaks, and may arise from wind, ice, rainstorms, hurricanes, and tsunamis, as well as direct anthropogenic and other animal disturbances such as forest clearing,

the introduction of exotic species, and keystone species effects (e.g., elephants in Africa that can dramatically alter ecosystems; Owen-Smith 1988, 1989). Disturbance forces outside the system often act quickly and dramatically, sometimes resulting in the removal of large amounts of biomass or dramatically altering physical infrastructure (envision vertical structure in an urban forest changing as trees are blown down in a storm, or damaged buildings in a city after a severe tornado or tsunami). For example, fires bring about both reorganization of ecosystems and renewal as species lost are replaced by fire-adapted species, thus altering the ecosystem in complex and sometimes dramatic ways (Bengtsson et al. 2003; Folke et al. 2004). Disturbances to SESs can also be human mediated and asymmetrically affect various components of the system, depending on the type of disturbance.

Although disturbance often results in the death of organisms and the loss of biomass in natural ecosystems, it can also function as a powerful force for change in the biophysical environment. Wind and moving water are two powerful agents of disturbance in natural ecosystems, but also in cities. High winds combined with heavy rain can destroy above- and belowground urban forest vegetation. A recent storm event in New York City illustrates this point. In 2010 New York City suffered the combined threat of nearly two weeks of steady rain followed by a morning of extremely high winds. Thousands of large forest canopy trees and street trees especially vulnerable to wind throw were blown down. The final result was hundreds of thousands of homes without power, damaged houses and property, and loss of biodiversity and habitat for susceptible species (McPhearson 2011).

The effect of natural disturbance on trees in cities is a particular urban concern because trees are often grown on poor soil, or in the case of street trees, very little soil, so roots are shallow and poorly anchored (McPhearson et al. 2010a; McPhearson, in press). Urban trees, such as street trees planted in sidewalks and along urban roads, provide an important function in urban ecosystems as habitat for other species, sites for stormwater absorption, sinks for carbon and other pollutants (Nowak et al. 2007), and places for residents to cultivate the earth, plant flowers, and otherwise directly engage with the biophysical environment (McPhearson 2011). Urban forests provide additional important social and ecological benefits to cities, including reduced air temperatures, increased wildlife habitat, forestry products, materials for community projects, neighborhood beautification, places for social bonding, increased safety, and neighborhood stability (Grove et al.

1994; Grove et al. 2005). Forests in urban parks, protected land, private land, and even urban wild areas (Pickett et al. 2001) and the SES they are connected to are especially vulnerable to disturbance because urban forests exist in patches often adjacent to residential areas that have increased edge areas (Moran 1984) with the margins under continual retreat due primarily to recreational use, which can hinder regeneration (Bagnall 1979). Regeneration failure is frequent in urban and suburban forest stands, owing to often artificially reduced natural disturbance or gap formation, or substitution for natural disturbances with unfavorable anthropogenic disturbances such as frequent ground fires, trampling, and competition with exotics (Guilden et al. 1990). When trees are lost following disturbances, the effect has both social and ecological consequences, including opening niche space for potentially more tolerant species to colonize.

Humans, functioning both as ecosystem engineers and keystone species, are also a source of disturbance in ecosystems. Human activity often has a more profound impact on ecosystems than weather-related or other disturbances because this activity is ongoing, involving continuous management of and pressure on ecosystems. Human disturbances include development, land and water transformation for agriculture and aquaculture, timber harvesting, habitat fragmentation, pollution, acts of war and terrorism, and numerous other direct and indirect changes in the ecosystem structure and function. The 2010 BP oil spill in the Gulf of Mexico illustrates the complex and wide-reaching effects human disturbances can exert on ecosystems (NRDC 2011). Indeed, the recent "triple-disaster" in Japan (earthquake, tsunami, and partial meltdown of a nuclear power plant reactor) illustrates the complexity of geoclimatic forces colliding with human industrial development.

Many measurable characteristics of ecological systems, such as the structure or the biological diversity of the system, are dependent on disturbance regimes. Consequently, natural and human-mediated disturbances can have profound immediate effects on ecosystems and can, accordingly, greatly alter the natural community. Immediate effects may be prolonged or create longer-term changes in the system. For example, often, when a disturbance occurs naturally, it may provide conditions that favor the success of different species over predisturbance organisms. The combination of physical disturbance, altered abiotic conditions, and changes in species composition can change an ecosystem for long periods of time and may fundamentally alter the structure and functioning of the ecosystem (Chapin et

al. 1997). In the absence of additional disturbance, many ecosystems will trend back toward predisturbance conditions. Alternatively, other systems, with or without additional disturbance, may flip the system into another ecological state altogether (Gunderson et al. 2002). In this case, the concept of resilience in complex systems is important to appreciate, where ecological resilience is measured by the magnitude of the disturbance that can be absorbed by the ecosystem before the structure of the system changes (see Folke 2006).

