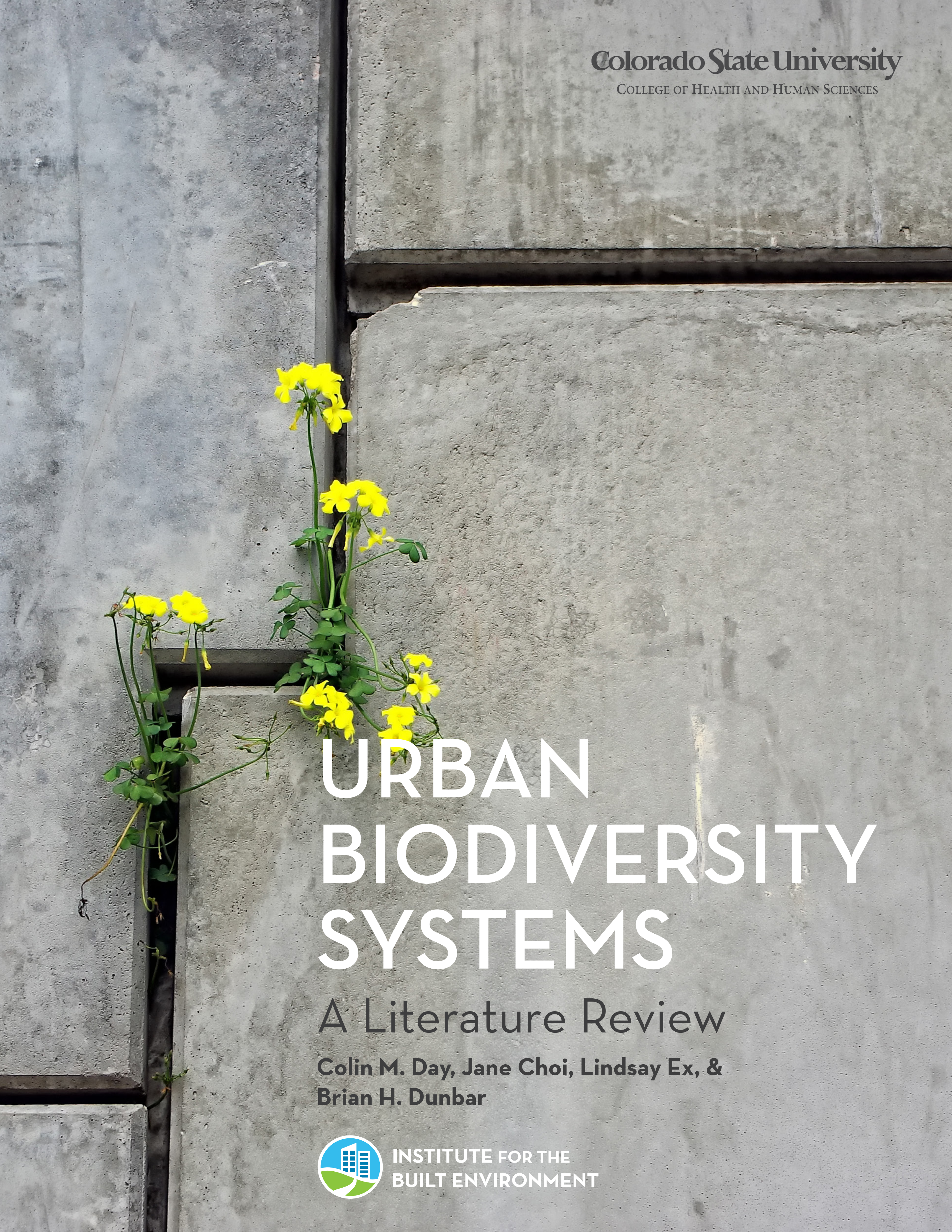

Colorado State University
College of Health and Human Sciences

URBAN BIODIVERSITY SYSTEMS

A Literature Review

Colin M. Day, Jane Choi, Lindsay Ex, & Brian H. Dunbar

INSTITUTE FOR THE BUILT ENVIRONMENT

ABSTRACT

As the global population shifts toward an increasingly urban matrix, the importance of developing a robust system of biodiversity management on a city scale will continue to grow. Conventional urban design has led to considerable problems with ecological health and human well-being and is not suited to deal with pressing urban issues such as natural resources conservation, climate adaptation and mitigation, and ecosystem stewardship. A more coherent blend of natural and built environments is possible, one that provides mutual benefit for species and humans. This review surveys the literature on urban ecosystems since 1994, utilizing currently accepted research on biodiversity, natural conservation, stewardship, management, and climate adaptation and mitigation in order to advance an ethic of best practices for cities and their biodiversity management goals.

Authors

Colin M. Day, M.L.A. colin.day@colostate.edu

Projects Manager, Institute for the Built Environment
Colorado State University

Jane Choi, M.L.A. jane.choi@colostate.edu

Assistant Professor, Landscape Architecture
Colorado State University

Lindsay Ex, M.L.A. lex@fcgov.com

Senior Environmental Planner
City of Fort Collins

Brian H. Dunbar, M.Arch, LEED Fellow

Executive Director, Institute for the Built Environment
Professor Emeritus, Colorado State University

Contributors

Josie Plaut, Associate Director of The Institute for the Built Environment; Jeni Cross, Director of Research of The Institute for the Built Environment; Stephanie Barr, Research Associate & Projects Manager at The institute for the Built Environment; Travis Lowder, Energy Analyst for the National Renewable Energy Laboratory; Taryn Finnessey, Climate Change Risk Management Specialist in the State of Colorado's Department of Natural Resources; and Dan Luecke, Consultant in Water and Environmental Resources Management

Citation

Day, C.M., Choi, J., Ex, L., & Dunbar, B.H. (2016). Urban Biodiversity Systems: A Literature Review. Institute for the Built Environment, Colorado State University. Fort Collins, CO.

Funding

The research reported in this publication was supported by The School of Global Environmental Sustainability at Colorado State University. The content is solely the responsibility of the authors and does not necessarily represent the official views of the School of Global Environmental Sustainability.

