

ECOLOGICAL URBANISM: A FRAMEWORK FOR THE DESIGN OF RESILIENT CITIES¹

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“Humans’ survival as a species depends upon adapting ourselves and our...settlements in new, life-sustaining ways, shaping contexts that acknowledge connections to air, earth, water, life, and to each other, and that help us feel and understand these connections, landscapes that are functional, sustainable, meaningful, and artful” (Spirn 1998, 26).

Ecological urbanism aims to advance this goal. It wedds the theory and practice of city design and planning, as a means of adaptation, with the insights of ecology – the study of the relationships between living organisms and their environment and the processes that shape both – and other environmental disciplines, such as climatology, hydrology, geography, psychology, history, and art. Ecological urbanism has an aesthetic dimension, but it is not a style; the works of its practitioners may be radically different in appearance even though based on the same principles.

An ecological approach to urban design is not new; it is grounded in a tradition of basic concepts and principles. Ecological urbanism is critical to the future of the city and its design: it provides a framework for addressing challenges that threaten humanity, such as global warming, rising sea level, declining oil reserves, rising energy demands, and environmental justice, while fulfilling human needs for health, safety, and welfare, meaning and delight.

This chapter describes the roots of ecological urbanism, with an emphasis on the Anglo-American tradition, and identifies fundamental concepts and principles with brief reference to ideas in related fields. The literature is vast, and a detailed review is not possible here. This overview provides historical context and a framework to guide more focused research and more comprehensive reviews of the literature and to advance the practice of ecological urbanism as a means to achieve cities that are more life-sustaining and more resilient, and less costly to build and maintain.

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ECOLOGICAL URBANISM: HISTORIC ROOTS AND CURRENT TRENDS

The theory and practice of ecological urbanism has a long history, a foundation of knowledge to support it, and built works that demonstrate its benefits. The roots of this tradition in Western culture are deep: from Hippocrates' treatise *Airs, Waters, Places* to contemporary authors (for a review, see Spirn 1985).

More than two thousand years ago, the Greek physician Hippocrates described the effects of "airs, waters, and places" on the health of individuals and communities. The Roman architect Vitruvius (ca. first century B.C.) described how the layout of streets and the orientation and arrangement of buildings should respond to seasonal patterns of sun and wind. Architect Leon Battista Alberti's treatise *On Architecture*, written in the mid fifteenth century, expanded these recommendations, advocating that the siting of cities and the design of streets, squares, and buildings should be adapted to the character of their environment so that cities might promote health, safety, convenience, dignity, and pleasure. "We ought never to undertake any Thing that is not exactly agreeable to Nature," Alberti warned, "For so great is Nature's strength that, although...some huge obstacle may obstruct her, or some barrier divert her, she will always overcome and destroy any opposition or impediment; and any stubbornness...displayed against her, will eventually be overthrown and destroyed by her continual and persistent onslaught." (Alberti 1988: 35-36). Alberti underscored this warning by cataloguing the disasters suffered by cities that had disregarded the power of nature. The pioneering environmental thinker George Perkins Marsh repeated this warning several centuries later, when he predicted that "human improvidence" was reducing the earth "to such a condition of impoverished productiveness, of shattered surface, of climatic excess" as to threaten the "extinction of the species" (Marsh 1865). Marsh proposed that "in reclaiming and reoccupying lands laid waste by human improvidence or malice...the task...is to become a co-worker with nature in the reconstruction of the damaged fabric." This was an approach embraced by Marsh's contemporary, landscape architect Frederick Law Olmsted, who designed urban parks, parkways, and neighborhoods as part of a broad program to promote the health, safety, and welfare of urban residents. In designs for landscape infrastructure of parkways, streetcar lines, rivers, and sewers, Olmsted sought to "hasten the process already begun" by nature, thereby achieving more than the "unassisted processes of nature" (Olmsted and Vaux 1887: 19, 8; Spirn 1995).

By the beginning of the twentieth century, some disagreed over whether the task was to rebuild existing cities or to build new "garden cities" in the countryside, such as those advocated by the author Ebenezer Howard, whose book, *Garden Cities for To-Morrow*, influenced the garden city and new town movements in England and the US (Howard 1902). Geographer and planner Patrick Geddes opposed

Howard's approach: "Here or nowhere is our Utopia," he argued (Geddes 1915). Geddes, who was educated as a biologist, viewed each city and its surrounding countryside as an evolving organic whole whose future plan should be based on an understanding of its natural and cultural history and its "life-processes in the present" (Geddes 1915: 2). To attain such understanding, Geddes advocated "regional surveys" of "things as they are and as they change...towards things as they may be," which would serve as the vehicle for town plans and city designs tailored to the particular "character and spirit" of each city. (Geddes 1915: 138-139). Author, critic, and historian of the city Lewis Mumford, like his mentor Geddes, promoted an integrative approach to cities and their regions: "once a more organic understanding is achieved of the complex interrelations of the city and its region, the urban and the rural aspects of environment, the small-scale unit and the large-scale unit, a new sense of form will spread through both architecture and city design" (Mumford 1968: 164). To Mumford, this new urban form "must include the form-shaping contributions of nature, of river, bay, hill, forest, vegetation, climate, as well as those of human history and culture, with the complex interplay of groups, corporations, organizations, institutions, personalities" (Mumford 1968: 164). Mumford influenced Kevin Lynch and Ian McHarg, both seminal figures in their respective fields of urban design and landscape architecture/regional planning. Lynch and McHarg shared the conviction that cities must be viewed in their regional context and that the natural environment has a social value to be cultivated in urban design. From that common ground, they diverge.

For Lynch, the city is first and foremost a human habitat, and he judged "good city form" by how well it sustains human life (Lynch 1981). Lynch stressed the importance of how people perceive the city, proceeding from human perception to understanding the sense of place. He explored the role that natural features play in enhancing the identity, legibility, coherence, and immediacy of urban form from the scale of the street to that of the region. His last book, *Wasting Away*, takes an ecological approach to managing resources and waste (Lynch 1990).

McHarg's point of departure was the natural environment: "Let us accept the proposition that nature is process, that it is interacting, that it responds to laws, representing values and opportunities for human use with certain limitations and even prohibitions" (McHarg 1969: 7). Like Geddes, McHarg asserted that "any place can only be understood through its physical evolution" (McHarg 1967: 105). As a prerequisite for planning and design, he advocated a survey, the "ecological inventory." It was always the same list (climate, geology, hydrology, limnology, soils, vegetation, and wildlife) no matter what the site's location, scale, or land use. McHarg's ecological inventory is a checklist of interrelated systems, useful not only to understand how a place came to be, but also as a diagnostic tool with which to identify

problems and opportunities that might otherwise be missed (Spirn 2000b). For McHarg, design was an evolutionary strategy, a means of adaptation. McHarg's professional practice was devoted predominantly to the planning of suburbs and metropolitan regions as opposed to downtown and inner-city districts. His approach is valuable for ecological urbanism, even though he viewed the city as a pathological environment (McHarg 1969).

Another important thinker in the history of ecological urbanism is Jane Jacobs, author of the classic book, *The Death and Life of Great American Cities*, among other works. For Jacobs, as for McHarg and Lynch, "human beings are... part of nature" as are cities (Jacobs 1961: 446). "Nature, sentimentalized and considered as the antithesis of cities, is apparently assumed to consist of grass, fresh air and little else," Jane Jacobs scorned, "and this ludicrous disrespect results in the devastation of nature." Like Lynch, she focused on the city as a human habitat and regarded urban design as a way to support and fulfill human needs. Jacobs advocated an ecological approach to designing and managing cities, arguing that cities are problems of organized complexity, akin to living organisms, and that there are lessons for urban design from the study of systems where "half-dozen or even several dozen quantities are all varying simultaneously and *in subtly interconnected ways*" (Jacobs 1961: 433). Jacobs urged urban designers and planners to think in terms of processes and to "work inductively, reasoning from particulars to the general, rather than the reverse," from grand theories to specific proposals (Jacobs 1961: 440).