We hypothesize that EE may also be dependent on disturbance regimes in SESs. If EE exists in the context of SESs, and, as noted above, SESs are constantly shifting in response to disturbances of various magnitudes and frequencies, then opportunities for EE and the efficacy of EE in practice will be dependent to some degree on the effects of disturbance in the SES at any particular point in time. We extend this hypothesis below to suggest that EE practitioners may be overlooking an important opportunity when niches open in the educational landscape following anthropogenic or other disturbances to the system.

The niche is an important ecological concept at the center of our hypothesis. The ecological niche (Hutchinson 1957) has various technical and sometimes ambiguous definitions, but it can be referred to simply as the position or space a species occupies in an ecosystem, with implications for the interactions that species has with other components of the system. Here, we apply the niche concept to urban landscapes and to the landscape or ecology of EE by applying a systematic approach to examining cities as SESs. In ecological science, once a niche is left vacant, other organisms can fill that space or position in the system. Similarly, the ecological niche opened in a city by, for example, the demolition of derelict buildings can be quickly occupied as community gardens take root. Disturbances are common modes for opening niches in a system. This is no less true for SESs such as cities. Further, identifying when a niche has opened in a system requires being able to resolve some of the complexity of the constant shifting dynamics in complex systems.

Ecologists have attempted to understand the complex shifting dynamics in ecosystems by using patch dynamics (Pickett and White 1985; Pickett et al. 2011) as a conceptual tool for studying ecosystems (McPhearson et al. 2012). Patch dynamics emphasize the dynamics of heterogeneity within a system (i.e., that each area of an ecosystem is made up of a mosaic of small "sub-ecosystems" or patches). Patches are diverse and have a definite shape

and spatial configuration, or heterogeneity (Cadenasso et al. 2007). Viewed from a landscape perspective, disturbances and ecosystem responses to disturbances can be characterized by a mosaic of smaller nested systems in a hierarchy that together build a landscape scale mosaic. From this perspective, smaller spatial-scale communities (patches) are components of a highly heterogeneous *mosaic* of patches where individual patches shift from one state to another. This perspective is helpful because it can simplify the complexity in systems and allow researchers to focus on a particular small-scale patch within a larger landscape of patches.

We bring up patch dynamics as an analytical tool to illustrate methods being used to analyze complex responses to disturbances in SESs, and because we are interested in the shift in a patch in a city from a particular state to another, from a state pre- to post-disturbance. Additionally, we are interested in how the larger system at the scale of the landscape, for example an entire city, may switch from a particular mosaic of patches to another when impacted by large-scale disturbances, such as urban disasters discussed in the case studies below. If we can better grapple with the complexity in SESs through the use of patch dynamics and other analytical tools, then it should be possible to better locate new opportunities for EE when niches open in SESs undergoing dynamic change.

Resilience in Social-Ecological Systems

The concepts of robustness, resilience, and adaptation to variability have received increased attention in the literature with respect to SESs in variable environments (Folke et al. 2010; Pickett et al. 2004; Gunderson and Holling 2002). A core idea emerging from resilience theory is that complex systems such as SESs organize around continuous change. Ecologists have approached the study of urban SESs by linking the challenging study of the ecology *of* the city to the more traditional study of the ecology *in* the city (Grimm et al. 2000; Pickett et al. 2001). Conceptual frameworks such as the Human Ecosystem Framework model (Machlis et al. 1997) have provided critical thinking towards a systems analysis approach to understanding SESs and foreshadowed the application of ecological theory to understanding the effect of disturbances in systems such as urban disasters. More recently, ecologists have begun applying the adaptive cycle to our understanding of how cities are organized and reorganized over time (Gunderson and Holling 2002). The model of the adaptive cycle in resilience theory focuses attention

upon processes of destruction and reorganization. Including these processes in our understanding of how complex systems change over time provides a more complete view of patterns of change in SESs that links together system organization, resilience, and dynamics. Ecology has traditionally focused on the concept of succession that describes the transition from a period when exploitation (i.e., the rapid colonization of recently disturbed areas) is emphasized to a time when conservation (i.e., the slow accumulation and storage of energy and material) is emphasized (Resilience Alliance 2002). Our current understanding of ecological dynamics, however, indicates that two additional functions—release and reorganization—are needed.