Support

This research was conducted under the direction of the Master of Landscape Architecture program, a part of the Department of Horticulture and Landscape Architecture in the College of Agricultural Sciences at Colorado State University.

ABOUT IBE

The mission of The Institute for the Built Environment is to advance the development of healthy, thriving built environments. We are based at Colorado State University and form interdisciplinary teams of faculty and students and off-campus professionals to take research to practice.

CONTENTS

INTRODUCTION

As the global population shifts toward an increasingly urban matrix, the importance of developing a robust system of biodiversity management on a city scale will continue to grow. Definitions of “urban” vary, but each typically relies on metrics such as population density, presence of building and infrastructure types, and percent impervious surface per unit of area (MacGregor-Fors, 2011). To date, more than half of the global population resides in urban areas and the proportion will likely grow as job availability increases and as urban populations continue to reproduce (Bhatta, 2010). Scholars and demographers project that 2 billion human inhabitants will be added to the global population between 2030 and 2050, with most growth occurring in urban centers, particularly those in the developing world (Alberti, 2010; Magle et al., 2012; McDonald, Kareiva, & Forman, 2008). If population growth trends in the developing world follow those of the developed world, urban populations could constitute up to 80% of the global population by 2050 (S. Pickett et al., 2008).

While cities are often considered to be efficient in their delivery of human services (Grimm et al., 2008), they nevertheless have an effect on ecosystem health that extends far beyond their boundaries. This is particularly true of cities in the developed world today, where levels of consumption are greater. In the longer term, cities in the developing world will continue to grow their ecological footprint as they expand and quality of life increases for inhabitants. The majority of this urban growth is anticipated to occur in cities of less than 500,000, and the geographic footprint of these cities will increase in correlation (McDonald, Kareiva, & Forman, 2008). Further, in spite of the fact that the overall land area set aside for conservation purposes within the United States of America has increased more than twentyfold since 1950, the overall spatial footprint of cities nevertheless surpasses that of conservation lands within the USA (McDonald et al., 2009). If this trend continues, buffer areas between urban communities and conserved lands will continue to decrease, bringing cities physically closer to conserved areas.

These trends point toward an urgent need to program biodiversity goals into the structure of urban planning and design. With the proper management of resources, within both urban centers and the hinterlands affected by resource extraction for urban uses, the environmental impacts of urbanization may be minimized while quality of life, species richness, downstream water quality, and overall species health could increase. An analysis of research relating to urban ecosystems and their integrity indicates that proper planning for ecosystem resilience can have proven positive impacts on species richness and health. This review aims to explore and understand the current trends in urban ecology and biodiversity and the impacts and effects of urbanization on natural systems.

An overview and summary will be given of current research related to urban ecology and biodiversity from peer-reviewed articles, including over 100 articles within these fields:

- Urban ecology
- Landscape ecology
- Sociology
- City and land planning
- Landscape architecture
- Behavioral psychology
- Sustainability
- Biology
- Animal and plant science
- Economics
- Environmental management and conservation, among others.

The research reviewed was selected based on its relevance to the study of the urban built environment and its impacts on animal, plant, human, and environmental health. While papers published since 1994 were considered, papers published since 2008 were given preference in order to represent more recent evidence and discourse. Studies of particular relevance included recommendations based on case studies grounded in quantitative and qualitative evidence. While these case studies will not be directly reviewed within this research, they are nevertheless viewed as substantiation of the research agendas that they accompany.

SECTION 2 | contains an introduction to the current trends in global urban growth and the attendant effects on ecological integrity and ecosystem function in urban settings. The background research findings will introduce urban ecosystems, ecosystem services, and their impacts on urban human health and urban species.

SECTION 3 | details approaches to biodiversity in urban planning and design. Sustainability and the concepts of regenerative development and biophilia serve to introduce the concepts of an environmental ethic in urban design and development.

SECTIONS 4 AND 5 | synthesize the reviewed materials with the goal of arriving at a set of best practices for cities and their biodiversity management goals.

Section 1

the research

THE RESEARCH FINDINGS

The current research on urban biodiversity and ecology within the social and natural sciences provides evidence that at once clearly illustrates the adverse human and urban impacts on global and regional ecology, and also the opportunity that cities have to provide unique responses to these challenges. Urban growth in the developed world during the 21st century follows patterns that were established during the latter half of the 20th century and have trended toward ever expanding cities, aided by the growth of automobile culture. This type of development pattern has impaired the health of flora and fauna species within their native ranges and their ability to adapt to environments that they are not well evolved to. Generalist and invasive species within cities have proven more adaptive and competitive in these types of environments than those species whose historical ranges have been appropriated. Further, cities have co-developed with commerce in such a way that resource budgets of city-dwelling humans are much larger than can be supported within city boundaries. Because of this, cities have a far-reaching effect on ecology outside the urban core. Likewise, climates within cities have been altered not only because of land-use and cover change, but also because of changing regional and global climate patterns, creating altered temperature and precipitation patterns within cities and in surrounding areas.

These effects have exacerbated the ability of species to remain competitive within the niches that they are adapted to. These climate and land-use alterations have also suppressed the functionality of the services that the ecosystem provides species, and causes resultant decreases in soil, air, and water health. Because of these shifts, overall species health has decreased, including overall health indices for humans within cities. Generally, these patterns indicate that traditional urban growth since the mid-20th century has had an adverse net impact on ecological composition and functionality locally, regionally, and globally. Because of these conditions, it is important that city-level planning considers not only local ecology, but also the larger-scale resource and environmental impacts, and that cities provide residents with access to and education about natural spaces in order to increase health, well-being, and stewardship over time. The following sections will explore these trends in greater depth.