Jacobs's, McHarg's, Lynch's, and Mumford's ideas about an ecological approach to the design of cities were supported by scientific knowledge about the place of cities in the natural world and the role of humans in shaping the environment. British botanist, Sir Arthur Tansley, who had defined the ecosystem concept in 1935, argued that human activities were among the factors that determine ecosystem structure and function (Tansley 1935). From the 1950s on, a succession of edited volumes brought together a body of knowledge about urban nature, which had been documented by climatologists, geologists, hydrologists, limnologists, soil scientists, botanists, zoologists, and ecologists (Thomas 1956, Dansereau 1970, Detwyler and Marcus 1972, Laurie 1979). Some fields were well-established prior to 1980, particularly urban climate (Oke 1974, Chandler 1976, Gandemer and Guyot 1976, Landsberg 1981), urban geology (Legget 1973, Leveson 1980), and urban hydrology (Dunne and Leopold 1978, Tourbier and Westmacott 1981). Although Japanese and European plant ecologists (Numata 1977; Sukopp and Werner 1982) pioneered the ecological exploration of post World War II cities and towns, mainstream ecological science was not reconciled with the isolated urban research of American ecologists such as Forest Stearns (Stearns 1971, Stearns and Montag 1974) until much later. In the 1970s,

with growing scientific documentation of the urban natural environment of particular cities, a few, like Toronto, assembled that information and applied it to the design of downtown districts (Juneja and Spirn 1976).

By 1980 there was a body of knowledge on urban nature and a growing interest in an ecological approach to urban design and planning. My own book of 1984, *The Granite Garden: Urban Nature and Human Design*, reviewed the existing scientific literature, employed that knowledge to argue that cities are part of the natural world, and applied it to demonstrate how cities can be designed in concert with natural processes. Organized into sections on air, earth, water, life, and ecosystems, the book presented principles for an ecological approach to the design of cities, illustrated by successful cases from the scale of the house and garden to those of the neighborhood, city, and region (Spirn 1984). This chapter draws heavily on the concepts presented in *The Granite Garden*. Michael Hough's book, *City Form and Natural Process*, published the same year, presented a wealth of additional cases (Hough 1984).

Many researchers, practitioners, and critics have contributed to the theory and practice of ecological urbanism since 1984, far too many to treat adequately in the context of this brief summary. Ecological urbanism is a broad approach to urban design and planning; related to it are aspects of multiple interrelated movements: ecological design (Hough 1995, Van der Ryn and Cowan 1996, Thompson and Steiner 1997, Corner 1997, Johnson and Hill 2002, Berger and Brown 2009, Saunders 2012), environmental art (Beardsley 1984, Spirn 1988a, Spirn 1988b, Nassauer 1997a, Brown 1998, Bargmann 2011); landscape planning (Steiner 2002, Leitão and Ahern 2002, Saunders 2012), sustainable design and planning (Calthorpe and Van der Ryn 1986, Lyle 1994, Hester 2006, Benson and Roe 2007, Newman and Jennings 2008, Newman et al. 2009), green architecture (Wines 2000, Fromont 2003), green infrastructure (Spirn 1991, Wenk 2002, Benedict and McMahon 2006, Ahern 2007), green urbanism (Beatley 2000, Lehmann 2010), landscape urbanism (Mohstafavi 2003, Waldheim 2006, Almy 2007), and industrial ecology (Graedel and Allenby 2003). A recent addition to this literature, *Ecological Urbanism*, is an illustrated compendium of brief contributions by more than a hundred authors (Mostafavi and Doherty 2010). Not all the works – written, drawn, or built – produced under the rubrics listed above qualify as ecological urbanism; they do belong to the extent that they embody key concepts and principles.

The literature and practice in other fields related to ecological urbanism also have blossomed since 1984. Fortunately, there are review articles that survey advances in numerous scientific disciplines, such as urban climate (Arnfield 2003) and urban ecology (Pickett et al. 2010). Particularly important was the emergence and development of landscape ecology in the 1980s, which expanded the spatial scale of

ecologists and acknowledged both biological and social spatial heterogeneity as fundamental aspects of the structure and function of ecosystems (Forman and Godron 1986, Pickett et al 1997, Forman 2008). The growing literature on the environmental history of particular cities provides a temporal context for understanding the ways that human activities and settlements respond to and shape their natural environments (Cronon 1991, Gandy 2002, Klingle 2007). More general urban environmental histories, such as those on urban pollution and sanitation, lend a comparative perspective (Tarr 1996, Melosi 2000). Despite the fact that artists such as Newton and Helen Harrison, Robert Smithson, and Alan Sonfist had highlighted natural processes in their work from the 1960s on, there was a split between the advocates of ecological design and landscape as art until the late 1980s. Reviews of environmental art were influential in healing that split (Sonfist 1983, Beardsley 1984); both the theory and practice of ecological urbanism have now integrated ecological understanding and artistic expression.

Ecological urbanism grew out of ideas and action in landscape architecture, architecture, and urban design and planning as represented by theorists and practitioners such as those described above. It has developed and matured in dialogue with the natural and social sciences and, in recent decades, with the arts and humanities. These lineages -- from the design and planning professions to the natural and social sciences to the arts and humanities -- together support principles for ecological urban design and planning.

ECOLOGICAL URBANISM: PROPOSITIONS AND PRINCIPLES FOR THE DESIGN OF RESILIENT CITIES

Important concepts of ecological urbanism include: cities are part of the natural world; cities are habitats; cities are ecosystems; urban ecosystems are dynamic and interconnected; every city has a deep, enduring context; urban design is a tool of human adaptation. These fundamental propositions are the foundation from which to derive principles for an ecological approach to the design of cities. *The Granite Garden: Urban Nature and Human Design* laid out these concepts and principles in 1984. They were based on the work of researchers and practitioners in diverse fields, and, since 1984, they have been refined and expanded by many others. The principles described here -- and the citations of important contributions -- are illustrative not exhaustive.

Cities are part of the natural world

“Nature in the city is far more than trees and gardens, and weeds in sidewalk cracks and vacant lots. It is the air we breathe, the earth we stand on, the water we drink and excrete, and the organisms with which we share our habitat... It is the consequence of a complex interaction between the multiple purposes and activities of human beings and other living creatures and of the natural processes that govern the transfer of energy, the movement of air, the erosion of the earth, and the hydrologic cycle. The city is part of nature....The realization that nature is ubiquitous, a whole that embraces the city, has powerful implications for how the city is built and maintained, and for the health, safety, and welfare of every resident....The city must be recognized as part of nature and designed accordingly. The city, suburbs, and surrounding countryside must be viewed as a single, evolving system within nature, as must every individual park and building within that larger whole.... Nature in the city must be cultivated, like a garden, rather than ignored or subdued” (Spirn 1984: 4-5).

“Despite their differences, all cities have transformed their environments in a similar fashion....The human activities that modify the natural environment are common to all cities: the need to provide security, shelter, food, water, and the energy to fuel human enterprises; the need to dispose of wastes, to permit movement...; and the ever-escalating demand for more space” (Spirn 1984: 12-13).

In most cities, human activities interact with natural processes to create a typical urban climate, urban soils, urban hydrology, urban plant and animal communities, and characteristic flows of energy and materials. Recent research, however, has revealed exceptions to these generalizations, which were based on studies of places with a temperate or Mediterranean climate (McDonnell et al. 2009). Arid cities, for example, are cooler than the surrounding deserts at some times of day due to irrigation (Brazel et al. 2000). Nonetheless, the fundamental proposition holds. Cities are part of the natural world.

Despite overwhelming evidence to the contrary, “the belief that the city is an entity apart from nature and even antithetical to it has dominated the way in which the city is perceived and continues to effect how it is built. This attitude has aggravated and even created many of the city’s environmental problems: poisoned air and water; depleted or irretrievable resources; more frequent and more destructive floods; increased energy demands and higher construction and maintenance costs than existed prior to urbanization; and, in many cities, a pervasive ugliness” (Spirn 1984: 5). At the root of this failure to recognize the city as part of nature is the notion that nature is a place (wilderness and countryside, but

not city) or a thing (mountain, river and tree, but no thing made by humans). But nature is an *idea*, not a place or a thing, and, furthermore, it is a set of ideas for which many cultures have no name, “a singular name for the real multiplicity of things and living processes” (Williams 1980). Conflicting ideas of nature coexist, and they affect perception and action (Cronon 1996, Spirn 1997). The idea of nature as consisting of the biological, physical, and chemical processes that create and sustain life, the earth, and the universe is fundamental to ecological urbanism. If one embraces this idea, then the false oppositions between city and nature, the given and the built, fall away.

The idea of nature as a nexus of processes resonates with the approach of contemporary ecological science, which went through a paradigm shift in recent decades (Botkin 1990, Wu and Loucks 1995, Pulliam and Johnson 2001). Whereas traditional ecology focused on entities and classification, contemporary ecology emphasizes change and process. In this view of the natural world as shaped and structured by processes, contemporary ecology has much to offer an ecological approach to urban design and planning (Johnson and Hill 2001, Leitão and Ahern 2002, Reed 2011).