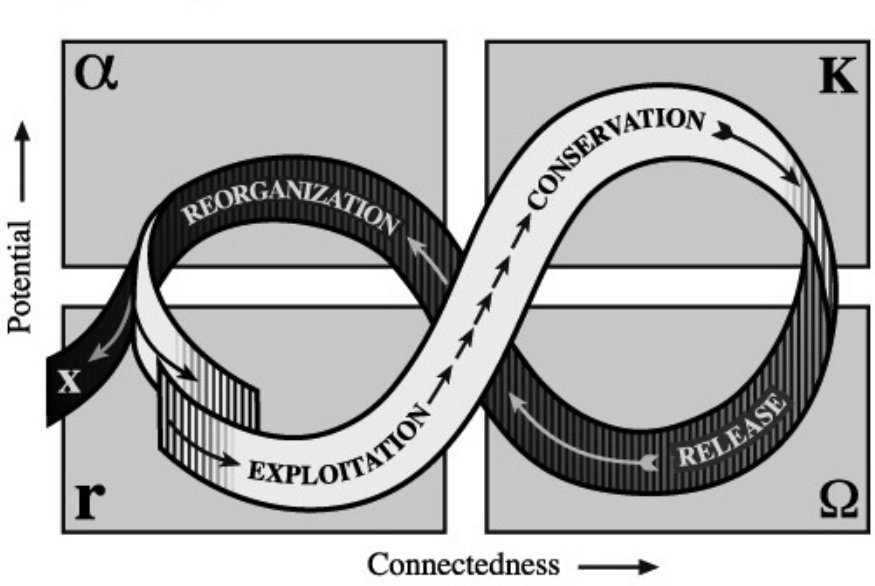

Figure 1. *The Adaptive Cycle.* In the first two phases of the front loop, rapid colonization of disturbed areas eventually leads to the slow accumulation and storage of energy and material as system structures and functions become more tightly organized. The back loop consists of the release and reorganization phases. Source: *Panarchy*, edited by Lance H. Gunderson and C.S Holling.

Resilience is the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore system identity (Walker et al. 2006). In SESs, periods of gradual change may be punctuated by rapid changes that can result in a significant transformation of a system's structure and behavior, a process known as regime shift. When a system lacks sufficient resilience, its structures and functions undergo changes that alter its identity (Biggs et al. 2009). In resilient systems, a shock or disturbance also creates opportunities for innovation. Existing structures and processes recombine into new trajectories while retaining the system's identity. By contrast, even small disturbances can force a system that lacks resilience to switch into a different state (Folke 2006).

Within the resilience framework, ecosystems are understood to have four phases that taken together make up its adaptive cycle: exploitation (r), conservation (K), release (Ω),and reorganization (α) (see Figure 1). In the first two phases, known as the front loop, rapid colonization of disturbed areas eventually leads to the slow accumulation and storage of energy and material as system structures and functions become more tightly organized. The back loop consists of the release and reorganization phases. This collapse and renewal can occur in relatively brief periods that bring about major system changes (Carpenter et al. 2001; Holling and Gunderson 2002). The metaphor of the adaptive cycle can be used to organize systems and events in order to help identify and understand transformations in SESs (Holling and Gunderson 2002).

Environmental Education in Social-Ecological Systems

Cities as described in SES resilience theory undergo well-understood patterns of change (Resilience Alliance 2007). We hypothesize that following significant urban crises, such as natural disasters, acts of terrorism, and periods of war, local communities tend to significantly invest in natural area protection and rehabilitation/restoration. There are multiple theories for why this may be (see Tidball and Krasny, 2013). The refocus of urban residents on natural systems following disturbance, regardless of the underlying cause, suggests a novel hypothesis and a reinterpretation of events following otherwise terrible events: *Disasters may open niches in the urban social-ecological fabric that represent new opportunities for EE*. It is possible, by corollary, that expanding EE during these niche opportunities may lead to more environmentally aware and active citizenry, which in turn

could yield greater environmental protection and conservation in communities and surrounding areas, creating a positive, adaptive force in disturbed urban landscapes.

There is evidence that EE is critical to designing and building more resilient SESs (Krasny et al. 2011). We agree that environmental educators not only need to bring a systems theory approach to urban EE initiatives, but also need to understand resilience theory, the adaptive cycle as applied to SESs, and, we add and emphasize, disturbance ecology, in order to recognize when niches open for new, more effective EE opportunities.

How can we recognize when a niche opportunity opens for EE? We hypothesize that large-scale disturbances may open large niches for urban greening and EE. Our hypothesis is based on case studies following disasters in two cities, New York City and New Orleans, that functioned as significant SES disturbances and led to increased civic ecology community responses in both cities (argued to be evidence of SES resilience; Tidball et al. 2010) and new opportunities for EE.

