FRAMEWORK FOR RECONCILIATION: ADAPTING AN URBAN PARK TO WELCOME LITTLE BROWN BATS (MYOTIS LUCIFUGUS)

by

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(Under the Direction of Eric MacDonald)

ABSTRACT

This thesis explores Michael Rosenzweig's concept of reconciliation ecology to advocate for including native wildlife as stakeholders in urban design to activate public spaces for conservation. The thesis begins with a brief review of biodiversity conservation within conservation biology, a field focused on species needs, and landscape architecture, a profession driven to improve the human environment. Guided by a select review of existing frameworks for conservation design, and a synthesis of urban wildlife habitat program guidelines, the thesis proposes a preliminary framework for reconciliation ecology site design that includes species within site programming. The framework identifies opportunities for habitat within existing landscape types, with their embedded cultural values, based on the life cycle habitat requirements of wildlife species. Projective design then applies the framework to a public park in Burlington, Vermont, for a focal species, the little brown bat (*Myotis lucifugus*). The selected site responds to Rosenzweig's call to include species in habitats where humans "live, work and play."

INDEX WORDS: reconciliation ecology, little brown bat, urban design, biodiversity, Vermont

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DEDICATION

Every city has some testimony to perception, intelligence and art,

there are oases of concern and creation. ....

We need nature as much in the city as in the countryside. In order to endure we must maintain the bounty of that great cornucopia which is our inheritance.

Ian McHarg

This thesis is dedicated to the Spirit and beings who shape oases in daylight and moon glow; the dedicated individuals who steward them; and all those who appreciate them, most especially, my dearest Madeleine, Elsa, Torunn and Pete. My oasis is in you. Thank you for believing in me and for the great adventure.

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To Cari Goetcheus, I am grateful for your guidance and friendship.

To my long-suffering family - the weight is lifted. Thank you for helping me carry it.

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CHAPTER 1

INTRODUCTION

Humans now dominate 90-95% of the terrestrial earth for our own uses, a trend that is continuing as our population grows (Miller 2008, 118). This era has been called the “urban century” (Gaston 2010c), with just over half of the world’s population living in urbanized areas and expected to increase to 66% by 2050 (United Nations Department of Economic and Social Affairs Population Division 2014). The dense concentration of people in urban areas and the land use patterns associated with urbanization “profoundly changes both the abiotic and biotic properties of ecosystems” not only within an urban area but also in landscapes surrounding urban areas (Gaston, Davies, and Edmondson 2010) as these areas are typically converted to zones of intensive agriculture (Ricketts et al. 2008). These patterns of intentional design and other human activities related to resource consumption pose the greatest threat to the earth’s ecosystems (Ricketts et al. 2008) and imperil the ability of natural ecosystems to provide the services on which we depend (Beck 2013).

Problems of the Anthropocene

The impact of urban development and associated patterns of behavior extend well beyond the local and regional landscape surrounding an urban center, to impact the global environment (McKinney 2010). Human resource use, material creation, and disposal have created such a strong imprint on the global biosphere, that “Earth has entered a new geological epoch" (Vaughan 2016). This new epoch, known as the Anthropocene, records a suite of human impacts and degradations occurring at an unprecedented rate and scale, with wide-ranging impacts to ecosystem health, biodiversity, and human health and well-being. Within the geological stratigraphy, the Anthropocene is visible through deposits of black carbon particulates from fossil fuel consumption, radioactive isotopes deposited through nuclear weapons testing in the mid-twentieth century; cumulative production of concrete; and ubiquitous micro-plastic particles in global waterways (Vaughan 2016).

Ecosystem Health

Throughout the history of urbanism, the forms and patterns of the built environment have evolved in response to changes in culture, technology, consumption patterns, religion and scientific awareness. Urban areas, as designed landscapes, are not only shaped by the values of society but also communicate them as well (Rogers 2001). Within American culture, the conceptual separation of humans from nature has resulted in built landscapes that seek to tame "wilderness"(Cronon 1996), which may have achieved its aesthetic height early in the 20th century during the Modernist period. A data-driven approach to spatial segregation and increasing urban density has become a "recurrent historical tendency" within the planning and design professions and is a standard response to any perceived problems within the urban environment (Margalit 2012).

Kunstler (1994) says modernism created "a physical setting for man that failed to respect the limits of scale, growth, and the consumption of natural resources, or to respect the lives of other living things." The process of achieving what is commonly regarded as an urban form and automobile-focused lifestyle (Kunstler 1994) results in intensely modifying and “often obliterating” the preexisting natural habitats (McKinney 2010). Urban areas tend to expand with suburban areas reaching farther into surrounding natural areas or formerly productive lands. This expansion of urban land use has grown faster than the preservation of land through parks or conservation areas (McKinney 2002). As a result of this process, urbanization is typically viewed as a “major cause of species extinction and ecological damage” (McKinney 2010). The environmental impacts of urbanization are greater and longer-lasting than those caused by logging, agriculture and mining (McKinney 2010) in part due to the ever-widening networks of resource extraction necessary to meet the current consumption demands of urban centers. As the global population continues to approach its potential maximum level of 10 billion people during this century, it is likely that food production will have to increase not only on existing agricultural land but new agricultural areas will also have to be cleared (Weller 2014). This trend has resulted in serious degradation of 60% of the earth’s ecosystems by 2005, a trend only expected to continue (2005).

The 2005 Millennium Ecosystem Assessment found that at the global scale, ecosystems were being degraded beyond their ability to continue providing the services that our social and economic systems have been built upon. The Assessment found that one cause of ecosystem degradation is the global reduction in “variety” of species, also known as biodiversity, which lowers the resiliency of ecosystems. One primary mechanism of biodiversity loss is the conversion of habitat to agriculture. This is compounded by the heavy reliance on manufactured fertilizer within large scale industrial agriculture, which causes a buildup of nitrogen in freshwater and coastal systems, further reducing biodiversity (Millenium Ecosystem Assessment 2005b). While humans are reducing resiliency, or the ability of an ecosystem to recover from a disturbance, by lowering biodiversity, we are simultaneously imposing on them “unprecedented” pressures (MEA Biodiversity 2005).

Biodiversity Crisis

In the last 50 years there has been a greater loss of biodiversity due to human activities than during any other period of human history (Millenium Ecosystem Assessment 2005a). Biodiversity is being lost up to 1000 times the natural rate resulting in the greatest extinction crisis since the dinosaurs (IUCN 2010). The main threats to biodiversity include habitat loss and degradation, invasive alien species, over-exploitation of natural resources, and human-induced climate change (IUCN 2010).

Urban areas, calculated as only three percent of Earth’s land area in 2005 (Millenium Ecosystem Assessment 2005b) have a disproportionately large impact on ecological systems at both the regional and ecological scales due to the intensive resource consumption and waste production (Collins and Kinzig 2000 in McCleery, Moorman, and Peterson 2014). The nearly universal attributes of urbanization include warmer temperatures, greater water inputs, disrupted nutrient cycles, altered chemistry (including the alkalinizing effect of concrete and the use of road salt), structural changes (loss of canopy and topsoil, more vertical obstacles), increased sound and light, and huge inputs of energy into the urban system. These changes affect species differently resulting in three categories of response that correlate to their presence/absence along the urban gradient: avoidance, adaptation, exploitation (McKinney 2006).

Species that are sensitive to urbanization (the “avoiders”) quickly disappear once a threshold of urban development has been crossed. Some species are able to survive in urban environments by adapting (e.g. using artificial nesting structures) while still making use of natural resources. These urban-adaptable species (also known as synanthropic) are most often edge-adapted species or those associated with early successional landscapes. These species are more common in areas with lower levels of urbanization such as that found in suburban and peri-urban areas. The species that are most abundant in urban areas are urban exploiters that become dependent on urban resources for food and other habitat needs. Finally, even synanthropic species that may have coevolved with human settlements can share a tenuous relationship with urbanizing areas and human land management actions.

Bats are a taxonomic group which may have co-evolved with humans (Voigt et al. 2015) but ironically, humans and human land use are major threats to bats. In urban landscapes, synanthropic species such as little brown bats (*Myotis lucifugus*) are attacked by pets; excluded from buildings during vulnerable times such as winter or in summer when the pups are flightless; poisoned by pesticides; and affected by light pollution and acoustic disturbance. The composition and three-dimensional structure of the urban landscape itself also poses threats to bats. Roads and vertical surfaces create barriers to movement, and serve as zones of impact, while open expanses of hard smooth paved ground plane can mimic the acoustic quality of smooth water, causing injury during attempts to forage. Outside of the urban landscape, agricultural pesticides and wind energy further impact individual survival. The cumulative impacts of these numerous threats to individual survival are gravely exacerbated by stochastic events such as disease that can prove perilous to species populations. At present populations of cave bat species within the United States are being decimated by the invasive fungus *P. destructans*, which causes White-Nose Syndrome. As a result, once common species such as little brown bats are showing significant population decline.

Human Health and Wellbeing

In addition to the concern over the economic and environmental sustainability of current modes of development and consumption, there is growing concern over the effects of urbanization on human health and wellbeing. According to the World Health Organization, urban air pollution kills approximately 1.2 million people each year around the world, a major cause of which is motor vehicle emissions (World Health Organization n.d.). There is also growing concern over the intensity of sensory information found in dense urban areas, which has been shown to affect memory and mood by over stimulating the brain and increasing its "cognitive load" (Benedictus 2014). The current patterns of urban development and consumption have also been shown to disproportionately benefit the wealthy and impact the poor (Millenium Ecosystem Assessment 2005b).

<u>Current Methods for Resolving Problems Associated with Urbanization</u>

As outlined above, the Anthropocene as created by human resource use and other land shaping activities presents a suite of core problems: loss of biodiversity, environmental degradation limiting ecosystem services, and impacts of landscape form and function on human health and well-being. In response to both the rapid loss of natural areas and the degraded functionality of the increasingly populated urban landscape, two trends have developed: a focus on ecological restoration to support wildlife, and the retrofitting of “green infrastructure” in cities. Within urban landscapes there is a growing trend toward increasing green space for cultural benefits (e.g., recreational and aesthetic). There is also increased attention to the need for addressing ecosystem degradation that reduces quality of life and functioning of urban systems. The use of open vegetated space, or “green infrastructure” to address these twin goals to improve quality of life and urban function has been criticized as narrowly focused on the provision of ecosystem services, primarily storm water management and recreational space (Lovell and Taylor 2013).