Recognize cities as part of the natural world and design them accordingly.

“There is a common tendency to focus on natural features (e.g. rivers and trees) rather than the processes that shape and structure them (e.g. flow of air, water, and materials; plant reproduction and growth). Ignoring natural processes leads to harmful consequences, including the failure of planners to accommodate dynamic change, their failure to make connections among seemingly unrelated issues and phenomena and to realize opportunities” (Spirn 2003: 204-205).

The key is to think in terms of the ways that human activities and urban form interact with natural processes of air (heat transfer and air flow), earth (geology and soils), water (water flow), life (reproduction, growth, and behavior), and ecosystems (flows of energy, information, and materials, succession of plant species and behavior of plants and animals). This is not just a matter of imitating or echoing the *shape* of natural features or of using indigenous materials, but of adapting urban form to natural processes. By focusing on the processes that shape and structure the environment, designers and planners can accommodate dynamic change, make connections among seemingly unrelated elements and issues, and can realize opportunities.

Many authors have described how this might be accomplished and many practitioners have demonstrated how: from projects by the offices of Olmsted and McHarg to those of contemporary designers such as James Corner, Anuradha Mathur and Dilip da Cunha, Alan Berger, Chris Reed (Stoss

Landscape Urbanism), and William Wenk. Other authors have documented how certain traditional urban settlement patterns and building forms are well adapted to natural processes (Fathy 1986, Agarwal and Sunita 1997).

Cities are habitats

“It is time to employ one of the greatest human talents, the ability to manipulate the environment, to transform an environment that has become hostile to life itself into a humane habitat which sustains life and nourishes growth, both personal and collective” (Spirn 1984: 275).

Cities are places for living: for individuals and groups, for humans and other species. As habitats, they must provide settings for the biological and social needs of the organisms who dwell there: for reproduction and growth, movement and exchange, communication, making and building, teaching and learning, work and play, reflection and worship. What could be more obvious? And yet, cities are full of places that are ill-adapted to the needs of their inhabitants: dysfunctional, contaminated, and vulnerable to natural hazards, exposing residents to discomfort, inconvenience, and even to danger (Spirn 2005, Cutter 2006).

Cities provide habitats for many nonhuman species from microbes to trees, from insects to fish, birds, and mammals (Sukopp et al. 1990, Burger 1999). Some species are indigenous, others are typical urban species, some are central to human health and prosperity, a few are hostile (Adams et al 2005). Ironically, most urban pests and weeds were imported by humans, deliberately or inadvertently, and are well-adapted to the habitats that humans create (Del Tredici 2010). Urban development tends to reduce biodiversity, with far-reaching adverse effects (McKinney 2008, Shochat et al. 2010). Enhancing biodiversity is not just important for plants and animals; Vandruff et al (1995) have argued that the presence of urban wildlife is closely linked to human well-being.

Design the city as a life-sustaining and life-enhancing habitat.

Every urban design project should enhance the quality of the urban habitat for humans and other species, even if that goal is not an explicit part of the designer’s brief. Kevin Lynch provides measures of “good city form” in terms of how well urban form sustains life (“vitality”), by how clearly it is perceived in space and time (“sense”), how well environment and behavior “fit,” and by whether these standards are provided in a manner that provides “access,” “control,” “efficiency,” and “justice” (Lynch 1981).

Many others, too numerous to cite here, have elaborated on how this might be accomplished (e.g. Alexander et al. 1977, Steiner 2002, Hill 2002, Hester 2006).

Like humans, each species has specific needs, and the most effective way to enhance their survival or establish control is often through the design and management of their habitat (Adams et al. 2005, McDonnell et al. 2009).

Celebrate the natural processes that shape the urban habitat and that sustain life, make them tangible and understandable.

“Design which juxtaposes and contrasts nature’s order and human order prompts the contemplation of what it means to be human....Design that resonates with the natural and cultural rhythms of a place, that echoes, amplifies, clarifies, or extends them, contributes to a sense of rootedness in place and time. Design that makes visible the operation of natural processes and their temporal cycles contributes to the experience of being connected to rather than separate from the past and the future....The hydrologic cycle, the nutrient cycle, and the food chain are essential to human life; they sustain us, and they link us to the environment in which we live and to the other organisms...that share our habitat. Yet to most people, these cycles are abstractions, something read about in textbooks...The urban landscape affords abundant opportunities to celebrate these cycles, to make legible and tangible the connections they forge” (Spirn 1988b).

Pleasure and meaning are basic human needs, and “the mental sense of connection with nature is a basic human satisfaction, the most profound aspect of sensibility....The movement of sun and tides, the cycles of weeds and insects and men, can also be celebrated along the city pavements” (Lynch 1981: 257). Wilson's biophilia hypothesis argues that humans have an innate attraction to life and life’s processes (Wilson 1984). Urban design that fosters and intensifies the experience of the natural processes that sustain life fulfills this need (Koh 1982, Howett 1987, Spirn 1988b and 1998, Gobster et al. 2007, Beatley 2011). Aesthetic experience of such places has the potential for “recentering human consciousness from an egocentric to a more bio-centric perspective” (Meyer 2008: 6). Meyer cites as models several contemporary projects.

Cities are ecosystems

“The ecosystem concept provides a powerful tool for understanding the urban environment: it furnishes a framework for perceiving the effect of human activities and their interrelationships; it facilitates weighing the relative costs and benefits of alternative actions; it encompasses all urban

organisms, the city's physical structure, and the processes which flow within it; and it is appropriate in examining all levels of life, from an urban pond to megalopolis" (Spirn 1984: 244).

The urban ecosystem, like any ecosystem, consists of all the organisms that dwell within it (including humans) and their interactions with each other and with their physical environment, which comprises built artifacts like buildings, roads, and sewers, as well as water, soil, and plants (Pickett and Grove 2009). The urban ecosystem is an open system: energy, material, and information flow through it as resources are imported, transformed, and consumed, then exported as wastes and goods (Wolman 1965, Brunner 2007). The less efficiently resources are used, the more wastes are produced and contamination increased. The urban ecosystem encompasses all the processes which flow within and through the city: cultural processes as well as natural processes, flows of capital, people, and goods, as well as flows of water, air, nutrients, and pollutants (Machlis et al. 1997; Pickett et al. 1997). The city as a whole, itself an ecosystem, is composed of many smaller ecosystems: of ponds and river corridors, parks, buildings and neighborhoods.

Landscape ecology and urban ecology have matured as fields in recent decades (Forman 2008, Pickett et al. 2010). Both fields offer insight and inspiration to the planners and designers of cities (Leitão and Ahern 2002, Felson and Pickett 2005, Reed 2011).

Design the city as a whole, as well as every park, building, and district within that larger whole, as ecosystems that require minimal inputs of energy and resources to build and sustain.

"Solutions to the problems of the city and its region must not be separated, but rather coordinated and undertaken with as much understanding of the urban ecosystem as current knowledge permits...to facilitate a comprehensive plan for the management of the urban ecosystem and to establish a frame within which individual components can be designed, every city should identify its most critical problems, and most significant resources, explore the potential links among them, and establish priorities for their resolution and protection....Every new building and park should be designed to require the minimum input of energy and materials, to generate minimal wastes, and whenever possible, to serve more than one purpose" (Spirn 1984: 260-261).

"Since ecosystem concepts can be applied to systems as small as a pond or as large as an urban region, even the design for a small park should be approached with an appreciation for both the smaller and the larger system of which it is part, and the requisite inputs of energy, water, and

materials and generation of wastes entailed by alternative designs” (Spirn 1984: 246).

The design of an urban ecosystem entails not just the composition of its structure, shape, and materials, but should include as well the means by which it will be built and maintained over time. The city, and every building, park, and infrastructure system within it, should be designed as much as possible as “closed” ecological systems: to import and consume fewer resources, produce fewer wastes, and to recycle wastes as resources. This goal is most easily understood and achieved at the scale of a park or a building and its immediate surroundings, and there are good examples (Lyle 1994, Wines 2000, Fromont 2003). At the district scale, increasing the density of urban development can make energy-conserving strategies such as shared transportation systems and district heating more feasible. At all scales from house to metropolitan region, wastes – the byproducts of one activity – may be a resource for another: the home composting of kitchen waste to produce garden amendments is analogous to the regional project of combining leaf litter and sewage sludge to produce new soil. Industrial ecology brings together industries whose waste and resource streams are symbiotic (Lynch 1990, Graedel and Allenby 2003).