Urban Environmental Disasters Create Niches in SESs

September 11, 2001: The New York City Case Study

The terrorist attacks on September 11, 2001, on the World Trade Center towers were extremely destructive and had repercussions in the social and ecological system of New York City (NYC), and the nation as a whole. The deaths of nearly 3,000 adults who were killed in the attacks or died in rescue operations resulted in more than 3,000 children losing a parent (Coates and Schechter 2004). The thousands of tons of toxic debris resulting from the collapse of the Twin Towers contained more than 2,500 contaminants, including known carcinogens (Gates 2006), and the EPA did not determine that air quality had returned to pre–September 11 levels until June 2002 (Heilprin 2003). It is estimated that approximately 18,000 people have developed illnesses as a result of the toxic dust (Shukman 2011). In total, the 9/11 disturbance resulted in more than 90 countries losing citizens (U.S. Department of State 2006). The 9/11 attacks also caused serious damage to the economy of Lower Manhattan, and had a significant impact on global markets. The stock exchanges did not open on September 11, 2001, and they remained closed until September 17. When they did reopen, the Dow Jones Industrial Average fell sharply and U.S. stocks lost $1.4 trillion in valuation

(in 2001 dollars) for the week (Barnhart 2001). In New York City, about 430,000 job-months and $2.8 billion dollars in wages were lost in the three months after the attacks. The city's GDP was estimated to have declined by $27.3 billion for the last three months of 2001 and all of 2002. Importantly for multiple social components of the NYC SES, 18,000 small businesses in Lower Manhattan were destroyed or displaced (Makinen 2002).

The 9/11 disturbance as a local disaster can also be viewed through the lens of disturbance ecology as a major anthropogenic disturbance to the NYC SES. From this perspective, the attacks constituted a disturbance to both the ecological (loss of human lives, reduction in air quality, additional damage to human health of residents in the neighborhood and workers at the site, pollution of nearby aquatic and terrestrial ecosystems) and social (destruction of buildings and business, damage to homes, loss of radio and cell phone communication, which disrupted social and economic networks) components of the SES. The 9/11 disturbance resulted in additional short- and longer-term effects on the system that cannot be fully summarized here. For this chapter, we focus on the civic ecological responses to the 9/11 attacks as a novel niche opportunity for expanding EE.

One significant short-term response to the 9/11 disturbance in the SES of NYC were the efforts by New Yorkers and citizens across the nation to create living memorials as nodes for social-ecological memories connected to the disaster (Svendsen and Campbell 2010; Tidball et al. 2010). Barthel and colleagues use the term social-ecological memory to refer exclusively to the memory of groups that engage in ecosystem management as a way to explore the means by which knowledge, experience, and practice regarding 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). These scholars describe social-ecological memory using a library analogy in which ecological knowledge and practical advice for management are reflected in how the library is built, structured, and organized by the people engaged with it, and in the contents of the books, with new books continuously added. These notions are consistent with Folke et al. (2003), who posit that memory is a critical subset of any social-ecological system, providing sources of resilience to deal with change.

Living memorials are landscaped spaces created to memorialize individuals, places, and events (Svendsen and Campbell 2010). Planting living memorials is not a new concept. Humans have long used nature as a symbolic and potentially innate (Tidball et al. 2010) response to mark the

cycles of life (for example, when the author's [McPhearson's] grandfather died, he and his family planted a unique tree as a memorial in a place where family members could go to remember and reflect). In response to the 9/11 disturbance, hundreds of stewardship groups and thousands of people across the United States created living memorials (Svendsen and Campbell 2010) to remember, but also to find ways to rebuild and strengthen social and ecological connections. The U.S. Congress eventually requested that the U.S. Forest Service create the Living Memorials Project (LMP) to recognize, study, and facilitate the memorialization process. The LMP attempted to facilitate community-based projects that were linked initially to trauma and/or loss in response to the September 2001 attacks.

Living memorials planted as part of the LMP varied widely, involving both the creation of new open space and the rededication of existing natural or open space, invoking the resonating power of nature to create linkages between people, social groups, and the environment they are embedded within. The memorials were planted on the grounds of town greens, sidewalks, hospitals, cemeteries, libraries, churches, homes, and existing community gardens, and they honored individual victims as well as, more generally, all victims who perished in the coordinated attacks on 9/11 (Tidball et al. 2010; Svendsen and Campbell 2012). Social scientists at the U.S. Forest Service Northern Research Station conducted a participatory social and site assessment of public spaces that were created, used, or enhanced in memory of this tragic event (Svendsen and Campbell 2005). Interestingly, when participants were asked about the purpose of their living memorials, 25% said that they wanted to promote stewardship and community engagement, and 48% said they would hold events related to community stewardship and management at the site (Svendsen and Campbell 2005). The act of tree planting and other memorialization was also an act of environmental stewardship.