There are several conceptual approaches to incorporating nature in cities: green infrastructure, multifunctional landscapes and urban ecological restoration. Each of these approaches is instructive of the multitude of issues to address in any urban design work. However, they do not provide a foundational concept or clear design goals related to biodiversity. As Snep and Opdam note, traditionally urban conservation starts from a perspective of particular use goal such as “water management, forest management, urban green management or wildlife management.” Unfortunately, biodiversity is rarely included as a goal in urban areas, perhaps in part due to the broadness of the concept, the lack of a clearly defined starting point for implementation or metric for evaluation (Groves 2008). Therefore this thesis explores reconciliation ecology as a species-based approach to finding opportunities for incorporating wildlife in urban environment. In order to address urban biodiversity, species conservation has to be an explicit design goal and landscape architects are in the position to facilitate this reconsideration of biodiverse urban form by adopting a truly ecological approach to site design.

Green infrastructure developed as a low-impact and ‘cost-effective’ approach to manage urban hydrology, specifically storm water management. The green infrastructure approach incorporates mechanisms to infiltrate and treat water closer to where rain falls rather than transporting it away from the built environment through pipes, culverts and other high velocity, low infiltration system components. Green infrastructure often involves water capture and storage (such as cisterns) detention ponds, rain gardens and other vegetated areas. These vegetated infiltration areas assist in recharging local ground water, support local vegetation such as street trees and consequently help to reduce urban heat island effects, while also improving the visual quality of urban landscapes (United States Environmental Protection Agency 2016).

While this approach to design provides a softer and more adaptive approach to meeting the infrastructural needs of urban areas, the framework is based on identifying ecological processes we identify as important and designing spaces that accomplish them in a manner that is economically defensible. Therefore, the incorporation of green infrastructure in urban areas does not imply the creation of ecological *systems* or habitat. Without supporting biodiversity which the Millennium Ecosystem Assessment (Millenium Ecosystem Assessment 2005a) identified as undergirding ecosystem services, green infrastructure has limited utility for addressing broader issues of urban sustainability, biodiversity conservation, and human health and well-being (Jorgensen and Gobster 2010).

In addition, the discourse of ecosystem services, which commoditizes nature as a source of services and products (Costanza et al. 1997) does not provide a mechanism for protecting the inherent value of natural ecosystems, their intricate structures sculpted over millennia, or the biological diversity they support. While the Millennium Ecosystem Assessment acknowledges the inherent value of “the variety of life” and identifies a “loss” many people would perceive after the variety is gone (Millenium Ecosystem Assessment 2005a), it is unlikely that urban citizens would experience a sense of loss for something they have never known.

With humans increasingly living in urban areas, Miller (2005) notes they are becoming “estranged” from nature, leading to an overall impoverishment of experience, exacerbated not only by the lack of nature within cities but also the pace and structure of urban life which limits direct experience of nature. The loss of ecological knowledge imperils the ability of citizens to understand not only the impacts of loss of biodiversity has on quality of life (Miller 2005), but also the import of increasing political attacks against science-based conservation measures. In late 2014 a bill was brought before the Michigan legislature that sought to forbid the consideration of biodiversity in land management decision-making and prohibited the designation of a parcel of land “specifically for achieving or maintaining biological diversity” (Samilton 2014).

Despite the unnatural state of urban areas, they frequently have high rates of biological diversity (McKinney 2008). Unfortunately, the diversity of urban species (is primarily composed of exotic or synanthropic species, many of which may be invasive. As ecologist Michael McKinney (2006) points out, the diversity and abundance of species that may exist in an urban area provides a “basic conservation challenge” in that urban residents of all socio-economic classes “become increasingly disconnected from local indigenous species and their natural ecosystems.”

The result of urban biotic homogenization is a loss of ecological heritage which extends beyond the aesthetic critique (e.g. Kunstler 1994) to include a skewed perception of the value and function of species within the urban environment and beyond. Additionally, urban residents who regularly experience urban biodiversity may have difficulty believing or understanding the magnitude of global decline in biodiversity. As the intensity of urban activities increases there is a correlated abundance and richness of non-native species and decline of native species (McKinney 2006), likely exacerbating the trend. Humans have already "appropriated 90-95% of the terrestrial portion of the earth for their own uses, including virtually all of the most productive lands" making the plight of global biodiversity all the more dire (Miller 2008).

The traditional approach to conserving biodiversity has focused on preserving large patches of "wild" land to maintain a separation between wildlife habitat and human-dominated spaces (Miller 2008, 115). Restoration is a second key conservation strategy that seeks to remove lands from human disturbance regimes to reestablish native communities and habitats. As cities grow in area as well as population, the land available for these nature-reserve style habitat is increasingly limited and is not likely to be an effective strategy for preserving many species (Miller 2008). This may be true even for smaller species such as insects that may require less land area (e.g. Bennett and Gratton 2012). In order to address the rapid loss of biodiversity, Miller (2008) proposes that ecologists and designers consider the conservation value of highly fragmented landscapes by blurring the distinction between remnant natural spaces and the city.

However, "traditional" ecological restoration that seeks to restore a landscape to a historic or (or even pre-historic) state may not be possible as a method to extend habitat into the city or other significantly altered human dominated landscapes (Apfelbaum and Haney 2012). In addition, ecological restoration is traditionally viewed as being at odds with economic development and urban life (Lovell and Taylor 2013).

The 2005 UN Millennium Ecosystem Assessment stated that in order to reduce, if not reverse, the impacts of our current pattern of resource use on ecosystem function, change needs to happen globally and at every scale and level of society (MEA 2005), which should include the level of the individual. Education on the impacts of individual resource consumption on ecosystems as well as increased awareness and access to natural environments and the services they provide have been identified as keys to influencing individuals to engage in more environmentally sustainable ways (MEA 2005).

Despite the opportunities for overlap among these related issues, there is limited consideration of the intersection of approaches to addressing these problems within the planning and design of urban landscapes, particularly in regard to the place of wildlife species.

Reconciliation Ecology as Approach to Urban Design

Biodiversity collectively identifies a community of many species which possess inherent value. Humans have acknowledged this value for millennia as retained in animist traditions and regional and global religions such as Jainism, Hinduism and Buddhism which follow the central tenet of Ahimsa, or compassion to all living beings. The value of a biodiverse community entered the academic discourse in the 20th century through the writings of Aldo Leopold. Leopold’s writings on the land ethic admonished human society to acknowledge our connection to the “soils, waters, plants, and animals, or collectively: the land” as an ethical obligation (Leopold 1949).

As the conflict between urbanization and wildlife expands there is greater need to also expand the considerations and criteria that shape urban form. The growing consideration of biodiversity as necessary to creation of ecosystem service provision can only serve to benefit native species. The same can be said for the increased attention to native species design to create a “sense of place” and the growing awareness of the role of biodiversity for quality of life (Miller 2008). However, the focus on these ecosystem services does not address the anthropocentric approach to landscape design that disregards an inherent right of native species in the urban landscape. Similarly, these broad considerations do not provide specific insight into how to maintain or re-establish biodiverse plant-animal communities within the urban framework in order to provide those human-derived benefits. As a result, urban design focused on ecosystem services of rainwater infiltration, heat mitigation, and carbon sequestration may not provide functional habitat for displaced native species, even for species such as little brown bats who have been present in human landscapes since the earliest settlements (Costanza et al. 1997).

This thesis proposes that landscape architects include wildlife as stakeholders in design in order to devise new urban forms and patterns. By actively considering species and their habitat needs, landscape architects will honor the inherent value of wildlife species. In addition, landscape architects will be better able to design for biodiversity rather than following simplified pathways for providing specific ecosystem services within the urban environment. Incorporating nonhumans into urban design provides a new direction for ecological design that acknowledges the mutual interaction of human and nonhuman natures (Roberts 2013) and provides a more ecologically sound, systems-based approach to urban design.

In 2001 Michael Rosenzweig coined the term “reconciliation ecology” to describe the process of modifying and diversifying existing human-dominated landscapes to sustain diverse species. This conceptual approach provides landscape architects a basis for re-envisioning and re-engineering ubiquitous human-dominated landscape types to make them functional for non-human species.

Landscape Architects as Reconciliation Designers

This thesis speaks to the cumulative effects incremental design and management actions have on biodiversity, and how landscape architects can reframe our individual actions to consider wildlife and hopefully slow the loss of species.

As a profession traditionally concerned with the design and programming of urban landscapes to accommodate multiple uses and user groups, landscape architects are key players in addressing the future of biodiversity conservation in the urban realm. Urban biodiversity design inherently involves designing spaces that facilitate or limit interaction between humans and non-human species. Effective design for biodiversity, particularly within the urban context, requires mediating between the structural and functional requirements of ecological systems, and human values, perceptions and societal and individual actions (Gobster 2010).

Key to the success of design for biodiversity is communicating the importance of species, habitat, and “scientific knowledge” to urban audiences in a “user-friendly” manner (Frankie, Thorp, Hernandez, et al. 2009, 119). Miller (2008, 118) cites Karasov

(1997) as identifying the "scale of personal experience" as being the most important element in creating a design that creates meaningful change in biodiversity. By extending natural habitat into the city, environmental designers will be creating spaces for interspecies interaction. In addition to providing habitat, Miller (2008) suggests these positive experiences will result in a greater desire to preserve natural areas outside the city, and modify behavior that is detrimental to ecological systems (Miller 2008).