Preservation, conservation, restoration, reconstruction, and renewal are distinct approaches to managing an ecosystem. Preservation and conservation are most appropriate when the ecosystem is vital and intact and the task is to manage it. The goals of preservation versus conservation have divided the US environmental movement since John Muir and Gifford Pinchot quarreled over the management of Yosemite in the 1890s: in preservation, the goal is to retain it in its current state and protect it from human use (Muir); in conservation, the goal is to manage the ecosystem for “wise use” by humans (Pinchot). The goal of restoration is to reconstruct or repair a damaged ecosystem in order to return it to a former, healthy condition. The purpose of renewal, unlike the other three approaches, is to improve the condition of an ecosystem through the introduction of a wholly new element: a building, a park or reserve, or a neighborhood. Fredrick Law Olmsted’s proposal for Yosemite is an example of conservation, his design for Niagara Falls and plan for Biltmore’s forest, examples of both restoration and conservation. His projects for the Fens and Riverway called for wholesale reconstruction (Spirn 1995). James Wescoat has applied the conservation approach of “wise use” to water systems in South Asian cities (Wescoat 2009a and 2009b), Kongjian Yu that of both conservation and renewal to new landscapes in China (Saunders 2012).

Urban ecosystems are connected and dynamic

“A knowledge of the system’s dynamics yields a different appreciation for boundaries in space and time than is normally permitted in day-to-day pursuits and highlights the shortcomings of designing solely within political boundaries and time spans of less than several generations” (Spirn 1984: 244).

“Take the example of how water, flowing, shapes and structures rivers, floodplains, watersheds and their topographies and boundaries. Water flow is not constant, but ever changing, and floodplains are dynamic zones, places where water rises and falls, pools and seeps. Changes in ground surface and permeability in one place within a watershed alter floodplain boundaries and the form and size of stream bed and banks in other places....Seen from the perspective of hydrological processes, the drainage system of neighborhood, city, or region consists not only in channels officially designated for stormwater flow, but also in all the surfaces and water reservoirs within a watershed: in roofs, roads, and parking lots, gardens, parks, and forests, in soil, plants, and valley bottoms as well as in ponds” (Spirn 2003: 205).

The many ecosystems that comprise the larger urban ecosystem are linked by the physical space they share and by the channels through which energy, material, and information flow (Wu and Loucks 1995, Cadenasso and Pickett 2007). There are ecosystems within ecosystems: a pond ecosystem, for example, exists within the larger ecosystem of its watershed (and there are watersheds within watersheds, from that of a small stream to a continental river basin); a building is an ecosystem within a neighborhood. Given this connectivity, changes to one ecosystem may produce repercussions in many others (Pickett et al 2004).

Identify and portray the interplay of natural and social processes that shape and structure the city.

“For designers, new techniques of notation and representation are required. Conventional techniques are inadequate to the portrayal of time and change, and they encourage the continued focus on visible and static form” (Spirn 1988b: 124).

Ian McHarg overlaid maps of diverse natural and social factors in order to better understand the interaction of natural and social processes (McHarg 1969). Such overlays can reveal surprising relationships among seemingly unrelated phenomena, such as the correlation between buried floodplains and vacant land in low-income inner-city neighborhoods, but they portray these relationships as static (Spirn 2000a). James Corner, Anu Mathur, Dilip da Cunha, and Alan Berger, among others, have

developed mapping techniques that enable designers to visualize how processes operate in space and time (Mathur and da Cunha 2001 and 2009, Berger 2006).

Address social and environmental challenges within appropriate boundaries at the appropriate spatial and temporal scales.

“Natural processes form territories, pathways, and boundaries, which may coincide with political and cultural boundaries or cut across them. Environmental problems felt in one place may be caused by activities that take place elsewhere. Solving an environmental problem may require taking action in a different location than where the problem is felt” (Spirn 2003: 205).

Strong winds at the base of a tall building are amplified by conditions upwind, floods and pollution by discharge upstream, vulnerability to hurricane-driven waves by erosion of marshes and swamps. Environmental and social problems in low-income neighborhoods are often created or aggravated by flows of capital and wastes to and from suburban communities (Spirn 2005). In these and many other cases, local intervention alone is doomed to failure. Designers should identify the systems to which their project site is connected and track the flows of energy, materials (food, water, waste), information, and capital that move in and out. No matter how small or large the project, the designer’s responsibility is to address the context of, and impact on, the ecosystems to which it is connected. Design proposals should not be limited to the area enclosed by the client’s boundaries, but should be expanded to include that area necessary to effectively address the challenges posed by site, program, and context (Berger 2009). Contemporary ecology has highlighted the importance of boundaries and the role they play in controlling flows of energy and materials in landscapes, so have studies of urban climate and urban watersheds (Cadenasso et al. 2003).

In Houston, Texas, for example, floods and ground subsidence in the city are aggravated by suburban developments many miles upstream, which are within the watershed of the city’s streams and/or on the recharge areas for an aquifer which underlies the city. In the early 1970s, Ian McHarg helped his client, the developer of Woodlands New Community, to understand how the construction of the new town would affect not only the environment of the site itself, but also that of the city of Houston and its region. McHarg persuaded his client to adopt a so-called natural drainage system, where the landscape was designed as a green framework to structure the new town, to reduce stormwater runoff, and to recharge the aquifer. At a much smaller scale, the Dayton Climate Project discovered that high winds at the base of tall buildings in downtown Dayton, Ohio could be reduced most effectively by the redesign of open parking lots, which were upwind, blocks away (Spirn 1984).

Define multi-purpose solutions to comprehensively defined problems.

“The quality of urban life depends upon opportunities for education and employment, the availability of affordable housing and transportation, an environment that supports and sustains human life, and an urban landscape that nurtures the body, mind, and spirit. Successful resolution to urban problems must integrate all these dimensions: social, economic, environmental, and aesthetic. Given limited resources, cities can no longer afford to address these issues separately. Single-purpose solutions to narrowly-defined problems are wasteful...and cause unanticipated consequences. We must define multi-purpose solutions to comprehensively defined problems. We must seek common solutions to social, economic, cultural, and environmental problems. One strategy for promoting such integration is for a city to start with its most pressing problem for which there is widespread public support, and then find ways to address other concerns as well. An economic or social problem, such as unemployment or social segregation may be the central, organizing issue within which environmental and aesthetic problems are addressed. Or, alternatively, an important environmental problem, such as air pollution or flooding, may serve as the focus, and ways found to incorporate solutions to social, economic, and aesthetic problems” (Spirn 1994: 165-66).

The “three E’s” of sustainable development – environment, economics, and equity – emerged in the 1980s in response to limited economic resources and a growing appreciation for how social, economic, and environmental challenges are intertwined. The seminal 1987 report by the UN’s World Commission on Environment and Development, *Our Common Future*, was followed up by other initiatives, such as the 1992 “International Conference on the Economic, Social, and Environmental Problems of Cities,” which was organized by the Organization for Economic Co-operation and Development and attended by ministers of housing, health and community services, urban development, and environment from OECD countries (Brundtland et al. 1987, OECD 1994). This recognition for the need to integrate the three “E’s” was matched in practice, by proposals such as those for Boston in 1985 (Spirn 2000a), Philadelphia in 1991 (Spirn 1991 and 2005), and New York City in 1996 (Yaro and Hiss 1996). Increasingly, designers and planners of cities are seeking integrated solutions to social, economic, cultural, and environmental challenges (Hester 2006, Bargmann 2012).

The integration of open urban land into a “green” infrastructure promises to extend the aesthetic and recreational value of parks and parkways to a crucial role in health, safety and welfare. Parks and plazas, rivers, streams, and floodplains, steep hillsides, and even parking lots and highway corridors

could be part of a cohesive system to improve air quality and climate, to reduce flooding and improve water quality, to limit the impact of geological hazards such as earthquakes, subsidence, and landslides, to provide a diverse community of plants and animals within the city, to conserve energy, water and mineral resources, and to enhance the safe assimilation of the city's wastes (Spirn 1984 and 1988 , Wenk 2002, Benedict and MacMahon 2006, Ahern 2007, Dreiseitl 2009).

Take account of history.

“Reconstructing the environmental history of an urban landscape provides a window into the interaction of natural and social processes through time. This kind of history can be gleaned from historical documents, especially maps and photographs, from verbal descriptions, and from landscapes themselves. Studying environmental change over time helps foster an understanding of urban landscapes as dynamic. It shows how natural processes are significant agents in urban development, and how social and cultural processes are active ingredients of urban ecosystems” (Spirn 2003: 204).