Several mechanisms emerged to foster social and environmental learning within and across Living Memorials sites. For example, in the Bronx, residents held a Sustainable South Bronx Living Memorial Trail Community Design meeting to plan their site. The Living Memorials website facilitated learning across sites by posting descriptions and photographs of all sites across the United States, as well as by creating a toolbox to assist individuals in navigating the social, biological, and physical challenges of developing a living memorial (Tidball et al. 2010). There appears to be still unrealized potential to foster environmental learning during the various LMP projects.

Though participants were clearly engaged in acts of environmental stewardship, they may have been open to more intentional and engaged EE, had EE practitioners been organized and motivated to respond to the 9/11 disturbance as a niche opportunity for increasing EE in affected communities.

There were also examples where nonprofit organizations *did* take advantage of the EE niche opened by the 9/11 disturbance. The fact that many of the living memorials involved tree planting yielded a unique opportunity for nonprofit environmental stewardship organizations such as Trees New York and New York Restoration Project (among many others) to engage citizens in tree care workshops, courses, and community learning activities in the context of EE and environmental stewardship. The tendency for people to respond to disasters by planting trees, creating gardens, and participating in other ecologically engaged actions to create or refresh social-ecology memory (Barthel et al. 2010) is a crucial locus that EE could better recognize and engage as novel opportunities for EE with a public that is particularly open to the environment through their own chosen act of enhancing and improving their environment as a memorial.

Every living memorial action harbored a potential unique opportunity for engaging participants in EE, from the act of tree planting itself to courses, workshops, and social events tied to the educational action embodied in the memorialization process. We suggest that the 9/11 disturbance in NYC disrupted social and ecological network connections dramatically, and EE initiatives that can serve to reconnect individuals are critical to have in place both before and after disturbance, to better reconnect and renew disrupted networks and enhance resilience in the SES. The LMP project was not overtly an EE initiative, but rather a process for memorialization. The LMP did, however, help provide additional EE opportunities through the various incarnations of the project (e.g., a tree memorial planting event linked to a nonprofit environmental stewardship education program provided residents access to an EE experience).

It is important to recognize the role of history in the resilient response by New Yorkers to the disaster in the city. For example, the community gardening protest movement that emerged during the Mayor Giuliani era (e.g., Chivers 2000) may have primed the system to protect and steward green infrastructure such as gardens and trees, because many values and memories were established earlier, in the 1970s, when community gardening began to significantly expand in NYC. According to Okvat and Zautra

(2011), community gardens have been found to improve the quality of life for people in the gardens; provide a catalyst for neighborhood and community development; stimulate social interaction; encourage self-reliance; beautify neighborhoods; produce nutritious food; reduce family food budgets; conserve resources; create opportunities for recreation, exercise, therapy, and education; reduce crime; preserve green spaces; create income opportunities and economic development; reduce city heat from streets and parking lots; and provide opportunities for intergenerational and cross-cultural connections.

We contend that the social-ecological memory recalled and further developed during Giuliani's campaign against community gardens (including the memory of the benefits from community responses such as community gardening and even protesting removal of community gardens) was important and available in reified form to be "called up" following the September 2001 disaster, for example through social-ecological memories of the value of horticultural therapy in dealing with grief and senseless tragedy (harkening back to gardens that memorialized a youth lost to gang violence) or dealing with the resulting negative portrayal of a neighborhood. This "memorialization mechanism" may have been drawn upon on a larger scale in the many memorials that emerged after 9/11, including those cataloged by the Living Memorials Project, and it became part of wider NYC consciousness. Though speculative, it is constructive to consider the possibility, then, that when in 2007 Mayor Bloomberg announced his long-term urban plan for NYC (PlaNYC 2030), which included a program to plant one million new trees in NYC by 2013 (Campbell et al. 2010), this was a part of a longer-term response by New Yorkers to increase engagement with the environment following a major disturbance in the NYC SES. Thus, unlike during the Giuliani era, the politics of Bloomberg's administration may reflect societal consciousness regarding the value and need for stewardship of green infrastructure.