Urban Ecosystems

Urban ecosystems have evolved through a composite of manufactured and natural processes. The urban ecological structure, as it exists at the beginning of the 21st century, is at once biotic and abiotic. The framework of industry, and its processes and products, define the structure of the urban built environment. While popular conceptions of the city are often dichotomous with the natural world, the reality is that natural processes and biodiversity are often observed to have increased productivity in urban settings due to increased availability of food sources as well as prolonged breeding seasons, among other variables (Hanski, 2012). As heterotrophic systems (systems that cannot fix carbon internally) urban environments are dependent on energy and resources produced outside of the system itself – often in the immediate surroundings or beyond. This effect magnifies the influence of cities on the environment at large. Cities have the largest resource budgets and carbon impacts of all forms of human settlement (Alberti, 2010). For example, the city of Vancouver requires 180 times more space than its physical footprint to accommodate its resource and energy budget (S. Pickett et al., 2008).

The Convention on Biological Diversity, signed by 150 nations at the 1992 Rio Earth Summit, defines three spheres of urban ecology: 1) urban biodiversity, 2) regional biodiversity influence, and

3) global biodiversity influence. Urban biodiversity refers to the ecology functioning within the urban fabric, regional biodiversity influence refers to the effect that urban processes have on adjacent ecosystems (such as through the effects of effluents on surrounding watersheds), and global biodiversity influence refers to the resource footprint of a city, which is often geographically and ecologically far reaching in its impacts (Mace, Norris, & Fitter, 2012; Puppim de Oliveira et al., 2011). The field of human ecology considers these spheres of influence as nested within each other at differing scales. Smaller human ecosystems, such as those at the household level, have a correlative impact on scales of ecology. At the urban level, the human ecosystem affects the larger web of regional and global ecology through the impacts of the resource needs of urban-scale population dynamics (Goddard, Dougill, & Benton, 2010; Machlis, Force, & Burch, 1997). In other words, as urban systems increase in size, their energy and resource budgets increase more or less in proportion. These budgets are currently dependent in large part on fossil fuel technologies, the burning of which exacerbates processes such as the urban heat island effect and locally altered rainfall patterns (S. T. Pickett et al., 2011). Traditional (currently accepted and standard) design approaches and non-renewable energy sources intensify the environmental challenges that cities face. These effects are well documented, and will be further amplified by a changing climate (Ernstson et al., 2010; Gasper, Blohm, & Ruth, 2011).

The Effects of Traditional Urban Development

As mentioned, traditional urban development and planning patterns have affected the spatial relationships of previously connected ecosystems. Moreover, the most productive patches of remnant ecosystem and corridors within cities are given over to recreational and cultural uses, further limiting their ability to provide the scale of habitat necessary to support robust native populations of flora and fauna within cities (Baschak & Brown, 1995). Evidence shows that at current growth rates, urban development in high-income countries requires nearly three times the area per resident than urban development in low-income countries does (McDonald, Kareiva, & Forman, 2008), and causes a greater degree of fragmentation over greater areas. Additionally, further climate disturbance and land-use change are probable with greater numbers of people moving beyond the suburban fringe to exurban (commuter) communities. Exurban development has increased fivefold since the post-WWII expansion of the 1950s and accounts for a greater degree of biodiversity and ecosystem alteration than have conventional agriculture and forestry land-uses (Hansen et al., 2005).

Traditional city planning has had measurable effects on climate patterns at the regional scale. The urban heat island effect is the best documented of these impacts, but studies also show that lack of planning for building and street orientation in relation to wind patterns has an effect on regional temperatures (Eliasson, 2000), and that such considerations are rarely prioritized at a city planning level. Shifts in temperatures in and around cities alter local climates and affect local and regional species compositions, weather patterns, and overall global climate patterns (Brown, 2011). These effects can be expected to have increasingly negative impacts on species richness and ecological health within cities if a business-as-usual approach is taken within governments.

Understanding Urban Growth and Environmental Change

Urbanization and its attendant land-use changes impact the regularity of hydrology, geomorphology, climate function, biota, nutrient cycling, and biogeochemistry (Alberti, 2010; Baschak & Brown, 1995). These shifts are caused by altered precipitation in and around cities (due in part to the urban heat island effect), increased nutrient loads (primarily through the application of agricultural inputs that support urban food supplies), and waterborne pollutants within increased runoff (due to urban industrial pollutants that readily accumulate on impervious surfaces). The amplified force and quantity of runoff linked to storm events and alterations in land cover (i.e., greater amounts of impervious surfaces within urban environments) increase the likelihood of watercourse soil erosion. This trend may exacerbate downstream eutrophication within riparian corridors already stressed by siltification associated with agricultural nutrient loads (Alberti, 2010; Bolund & Hunhammar, 1999; Hostetler, Allen, & Meurk, 2011). Although ecological processes such as litter decomposition and nitrification increase in speed and velocity in urban environments (Alberti, 2010), these processes have been observed to have less positive impact on overall primary productivity in cities than in surrounding undeveloped areas (Bolund & Hunhammar, 1999).

Urban settings have developed spatial heterogeneity while increasing biotic homogeneity in comparison to surrounding rural and undeveloped native lands, without calculating for exotic species introductions by urban residents. After accounting for the presence of introduced exotics, urban ecologies appear to have a greater degree of species richness; in areas with a greater density of human populations, introduced plant species and communities likewise appear at higher frequencies (Kowarik, 2011). Compositional differences in land cover and spatial use patterns have altered the feedback mechanisms that drive ecological function in urban areas and have shifted environmental patterns at local and global levels (Alberti, 2010; S. T. Pickett et al., 2011). This trend has increased consistently since the middle of the 20th century; the quantity of land set aside for conservation globally has increased by over 10% since 1950 (McDonald et al., 2009). However, the distances between cities and biodiversity hotspots or areas set aside for conservation have decreased and will continue to diminish under current trends and projections. This pattern of growth will serve to increase pressure on ecosystems and species not well adapted to the ecological stressors of urban habitats (McDonald et al., 2009). Native species richness and productivity decrease dramatically along the urban-rural gradient, the presence of introduced food sources and changing climate conditions on the urban fringe has altered the habitats of many bird, butterfly, carabid (ground-dwelling) beetle, and moss and lichen communities (Kowarik, 2011). However, introduced exotics have tended to thrive in these habitats, often accounting for a net increase in overall biodiversity in and around cities (Hansen et al., 2005). Because of the observed increase in the frequency of many species along the urban-rural gradient, a clear understanding of overall species health has been difficult to achieve in the field of landscape ecology.