Urban design is an art of time as well as space; it is a projection into the future, which is complicated by the fact that the urban ecosystem is constantly changing in unpredictable ways. Knowing how a place has been shaped over time is essential to understanding its present and possible future. The urban designer must ask: What is this place in the process of becoming? Which of its features are clues to ongoing processes that continue to exert a decisive influence, and which are merely artifacts of the past that assert little influence now? Which features are amenable to change and which are resistant? It is difficult to answer such questions without understanding how a place evolved, through what processes and actions, when, and which of its features have had a sustained impact on their surroundings over time. The environmental history of a place provides a window into the ways natural and social processes interact through time, and how planners have intervened, for good or bad effect (Cronon 1991, White 1996, Klinge 2007). This has little to do with imitating historic built form. Taking account of history means more than conserving historical structures and using history as a source of formal precedent (though certain historic architecture and settlement patterns are examples of environmental adaptation, see, for example, Fathy 1986, Agarwal and Sunita 1997). History is a way of extending human memory beyond the human life span.

Every city has a deep structure or enduring context

“Civilizations and governments rise and fall; traditions, values, and policies change; but the natural environment of each city remains an enduring framework within which the human community builds. A city’s natural environment and its urban form, taken together, comprise a record of the interaction between natural processes and human purpose over time. Together, they contribute to each city’s identity” (Spirn 1984: 12).

“Landscapes evolve continually in time, in predictable and unpredictable ways, in response to natural processes and changing human purposes. The forms we see on the surface of the landscape are a sum of all these processes, both natural and cultural: the patterns they produce are juxtaposed, interwoven and overlain. This surface structure is thus in flux. Underlying this surface, however, there is a more enduring structure, with distinctive rhythms, to which all organisms within that landscape respond. Deep structure expresses the fundamental climatic, geomorphic, and biotic processes in a particular place. Deep structure is the product of these processes operating and interacting across vast scales of time at the scale of large regions and at the microscale. Deep structure is evident in the patterns of hills and valleys, rivers and seas that extend across the regional landscape, in the spatial location and arrangement of indigenous plant communities, and in the form of the individual plants of which those communities are composed....The concept of deep structure provides a way to distinguish between landscape structure that is formed over very long time scales from landscape structure in which change is manifest over a much shorter time span. The significance of the concept ...is to focus attention on the fundamental underlying ecological and geological phenomena that ultimately control the dynamic surface activity” (Spirn 1993: 9-10).

Not all features of the urban natural environment are equally significant; some are ephemeral, others more enduring. While urbanization radically changes the surface of the landscape, the deep structure of a city, with its distinctive rhythms, is expressed in that city’s climate (hot, cold, or temperate; humid or arid; and seasonal variations), geology (rock type and structure, seismic and volcanic activity), physiography (plain, basin, piedmont, or mountain), and bio-climatic zone (tundra, forest, prairie, or desert). Deep structure remains crucial to the history and future of a place – why it was settled, its initial location, its transportation routes, its economic development and population distribution, the character of its buildings, streets, and parks, and the health and safety of its residents. The design of cities that are in agreement with the deep structure of a region, rather than counter to it, is essential to fostering resilient urban form. The work of Anuradha Mathur and Dilip da Cunha in the low-lying, “aqueous terrain” of

Mumbai is a model for this approach. Their proposal, *Soak*, “is about making peace with the sea; about designing with the monsoon in an estuary” (Mathur and da Cunha 2009).

Adapt the physical shape and structure of a city – the infrastructure of roads and sewers, the buildings and parks – to its deep structure.

“Deep structure can be masked, but it cannot be erased. When surface structure obscures or opposes deep structure, it will require additional energy, materials, and information to sustain. If these resources cease to be applied, the deep structure will reassert itself” (Spirn 1993: 10).

Planting trees and lawn in a desert or burying a river in a sewer and filling in its floodplain are examples of urban form that obscures or opposes a city’s deep structure. In contrast, urban form that reveals and responds to deep structure is likely to be more functional, more economical, and more resilient than design that disregards it. This is especially important for the design of the infrastructure (water, sewer, power, transportation) that supports the city, whether at the scale of building, neighborhood, city, or region (see, for example, Spirn 2000a and 2005, and Philadelphia Water Department 2009). Such design may also afford an aesthetic experience of unity with the processes which shape the landscape and which sustain life (Spirn 1988b, Brown 1998, Meyer 2008, Bargmann 2011, Miss 2012).

Anticipate and exploit natural catastrophes.

As a function of its deep structure, every city is prone to specific natural hazards whose precise timing is unknown (Cutter 2001). San Francisco will experience a major earthquake; Las Vegas and Phoenix, severe drought; St. Louis and Pittsburgh, major floods. It was inevitable that a major hurricane would strike New Orleans. After a catastrophe, there is a will to rebuild and to “do things right,” but that window of opportunity is small. Urban designers should anticipate future redesign and rebuilding in order to seize the opportunity when catastrophe strikes; historical examples provide lessons of failure and success (Vale and Campanella 2005).

Catastrophes are an extreme form of what ecologists call “disturbance” -- temporary changes to an ecosystem caused by environmental events like fires or floods or by human activities like bulldozing soil. Ecologists recognition of the pervasiveness and unpredictability of natural events that act as disturbances may offer insights for how to design cities that can adapt well to change (Pickett and White 1985, Reice 2001, Pulliam and Johnson 2001).

Urban design is a powerful tool of adaptation

“The origins of architecture lie in making shelter, creating refuge, in marking the place of humans within nature, in making space for the institutions that shape our relationships to each other and to the natural world. Through these institutions and through architecture, our species spread across the earth from the warm savanna to cool, shady forests and even to the cold, open land of the arctic tundra. More and more, we have become architects of the environment” (Spirn 1990: 38).

Most humans now live in cities, and urban design is a powerful tool of adaptation. No matter how well one understands a city’s history, its ecosystems, and its enduring context, no matter how carefully one tries to anticipate the future, there will always be unforeseen circumstances to which a city must adapt.

Design resilient cities.

“Ecosystems differ in their ability to withstand disturbance and assimilate waste. Resilience is a measure of the system’s capacity to absorb change, and some ecosystems are more resilient than others” (Spirn 1984: 245).

The concept of resilience (as opposed to the concept of sustainability, for example, which implies maintenance of a stable state) is useful for urban designers who strive to create cities that are adaptable to changing conditions and needs (Pickett et al. 2004, Vale and Campanella 2005). In *The Resilient City*, Vale and Campanella brought together cases of twelve cities that recovered from a variety of historic disasters, such as war, fire, earthquakes, and floods, in order to draw lessons for how cities might better prepare for and respond to catastrophe, whether predicted or not.

The risk of earthquakes, hurricanes, floods, and drought in a particular place are well known, but “natural” hazards are also the product of human activities : e. g. the location of vulnerable land uses, the design and construction of buildings, actions that trigger an event, and, ironically, even the very measures designed to mitigate certain catastrophes (Cutter 2001, Mileti 2008, Mathur and da Cunha 2001 and 2009). Urban form that is congruent with the “deep structure” or enduring context of a city’s natural environment will be more resilient.

Unlike certain natural hazards, phenomena like shifts in economy and culture, new technology, and changes in the global environment are relatively unpredictable. Kevin Lynch describes a range of

additional physical design strategies for enhancing the ability of urban form to adapt to future change: avoid urban form that is too narrowly specialized such as districts that consist entirely of a single, specialized land-use; encourage a diversity of buildings and neighborhoods; adopt an additive structure, such as a grid, that can accommodate growth or decline at the periphery without major change to the overall structure at the center of a neighborhood or city; employ temporary structures or uses, when appropriate, especially true for uses in which technology is changing rapidly; utilize communication systems to accommodate changing needs rather than radical alteration of the city's physical structure (Lynch 1958).

Act comprehensively and incrementally.

“Plan both for large-scale change and incremental improvements. Both strategies are valid; which is most appropriate in a given situation depends upon context. Although the impact of the grand scheme is greater, its scale is daunting and may not be replicable in another city. The modest project can be readily repeated in infinite variations, adapted to the special character of other places. Sweeping, comprehensive change is most easily implemented in rapidly growing cities and in new towns and has immediate, major results. Incremental change, however, is frequently more feasible. When guided by a comprehensive understanding of long-term goals for change, it may even be more effective. An incremental approach to change permits the assessment of successes and failures and the refinement of subsequent interventions” (Spirn 1994: 170).