Landscape architects are trained to design at the site scale, or, "scale of personal experience." In addition, since the 1960s when Ian McHarg wrote *Design with Nature*, landscape architecture as a field has increasingly focused on the relationship of a site to its larger ecological context. Further, the multi-scalar conceptual approach to design landscape architects employ are applicable to urban biodiversity design. While the pattern of green space on the landscape is important, it does not equate to habitat. Rather, it is the blending of site level and micro-level design with the larger landscape ecology that creates habitat (Miller 2008). The successful and purposeful inclusion of species habitat needs at the site scale may facilitate the creation of successful habitat and populations at the landscape scale, thereby contributing to long-term conservation efforts.

Landscape architecture has an established practice for designing and programming landscapes to accommodate the needs of diverse use groups, as well as a theoretical framework for establishing inclusivity in public spaces. By extending foundational principles of democratic public space and universal design to non-human species, landscape architects may be able to reconcile human-dominated landscapes to welcome bats and other species, enriching the land community Leopold described, and strengthening the web of biodiversity which supports our continued existence.

Research Questions and Objectives

The primary goal of this thesis is to reconcile an urban park within Burlington, Vermont for little brown bats (*Myotis lucifugus*) a flexible framework that landscape architects can use in designing bat friendly habitat within the urban gradient of Burlington, VT. To guide this and to synthesize the literature reviewed, the secondary goal is to propose a general framework for reconciling urban sites to incorporate non-human species. The framework is intended to identify possible points of intersection between existing urban landscape types with their embedded cultural uses, and the needs of target wildlife species.

Therefore, the question this thesis seeks to answer is, **how can landscape architects reconcile urban public spaces to benefit little brown bats?**

The secondary research questions this thesis addresses include:

1. Do urban landscapes hold opportunities for greater inclusion of native wildlife species?
2. How does reconciliation ecology differ from previous approaches to wildlife conservation?
3. How does landscape architecture as discipline and practice address urban wildlife conservation?
4. What considerations must be addressed to reconcile urban sites?
5. Does research or practice provide guidance on reconciling human use spaces for other species?
6. Are little brown bats compatible species for reconciliation within urban public space and what are their habitat requirements?

Objectives

A. Synthesize a broad literature review to understand both the biological and social/cultural components of successful urban wildlife habitat
B. Identify examples of urban reconciliation ecology that can inform landscape architecture practice
C. Demonstrate through projective design how species habitat can be reconciled with human use and cultural values for a target site
D. Contribute to an understanding of design as a tool for improving taxonomic biodiversity.
E. Advocate for landscape architects to consider native species as stakeholders in urban design and incorporate them in site programming, design and management

Organization

The proceeding chapters of this study organize four sections. First, chapter two will review the literature on urbanization effects on native wildlife and broad patterns of biodiversity along with current modes of biodiversity conservation. Reconciliation ecology is then introduced as a conceptual approach to urban design.

A synthesis of relevant literature and habitat programs provides an understanding of species biological requirements and the social components that must be reconciled to provide successful wildlife habitat. The results of literature review are crafted into a framework to guide reconciliation ecology design, which is then applied to reconcile an urban park in Burlington, Vermont for little brown bats.

Finally, the reconciliation design is presented with a discussion of their potential efficacy in creating habitat, as well as an overall review of the framework utility and suggestions for future reconciliation ecology design research.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the impacts of urbanization on biodiversity and the categories of wildlife commonly found in various urban settings. The chapter then introduces core principles of conservation biology, a field established to address global biodiversity loss and species conservation. Following an introduction of existing legal frameworks for species protection and traditional approaches to species conservation, reconciliation ecology is presented as a complementary approach to species conservation within human-dominated landscapes. Following a review of biodiversity conservation within landscape architecture the chapter discusses design as an interdisciplinary approach to address knowledge gaps and complex human-nature land use challenges such as reconciliation ecology. The chapter concludes by provides a general description of bats (order *Chiroptera*), their unique characteristics, ecological importance, and what is known about the impacts of human development on bats at a macro scale. The review then focuses on little brown bats life history and conservation status and status in Vermont, before closing with established guidance for bat habitat improvements.

Urbanization Effects on Biodiversity

Land use decisions within and external to urban areas have far-reaching effects and constitute a "fundamental source of change in the global environment" (Dale et al.

2000, 639). While accounting for only about three percent of Earth's land area, cities exhibit a disproportionately strong impact on both regional and global ecology through intensive use of resources and high levels of waste production (McCleery, Moorman, and Peterson 2014). Urban centers are characterized by high concentrations of people, shaping a mosaic of uses: residential, commercial and industrial spaces, civic. Interspersed within these uses are open greenspaces composed of parks, golf courses, cemeteries, trails, patches of lawn, and in places, remnants of native vegetation (McCleery, Moorman, and Peterson 2014). As ecological systems, urban areas are often characterized as landscapes that have "become completely unbalanced" resulting in pollution, pathogenic diseases (Tarsitano 2006, 799), unsustainable patterns of resource use, poor human health and well-being, and reduced biodiversity (Jorgensen and Gobster 2010, Sargolini 2013, McDonald, Kareiva, and Forman 2008). This imbalance is caused in part by intensive patterns of importing life sustaining resources as food, water and fuel and associated export of waste (McCleery, Moorman, and Peterson 2014).

As a result of these altered landscape forms and processes, urbanization results in native species reduction and is a major cause of local species extinction (McKinney 2002). Global patterns of human-centered urban development is also resulting in a biotic homogenization through two primary mechanisms: the expansion of 'cosmopolitan' non-native species, and the contracted ranges of local and regionally endemic, native species (Olden et al. 2004). Human introduction of non-native species and the loss of native species due to altered habitat results in the replacement of diverse native species with a smaller suite of non-native species, which McKinney and Lockwood (1999) refer to as "winners" and "losers." The mix of native and non-native species and altered landscape structure results in ecologically 'novel' urban landscapes defined by unique conditions without a historical reference (Hobbs, Higgs, and Harris 2009). These "novel" urban landscapes often display "fundamental processes and structures" strongly influenced by human culture and economic activities (Lundholm and Richardson 2010, 967). Common underlying physical and cultural processes that shape urban and industrial environments result in landscapes that often share more biota in common with one another than with surrounding natural habitats (Lundholm and Richardson 2010). The higher order effects of biotic homogenization on genetic, taxonomic and functional biodiversity are not yet clear (Olden et al. 2004).

Compared to other anthropogenic landscape changes such as mining, agriculture and forestry, urbanization has a greater effect on wildlife populations due to the persistence of urban forms, their dissimilarity to the pre-existing native landscape (Marzluff and Ewing 2001), and the tendency of urban areas to spread (McKinney 2002). Furthermore, urbanization is associated with companion land uses such as recreation, transportation systems and agricultural production that extend anthropogenic effects beyond the urban core. These impacts can include increasing natural predators and parasites; attracting exotic diseases, predator and competitors; altering trophic structures; obstructing migratory and dispersal routes; removing important resources such as woody debris; and altering hydrological and nutrient cycles (Marzluff and Ewing 2001).

The effects of urbanization on biodiversity are not uniform. Rather , urbanization has variable effects on species, depending on the taxonomic group studied, the scale of the study, and surrounding natural ecological landscape context (McKinney 2008). Urbanization may provide greater diversity of plant species due to introduction of non-native species through horticultural activity (McKinney 2008) and it is possible that low levels of urbanization may increase heterogeneity of landscape structure and plant materials, expanding habitat areas within more homogeneous landscape contexts (McKinney 2008, Coleman and Barclay 2011). However, the general trend suggests that increasing urban density results in lower species diversity through structural simplification of planting material, disturbance, and the amount of area available to support adequate feeding, breeding and shelter for local populations. Similarly, the number and diversity of non-native species, tends to increase with urbanization (Urban Wildlife Working Group 2012). Urbanization has been identified as a primary cause either alone or in conjunction with other factors for the decline in more than half the species listed as threatened or endangered under the US Endangered Species Act, or determined 'imperiled' though not listed (Miller and Hobbs 2002).

Urban areas are frequently defined through physical gradients using metrics such as housing density, impervious surface, road density, and through environmental changes including soil compaction, temperature, and precipitation (Alberti 2009, McKinney 2002). In general, these physical landscape changes limit habitat potential along a gradient from surrounding natural (i.e. pre-existing) landscape through agricultural and suburban areas to the urban core, which generally exhibits the most fragmented habitat and lowest diversity (McKinney 2002). Characteristics of the urban landscape including habitat loss, light and noise pollution, invasive species, stormwater runoff and chemical pollution all impact the ability of wildlife species to survive in urban landscapes through direct, indirect or cumulative impacts (Urban Wildlife Working Group 2012).

Biodiversity loss begins early in the urban development process as sites are typically cleared of most of the existing native vegetation and even topsoil to facilitate construction (McKinney 2002). After buildings and impervious surfaces are established, removing the ability for those areas to provide habitat, sites are typically planted with non-native vegetation with low habitat value. While McKinney (2002) notes the best approach to habitat conservation is to preserve as much existing vegetation as possible, short-term economic motivations usually win out. The process of urban development typically involves removing or fragmenting native habitat, resulting in four types of replacement habitat: the built environment structures and impervious surfaces; managed vegetation in residential, commercial and regularly maintained public spaces; ruderal vegetation found in unmanaged green spaces, empty lots and oldfields; and fragmented and isolated islands of remnant native vegetation (McKinney 2002).

The fragmentation of habitat during the urbanization process is exacerbated by high rates of private ownership limiting the potential for centralized planning. In addition to creating greater amount of edge habitats, smaller habitat patches are less able to support local species populations. When combined with trapping and other human efforts to reduce “nuisance” species, urban habitat patches can serve as population “sinks” for urban wildlife species (Hadidian and Smith 2001). Further compounding the effects of habitat loss on native species is the fact that non-native “weedy” (McKinney 2002) species, which are typically tolerant of urban disturbance (e.g. light, sound, pollution), replace native species, resulting in further biotic homogenization. However, there is limited research into the basic ecological relationships among urban wildlife species, or their life histories and the impacts of anthropogenic stresses to their health (Hadidian and Smith 2001).