Urban Ecosystem Services

Ecosystem services have been defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al., 1998). These benefits include water and air filtration, carbon sequestration, and moderation of climate, erosion, and soil health (Alberti, 2010; Bolund & Hunhammar, 1999). These functions increase the integrity of biodiversity, socioeconomic and human health (Alberti, 2010; Baschak & Brown, 1995; La Rosa & Privitera, 2013). Some 60% of ecosystem services have been documented as currently in decline or overused (Mace, Norris, & Fitter, 2012). The value of these functions globally has been calculated at a minimum of US$33 billion/year at the end of the 20th century (Costanza et al., 1998). While those figures are controversial within academia, and have likely changed through the beginning of the 21st century, they serve to illustrate the potential financial impacts that a further decline of ecosystem services could have on the global economy.

Human land-use decisions, especially those related to resource use and settlement patterns, have had a direct influence on the functionality of ecosystems and the services they provide.

These impacts have affected ecosystem services, often adversely, at both the coarse and fine scales. However, these impacts are sometimes beneficial. The effect of the domestic garden on ecosystem function is an example of a fine-scale land use that may positively impact ecosystem services within the city. The form and composition of the urban domestic garden positively influence the provisioning, regulating, cultural, and supporting capacities of urban ecosystems. Gardens improve urban hydrology (flood mitigation, evapotranspiration, and groundwater recharge), energy use (insulation, wind buffering, and cooling capacities), pollinator health, air filtration, and biodiversity and habitat creation.

Behaviorally, the private domestic garden plays an important role in the development of perceived personal relationships with the natural world (Goddard, Dougill, & Benton, 2010). The negative impacts of urban domestic gardens may include potential increases in greenhouse gas emissions (through the use of motorized equipment and carbon intensive manufactured products such as concrete for hardscape and mined peat resources), the introduction of invasive plant species, the overuse and misuse of water for irrigation, and the domestic use of industrial fertilizers, herbicides, pesticides, and fungicides. However, the potential negative impacts of the urban domestic garden can be avoided through the introduction of heterogeneous, non-invasive plant guilds, the reuse of water and biomass in the garden landscape, and by decreasing energy demands through the use of canopy and windbreak-producing plants with high albedo (Cameron et al., 2012). This example illustrates the capacity that humans have to positively influence the performance of urban ecosystems through personal choices. Overall, ecosystem services are directly impacted by measures of biological composition, or biodiversity. Healthy and balanced ecosystems play a key role in the delivery of ecosystem services (Mace, Norris, & Fitter, 2012), which improve the health and experience of urban residents. For example, mixed forest stands sequester up to 15 tons of airborne carbon/hectare annually, while spruce stands may be two to three times as effective because of the larger leaf area that coniferous trees possess. In the city of Chicago, urban trees sequester over 5,000 tons of carbon annually, providing the city with US$9 million of air filtration per year (Bolund & Hunhammar, 1999). These numbers show a case for the conservation and restoration of ecosystem services at various governmental levels. Additionally, educational programs that enable urban residents to understand how to best support ecology within the city, and why personal decisions are important to overall urban health, may be useful tools in transforming interactions between citizens and ecosystems.

Urban Human Health

Urban life presents a variety of environmental/industrial dynamics that are not present in surrounding rural settings. For instance, urban residents suffer a greater number of traffic-related injuries and a higher rate of asthma than those living in non-urban areas (Douglas, 2012). These problems are largely related to the presence of unsafe pedestrian conditions, higher traffic counts and air pollution, the presence of pests such as cockroaches and rats, and mold associated with water leaks in buildings. These and other factors affect human behavior: violent crime is a persistent problem in many urban centers. While urban crime rates may be more closely correlated to levels of income and education, evidence suggests that urban residents with access to walkable greenspace are less likely to engage in incivility, aggressive and violent crime than those who have no such access (Douglas, 2012; Kuo & Sullivan, 2001). Perhaps this is because exposure to natural settings within cities has the perceived impact of making stressors more manageable.

Access to greenspace has a measurable positive impact on urban residents' physical, cognitive, and social levels. With a greater provision of access to greenspace in urban settings, general quality of life increases: physical activity and functionality increase, cardiovascular and pulmonary diseases decrease, longevity increases (especially among the elderly), students and workers who have visual access to trees perform better, and hospital patients with visual and physical access heal and are discharged more quickly (Bolund & Hunhammar, 1999; Douglas, 2012; Mansor, Said, & Mohamad, 2012). At the residential scale, the act of gardening increases physical health, community engagement, and creative expression (Cameron et al., 2012). The presence of physical and visual access to greenspace improves the overall health of urban residents, while supporting a greater degree of ecosystem functionality, thereby improving local, regional, and global environmental quality.

Urban Species

Many urban areas were originally established in biologically rich zones, such as those along watercourses and coastal regions. Moreover, the proximity of cities to biodiversity hotspots has increased as cities have spread outward in size from the urban core and this growth habit is directly responsible for several species extinctions, with a greater rate of such extinctions anticipated in coming years (Heller & Zavaleta, 2009; McDonald, Kareiva, & Forman, 2008). As cities have become increasingly urban, attendant spatial and compositional fragmentation has increased the environmental stressors that species face and has disconnected local species populations. It is also well documented within the field of landscape ecology that population fragmentation within species and between gene pools is an effect that occurs at a greater frequency within urban settlements due to factors such as roads blocking the genetic movement within species populations (Lesbarreres & Fahrig, 2012). Many species are unable to thrive in their former habitats due to the fundamental environmental changes caused by urbanization. Alterations in avian species compositions within urban settings are perhaps the best documented of any species group commonly found within cities. Ground-dwelling birds suffer greater predation with the presence of increased numbers of domestic pets such as dogs and cats; cavity-nesting species suffer habitat loss through the clearing of vegetative debris by urban forestry programs (Evans et. al, 2011); and avian mortality occurs with higher frequency due to aerial collision with vehicles and buildings (Jokimäki et al., 2011). This evidence points to a variety of environmental stressors and obstacles that inhibit the safe habitation of species within their traditional ranges where those ranges are interrupted by urban development. The accelerating rate of these changes, coupled with the habitat stressors associated with climate change, will further inhibit the ability of species to adapt to rapidly changing environments (Heller & Zavaleta, 2009).