Major challenges like climate change and recovery from economic recession may require a comprehensive and rapid response, but it is dangerous to implement a single model for change. Massive large-scale interventions often produce unforeseen effects, which may be devastating, such as those precipitated by urban renewal of the 1950s and 1960s. Diverse approaches, implemented incrementally, provide the opportunity to learn from failure and success and to respond; such solutions should fit local conditions, tailored to the needs of specific people in particular places. But incremental projects should be undertaken as part of a comprehensive framework for large-scale investment that addresses regional needs. The local view gives an intimate view of the habitat of individuals and small groups; an overview gives a broader perspective of larger systems. *The Granite Garden* offers a checklist for the designers and planners of cities; each section of the book – Air, Earth, Water, Life, and The Urban Ecosystem -- concludes with suggestions for “What Every City Should Do,” which range from the scale of the street

corner to the scale of the region (Spirn 1984).

ECOLOGICAL URBANISM AND THE FUTURE OF URBAN DESIGN

Much is known about the urban natural and social environment, and there exist many successful models of ecological urbanism. Yet most of these examples are not known to the public, to natural and social scientists, or even to urban designers and planners. Ignorant of existing knowledge and precedents (or choosing not to cite them), researchers and practitioners repeatedly reinvent the wheel and/or stress novelty over the extension of a tradition; this has been a persistent problem in the literature of architecture and urban design (e.g. Waldheim 2006, Mostafavi and Doherty 2010). What is needed is a series of literature reviews on ecological urbanism and its subfields, reviews that provide a critical, comprehensive overview of what is known: the principal themes and threads of inquiry, the key works and contributions in each area, regions of agreement and the disputed territories, gaps in knowledge, potentially fertile areas of inquiry, and models of practice that deserve to be replicated. The concepts and principles presented here aim to help frame those reviews.

Much is still not known about the urban natural environment and the processes that shape it, and there is great opportunity for future research. Particularly promising are recent collaborations between urban designers and experts in other disciplines, such as ecology, economics, engineering, and art. Landscape architect Alex Felson and ecologist Steward Pickett, for example, describe design projects that are also ecological experiments (Felson and Pickett 2005), and Joan Nassauer and Paul Opdam make a case for the incorporation of design into ecological research (Nassauer and Opdam 2008).

The reasons for embracing and promoting ecological urbanism are compelling. At stake is the future of humanity: whether we can adapt our behavior and settlements to meet the challenges we face (those posed by climate change and environmental contamination, for example, and by inequities in exposure to the hazards they represent) and whether we can do so in ways that are life-enhancing and life-expanding. Ecological urbanists have an essential role, not merely in producing safer and healthier urban habitats, but in making legible and tangible the systems that support life, and in changing the perception of what is possible.

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REFERENCES

- Adams, C. E., Lindsey, K. J., and Ash, S. J. (2005), *Urban Wildlife Management*, CRC Press.
- Ahern, J. (2007), "Green Infrastructure for Cities: The Spatial Dimension," in V. Novotny and P. Brown, eds., *Cities of the Future: Towards Integrated Sustainable Water and Landscape Management*, London: IWA Publishing, 267-283.
- Alberti, L. B. (1988), *On the Art of Building in Ten Books*, translated by J. Rykwert, N. Leach, and R. Tavernor, Cambridge, Mass.: MIT Press.
- Alexander, C., Ishikawa, S., and Silverstein, M. (1977), *A Pattern Language: Towns, Buildings, Construction*, New York: Oxford University Press.
- Almy, D. J., ed. (2007), *On Landscape Urbanism*, Austin, Texas: Center for American Architecture and Design, University of Texas.
- Agarwal, A., and Sunita N. (1997), *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water*

Harvesting Systems, New Delhi: Centre for Science and Environment.

Arnfield, A. J. (2003), "Two Decades of Urban Climate Research: A Review of Turbulence, Exchanges of Energy and Water, and the Urban Heat Island," *International Journal of Climatology* 23, 1-26.

Bargmann, J. (2012), "Just Ground: A Social Infrastructure for Urban Landscape Regeneration," in M.L. Cadenasso, S.T.A. Pickett, B.P. McGrath, and K. Hill, eds., *Resilience in Ecology and Urban Design: Synergies for Practice and Theory in the Urban Century* (Springer).

Beardsley, J. (1984), *Earthworks and Beyond: Contemporary Art in the Landscape*, New York: Abbeville.

Beatley, T. (2000), *Green Urbanism: Learning from European Cities*, Washington, D.C.: Island Press.

(2010), *Biophilic Cities: Integrating Nature into Urban Design and Planning*, Washington, D.C.: Island Press.

Benedict, M. A., and McMahon, E. T. (2006), *Green Infrastructure: Linking Landscapes and Communities*, Washington, D. C.: Island Press.

Benson, J., and Roe, M., eds. (2007), *Landscape and Sustainability*, London: Routledge.

Berger, A. (2006), *Drosscape: Wasting Land in Urban America*, New York: Princeton Architectural Press.

___. (2009), *Systemic Design Can Change the World*, Amsterdam: Sun Publishers.

— and Brown, C. (2009), "A New Systemic Nature for Mussolini's Landscape Urbanism," *VIA: DIRT* (September 2009), 27-36.

Botkin, D. B. (1990), *Discordant Harmonies: A New Ecology for the Twenty-first Century*, Oxford

University Press: New York.

Brown, B., ed. (1998), *Eco-Revelatory Design: Nature Constructed/Nature Revealed*, Special Issue

Brundtland, G. H., et al., and World Commission on Environment and Development (1987), *Our Common Future*, New York: Oxford University Press.

Brunner, P. H. (2007), "Reshaping Urban Metabolism," *Journal of Industrial Ecology* 1: 3-19.

Burger, J. (1999), *Animals in Towns and Cities*, Dubuque, Iowa: Kendall/Hunt.

Cadenasso, M. L. et al. (2003) "An Interdisciplinary and Synthetic Approach to Ecological Boundaries," *BioScience* 53:717-722.

— and Pickett, S. T. A. (2007) "Boundaries as Structural and Functional Entities in Landscapes: Understanding Flows in Ecology and Urban Design," in B. McGrath et al., eds., *Designing Patch Dynamics*, New York: Columbia University Graduate School of Architecture, Planning and Preservation.

Calthorpe, P., and Van der Ryn, S. (1986), *Sustainable Communities: A New Design Synthesis for Cities, Suburbs and Towns*, San Francisco: Sierra Club.

Chandler, T. J. (1976), *Urban Climatology and Its Relevance to Urban Design*, Technical Note 149, Geneva: World Meteorological Organization.

Corner, J. (1997), "Ecology and Landscape as Agents of Creativity," in G. Thompson and F. Steiner, eds., *Ecological Design and Planning*, New York: Wiley.

Cronon, W. (1991), *Nature's Metropolis: Chicago and the Great West*, New York: W. W. Norton.

Cronon, W. ed. (1995), *Uncommon Ground: Toward Rethinking the Human Place in Nature*, New York: W. W. Norton.

Cutter, S. L., ed. (2001), *American Hazardscapes: The Regionalization of Hazards and Disasters*, Washington, D. C.: Joseph Henry Press.

— (2006), *Hazards, Vulnerability, and Environmental Justice*, Sterling, VA: Earthscan.

Dansereau, P, ed. (1970), *Challenge for Survival: Land, Air, and Water for Man in Megalopolis*, New York: Columbia University Press.

Del Tredici, P. (2010), *Wild Urban Plants of the Northeast: A Field Guide*, Ithaca: Cornell University Press.

Detwyler, T. R., and Marcus, M. G., eds. (1972), *Urbanization and Environment: The Physical Geography of the City*, Belmont, Calif.: Duxbury Press.

Dreiseitl, H. (2009), *Recent Waterscapes: Planning, Building, and Designing with Water*, Basel: Birkhäuser.

Dunne, T., and Leopold, L. B. (1978), *Water in Environmental Planning*, San Francisco: W. H. Freeman.

Fathy, H. (1986), *Natural Energy and Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates*, Chicago: University of Chicago Press.

Felson, A., and Pickett, S. T. A. (2005), “Designed Experiments: New Approaches to Studying Urban Ecosystems,” *Frontiers in Ecology and Environment* 3: 549-556.

Forman, R. T. T., and Godron, M. (1986), *Landscape Ecology*, New York: John Wiley.

Forman, R. T. T. (2008), *Urban Regions: Ecology and Planning Beyond the City*, New York: Cambridge University Press.