Urban areas are complex and despite qualities that degrade native biodiversity (e.g. species area effect, impervious surfaces), urbanization also presents some physical characteristics that can support biodiversity including spatial heterogeneity, nutrient inputs (e.g., water and fertilizers), and the importation of non-locally native species (McKinney 2008).

Urban ecosystems differ from natural systems so widely that authors have attempted to devise discrete sets of hierarchical principles to explain the organization and function of urban ecosystems (Forman 2016, Pickett and Cadenasso 2017). The transfers of materials and energy within the urban landscape impact species presence and survival and require consideration for developing urban conservation actions.

Forman (2016) has determined a unique set of principles that define urban ecosystems including the relationships of species movement and prevalence to urban building patterns, vegetation and disturbance. He organizes these urban conservation biology principles into four major categories: land use; built objects; permeating anthropogenic flows (including human produced chemicals, noise and light, human wastewater and vehicles); and human decisions/activities (including current and past societal actions and activities and individual decisions) (Forman 2016). Among Forman's unique urban conservation biology principles are seven describing the relationships between wildlife and the urban landscape (Table 2.1):

Table 2.1. Urban Ecology Principles for Urban Animals/Wildlife. Following from Forman (2016)

Relationship between animals/wildlife and urban landscape
Most wildlife species strongly respond to the species and arrangement of trees and shrubs, especially in areas with high impervious-surface cover.
Animals tolerate and communicate in endless urban noise—some loud, most low frequency.
Many terrestrial wildlife species are nocturnal, avoiding daytime people and traffic, and respond to diverse changing urban lights.
Pets respond strongly to human behavior and feeding, while only slightly affecting surrounding animals and plants.
Genetic adaptation and differentiation includes urban-rural population divergence, while selective forces include pollution, human-provided food, and low-frequency noise.
Wildlife distributions and routes are commonly rectilinear, mainly reflecting road, street, walkway, rail, and pipe infrastructure networks.
Streets and roads are barriers against, and conduits for, animal movement, in both cases with increasing traffic strongly decreasing movement rate.
Food webs are typically simplified, and their predator links reduced, with increasingly intensive urbanization.

As Forman's principles suggest, urban wildlife behavior is strongly influenced by the noise, lights and organization of the urbanized landscape which presents limitations and alterations to movement, forage, communication and individual fitness.

Wildlife in Urbanized Landscapes: Exploiters, Adapters, Avoiders

Cities often are designed for humans without consideration given to a large animal population, including pets and wildlife species, that live alongside us (Tarsitano 2006). Consequently, urban landscapes have not historically been considered as potential wildlife habitat. Instead, urban spaces and wildlife are often viewed as diametrically opposed to one another, with urban areas "considered depauperate in comparison to their rural counterparts in terms of flora and fauna, with the exception of a few notable species that were widely categorized as pests" (Gaston 2010b, 35). As a result, study of urban wildlife has historically been limited, although this trend is changing (McCleery, Moorman, and Peterson 2014). Growing awareness of the habitat degradation and fragmentation that results from sprawling development and resource extraction has prompted consideration of urban spaces for wildlife conservation. In addition, urban areas are being recognized as opportunities to foster ecological understanding and shape safe and enriching interactions among wildlife and urban residents (McCleery, Moorman, and Peterson 2014).

Despite the negative effects of urbanization on biodiversity discussed above, urbanized areas have been shown to support "significant" levels of biodiversity and can play an important role in regional conservation, particularly when the surrounding area has already been significantly altered such as through intensive agriculture (Fuller and Irvnie 2010). While inventories of urban wildlife species are limited, and there is an overall reduction in biodiversity observed in urban landscapes, many wild animals show "affinity" for the complex and diverse habitats within the urban gradient comprised of cities, suburbs, and rural fringes (Hadidian and Smith 2001). This may be due in part to human selection of environments rich in resources such as water, productive soils, in which to establish settlements. Globally, there is a correlation between human settlements and biodiversity hotspots, which are areas, primarily in tropical regions which hold a large number of endemic species (meaning they are not found anywhere else in the world) that are threatened by habitat loss and degradation (Conservation International 2017). Despite being drawn to opportunities within the urban landscape, the variation, and constant change that characterize urban landscapes thwart attempts by many species to colonize and maintain viable populations within the urban gradient (Hadidian and Smith 2001). Elements of the urban landscape affecting the presence and movement of wildlife species include clustered anthropogenic food sources, and linear range borders such as buildings and roads (Ryan 2014).

Wildlife species vary in their ability to adapt to changes in the physical environment and patterns of disturbance that are common along the development gradient from rural areas to urban cores. The resulting non-random assemblages of species reflects the ability of species to survive along the urban gradient, and are often classified according to three groups: associates/exploiters, adapters, and avoiders (McKinney 2002, "Urban Wildlife Basics" Urban Wildlife Working Group 2012). A fourth category of urban animal discussed by the Urban Wildlife Working Group includes “obligate” species such as cats, dogs and livestock that often compete with, disturb, or predate upon native wildlife species.

Urban Exploiter Species

Exploiter species are successful in the urban landscape, and are also known as associates, or synanthropes, (McKinney 2006) are typically generalist feeders capable of utilizing a variety of resources including human food sources. Often these species are strong competitors that can exclude native species, tolerate greater human disturbance, and modify their behavior (behavioral plasticity) to adapt to major environmental disturbance ("Urban Wildlife Basics" Urban Wildlife Working Group 2012). These species utilize or colonize a variety of habitats including cemeteries, orchards, and roadsides (Hadidian 2001) along with buildings and other built structures.

Within the plant kingdom, urban exploiters tend to be “ruderal” species that can tolerate high disturbance levels, including compaction, trampling, and chemical inputs such as smog and nitrogen enriched soils. Urban exploiting animal species are often those adapted to “cliff-like rocky areas” or those that are able to use human dwelling for cavity nesting. Examples include peregrine falcons, mice, and house finch (McKinney 2002). In his review of biodiversity along an urban gradient, McKinney (2002) found that the species assemblages in rural landscapes generally contained only a few percent of non-native species, while the urban core typically contained over 50% non-native species. This pattern was particularly clear for plants and bird species. The distribution of non-native species within the urban gradient is based on disturbance patterns as well as intentional human inclusion or exclusion of species (McKinney 2006). Exotic plants are introduced for decorative or productive purposes and animal species are introduced as pets.

In North America, associate, or exploiter, species take advantage of human food resources. Examples include native species such as raccoons, and non-native species such as European Starlings.

Urban Adapter Species

Adapter species typically occupy the urban periphery. While they do not necessarily benefit from human dominated landscapes, they often are generalists capable of utilizing resources available in urbanized areas.

Urban Avoider Species

Human avoider species are most vulnerable to spreading urbanization, suffering higher mortality rates or lowered reproduction. Avoiders may occasionally be found in developed areas as they attempt to disperse or migrate through a fragmented landscape, but are not otherwise found in human landscapes. This may stem from a history of conflict with humans (a common phenomenon for species such as wolves, mountain lions or coyotes), or because the species has specific habitat needs that are limited or non-existent in the urban environment ("Urban Wildlife Basics"Urban Wildlife Working Group 2012).Urban avoiders include large predators and ground nesting and forest interior bird species. They quickly disappear during “initial stages of suburban encroachment” unless significant effort is undertaken to retain and protect large tracts of existing habitat during expansion of urban development (McKinney 2002). In addition to removing key habitat resources through clearing land, urbanization disrupts hydrology and nutrient flows (Marzluff and Ewing 2001). McKinney (2002) notes Kendle and Forbes (1997) found that rare species are uncommon in densely populated urban areas, however instances exist of rare plant and insect populations, which McKinney suggests could be a new focus for conservation and restoration efforts. However, most rare species in urbanized areas are found in remnant habitats that experience limited disturbance including railroad areas, transmission corridors, parks and cemeteries (McKinney 2002).

Review of Conservation Biology Principles and Approaches

Conservation biology is a discipline focused on addressing the loss of biodiversity at local to global scales. While the concept of conservation biology emerged in the late 1960s and early 1970s through the work of Dasmann and Ehrenfeld, in the early 1980s Michael Soulé was instrumental in developing conservation biology as a discipline (Gerber 2010). Soule introduced the field of conservation biology and coined the name within the journal *BioScience* in 1985 as, “a new synthetic discipline” charged with addressing “the dynamics and problems of perturbed species, communities, and ecosystems” (Soule 1985). That same year the Society for Conservation Biology formed following a National Forum on Biodiversity in Michigan, organized by the US National Academy of Sciences and Smithsonian Institution (Meine 2010). Soulé’s work to coalesce a response to loss of habitats and species incorporated twentieth century scientific advancements including genetics, and population biology. The proposed field included concepts such as an ecosystem connected by trophic levels, biological diversity, keystone species, ecosystem ecology, and remote sensing. These advancements gained new traction among biologists in the 1970s with the realization of alarming losses of species and habitats within remote and often tropical areas that were common study sites for wildlife scientists. Observation of species and habitat loss within biodiversity hotspots converged with watershed legislation in the early and mid-1970s including the National Environmental Protection Act (1970), the Endangered Species Act (1973), and the Convention of International Trade in Endangered Species of Flora and Fauna (1975), all of which elevated the responsibilities of biologists in conservation of the natural environment (Meine 2010).

As Curt Meine (2010) notes in his history of the field, conservation biology distinguished itself from previous land and wildlife management fields by adopting an implicitly ethical and multi-disciplinary approach to studying the natural world. Conservation biology is grounded in an ethical argument that biodiversity and species hold inherent value (Meine, Tromulak et al 2004, Hadidian and Smith 2001). Michael Soulé (1985) established the following four principles to provide a "basis of an ethic of appropriate attitudes toward other forms of life" and serve as standards for measuring conservation actions:

1. Diversity of organisms is good (corollary: untimely extinction is bad)
2. Ecological complexity is good
3. Evolution is good
4. Biotic Diversity has intrinsic value

These axioms underpin the ethical approach to conservation biology, guiding lines of inquiry and strategic action to conserve species regardless of their potential direct utility to humans.