Due to the environmental needs of many native specialist species whose habitats have been permanently altered by urbanization, it may not be possible to re-establish a complete composition of such pre-settlement conditions (Dearborn & Kark, 2010). It may, however, be possible to maximize the efficacy of city planning and design to promote species richness, and to profit from the improvements in environmental health resulting from high levels of introduced genera found within cities. Both genetic diversity and species diversity contribute to maximizing the overall benefits that urban residents derive from ecosystem services by maximizing the resilience of the system (Mace, Norris, & Fitter, 2012). Increasing resilience can be accomplished, in part, through planning and design decisions such as providing ecopassages for species to cross barriers such as roads and fencing to lead terrestrial animals to these crossings (Lesbarreres & Fahrig, 2012) and by providing greater connectivity of parks and open spaces, especially longitudinally (Heller & Zavaleta, 2009).

Section 2

in practice

APPROACHES TO BIODIVERSITY AND EDUCATION IN URBAN PLANNING AND DESIGN

Overview

The preceding section has outlined the challenges that traditional urban development causes for human and non-human species within cities, from decreased ecosystem functionality, to increased competition for habitat and food resources from generalist and invasive species, to overall climate shifts in and around cities. Looking forward, there are a variety of approaches that have been explored by city planners to alleviate these challenges, and to provide better support for local, regional, and global ecosystems. These approaches range from mitigating the effects of development, adapting to expected climate changes before they come to pass, and increasing the resilience and productive capacity of urban developments and the supportive resource shed they require. Further still, by understanding the patterns of changing climates and the species relationships that are developing anew because of these shifts, there is a potential to utilize these new relationships to increase the productivity and health of localized ecosystems. By supporting public discourse about the importance of nature and the ways in which it has been altered due to human activity, cities are capable of instilling a value of inherited and intrinsic appreciation for the nature found with and surrounding their jurisdictions.

Sustainable Development

The widely accepted definition of sustainable development was introduced by the United Nations in the 1987 Brundtland Report. According to the commission, sustainable development is "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). From the perspective of urban design and planning, the use of methods proven to increase ecosystem health is an effective approach to improving the quality of life of current residents while improving the likelihood of ecosystem functionality and the physical health of city residents in the future (Spyke, 2001). Although the concept of sustainability is not well defined in relation to development, and can have political connotations for many, the reality is that cities have a better capacity than other scales of government to address the sustainability of ecosystems as they relate to development patterns (Spyke, 2001). Supporting ecosystem services is an effective method for improving the ecological resilience of cities, and is achieved through proactive governance (Ernstson et al., 2010). For example, the installation of a neighborhood park serves to offset the urban heat island effect by decreasing neighborhood temperatures and increasing relative humidity (Brown, 2011). Offsetting the environmental and resource impacts of cities through localized design choices is one approach to stabilizing ecosystem health and functionality.

Through this frame, "sustainability" may be viewed as the attempt to achieve stasis within a system, and to maintain the current function of that system, without increasing its resource budget or its negative impacts on the environment. Within the context of climate change, sustainability is best achieved through a combination of mitigation (through reducing greenhouse gas loads) and adaptation (through adjusting the design and configuration of the built environment to the improve cities' resilience to the effects of further climate shifts) (Hamin & Gurran, 2009). "Resilience," within the context of development, refers to a city's capacity to adapt to and decrease the impacts of the effects of large-scale climate changes and disturbances. Urban densification is an essential component of increasing resilience now and in the future (Hamin & Gurran, 2009; Heller & Zavaleta, 2009). This approach refers to the tendency toward increasing urban density while decreasing suburban sprawl and exurban development in order to reduce both vehicle miles traveled, as well as the linear distance of the urban-rural gradient.

Beyond Sustainable: Regenerative and Adaptive Approaches

Sustainability has the effect of improving the resilience of a system beyond the capacity of traditional development. The positive influences of a more resilient system could be beneficial to both the development of ecology within and surrounding urban areas, as well as human health. There is a divide in the resilience discourse between a focus on resilience in cities (often achieved through local sustainability approaches) and the resilience of cities (which considers the greater impacts that cities have on the landscape and climate) (Ernstson et al., 2010). The resilience of cities approach may be a more useful approach to regenerate system functionality at a landscape scale due to its capacity to establish greater reciprocity between cities and their larger environmental contexts.

Finnish land planners have proposed the concept of “future natures,” which attempts to predict and integrate “eco-social novelties” or emergent ecological relationships across scales into an adaptive and participatory process, thereby establishing an “urban green governance” (Asikainen & Jokinen, 2009). This approach is useful within the context of research on methods that maximize urban biodiversity, adaptation to a changing climate, and the study of novel ecosystems. A novel ecosystem is one that is defined by the presence of climatic disturbance and spatial alterations to the degree that the local ecology evolves functionally to adapt to these changes (Hobbs, Higgs, & Harris, 2009; Kowarik, 2011). It is not well understood if these changes are positive or negative to long-term ecological function, only that human development patterns have the effect of creating sufficient changes to alter species composition and configuration. It is possible that by systematically utilizing the patterns observed within novel ecosystems that cities can increase biodiversity and resilience, especially in the face of a changing climate (Kowarik, 2011). Furthermore, these “hybrid” systems may be those best suited to adapt to unprecedented abiotic conditions such as those found in cities (Hobbs, Higgs, & Harris, 2009).