Fromonot, F. (2003), *Glenn Murcutt : Buildings and Projects, 1962-2003*, London: Thames and Hudson.

Gandemer, J., and Guyot, A. (1976), *Intégration du phénomène vent dans la conception du lieu bâti*, Paris: Ministère de la Qualité de la Vie.

Gandy, M. (2002), *Concrete and Clay: Reworking Nature in New York City*, Cambridge: MIT Press.

Geddes, P. (1915), *Cities in Evolution*, rev. ed. (1949), London: Williams and Norgate.

Gill, D., and Bonnett, P. (1973), *Nature in the Urban Landscape: A Study of Urban Ecosystems*, Baltimore: York Press.

Gobster, P. H., Nassauer, J. I., Daniel, T. C., and Fry, G. (2007), “The Shared landscape: What Does Aesthetics Have to Do with Ecology?” *Landscape Ecology* 22: 959-972.

Graedel, T.E., and Allenby, B.R. (2003), *Industrial Ecology*, Upper Saddle River, NJ: Prentice-Hall.

Hester R. (2006), *Design for Ecological Democracy*, Cambridge: MIT Press.

Hill, K. (2002), “Design and Planning as Healing Arts: The Broader Context of Health and Environment,” in B. R., Johnson and K. Hill, eds., *Ecology and Design: Frameworks for Learning*, Washington: Island Press.

Hill, K. (2007), “Urban Ecological Design and Urban Ecology: An Assessment of the State of Current Knowledge and a Suggested Research Agenda,” in V. Novotny and P. Brown, eds., *Cities of the Future: Towards Integrated Sustainable Water and Landscape Management*, London: IWA Publishing, 251-266.

Hippocrates (ca. fifth century B.C.), “Airs, Waters, Places,” in *Hippocrates*, vol. 1, The Loeb Classical Library, T. E. Page, ed., Cambridge: Harvard University Press, 1962.

Hough, M. (1984), *City Form and Natural Process*, London: Croom Helm.

— (1995), *Cities and Natural Process*, London: Routledge.

Howard, E. (1902), *Garden Cities of To-Morrow*, Cambridge, MA: MIT Press, 1965.

Howett, C. (1987), "Systems, Signs, Sensibilities: Sources for a New Landscape Aesthetic," *Landscape Journal* 6: 1-12.

Jacobs J. (1961), *The Death and Life of Great American Cities*. New York: Vintage.

Johnson, B. R., and Hill K., eds. (2002), *Ecology and Design: Frameworks for Learning*, Washington: Island Press.

Juneja, N., and Spirn, A. W. (1976), *Environmental Resources of the Toronto Central Waterfront*, Philadelphia, Penn.: Wallace McHarg Roberts and Todd. (<http://www.annewhistonspirn.com/pdf/Spirn-Toronto-1976.pdf>)

Klinge, M. (2007), *Emerald City: An Environmental History of Seattle*, New Haven: Yale University Press.

Koh, Jusuck (1982), "Ecological Design: A Post-Modern Design Paradigm of Holistic Philosophy and Evolutionary Ethics," *Landscape Journal* 1: 76-84.

Landsberg, H. (1981), *The Urban Climate*, New York: Academic Press.

Laurie, I. C., ed. (1979) *Nature in Cities*, Chichester, England: Wiley.

Legget, R. (1973), *Cities and Geology*, New York: McGraw-Hill.

Lehmann, S., ed. (2010), *The Principles of Green Urbanism: Transforming the City for Sustainability*, London: Routledge.

Leitão, A. B., and Ahern, J. (2002), "Applying Landscape Ecological Concepts and Metrics in Sustainable Landscape Planning," *Landscape and Urban Planning* 59:2, 65-93.

Leveson, D. (1980), *Geology and the Urban Environment*, New York: Oxford University Press.

Lyle, J. T. (1985), *Design for Human Ecosystems: Landscape, Land Use, and Natural Resources*, New York: Van Nostrand Reinhold.

— (1994), *Regenerative Design for Sustainable Development*, New York: John Wiley.

Lynch, K. (1958), “Environmental Adaptability,” *Journal of the American Institute of Planners* 24 (1): 16-24.

— (1981), *A Theory of Good City Form*, Cambridge: MIT Press.

— (1990), *Wasting Away*, San Francisco: Sierra Club.

Machlis, G. E., Force, J. E., and Burch, W. R. (1997), “The Human Ecosystem Part 1: The Human Ecosystem as an Organizing Concept in Ecosystem Management,” *Society & Natural Resources* 10: 347-367.

Marsh, G. P. (1864), *Man and Nature; or Physical Geography as Modified by Human Action*, Cambridge: Harvard University Press, 1965.

Mathur, A, and da Cunha, D. (2001), *Mississippi Floods: Designing a Shifting Landscape*, New Haven: Yale University Press.

— (2009), *Soak: Mumbai in an Estuary*, Rupa.

McDonnell, M. S., Hahs, A. K., and Breuste, J. H. (2009), *Ecology of Cities and Towns*, Cambridge: Cambridge University Press.

McHarg, I. L. (1967), “An Ecological Method for Landscape Architecture,” *Landscape Architecture* 57 (January): 105-7.

— (1968), “Values, Process, and Form,” in Smithsonian Annual II. *The Fitness of Man’s Environment*: 207-227.

McKinney, M. L. (2008), “Effects of Urbanization on Species Richness: A Review of Plants and

Animals.” *Urban Ecosystems* 11:161-176.

— (1969), *Design with Nature*, Garden City: Natural History Press.

Melosi, M. V. (2000), *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present*, Pittsburgh, PA: University of Pittsburgh.

Meyer, E. (2008), “Sustaining Beauty,” *Journal of Landscape Architecture* 1: 6-23.

Mileti, D. S. (2008), *Disasters by Design: A Reassessment of Natural Hazards in the United States*, Washington, D. C.: Joseph Henry Press.

Miss, M. (2012), “Art and Ecology in Urban Design,” in M.L. Cadenasso, S.T.A. Pickett, B.P. McGrath, and K. Hill, eds., *Resilience in Ecology and Urban Design: Synergies for Practice and Theory in the Urban Century* (Springer).

Mostafavi, M., and Najle, C., eds. (2003), *Landscape Urbanism*, London: Architectural Association.

Mostafavi, M., and Doherty, G., eds. (2010), *Ecological Urbanism*, Baden, Switzerland: Lars Müller.

Mumford, L. (1968), *The Urban Prospect*, New York: Harcourt Brace Jovanovich.

Nassauer, J. I., ed. (1997a), *Placing Nature: Culture and Landscape Ecology*, Washington, D. C.: Island Press.

— (1997b), “Cultural Sustainability: Aligning Aesthetics and Ecology,” in J. Nassauer, ed., *Placing Nature: Culture and Landscape Ecology*, Washington, D. C.: Island Press, 67-83.

—, and Opdam, P. (2008), “Design in Science: Extending the Landscape Ecology Paradigm,” *Landscape Ecology* 23: 633-644.

Newman, P., and Jennings, I. (2008), *Cities as Sustainable Ecosystems: Principles and Practices*, Washington, D. C.: Island Press.

- Newman, P., Beatley, T., and Boyer, H. (2009), *Resilient Cities: Responding to Peak Oil and Climate Change*, Washington, D. C.: Island Press.
- Numata, M. (1977) "The Impact of Urbanization on Vegetation in Japan, in A. Miyawaki and R. Tuxen, eds., *Vegetation Science and Environmental Protection*, Tokyo: Maruzen.
- OECD (1994), *Cities for the 21st Century*, Paris: Organization for Economic Co-operation and Development.
- Oke, T. R. (1974), *Review of Urban Climatology, 1968-1973*, Technical Note 134, Geneva: World Meteorological Organization.
- Olmsted, F. L., and Vaux, C. (1887), *General Plan for the Improvement of the Niagara Reservation*, New York: Gazette Book and Job Office.
- Philadelphia Water Department (2009), *Green City, Clean Waters: Combined Sewer Overflow Long Term Control Plan Update*, Philadelphia: City of Philadelphia.
http://www.phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan
- Pickett, S. T. A., and White, P. S., eds. (1985), *The Ecology of Natural Disturbance and Patch Dynamics*, Orlando, FL: Academic Press.
- Pickett, S. T. A., Burch, W., Jr., Dalton, S. E., Foresman, T. W., Grove, J. M., and Rowntree, R. (1997), "A Conceptual Framework for the Study of Human Ecosystems," *Urban Ecosystems* 1: 185-199.
- Pickett, S. T. A., Cadenasso, M. L., and Grove, J. M. (2004), "Resilient Cities: Meaning, Models, and Metaphor for Integrating the Ecological, Socio-economic, and Planning Realms," *Landscape and Urban Planning* 69: 4: 369-384.
- Pickett, S. T. A., Cadenasso, M. L., and Grove, J. M., Boone, C. G., Irwin, E., Groffman, P. M., Kaushal, S. S., Marshall, V., Mcgrath, B. P., Nilon, C. H., Pouyat, R. V., Szlavecz, K., Troy, A., Warren, P. (2010), "Urban Ecological Systems: Scientific Foundations and a Decade of Progress," *Journal of*

Environmental Management, 92: 331-362.