Conservation biology also adopts an interdisciplinary and systems oriented approach to holistically consider ecological, social and economic goals related to species conservation (Meine 2010). Soulé defined conservation biology as holistic in two senses: first, that conservation must address multiple scales (e.g. individual species and communities of species); second, that conservation biology must adopt a multi-disciplinary approach (Soule 1985).

Conservation biology is focused on protecting species and ecosystems from direct or indirect 'perturbations' introduced by human activities or other 'agents' (Soule 1985) such as disease and climate change. Conservation biologists are driven to act quickly in the face of political maneuvering and landscape altering actions, often without full knowledge of the causes and compounding factors of species, community or ecosystem decline. As a result, Soulé classified conservation biology as a “crisis” discipline (Soule 1985). By necessity, conservation biology is a ‘mixture of science and art’ applying available data-driven theory as interventions in landscapes and systems to reduce or end disturbances that threaten species survival (Soulé 1985).

At its mission, conservation biology ‘focuses on how to protect and restore biodiversity, or the diversity of life on Earth” including all forms of life from bacteria to vertebrates (Society for Conservation Biology 2017). Biodiversity is generally conceptualized at three hierarchical levels (Gaston 2010a) ranging from the level of individual organisms (genetic diversity) through groups of similar organisms (species diversity), to groups of species that form communities (ecosystem diversity) (Society for Conservation Biology 2017). In addition to biological diversity of ecosystems, conservation biology seeks to maintain two additional aspects of life, ecological integrity and ecological health, defined by the Society for Conservation Biology as follows:

> *Ecological integrity*: the composition structure, and function of those systems
> *Ecological health*: the resilience and ability of systems to endure over time

Biodiversity is a complex concept, and Gaston (2010a) notes there is no single metric for judging biodiversity. However, the Society for Conservation Biology website states the biodiversity of a defined area is quantified by the number of species present. The interaction of these species and non-living components within a defined boundary constitutes an ecosystem (Society for Conservation Biology 2017).

Understanding of ecosystem biodiversity is inhibited by several factors including the "sheer magnitude and complexity" of the concept, the lack of data from many parts of the globe, and human alteration of global patterns and pre-existing biodiversity levels (Gaston 2010a).

Conservation under the Endangered Species Act

As introduced above, the role of conservation biologists in wildlife management and policy formation was bolstered by key national and international laws that provide frameworks for identifying and protecting species threatened by extinction. Within the United States, biodiversity is protected primarily through endangered species laws at the state and federal levels. The Federal Endangered Species Act (ESA), first signed into law in 1973, was created to protect imperiled species primarily from actions taken by government agencies that result in "take," or the harming of species legally designated as threatened by extinction. The ESA defines take as "…to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct" (U.S. Fish & Wildlife Service 2013). In addition to covering direct threats, this definition includes "significant" modifications to habitat that injures or kills individuals of a species by "impairing essential behavior such as breeding, feeding, or sheltering" (U.S. Fish & Wildlife Service 2013). The law has been credited with helping to "stave off species extinction when implemented promptly;" however, it has also been "subject to political whims" and the legislation has been altered, stalled, reduced, and unpassed in its forty year history (Burgess 2001).

The ESA is credited with several notable success stories including recovery of the American bald eagle, black-footed ferret and California condor (U.S. Fish & Wildlife

Service 2011). However, the law does not directly protect biodiversity through preemptive protection of species or habitats. Despite clearly stating the intent to "conserve endangered and threatened species *and* the ecosystems on which they depend" (Burgess 2001, 23) the act is focused on at-risk species and provides limited assistance in the conservation of national biodiversity. Rather, the Endangered Species Act only protects a single species and only at a critical time, "when the entire population of that species is in jeopardy" (Burgess 2001, 21).

The Endangered Species Act holds other limitations in protecting species and biodiversity, including unequal protection of different biological groups. Plants and invertebrates receive "considerably less" protection than vertebrates, which ignores both the vital trophic relationships between species (Burgess 2001, 23) and species inherent value. A second important limitation is the act's inadequate protection of habitat from fragmentation and other disturbance (Burgess 2001).

When a species is listed as threatened or endangered, a geographic range, known as "critical habitat," must be identified to support the full life cycle of the current population while providing for population growth. Critical habitat is designated only when it is deemed "prudent and determinable" (U.S. Fish & Wildlife Service 2013).

According to the U.S. Fish and Wildlife Service (USFWS) website, 523 of the 1317 U.S. species that have been identified as threatened or endangered have had critical habitat designated. This is due to two primary reasons. First, prior to 1996, there was a moratorium placed on listing species. After it was lifted, the USFWS focused its limited staff and funding on the backlog of species identified as candidates for listing, rather than on designating critical habitat. The Endangered Species Act provides protections for individual species when they have hit a critical stage, but does not fully protect species habitat needs or address the needs of species prior to dropping to critically low numbers. For these reasons, Goble, Scott, and Davis (2006, 15) note in their review of the first thirty years of the Endangered Species Act, "it is not a comprehensive *biodiversity preservation* act," but rather, "a tool of last resort." In order to better preserve American biodiversity, the authors suggest broader efforts than reliance on the ESA, and propose conservation biologists "craft ways to accommodate more native species in the areas where we live, work, and recreate" (Goble, Scott, and Davis 2006, 15).

The Endangered Species Act provides a primary mechanism for protecting the nation's species but only does so when species are at a most critical juncture. Moreover, it does not provide broad protections for biodiversity. This is partly because the ESA does not directly protect species habitat, which can be eroded in size or degraded in quality through individual actions, particularly on privately-owned land. While the ESA can limit land use activities, it does not require land owners to manage their land for the benefit of protected species. Further, the Endangered Species Act is unable to address the broad-scale degradation of biodiversity and loss of species spurred by urbanization and other land uses (Burgess 2001, Goble, Scott, and Davis 2006).

Established Approaches to Conservation

Despite incomplete understanding of the "sheer magnitude and complexity" that constitutes biodiversity (Gaston 2010a, 41), conservation biology sets as a goal the "long-term viability of whole systems and species, including their evolutionary potential," which implies and depends on the "persistence of diversity, with little or no help from humans" (Soulé 1985). To achieve that likely unrealistic goal, conservation biology practices consistent management to address persistent threats to species that are both direct (e.g., poaching and disease) and indirect (e.g., reduced habitat size, invasive species, loss of habitat connectivity) (Soulé 1985).

Conservation work addresses threats to species based on core principles that inform an understanding of biodiversity, ecological integrity and ecological health, as defined above. The Society for Conservation Biology Education Committee defines principles of conservation which they organize into five key themes. The framework of themes organizes principles that define goals for conservation biology; establish core values inherent in the profession; identify foundational concepts for the field; consider key threats; and define core practices. These principles frame a 'body of knowledge' for conservation literacy that guide nine associated conservation actions toward improving population health and limiting species extinction (Trombulak et al. 2004), outlined in Table 2.2.

In addition to establishing core scientific concepts to assessing ecological integrity and health, the themes outlined by Trombulak *et al.* (2004) include human value systems that inform our actions and perceptions of the natural world. The authors determine conservation biologists must account for social values in order to achieve conservation goals. Among these Trombulak et al. note the emergence of ecological economics as a corrective measure to land degrading actions guided by "neoclassical economic theory." The authors identify neoclassical economic theory as threatening biodiversity conservation by creating threat vectors such as global climate change. Related to the economic foundation for species and land use decisions, the authors state the peoples understanding of and familiarity with ecological integrity impacts implementation and success of proposed conservation efforts. As they state, “People’s perception of the magnitude of a threat are strongly influenced by how much change they have seen occur, such that each generation develops a different standard for what is normal or natural” (Trombulak et al. 2004, 1184). As each generation is born into a world of reduced biological diversity and ecological integrity, their understanding of what constitutes a “normal” natural condition is lessened. This reductionist view of nature affects people’s ability to understand the full impacts of land-use decisions on the natural world, a phenomenon referred to as “shifting baseline syndrome” by Daniel Pauly (2010).

To operationalize the conservation literacy principles they define, Trombulak et al. (2014) develop a series of actions to guide protection and restoration of biological diversity and ecological integrity. While the authors note that no natural ecosystem can ever be restored “exactly … in its composition, structure, and function,” restoration efforts should focus on returning an ecosystem as close to its natural condition as possible, without cultural modifications. In addition to four strategies that directly relate to species (i.e., species protection, reserves, restoration, population augmentation), the authors identity five conservation strategies that engage human actions and culture. These include modifying human uses of nature to reduce impacts on ecological systems; controlling harvesting to reduce impacts to population size; reducing the spread of non-native species; political participation and advocacy; and educating all levels of society about conservation.

Table 2.2: Five Themes for Conservation Biology Literacy. Adapted from Trombulak *et al*. (2004)

Conservation Biology Themes	**Primary Principles of Conservation Biology Themes**	**Corresponding Strategies of Action (Theme 5)**
Theme 1: Goals for conservation biology	Maintain biological diversity, ecological integrity, and ecological health	▪ Protect species at risk of extinction ▪ Designate ecological reserves ▪ Lessen the magnitude of human impacts on natural systems ▪ Restore ecosystems that have been degraded
Theme 2: Values	The conservation of nature is important for nature's intrinsic values, its instrumental values (utility to humans), and its psychological values	▪ Educate others about the importance of conservation
Theme 3: Concepts for understanding	An understanding of conservation is based on key concepts in taxonomy, ecology, genetics, geography, and evolution	▪ Augment populations with individuals raised in cultivation or captivity
Theme 4: Threats	Nature has faced and continues to face numerous threats from humans, including direct harvesting, habitat destruction, and introduction of non-native species	▪ Control the number of individuals harvested in nature ▪ Prevent the establishment of non-native species, and eliminate non-native species that have become established ▪ Understand and participate in the policy-making process
Theme 5: Actions for biodiversity protection and restoration	Conservation requires a combination of many different strategies	(organized above according to theme)

Since the field's formal coalescence in the mid-1980s, conservation efforts have primarily focused on single species protection (Society for Conservation Biology 2017). Increased awareness and advances in conservation science during the 1990s facilitated development of systematic, landscape-based planning strategies for conservation rather than the ad-hoc approaches employed previously (Groves et al. 2002). Current practices often focus on whole ecosystems or landscapes, a trend that increases the probability of conserving the large-scale processes that enable biodiversity (Society for Conservation Biology 2017). Central to this evolution was a growing endangered species list that indicated a need for proactive rather than reactive conservation. This was complemented by growing attention to supporting the ecological processes underpinning biodiversity at multiple scales and levels of biological organization (Groves et al. 2002).