Potentially, restoration could be approached through the anticipated future conditions (in relation to climate change) instead of through traditional approaches to re-establishing irrevocably altered historical regimes (Heller & Zavaleta, 2009). By viewing the ecology of urban environments in terms of their potential to be usefully adapted to human habits—and to maximize biodiversity and ecosystem services while doing so—urban planners may be liberated from traditional conservation strategies that have been of marginal use or have proven obsolete. The concept of future natures and the study of novel ecosystems may provide the currency necessary to successfully approach public narratives surrounding planning strategies for urban greenspace, its ethic, and its governance in the 21st century.

Socio-Ecological Education and Values

The frames through which the public views nature are diverse. Through processes of public engagement, nature has been variously described as an object, a threat, an amenity, a restriction, and a process; and that it is possible to re-frame the context of nature for the public through the planning process (Asikainen & Jokinen, 2009). The importance of enabling dialogue about and supporting access to nature is fundamental in keeping urban residents engaged with species, ecosystems, and natural processes. Without the presence of a healthy ecology, interaction with natural processes in daily life leads to a decreased knowledge of the natural world. Urban residents with poor access to natural areas may potentially suffer an "extinction of experience" whereby general knowledge of natural processes and systems is never acquired (Goddard , Dougill, & Benton, 2010; Kowarik, 2011; Mansor, Said, & Mohamad, 2012).

Within this context, information can be seen as a critical resource for ecosystems and social structures. Healthy flows of energy and matter provide the means for survival, while information creates the fabric of society and common worldviews that are exchanged within social networks (Ernstson et al., 2010). Providing environmental education about local ecosystems is an effective way to integrate knowledge of natural systems into the experiential lexicon of urban residents (Magle et al., 2012). With this in mind, educational programming at the city level can be utilized to inform residents about the importance of individual decisions and views to regional ecology.

Biophilia and an Environmental Ethic

As previously noted, keeping gardens in urban settings increases personal connections to the natural world. The garden itself plays a proven role in the connection of natural systems within cities, as gardens have been shown to support significant bird and pollinator populations in the urban setting (Goddard, Dougill, & Benton, 2010). It is possible that in the process of supporting the health of natural systems on a personal level, gardeners are exhibiting an environmental ethic that extends beyond their own immediate experience. This ethic has been described as "biophilia," which is defined as humanity's "innate tendency to focus on life and lifelike processes" (Wilson, 1984). Biophilia research has proven the intrinsic psychological connection between human populations and their natural settings (Kahn Jr, 1997).

The inherited connection to the environment is expressed in a variety of ways. Although the frames through which the general public views nature differ on individual levels, studies on personal preferences suggest that across cultures and demographics, natural settings account for the majority of sites that respondents value most (Van den Born et al., 2001). The same studies indicate that the intrinsic value of the environment and its importance to human health and future generations were commonly held beliefs. Earlier research on the psychology of nature discovered that humans prefer natural to built environments, and built environments with a variety of natural amenities to those that lack such features (Kaplan & Kaplan, 1989). These findings form much of the fundamental structure of the biophilia hypothesis and reveal that, while humans maintain many fears associated with nature, it is nonetheless accepted within the field of psychology that humans have an inherent connection to the natural world.

Our psychological associations with nature extend beyond the general inclination to natural settings and features. The origin of these preferences has been explored by psychoevolutionary theory, which holds that humans have adopted risk aversions to potentially dangerous or damaging settings, and preference for locales that support survival and reproduction (Plutchik, 2001). Subsequent research within the field of psychoevolutionary theory additionally links architecture and design that utilize natural forms to healthy emotional and cognitive functions (Joye, 2007). From this perspective, it may be stated that built environments that contain a variety of natural amenities and settings, employ forms found in nature within their design and construction, and support human health and well-being correspond with psychological preferences that have evolved over the course of human history.

Section 3

synthesis

URBAN DESIGN BIODIVERSITY RECOMMENDATIONS

By synthesizing the previously discussed positive impacts of well-integrated urban ecology, city planners and designers can make decisions that maximize all species' capacity for wellness and survival. For example, the connection of ecological remnant patches and corridors to one another within the city, and to larger-scale ecosystems surrounding the city, will increase both the competitive advantage of many species not well suited for urban ecosystems (Baschak & Brown, 1995). The preservation and restoration of native plant habitats and the allowance for higher levels of succession (particularly along riparian corridors) within cities is a primary consideration for the sustained productivity of urban ecosystems (Baschak & Brown, 1995). Further, the positive impacts of ecosystem services on human inhabitants provided by natural spaces within and surrounding cities can be maximized through proper environmental planning and management. On a basic level, by managing ecologically sensitive areas and recreational uses in separate locations, habitats can be protected and restored and stewardship prioritized within the public consciousness (McDonald et al., 2009).

Further, promoting public education and awareness should be an important component of any city's conservation and biodiversity plan. The involvement of the public in educational and stewardship opportunities may be the best way to ensure biological conservation in urban settings now and in the future. By increasing public access to natural systems, and education about their importance, cities can ensure that values will be inherited. Offering children firsthand contact with natural systems provides them with the ability and incentive to become engaged with nature and to integrate it into their ethical systems (Dearborn & Kark, 2010). Access to natural areas, educational programming about and within these spaces, and the opportunity to view charismatic and beautiful species have a positive impact on the human experience of nature, with the positive consequence of shifting ethics and behaviors regarding nature.