In the four years since PlaNYC was initiated in 2007, more than 600,000 trees have been planted (McPhearson 2011) and environmental educators are beginning to take advantage of the opportunity to teach New Yorkers tree care skills and also to expand EE more generally. Through MillionTreesNYC, which we argue is part of a continued social-ecological response to the 9/11 disturbance, many new EE programs have been created. For example, the MillionTreesNYC Training Program offers experiential learning in tree care, ecological restoration, and landscape design and

gardening, and seeks to provide underserved youth with the professional skills to help them attain green jobs in the city. Similarly, generationOn's service-learning lesson plans (generationOn 2012) teach young people about environmental stewardship through lesson plans and resources that teach giving and volunteerism, civic engagement, and character through service. The Urban Park Rangers maintain a series of educational programs to immerse students in the living laboratory of urban nature. The City Parks Foundation also has a field-based program for public schools to use city parks as an extension of the classroom through their Seeds to Trees programs. GrowNYC has an environmental service-learning program that puts middle and high school students directly in connection with the urban ecosystem by planting trees, building models for green buildings, and identifying environmental hazards in their communities. Many organizations—too many to list here, but including Trees New York, New York Restoration Project, the New York City Department of Parks & Recreation, Partnership for Parks, and other organizations and community groups—are continuing to build the necessary EE programs in an effort to keep pace with the public need for greater connection to their urban environment.

The MillionTreesNYC campaign is part of a series of social and ecological responses to disturbances in the NYC SES that involves replanting in combination with redesigning and rebuilding (through PlaNYC) the SES to be more sustainable, and ultimately to enhance the resilience of the social and ecological components of the system. The MillionTreesNYC campaign has been most embraced and noticed by citizens in areas where high-visibility street tree planting occurs, often in neighborhoods that previously have had poor street tree density (Lu et al. 2010). However, the majority of new trees that are currently being added to the existing five million trees in NYC's urban forest are being planted in the less used parts of public parks, on natural resource land, and on degraded or otherwise "unused" land (McPhearson et al. 2010a, 2010b; McPhearson, in press), with little visibility or obvious direct utility to the general public (McPhearson 2011). This process is noteworthy and arguably impossible to financially and politically sustain if not for ongoing efforts to link the social and ecological components of the city via social-ecological memory that began with post-disaster efforts such as the LMP and continued in the new EE efforts, primarily in the nonprofit community in NYC.

The most effective EE involves experiential learning (Sriskandarajah et al. 2010), and projects such as the LMP and MillionTreesNYC are designed to facilitate learning while also facilitating connectivity between the social and ecological components of the NYC SES. Environmental education practitioners may find additional success when programs are designed to facilitate transformations at the individual level while also fostering resilience at the level of the SES (Sterling 2010; Krasny et al. 2011). Even in the various successes of the LMP and ongoing MillionTreesNYC education and tree planting programs, there are missed opportunities for implementing a wider EE agenda. For example, there is still an unmet need for broader participatory urban tree stewardship in NYC (Moskell et al. 2010). It is possible that lack of environmental knowledge in general is contributing to the difficulty in establishing a citywide urban forest stewardship program in NYC with broad participation. The epistemic dimension of urban EE deserves greater attention among educators, and is crucial for those working with SESs as a foundation for building resilience (Sriskandarajah et al. 2010). For example, across the many local neighborhoods in NYC, communities draw upon their reserves of knowledge to respond to changes within their local environments. Such knowledge can serve as a source of community resilience through enabling people to sustain their livelihoods and community well-being, and thus better adapt to environmental changes and displacement (Shava et al. 2010) such as occurred post–9/11. Urban EE programs and other civic ecology practices (Krasny and Tidball 2012) situated within adaptive co-management practices such as the MillionTreesNYC program could foster learning and contribute directly to environmental quality and environmental stewardship while building and distributing multiple forms of knowledge among participants (Krasny and Roth 2010). For example, civic ecology practices such as community gardening, community forestry, watershed enhancement, and similar forms of small-scale, citizen-led restoration may result in greater tree canopy, plant and insect diversity, restored native plant communities, and wildlife or fisheries habitat, while also providing a context for environmental learning (Tidball and Krasny 2011). Such practices may become particularly important during times of stress and traumatizing events including war, terrorist attacks, and natural disasters, such as the 9/11 attacks in NYC and Hurricane Katrina in New Orleans in 2005.

Hurricane Katrina: The New Orleans Case Study

Ernstson et al. (2010) describe how New Orleans reached its peak urban population in the early 1960s, and in the ensuing years prior to Hurricane Katrina, how the city was experiencing trends that together worked to make it increasingly vulnerable. These and other scholars reference trends such as rising seas, a compacting deltaic landscape, population decline, suburban sprawl in areas below sea level, coastal wetland loss, economic decline, and low maintenance of levee systems. Based on the above indicators and implications, which were well known before the hurricane, the city was slowly approaching crucial thresholds, but, as Ernstson and colleagues point out, Hurricane Katrina introduced a shock to the New Orleans urban SES that "pushed the system state half a century into what its future would have been had the hurricane, or a similar shock, not struck the city during that period" (Ernstson et al. 2010, 533–534).