Regardless of the scale of conservation study or implementation, the multidisciplinary field makes use of three empirical principles: measuring species and abundance; correlation to indices of environmental changes; and estimating risk, including extinction (Bradshaw and Brook 2010). Conservation biology focuses on providing "answers to specific questions that can be applied to management decisions" in order to establish workable methods and strategies for "protecting threatened species, designing nature reserves, initiating breeding programs to maintain genetic variability in small populations, and reconciling conservation concerns with the needs of local people" (Gerber 2010). Statistical models factor prominently in research studies that aim to make informed conservation decisions despite what is often a limited understanding of complex and dynamic ecosystem structure and function (Gerber 2010).

There are two primary landscape-based conservation strategies for maintaining Earth's habitats and biodiversity: reservation ecology and restoration ecology (Rosenzweig 2003).

Reservation ecology first appeared with the creation of national parks and is focused on saving specific valued patches of natural habitat. Conservation planning has become a core practice of conservation biology and ecology to prioritize habitats that should be preserved. Utilizing concepts such as "vulnerability" and "irreplaceability," conservation planning identifies through a process of prioritization areas that are most in need of protection, known as key biodiversity areas (Brooks 2010). Brooks (2010) identifies three levels of ecological organization for prioritizing and implementing conservation planning: species, site, and landscape scale. These scales of action address biodiversity created and measured at genetic, species and community scales

Species are fundamental units of biodiversity and "avoiding species extinction can be seen as the fundamental goal of biodiversity conservation" because species extinction is irreversible (Brooks 2010, 204). However, a species-specific approach is limited by several factors including available data on species life history and population numbers. Acknowledging the "daunting" task of saving species individually, with so many that have been identified globally as at risk of extinction, conservation biologists have adopted site-level conservation approaches (Brooks 2010, 206). Site scale planning and implementation has evolved since the 1990s to be data-driven, map-based and quantitative, and involving stakeholder buy-in to culminate in the key biodiversity area approach. Limitations to a site scale (or key biodiversity area) approach include prioritization and limited data available to identify target conservation sites. (Brooks 2010).

Developments within landscape ecology over the past thirty years suggest that species and site-planning efforts are not sufficient for biodiversity persistence, pushing conservation biology to broaden its practice by adopting a landscape conservation approach (Brooks 2010). This approach focuses on connecting protected areas and broader landscapes through corridors, which were generic when first implemented in the 1970s, but following criticism have become more tailored to functioning for specific species (Brooks 2010).

A newer approach to landscape-based conservation is restoration ecology, which seeks to assist in the recovery of historic ecosystems (Standish, Hobbs, and Miller 2013). The goal of restoration ecology is to return a site or landscape to an "original" state, providing habitat for native species assemblages. In the United States, this "original" state is typically understood to mean what existed at the time of European settlement (Hobbs 2014). Restoration is also tasked with the goal of restoring the land's capacity for self-renewal (Apfelbaum and Haney 2012). Within urbanized contexts, the restoration requires two steps: first, designing and establishing reserves of native vegetation; second, restoring and maintaining ecological function within the reserves (Marzluff and Ewing 2001).

The process of conservation, either through reservation or restoration, begins with prioritizing habitat patches based on rarity, habitat value, and patch connectivity (Apfelbaum and Haney 2012). Rather than utilizing subjective estimates of how much natural land a city, state or region can willingly set aside as protected habitat, conservation biologists seek to develop plans based on biological needs of species or ecological communities (Groves et al. 2002). Restoration focuses on identifying a natural analog (a reference ecosystem) for the project site, and planning interventions to accomplish conservation goals (known as a trajectory), to achieve the predefined end state (Apfelbaum and Haney 2012). When conservation is focused specifically on species preservation, the conservation planning process has three primary goals: maintaining habitat necessary to accommodate all life stages of a species including dispersal; reducing or mitigating threats; and maintaining genetic diversity (Hasse 2004).

Conservation plans typically meet species needs by focusing on land away from human populations in order to reduce potential conflicts associated with management (e.g., prescribed burns) and interactions (that could be detrimental to species or potentially dangerous to humans), and to reduce the likelihood that humans will perceive either the species or the conservation measures as nuisances. The separation of humans from conservation areas also reduces potential impacts to the stability of community structure and form. To maintain the functional connectivity of habitat patches within a fragmented landscape context, Marzluff and Ewing (2001) find the conservation biology literature is focused on two approaches: establishing corridors connecting habitat patches; and, increasing the size and interior area of native patches through native habitat buffers.

A second consideration of traditional conservation planning is scale (Miller 2008), with the goal of reserving large tracts of land to accommodate habitat needs without risk of fragmentation caused by urbanizing areas. The focus on large tracts of land is based on contemporary and historic data and the fossil record, which indicates a linear relationship between the area of a biogeographical region and the amount of species diversity it can support. Area is an "inherent property of every biome" likely making it impossible for a remnant patch to maintain the same dynamic function of its components when it is reduced to a fraction of its original size (Rosenzweig 2001).

Large areas may better support habitat needs for foraging, breeding sites, and dispersal (the movement away from birth sites to breeding sites). As introduced above, the Endangered Species Act requires consideration of critical habitat areas as part of listing (U.S. Fish & Wildlife Service 2017). These areas are geographically defined to include "primary constituent elements," or the biological and physical features a species needs to fulfill life processes and successfully reproduce (U.S. Fish & Wildlife Service 2009). The U.S. Fish and Wildlife Service (2017) identifies the following five primary constituent elements:

- Space for individual and population growth and normal behavior
- Cover or shelter
- Food, water, air, light, minerals, or other nutritional or physiological requirements
- Sites for breeding and rearing offspring
- Habitats that are protected from disturbances or are representative of the historic geographical and ecological distributions of a species

Species conservation requires a consideration of landscape scale resources to ensure all of a species habitat requirements are met. The USFWS list of constituent elements required for critical habitat identifies the range of resources species may require, over areas of variable size. The field of landscape ecology seeks to understand the scales at which species utilize and interact with habitat resources.

Ecology can be described as the study of the interactions of organisms and the environment (Forman 2016), providing understanding of the processes supporting habitat and stable wildlife populations. Landscape ecology describes the relationship between habitat and stable wildlife populations that inform contemporary conservation actions.

The Ecological Society of America has identified five principles of landscape ecology that are particularly pertinent to understanding the impacts of land use on biodiversity: time, species, place, disturbance and landscape (Dale et al 2000). As Dale *et al.* (2000) discuss these principles describe the relationships among species, and between species and the surrounding landscape, which changes over time and can be impacted by disturbances. Further, they discuss the important concept that each site is a unique “place” that must be understood as it functions for species and considered as to how it relates to broader landscape processes and functions. Finally, landscape ecology considers the attributes and patterns of habitat patches that define how the landscape functions for species. These principles dictate guidelines for land use that serve as “practical rules of thumb” to incorporate ecological principles into the process of land-use decision making, as outlined in Table 2.3.

Table 2.3. Landscape Ecology Principles and "Rules of Thumb." Adapted from Dale *et al* (2000).

Landscape Ecology Concept	Principle	Land Use Decision-Making 'Rule of Thumb'
Time	Landscape shaping processes have temporal dimensions	• Plan for long-term change and unexpected events
Species	Species and networks of species have far-reaching effects on ecological processes	• Preserve species associated with rare landscape elements
Place	Each site or region is the result of a unique set of biotic and abiotic conditions that shape or constrain ecological processes	• Examine impacts of local decisions in a regional context • Avoid or compensate for the effects of development on ecological processes
Disturbance	Important and ubiquitous ecological events with effects that strongly influence species populations	• Avoid land uses that deplete natural resources • Minimize the introduction and spread of nonnative species
Landscape	Shape, size, and spatial relationships of habitat patches affect ecosystem function	• Preserve rare landscape elements • Retain large contiguous or connected areas that contain critical habitats

These principles broaden a consideration of land use planning to consider the site impacts over time, and the broader landscape patterns and processes that are impacted by land use changes. Of particular interest, the authors state the importance of identifying species that fill unique ecological functions within the landscape, and the importance of preserving these species. While the principles discuss the importance of identifying and understanding the unique qualities of the site particularly within the broader context, the principles do not provide any guidance on how to modify site ("place" as listed in the principles) level design or planning to avoid or minimize those impacts.

Reconciliation Ecology Defined and Examples

Several authors have noted the inadequacy of traditional modes of biodiversity conservation for addressing the unrelenting pace of land use change and resultant habitat loss that characterizes contemporary modes of development at the national and global scales (Rosenzweig 2001, Hobbs, Higgs, and Harris 2009, Kowarik 2011, Hobbs 2014). In addition to the continued loss of remnant habitat, a reliance on traditional reservation and restoration approaches to habitat conservation is criticized as not considering the diffuse impacts of human activities that reach isolated, undeveloped land such as pesticide residue from agricultural landscapes (Rosenzweig 2003). Further, there is growing recognition that the ecological footprints of cities extend well beyond their borders due to importation of resources (Ricketts and Imhoff 2003). This may be compounded by the prediction that distances between urban and protected conservation areas will significantly shrink, resulting in greater conservation impacts to rare species particularly in developing countries (McDonald, Kareiva, and Forman 2008). Finally, traditional approaches have been criticized for not acknowledging the presence of an ecological "tipping point" requiring "last ditch" alternatives in order to preserve species (Rosenzweig 2003).