In order to provide cohesive and coordinated approaches to planning, integrating values that support biodiversity and establishing an urban green governance on a city level require institutional learning, adoption of new and adaptive policies, and participatory, inclusive, and multidisciplinary approach to urban ecology (Asikainen & Jokinen, 2009; Heller & Zavaleta, 2009). While ecosystem management is best achieved with the cooperation of federal, state, and local scales, city-level governance may be the best and most flexible approach to shift zoning policies and to garner the support of the citizenry (Spyke, 2001). Further, innovation at the municipal level has the capacity to radically shift social and ecological patterns within the urban environment and to create a "socio-ecological" network and dynamic (Ernstson et al., 2010). The diversity of natural settings accessible within cities, coupled with innovative approaches, has an increased positive impact on the experience and health of urban residents (Mansor, Said, & Mohamad, 2012). These spaces can and should include non-traditional greenspaces and green infrastructures such as those found in incidental settings, friche (former fallow industrial and waste sites), pocket parks, sites utilized for informal recreation, community and private gardens, tree lawns, and green alleyways (Mansor, Said, & Mohamad, 2012; Wolch et al., 2010). This is especially true if these spaces include vegetation in sufficient quantity to improve ecological function and human and environmental health (La Rosa & Privitera, 2013). Novel ecosystem trends should be considered as a possible approach to improving the biodiversity and resilience of cities, particularly if the introduced system provides ecosystem services, does not promote invasive and exotic suppression of native species, and provides opportunities for community engagement (Hobbs, Higgs, & Harris, 2009). These sites and systems should be identified through analytical mapping tools and grounded in evidence-based research in order to best utilize their possible benefits and create innovative conservation approaches for healthy ecologies and biodiversity within the context of the city.

Conclusion

While it is well documented that traditional urban development exacerbates environmental degradation and local, regional, and global scales, various levels of government have the capability to shift this trend now and in the future. Through intentional planning and educational programming at the city level, municipal governments have the capacity to support ecological functions within and surrounding cities and to inform individual views of and responses to the sphere of urban biodiversity. Denser development within city boundaries that reverses the trend of suburban growth witnessed during the latter half of the 20th century can improve the functionality and species richness of ecosystems along the urban-rural gradient and maintain safe distances between cities and areas removed from city boundaries that have been set aside for conservation purposes. Within the city, the distribution, density, and health of species' communities can be supported through the separation of recreational and natural habitat zones and through the provision of corridors that connect ecosystem patches. An ethic that supports these goals must be engendered within the population if policy makers and planners intend to encourage future inheritance of these values. This approach has the potential to build a social value structure that surpasses the goal of parity proposed by sustainability. With a proper understanding of the research on urban biodiversity, urban design, city planning, and the observed connections between ecological functionality and human health and well-being, policy makers and planners have the opportunity to positively affect the experience that all species have of city life. A variety of well-researched approaches to urban biodiversity may be used by city governments and planners in order to regenerate environmental functionality and productivity within the city and to positively impact the health of the city itself, surrounding regions, and overall global environmental patterns now and in the future.

CITATIONS

Alberti, M. (2010). Maintaining ecological integrity and sustaining ecosystem function in urban areas. Current Opinion in Environmental Sustainability, 2(3), 178–184. doi: 10.1016/j.cosust.2010.07.002.

Asikainen, E., & Jokinen, A. (2009). Future natures in the making: Implementing biodiversity in suburban land-use planning. Planning Theory & Practice, 10(3), 351–368.

Baschak, L. A., & Brown, R. D. (1995). An ecological framework for the planning, design and management of urban river greenways. Landscape and Urban Planning, 33(1), 211–225.

Bhatta, B. (2010). Causes and consequences of urban growth and sprawl. An analysis of Urban Growth and Sprawl from Remote Sensing Data, 17 - 36. New York: Springer.

Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. Ecological economics, 29(2), 293–301.

Brown, R. D. (2011). Ameliorating the effects of climate change: Modifying microclimates through design. Landscape and Urban Planning, 100(4), 372-374. doi: 10.1016/j .landurbplan.2011.01.010

Brundtland, G. H. (1987). Brundtland Report. Our Common Future. Comissão Mundial.

Cameron, R. W. F., Blanuša, T., Taylor, J. E., Salisbury, A., Halstead, A. J., Henricot, B., & Thompson, K. (2012). The domestic garden–Its contribution to urban green infrastructure. Urban Forestry & Urban Greening, 11(2), 129–137. doi: 10.1016/j.ufug.2012.01.002.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., . . . Paruelo, J. (1998). The value of the world's ecosystem services and natural capital. Ecological Economics, 25(1), 3–15.

Dearborn, D. C., & Kark, S. (2010). Motivations for conserving urban biodiversity. Conservation Biology, 24(2), 432–440. doi: 10.1111/j.1523-1739.2009.01328.x.

Douglas, I. (2012). Urban ecology and urban ecosystems: understanding the links to human health and well-being. Current Opinion in Environmental Sustainability, 4(4), 385–392. doi: 10.1016/j.cosust.2012.07.005.

Eliasson, I. (2000). The use of climate knowledge in urban planning. Landscape and Urban Planning, 48(1), 31–44.

Ernstson, H., Leeuw, S. E., Redman, C. L., Meffert, D. J., Davis, G., Alfsen, C., & Elmqvist, T. (2010). Urban transitions: On urban resilience and human-dominated ecosystems. Ambio, 39(8), 531–545. doi: 10.1007/s13280-010-0081-9.

Evans, K. L., Chamberlain, D. E., Hatchwell, B. J., Gregory, R. D., & Gaston, K. J. (2011). What makes an urban bird? Global Change Biology, 17(1), 32–44. doi: 10.1111/j.1365-2486.2010.02247.x.

Gasper, R., Blohm, A., & Ruth, M. (2011). Social and economic impacts of climate change on the urban environment. Current Opinion in Environmental Sustainability, 3(3), 150–157.

Goddard, M. A., Dougill, A. J., & Benton, T. G. (2010). Scaling up from gardens: Biodiversity conservation in urban environments. Trends in Ecology & Evolution, 25(2), 90V98. doi: 10.1016/j.tree.2009.07.016.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. Science, 319(5864), 756–760.

Hamin, E. M., & Gurran, N. (2009). Urban form and climate change: Balancing adaptation and mitigation in the U.S. and Australia. Habitat International, 33(3), 238–245. doi: 10.1016/j.habitatint.2008.10.005.

Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, K., Gude, P. H., & Jones, K. (2005). Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. Ecological Applications, 15(6), 1893–1905.