Hurricane Katrina made landfall in New Orleans on August 29, 2005, devastating the area, leaving 1,500 people dead and tens of thousands without homes in one of the deadliest and costliest disasters in the history of the United States. Approximately 80% of New Orleans was flooded, with some parts under 15 feet (4.5 m) of water. Most roads and critical infrastructure were rendered inoperable. Mortality and severe structural damage were wrought upon approximately 320 million large trees throughout the Gulf Coast, many thousands of which were destroyed in New Orleans (Chambers 2007; Nowak and Greenfield 2012). According to Edward Macie (personal communication), regional urban forester for the Forest Service's Southern Region, about 75% of the trees in New Orleans were lost due to the storm. The story of New Orleans's struggle to endure weeks of inundation and devastation, and months of disorganized efforts to recover from the disaster, is well known. However, the important symbolic roles of trees and the act of tree planting in post-Katrina New Orleans are less known (Tidball 2009), as are the vital roles urban EE and community stewardship played in supporting these efforts.

As reported elsewhere (Tidball 2012b) New Orleans is said to be home to some of the largest collections of mature trees in the world, containing nearly 50 species including magnolia, pine, live oak, bald cypress (Louisiana's official state tree), and red maple. Historically, trees have held special symbolic significance to residents of New Orleans, across ethnicities and other demographics, contributing to identity and sense of place

(Anderson 2004). Residents returning to New Orleans after the hurricane told many stories about the New Orleans landscape before Hurricane Katrina, the role that trees played in their lives, how after the storm they used trees as landmarks to find the places where their homes once stood, and how the surviving trees gave them hope that they too would persist, would persevere, and would maintain their roots in New Orleans. Tidball has described elsewhere how the role of the relationship between individuals or communities and trees, especially in symbolic terms, is an important part of individual or community recovery and resilience after a disaster (Tidball and Krasny 2012). This importance of trees has been related to notions of sense of place in other hurricane-ravaged cities as well (Hull 1992), and recognized as a part of community healing rituals and memorialization, as described above in reference to New York City (Tidball et al. 2010).

Hurricane Katrina's destructive force effectively disturbed and destroyed important elements that contributed to the placeness of New Orleans, and to the individual, family, neighborhood, and community identities associated with the place, and the trees. Consequently, many residents immediately began to organize and rally around tree recovery, tree removal, and tree planting. Not-for-profit organizations as well as academic and extension institutions quickly recognized and responded to the emergence of tree stewardship as a form of symbolic and substantive recovery effort for New Orleans. Parkway Partners, a nonprofit organization whose mission is to "empower residents to improve quality of life through the preservation, maintenance and beautification of neutral grounds, green spaces, playgrounds, parks, community gardens and the urban forest in New Orleans," took the lead in education and action regarding restoration of the urban forest. Through their EE efforts, namely a citizen tree training program called Tree Troopers in which more than 75 citizens completed in-depth tree training, tens of thousands of trees have been planted throughout New Orleans (see Figure 2). Parkway Partners and the Tree Troopers program trained a number of highly motivated New Orleans residents with deep interest in the importance of the urban forest, including Monique Pilié, founder of Hike for KaTREEna (Hike for KaTREEna 2012), another not-for-profit organization in New Orleans that has planted thousands of trees in addition to those planted by Parkway Partners.