The large tracts of land required to isolate conservation areas are becoming increasingly rare as urban sprawl continues to encroach upon them (Miller 2008). As Bennett and Saunders (2010, 99) note, despite holding great value, "National parks and dedicated conservation reserves…are too few, too small, and not sufficiently representative to conserve all species." In addition, land is increasingly held by private owners which makes large-scale conservation efforts difficult if not impossible. In the United States, over 60% of land area is privately owned (Nickerson 2011), complicating large-scale habitat conservation and management.

From a biological perspective, trying to preserve species diversity through remnant patches could be viewed as doomed to failure (Rosenzweig 2001). Due to habitat fragmentation and degradation, species are trapped on 'islands' of habitat. Consequently, they are more easily lost entirely to stochastic events of disease, predation or further habitat loss – all of which may be exacerbated by climate change and the fact that there are no new habitat patches being created in which species can find refuge (Rosenzweig 2001). As a result, the 'reserve' model for biodiversity conservation may no longer be the only or most effective approach to preserving many species (Miller 2008).

In addition to not providing an effective means of permanently preserving species, many ecosystems have been so radically altered from their historical trajectory that they can no longer be designed and managed using conventional restoration goals and methods. As an alternative, Hobbs et al (2014) advocate for a new "mosaic" approach to ecological landscape management that acknowledges the very different ecosystems that now compose landscapes including remnant (or, historic) patches, and "novel" patches that have been "pushed beyond their historical range of variability" but that can still be "manipulated to meet desired future ecological conditions." As the "long-held belief that rural landscapes are better for native biota is breaking down in some parts of the world" in particular due to the expansion of intensive agriculture, researchers have begun focusing on the benefits of urban green space (Gaston, Davies, and Edmondson 2010). However, urban places are profoundly affected by human activities and therefore have only tenuous connections to analogous "natural ecosystems." As a consequence ecologists have been tasked with developing an urban-specific understanding of ecosystem function (Gaston, Davies, and Edmondson 2010). While many urban habitats are likely "redeemable" from their current state given enough time and money, they can be considered novel because they are very unlikely to ever revert from urban use (Hobbs 2014).

Despite drastic changes to the form and composition, the urban landscape may still hold promise as potential habitat even if urban sites may no longer resemble the pre-existing natural landscape. For Michael Rosenzweig, reconciliation ecology complements the biodiversity reserve approach to conservation by forcing a reconsideration of human use spaces.

Reconcile means "to restore to friendship or harmony" (Merriam-Webster 2017), and according to Rosenzweig, the goal of this approach is to give native species "back their geographical ranges without taking away ours" (Rosenzweig 2001, 5409). As he states, in this book *Win-Win Ecology: How the Earth's species can survive in the midst of human enterprise*" the work of reconciliation requires "inventing, establishing, and maintaining new habitats to conserve species diversity in places where people live, work, or play"(Rosenzweig 2003, 7).

Despite the complexity of his concept, Rosenzweig (2003, 7) states reconciliation ecology is simple

> “we must learn what species need in order to get along with us, and we must do that job for thousands of separate species. Then we must diversify the habitats of our surroundings instead of creating, as we now do, the very limited number of habitat architectures that we have come to like. Every front lawn need not look like a golf course. Every city park need not look like a savannah. Every schoolyard need not look like a desert.”

The call to “integrate conservation efforts with other human activities” has been echoed within more recent conservation biology literature in acknowledgement that roughly 25% of threatened species in the world live outside of protected conservation areas (Koh and Gardner 2010). In order to accommodate new species in the urban landscape we need to determine what components of the species life history are essential to their survival and then “reassemble the critical components into new habitats and landscapes of which we are also a part” (Rosenzweig 2003, 8). Reconciliation ecology proposes that a habitat patch be able to support wild species throughout their life history rather than providing\g a sole resource, such as only shelter, or forage only at one time of the year. This requires scalable, species-specific conceptualizations of habitat that Rosenzweig (2003) suggests will necessitate partnerships and community building at multiple levels of society from neighborhood to national scales to create and manage habitats. Based on his description, Reconciliation Ecology follows a fairly simple outline: first identify the species to reconcile, determine what their habitat requirements are, and the primary threats they face, then define their habitat range and develop design and management approaches to incorporate them within sites. However, Rosenzweig’s discussion does not clearly identify who should be tasked with starting and curating this process and how the purposeful efforts for reconciliation begin and are incorporated in site-level action.

Rosenzweig's book sets the stage for the range of factors involved in reconciliation ecology clearly indicating reconciliation ecology is both ecological and cultural. Re-engineering human habitats to become habitats for other species also requires understanding human environmental preferences, and social and economic values that guide land use, design, and management decisions. As Rosenzweig states, the "secret weapon" of reconciliation ecology is the double-edged sword of human culture which allows humans to be accustomed to "almost anything. And what we get used to we come to prefer" (Rosenzweig 2003, 176).

In *Win-Win Ecology* Rosenzweig makes repeated reference to three human landscape categories (live, work and play) to establish his thesis that humans must reconcile the broad range of landscapes we create with other species. Although they are not defined within *Win-Win Ecology*, the three land types suggest a system of classifying landscapes based on human uses and values that must be mediated in determining strategies for reconciliation.

To illustrate the feasibility of his proposition in *Win-win Ecology*, Rosenzweig provides examples of reconciliation ecology from United States, England, and Israel. His case studies demonstrate how reconciliation is facilitated through intentional design and management interventions, as well as through "happy accidents" that have preserved populations of threatened species.

A review and categorization of case studies included in *Win-Win Ecology* identified six elements critical to reconciling wildlife species within human-dominated landscapes:

1. Species
2. Site type
3. Threat
4. Critical component of species biology
5. Root human cause of threat
6. Reconciliation design

This categorization, presented in Table 1, identifies the importance of determining the threats to critical components of a species biology and the underlying human actions that result in a threat. Analysis and categorization also determined Rosenzweig's examples of purposeful reconciliation included three reconciliation approaches: new design, modification of existing design, and altered management strategies.

Other examples of reconciliation in the include the redesign of building roofs for insect and avian species (Rosenzweig 2016) and enhancement of existing seawall structures to provide habitat in urbanized coastal habitats (Chapman and Blockley 2009) as living shorelines. Engineered green roofs hold particular promise for reconciling a largely underused ubiquitous element of the urbanized landscape to create new ecosystems (e.g., Brenneisen, Rosenzweig 2016). Despite examples of green and brown engineered roofs that provide habitat for spiders, insects and shore nesting birds, Rosenzweig (2016) admits that broad-scale rooftop reconciliation requires expert judgement and trial-and-error. This conclusion begs the question that if biologists have not yet figured out the formula for modifying a ubiquitous urban form such as rooftops to provide habitat, should landscape architects bother trying to engage the process? If so, then how? Rosenzweig's article highlights that data is required to further rooftop reconciliation efforts and that knowledge production is a critical component to expanding the conservation focus to include urban areas.

Table 2.4: *Win-Win Ecology* Examples of Successful Reconciliation. Adapted from Rosenzweig (2003)

Species	**Site Type**	**Threat**	**Critical Component**	**Root Human Cause**	**Reconciliation Design**
Eastern Bluebird	Residential yards (Live)	Habitat loss, Invasive Birds	Nesting	Management (removal of dead/dying trees)	Design - constructed nesting boxes with small holes to exclude sparrows and starlings
Shrike	Ranchland (Work)	Habitat loss	Mating display	Management (loss of perch shrubs/trees)	Modification - added fence posts with barbed wire to cattle pasture (allows shrike to impale prey)
Natterjack Toad	Natural	Habitat competition from common toad	Habitat	Management (change in habitat composition, structure)	Management - increased grazing to control dense growth, pond maintenance
Chiricahua Leopard Frog	Ranchland (Work)	Invasive frogs	Nesting	-	Design - water tanks on cattle ranches provide habitat – easily monitored, protection against drought.

In the great experiment of re-engineering and re-imagining what landscapes of live, work, and play look like and function for humans and other species, Rosenzweig (2016) acknowledges there is no clear answer as to how many species can be incorporated into a reconciliation project. Instead he urges society to strive for a diversity of novel habitats and approaches. Rosenzweig further advises against seeking to devise a "single answer" to what reconciliation looks like and what it constitutes, for fear that it "gets incorporated into a bureaucratic manual of new ecosystem requirements" (2016, 10).

Balanced against the fact that each site and species pairing requires a unique assessment and reconciliation response, several authors have begun to address core considerations that may be broadly applicable to mediating between human uses in urban landscapes and the needs of species. Couvet and Ducarme (2014) suggest reconciliation ecology should focus on preserving "ordinary" biodiversity that forms part of common experience rather than globally rare and exotic species. Ordinary species, they find, are part of our natural heritage, support locally-valued ecological processes, improve our quality of daily life and provide context and setting for our activities. To that end, they define key biological and social questions to move reconciliation ecology forward. Within the biological realm Couvet and Ducarme suggest a focus on identifying and describing changes to biodiversity in order to determine causes. They propose that reconciliation address functional processes and those species that perform roles that no other species can perform to keep ecosystems intact. Couvet and Ducarme identify the social components of reconciliation ecology as a process of determining how to "frame the relationship between societies and biodiversity, so that the fate of ordinary biodiversity matters when public policies are considered."

As introduced earlier in this chapter, the urban landscape is often far different from surrounding remnant natural landscapes, exhibiting unique "fundamental processes and structures" that strongly influenced by human culture and economic activities and which have no clear analog within the natural world (Lundholm and Richardson 2010, 967). Often called "novel" because they have no obvious reference in the natural world to guide restoration or habitat creation, urban landscapes present a challenge to reconciliation. However, Lundholm and Richardson (2010) suggest that urban areas may not be as novel as commonly thought. Rather, under closer inspection, urban landscapes may present specific spaces and microclimates may hold habitat value that is not "perceived as novel by colonizing organisms" (972). Their review found that sites may actually have analogs that exist thousands of miles away rather than within adjacent natural remnants. Overall Lundholm and Richardson (2010) suggest that urban areas can still be assessed as holding natural analogs that can be augmented as part of reconciliation design, and they identify several examples of species overcoming dispersal obstacles to colonize unlikely urban habitats. They suggest that attention be paid to modifying the urban form to improve functional similarity to natural landscapes, highlighting the potential for the concrete covered urban surface to house rock barrens and outcrop species. Similarly, Locke and Rissman (2015) suggest that artificial substrates, ubiquitous concrete, and other abiotic elements are often easier to manipulate than biotic elements, and should be a focus of restoration and reconciliation efforts.