Hanski, I. (2012). Urban ecology: More than you expected. Trends in Ecology & Evolution, 27(6), 314–315. doi: 10.1016/j. tree.2012.03.006.

Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. Biological Conservation, 142(1), 14–32. doi: 10.1016/j.biocon.2008.10.006.

Hobbs, R. J., Higgs, E., & Harris, J. A. (2009). Novel ecosystems: Implications for conservation and restoration. Trends in Ecology & Evolution, 24(11), 599–605. doi: 10.1016/j.tree.2009.05.012.

Hostetler, M., Allen, W., & Meurk, C. (2011). Conserving urban biodiversity? Creating green infrastructure is only the first step. Landscape and Urban Planning, 100(4), 369–371. doi: 10.1016/j.landurbplan.2011.01.011.

Jokimäki, J., Kaisanlahti-Jokimäki, M.-L., Suhonen, J., Clergeau, P., Pautasso, M., & Fernández-Juricic, E. (2011). Merging wildlife community ecology with animal behavioral ecology for a better urban landscape planning. Landscape and Urban Planning, 100(4), 383–385. doi: 10.1016/j. landurbplan.2011.02.001.

Joye, Y. (2007). Architectural lessons from environmental psychology: The case of biophilic architecture. Review of General Psychology, 11(4), 305.

Kahn, P.H., Jr. (1997). Developmental psychology and the biophilia hypothesis: Children's affiliation with nature. Developmental Review, 17(1), 1–61.

Kaplan, R., & Kaplan, S. (1989). The experience of nature: A psychological perspective: CUP Archive.

Kowarik, I. (2011). Novel urban ecosystems, biodiversity, and conservation. Environmental Pollution, 159(8–9), 1974–1983. doi: 10.1016/j.envpol.2011.02.022.

Kuo, F. E., & Sullivan, W. C. (2001). Environment and crime in the inner city: Does vegetation reduce crime? Environment and Behavior, 33(3), 343–367.

La Rosa, D., & Privitera, R. (2013). Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts. Landscape and Urban Planning, 109(1), 94–106. doi: 10.1016/j

.landurbplan.2012.05.012.

Lesbarreres, D., & Fahrig, L. (2012). Measures to reduce population fragmentation by roads: What has worked and how do we know? Trends in Ecology & Evolution, 27(7), 374-380. doi: 10.1016/j.tree.2012.01.015.

Mace, G. M., Norris, K., & Fitter, A. H. (2012). Biodiversity and ecosystem services: a multilayered relationship. Trends in Ecology & Evolution, 27(1), 19–26. doi: 10.1016/j.tree.2011.08.006.

MacGregor-Fors, I. (2011). Misconceptions or misunderstandings? On the standardization of basic terms and definitions in urban ecology. Landscape and Urban Planning, 100(4), 347–349. doi: 10.1016/j.landurbplan.2011.01.013.

Machlis, G. E., Force, J. E., & Burch, W. R. (1997). The human ecosystem Part I: The human ecosystem as an organizing concept in ecosystem management. Society & Natural Resources, 10(4), 347–367. doi: 10.1080/08941929709381034.

Magle, S. B., Hunt, V. M., Vernon, M., & Crooks, K. R. (2012). Urban wildlife research: Past, present, and future. Biological Conservation, 155, 23–32. doi: 10.1016/j.biocon.2012.06.018.

Mansor, M., Said, I., & Mohamad, I. (2012). Experiential Contacts with green infrastructure's diversity and well-being of urban community. Procedia—Social and Behavioral Sciences, 49, 257–267. doi: 10.1016/j.sbspro.2012.07.024.

McDonald, R. I., Forman, R. T. T., Kareiva, P., Neugarten, R., Salzer, D., & Fisher, J. (2009). Urban effects, distance, and protected areas in an urbanizing world. Landscape and Urban Planning, 93(1), 63–75. doi: 10.1016/j.landurbplan.2009.06.002.

McDonald, R. I., Kareiva, P., & Forman, R. T. T. (2008). The implications of current and future urbanization for global protected areas and biodiversity conservation. Biological Conservation, 141(6), 1695–1703. doi: 10.1016/j.biocon.2008.04.025

Pickett, S., Cadenasso, M., Grove, J., Nilon, C., Pouyat, R., Zipperer, W., & Costanza, R. (2008). Urban ecological systems: Linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. In Urban Ecology, 99–122. New York: Springer.

Pickett, S. T., Cadenasso, M. L., Grove, J. M., Boone, C. G., Groffman, P. M., Irwin, E., . . . Warren, P. (2011). Urban ecological systems: Scientific foundations and a decade of progress. Journal of Environmental Management, 92(3), 331–362. doi: 10.1016/j.jenvman.2010.08.022.

Plutchik, R. (2001). The Nature of Emotions Human emotions have deep evolutionary roots, a fact that may explain their complexity and provide tools for clinical practice. American Scientist, 89(4), 344–350.

Puppim de Oliveira, J. A., Balaban, O., Doll, C. N. H., Moreno-Peñaranda, R., Gasparatos, A., Iossifova, D., & Suwa, A. (2011). Cities and biodiversity: Perspectives and governance challenges for implementing the convention on biological diversity (CBD) at the city level. Biological Conservation, 144(5), 1302–1313. doi: 10.1016/j.biocon.2010.12.007.

Spyke, N. P. (2001). Charm in the city: Thoughts on urban ecosystem management. Journal of Land Use & Environmental Law, 153–197.

Van den Born, R. J., Lenders, R. H., Groot, W. T. D., & Huijsman, E. (2001). The new biophilia: An exploration of visions of nature in Western countries. Environmental Conservation, 28(01), 65V75.

Wilson, E. O. (1984). Biophilia. Cambridge: Harvard University Press.

Wolch, J., Newell, J., Seymour, M., Huang, H. B., Reynolds, K., & Mapes, J. (2010). The forgotten and the future: Reclaiming back alleys for a sustainable city. Environment and Planning. A, 42(12), 2874.

INSTITUTE FOR THE
BUILT ENVIRONMENT
Taking Research to Practice