Pulliam, H. R., and Johnson, B. (2001), "Ecology's New Paradigm: What Does It Offer Designers and Planners?" in B. Johnson and K. Hill, eds., *Ecology and Design: Frameworks for Learning*, Washington: Island Press.

Reed, C. (2011), "The Agency of Ecology," in M., Mostafavi and G. Doherty, eds. (2010), *Ecological Urbanism*, Baden, Switzerland: Lars Müller.

Reice, S. R. (2001) *The Silver Lining: The Benefits of Natural Disasters*, Princeton, N. J.: Princeton University Press.

William Saunders, ed. (2012) *Designed Ecologies: The Landscape Architecture of Kongjian Yu*, Basel: Birkhauser.

Shochat, E., Lerman, S. B., Anderies, J. M., Warren, P. S., Faeth, S. H., Nilon, C. H. (2010) "Invasion, Competition, and Biodiversity Loss in Urban Ecosystems," *BioScience* 60:199-208.

Sonfist, A., ed. (1983), *Art in the Land: A Critical Anthology of Environmental Art*, New York: Dutton.

Spirn, A. W. (1984), *The Granite Garden: Urban Nature and Human Design*, New York: Basic Books.

— (1985), "Urban Nature and Human Design: Renewing the Great Tradition," *Journal of Planning Education and Research* 5:1: 39-51. Reprinted in J. M. Stein, ed. (1995), *Classic Readings in Urban Planning*, New York: McGraw-Hill.

— (1986), "Landscape Planning and the City," *Landscape and Urban Planning* 13: 433-441.

— (1987), "Air Quality at Street Level: Strategies for Urban Design," in A. V. Moudon (ed.), *Public Streets for Public Use*, New York: Van Nostrand Reinhold. (Abridged version, for full report see: http://www.annewhistonspirn.com/pdf/Air-Quality_1986.pdf)

- , ed. (1988a), *Nature, Form, and Meaning: A Special Issue*, *Landscape Journal* 7 (2).
- (1988b), “The Poetics of City and Nature: Toward a New Aesthetic for Urban Design,” *Landscape Journal* 7: 108-126.
- (1990), “Toward a Unified Vision: Architecture in the Landscape,” *Landscape Architecture Magazine* 80: 8 (August): 36-41.
- (1991), *The West Philadelphia Landscape Plan: A Framework for Action*, Philadelphia, Penn.: University of Pennsylvania, Department of Landscape Architecture.
(<http://www.annewhistonspirn.com/pdf/spirn-wplp-plan.pdf>)
- (1993), “Deep Structure: On Process, Form, and Design in the Urban Landscape,” in T. M. Kristensen, et al., eds., *City and Nature: Changing Relations in Time and Space*, Odense, Denmark: Odense University Press.
- (1994), “The International Conference on the Economic, Social, and Environmental Problems of Cities: The Impact and Next Steps,” in *Cities for the 21st Century*, Paris: Organization for Economic Co-operation and Development.
- (1995), “Constructing Nature: The Legacy of Frederick Law Olmsted,” in W. Cronon, ed., *Uncommon Ground: Toward Rethinking the Human Place in Nature*, New York: W. W. Norton.
- (1997), “The Authority of Nature: Conflict and Confusion in Landscape Architecture,” in J. Wolschke-Bulmahn, ed., *Nature and Ideology*, Washington: Dumbarton Oaks.
- (1998), *The Language of Landscape*, New Haven: Yale University Press.
- (2000a), “Reclaiming Common Ground: Water, Neighborhoods, and Public Spaces,” in R. Fishman, ed., *The American Planning Tradition: Culture and Policy*, Baltimore, MD: Johns Hopkins University Press.

— (2000b), “Ian McHarg, Landscape Architecture, and Environmentalism: Ideas and Methods in Context,” in M. Conan, ed., *Environmentalism and Landscape Architecture*, Washington: Dumbarton Oaks.

— 2003), “Urban Ecosystems, City Planning, and Environmental Education: Literature, Precedents, Key Concepts, and Prospects, in A. R. Berkowitz, C. H. Nilon, and Karen S. Hollweg, eds., *Understanding Urban Ecosystems*, New York: Springer-Verlag.

— (2005), “Restoring Mill Creek: Landscape Literacy, Environmental Justice, and City Planning and Design,” *Landscape Research* 30: 359-377.

— (2008), “One with Nature”: Landscape, Language, Empathy, and Imagination,” in R. DeLue and J. Elkins, eds., *Landscape Theory*, New York: Routledge.

Stearns, F. (1971), *Urban Botany: An Essay on Survival*. University of Wisconsin Field Station Bulletin 4:1-6.

— and Montag, T. (1974), *The Urban Ecosystem: A Holistic Approach*, Stroudsburg, Pa.: Dowden, Hutchinson, and Ross.

Steiner, F. R. (2002), *Human Ecology: Following Nature’s Lead*, Washington, D. C.: Island Press.

Sukopp, H., and Werner, P. (1982), *Nature in Cities: A report and Review of Studies and Experiments Concerning Ecology, Wildlife, and Nature Conservation in Urban and Suburban Areas*, Strasbourg: Council of Europe.

Sukopp, H., Hejny, S., and Kowarik, I., eds. (1990), *Urban Ecology: Plants and Plant Communities in Urban Environments*, The Hague: SPB Academic Publishers.

Tansley, A. G. (1935), “The Use and Abuse of Vegetational Concepts and Terms,” *Ecology* 16:284-307.

Tarr, J. A. (1996), *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective*, Akron,

Ohio: University of Akron Press.

Thomas, W. L., Jr, ed. (1956), *Man's Role in Changing the Face of the Earth*, Chicago: University of Chicago Press.

Thompson, G., and Steiner F., eds. (1997), *Ecological Design and Planning*, New York: Wiley.

Tourbier, J. P., and Westmacott, R. (1981), *A Handbook of Measures to Protect Water Resources in Land Development*, Washington, D. C.: Urban Land Institute.

Vale, L. J., and Campanella, T. J., eds. (2005), *The Resilient City: How Modern Cities Recover from Disaster*, New York: Oxford.

Van der Ryn, S., and Cowan, S. (1996) *Ecological Design*, Washington: Island Press.

Vandruff, L. W., Leedy, D. L., and Stearns, F. W. (1995), "Urban Wildlife and Human Well-Being," in H. Sukopp, M. Numata, and A Huber, eds., *Urban Ecology as the Basis of Urban Planning*, The Hague: SPB Publishing.

Waldheim, C., ed. (2006), *The Landscape Urbanism Reader*, New York: Princeton Architectural Press.

Wenk, W. (2002), "Toward an Inclusive Concept of Infrastructure," in B. R Johnson and K. Hill, eds., *Ecology and Design: Frameworks for Learning*, Washington: Island Press.

Wescoat, J. L., Jr. (2009a), "Waterscapes and Water-Conserving Design," *Landscape* 25 (Monsoon): 83-87.

— (2009b), "Water Shortages and Water-Conserving Urban Design in Pakistan," *Pakistan's Water Crisis*, M. Kugelman, ed., Washington, DC: Woodrow Wilson Center: 129-152.

White, R. (1996), *The Organic Machine*, New York: Hill and Wang.

Williams, R. (1980), "Ideas of Nature," in *Problems in Materialism and Culture*, London: Verso.

Wines, J. (2000), *Green Architecture*, New York: Taschen.

Wolman, A. (1965), "The Metabolism of Cities," *Scientific American* (March): 178-90.

Wu, J., and Loucks, O. (1995), "From Balance of Nature to Hierarchical Patch Dynamics: A Paradigm Shift in Ecology," *Quarterly Review of Biology* 70: 439-466.

Yaro, R., and Hiss, T. (1996), *A Region at Risk: The Third Regional Plan for the New York-New Jersey-Connecticut Metropolitan Area*, Washington, D. C.: Island Press.