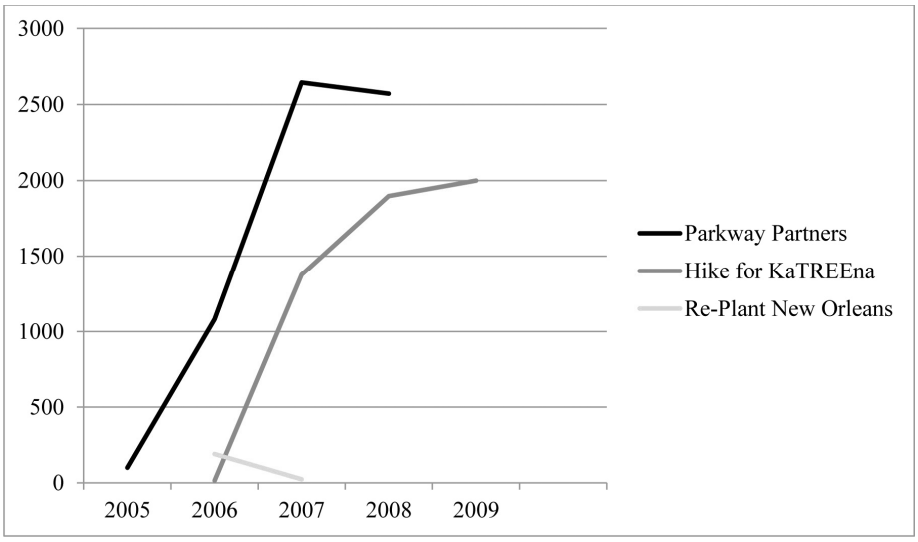

Figure 2. Numbers of trees planted in New Orleans since Hurricane Katrina demonstrate the emergence of tree stewardship as a form of symbolic and substantive recovery efforts for New Orleans. Source: K.G. Tidball, 2012b.

The Katrina disaster has also created "openings" for other important EE activities that are flourishing and contributing to the recovery of the New Orleans SES and the enhancement of its resilience. Examples include multiple efforts in community gardening and urban agriculture (New Orleans Food and Farm Network 2012), awareness building about the importance of wetlands for storm protection (Campos et al. 2006; Wetland Watchers 2012), and education about larger regional watershed policy issues regarding Mississippi River and delta management (America's Wetland Foundation 2012).

Conclusion

Cities face a wide array of stresses including, in some places, rapid urbanization, suburban sprawl, rising temperatures, changing weather patterns, and other large- and small-scale disturbances. New York City and New Orleans are two cities that have recently suffered from major disasters that have altered their respective SESs. However, both cities have shown remarkable resilience to these dramatic social and ecological disturbances via strong civic ecology and environmental stewardship responses of urban

citizens, demonstrated in both cases by the overlapping examples of tree planting and living memorials. We have suggested that tree planting and other civic ecology or environmental stewardship actions are motivated initially by social-ecological memory and an expanding ecological identity. The two case studies situated in post-disaster cities, NYC and New Orleans, demonstrate some of the possible opportunities for expanding EE in post-disaster situations. We consider the niches opened by the disturbances affecting these cities as novel opportunities for expanding EE, especially when informed by an understanding of ecological identity and how social-ecological memory can generate, or recover, positive environmental attitudes and actions following disturbances. Using the heuristic approach of the adaptive cycle, we conclude that attitudes towards urban nature following an SES disturbance may have changed, either driven by, or as a result of, citizen initiatives to deepen their connections to their respective social and ecological communities. Living memorials and tree planting are two conspicuous examples of how individuals and communities engaged within the SES. In NYC, tree planting and other acts of memorialization were an initial node in the post-disaster grieving process that was followed by a succession in the SES that led to the establishment of a public-private partnership to plant a million trees in the city (McPhearson et al. 2010b; McPhearson 2011), which, importantly, generated new opportunities for EE initiatives. In New Orleans, the communities of practice that emerged around restoring trees and the urban forest were a way to demonstrate New Orleans's SES resilience and recovery resistance, while also taking initial steps towards resilient adaptive management of the SES. The capacity for expanding EE in post-Katrina New Orleans appears to be yet unrealized.

Following significant disturbances in SESs, niche space opens either from the loss of specific opportunities (e.g., loss of schools, programs, services, etc.) or from the creation of additional complexity in the social-ecological fabric (e.g., creation of new civic networks and institutions). Disasters and other forms of social-ecological disturbance often negatively impact natural areas, opening up niche space in the SES for restoration/protection and thereby new opportunities for engaging the public in EE. Community-based projects such as LMP, which are linked initially to trauma or loss, are embedded with social and ecological meaning, shaped by local identity, values, and traditions, but are also affected by regional networks and more global events. Projects and EE programs that have the greatest potential to increase social and ecological cohesion are those that

help reestablish a locus of control and neighborhood efficacy. Living memorials were important to this effort in NYC, as are community gardens, tree planting programs, and other forms of community-based environmental stewardship. Similar examples exist for tree planting and environmental stewardship in post-Katrina New Orleans. Environmental education that takes an overtly SES approach to learning (Krasny et al. 2010), recognizing the moments in time and space when disturbances create niche opportunity for enhancing or advancing EE, may have higher potential for being an effective component of resilience in cities and for advancing the environmental knowledge of the public. The need for expanding EE is clear, given the wide range of environmental difficulties facing local, national, and global communities and the sometimes shocking lack of environmental literacy among the public. Urban disturbances such as natural and human-mediated disasters create openings for adaptation through EE. Use of social-ecological memory, where humans "remember" their intrinsic relatedness and dependency on "nature" when faced with disaster, is a tendency that EE could more directly engage, especially in times of crisis. Therefore, disturbances are key to presenting "teachable moments" and catalytic change.

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