Urban Wildlife Conservation Programs

There are numerous organizations focused on improving the habitat value of urban landscapes at the "backyard" and city scales. These certification programs identify guidelines for habitat improvement within different types of human sites and as such provide further examples of reconciliation ecology design in practice. For most of these programs, a menu of habitat interventions provides opportunities to improve the habitat value of sites, recognizing that each site may be unique depending on size, use, and placement in the urban gradient.

A categorization of these programs is provided in Table 7, which helps to synthesize the types of species being actively invited into human sites and the methods considered necessary for successful habitat creation.

Backyard Habitat Programs

There is a growing movement of people interested in addressing biodiversity loss through the design and management of their own property. The "backyard habitat" movement, as it is known, intends to attract wildlife through native planting and addition of other resources such as water and shelter (Rosenzweig 2003). Entomologist Doug Tallamy is a strong proponent of the bottom-up approach, advocating for greater balance between vegetation selected for decorative purposes and those that provide food web value and ecosystem services such as soil restoration and carbon sequestration (Tallamy 2014). In his popular book, *Bringing Nature Home*, Doug Tallamy notes the importance of utilizing native host plants to support species diversity among arthropods, and highlights the important role native vegetation plays in establishing a biodiverse food web. He writes that many migratory birds, though sustained on human provided seeds as adults, require caterpillars and other insects to feed their young (Tallamy 2011). To encourage and guide backyard habitat as a way of incrementally establishing a habitat matrix and migratory corridors, a variety of local and national organizations including Wild Ones and the National Wildlife Federation have established certification programs for “backyard habitats”

Community Level Programs

While acknowledging that the movement to create backyard habitat is culturally important as an awakening of consciousness about the effects of urban design, Rosenzweig (2003) points out two critical flaws with the backyard habitat approach to biodiversity conservation. First, backyard habitat is typically generic and not specific to the needs on individual species. In order for design interventions to be effective at conserving biodiversity, they must create “specific habitats for well-identified species.” Second, backyard habitats cannot “attract wildlife” if wildlife is not locally present. Rosenzweig further suggests that backyard habitat is only effective if it is adjacent to a “large park or wildlife preserve” that provides a source population that might utilize the resources provided within the backyard habitat. Rosenzweig concedes that backyard habitats may improve biodiversity if they are designed for specific species rather than simply to supply “native” plants, and if they are designed to support the species throughout its life cycle. Instead of having a patchwork of temporary efforts to attract species to back yards, Rosenzweig argues that a large-scale approach to creating “diverse anthropogenic habitats” is necessary to give species “time and space” in which to adapt to novel habitats and new processes. Accomplishing this, Rosenzweig notes, will require creating partnerships at multiple levels, from local communities to nations, with the species defining the scale of partnership.

Large-scale efforts for creating habitat within urban landscapes currently exist, and online searches identified several national and state organizations that certify local communities for providing wildlife habitat. Among these programs are the National Wildlife Federation, Bee City USA and Bird City Wisconsin. Over 90 communities have become Certified Community Wildlife Habitat Communities through the National Wildlife Federation (National Wildlife Federation 2017). Although the Audubon Society does not maintain a habitat certification program, the organization does report efforts to improve the habitat value of urban areas by "transforming our communities into places where birds flourish" (Audubon 2017). The Audubon Society promotes solutions to urban threats on birds that honor the 'unique ecological and cultural story" of each community. These solutions include bird-friendly native planting; bird-friendly buildings (reduced reflection during day and low lights at night); and providing avian architecture as artificial nesting and burrowing sites (Audubon 2017).

Summary of Urban Wildlife Conservation Programs

Each of these programs provides steps toward incorporating targeted wildlife species into the urban landscape through meaningful, biologically-based interventions and public promotion. As a result, they provide examples of reconciliation ecology through targeted inclusion of species habitat within existing human use spaces. Overall, the programs require certified habitats address life history needs and the need to gain public support for long-term success. Some programs, such as the Wild Ones Butterfly

Garden Recognition Program require a temporal commitment to habitat plantings and will only certify established habitat plantings over two years old. Also, while most programs recommend using native plants, Wild Ones requires at least 75% native plant species within the habitat patch, not including ‘nativars.’

As Table 2.5 shows, most of the existing habitat certification programs reviewed are focused on incorporating pollinating insects and birds into urbanized landscapes. Most programs also required overall approach to sustainability such as water harvesting. They also focus on minimizing toxicity and disturbance within site management, including limiting or forbidding use of herbicides and pesticides. Table 7 also indicates the importance many of the certification programs place in communicating habitat value and promoting the mission of habitat creation to a larger audience.

Interestingly, analysis of program requirements indicates that several certification programs utilize human use typologies to evaluate the opportunities and constraints for habitat within sites ranging in scales from balcony container gardens to roadsides. These typologies are is used to identify the fullest range of potential habitat interventions possible for a site given its size and the habitat potential of the sites landscape context. Similarly, the National Wildlife Federation includes specific requirements for different types of sites, for example through the Sacred Grounds program for places of worship. As community gathering sites, and places valued for leadership, places of worship present unique opportunities to engage and inform people about the importance of urban habitat, which they are required to provide through workshops, tours and other community events.

In addition to habitat certification programs, organizations such as the North American Pollinator Protection Campaign (NAPPC) and Xerces Society work to develop pollinator habitat enhancement and best management guidance for ubiquitous human site types such as roadways. These efforts also provide examples of reconciliation design in practice.

Table 2.5. Categorization of Habitat Certification Programs
Other requirements: (F)=community forest management (C)=conservation measures such as rainwater harvesting, composting (A)=Aesthetic considerations such as edge treatments, focal points like bird baths, structure and screening elements (P)= park planning incorporates habitat

Organization/ Certification/ Design	*Scale*	Target species/ group (Implied or Stated)	**Human Site Typologies**	**Considers human use/value**	**Requirements**	Legal Protection	Designate Managing Organization	Public (U) / Private (R) Land / Both	Full Life Cycle Habitat	Address Architecture	Low Chemical Use	Promote Program	Public Education	Locally native plants	Control of Cats /other domestic/ animals	Monitoring	Invasive Species Control	Other
Wild Ones Butterfly Garden Recognition Program	Site	Butterflies	X					R	X		X	X	X	X		X	X	
Bee City USA	City	Bees				X	X	B	X		X	X	X	X				X
Bird City Wisconsin	City	Birds				X		B					X		X			P, F
NWF Garden for Wildlife	Site	Multiple						B	X			X						A, C
NWF Community Wildlife Habitat	City	Multiple	X	X				B	X			X	X					
Best of Texas Backyard Habitat Certification	site	Multiple	X	X				R	X						X		X	C
Monarch Waystation	Site	Monarch	X					B	X			X						C
North American Butterfly Association	Site	Butterflies	X					B			X	X	X					
Pollinator Pathway	Site/ City	Pollinators		X				B		X		X	X					

Biodiversity Conservation within Landscape Architecture

Michael Rosenzweig proposed reconciliation ecology as a conservation strategy that focuses on including native species within a range of human-dominated landscapes, including agricultural, industrial, and urban spaces. Through modifying existing forms and modes of living, working and recreating within these landscapes, humans may be able to create and sustain new habitats for conservation of species. To assess the state of biodiversity design within landscape architecture and urban planning, the following section briefly identifies foundational texts and a review of the literature within *Landscape Journal*.

Ian McHarg published *Design with Nature* in 1969 establishing an approach to planning and design by assigning land uses based on environmental suitability. McHarg provided a series of landform- and place-based examples to advocate for situating human settlements, land uses and values more sensitively and sustainably within existing natural systems.

Several decades later, Dramstad, Olson, and Forman (1996) published the primer *Landscape Ecology Principles in Landscape Architecture and Land Use Planning,* which explained and illustrated key concepts of landscape ecology that could be applied to landscape planning and design in order to minimize degradation and maximize ecological integrity. The authors noted that during site design, landscape architects "seldom…incorporate a more broad-reaching, landscape ecological approach" to consider the potential impacts of proposed planning or design on the broader regional ecological context (Dramstad, Olson, and Forman 1996, 47). To address the lack of ecological awareness among landscape architects, Dramstad, Olson and Forman introduced core landscape ecology concepts to provide a conceptual understanding of landscape composition and structure.

A targeted review of literature within *Landscape Journal* sought to gauge the level of knowledge production toward the development of a biodiversity-focused practice within landscape architecture. Table 2.6 provides a categorization of articles reviewed.

The articles identified in the literature search provide some examples of a developing reconciliation ecology approach and trans-disciplinary efforts to improve ecological design. Articles by landscape architects focused primarily on raising awareness of the need for ecologically-based design, with some efforts to Natural resource managers Rodiek and DelGiudice (1983) introduced the value of data-driven design to landscape architecture, a profession that they characterized as previously guided primarily by intuition and personal judgment. The authors outlined a method for incorporating research data into the planning and design process to improve elk habitat within managed forest land.

Table 2.6. Biodiversity Literature Search Results from *Landscape Journal*.

Author	Year	Title	Purpose	Habitat Guidance	Social/ Biological Issues	Planning/ Site Design	Author Discipline
Rodiek and DelGiudice	1983	Designing for Wildlife Habitat in Managed Forests	Tool Development	Y	B	P/D	CB
McPherson and Nilon	1987	A Habitat Suitability Index Model for Gray Squirrel in an Urban Cemetery	Tool Development	Y	B	D	CB
Dawson	1988	Flight, fancy and the garden's song	Tool Development	N	S	D	LA
Merchant	1998	Partnership with nature	Issue Awareness	N	S/B	P	LA
Heater Jr. et al.	1999	Who's Wild? Resolving Cultural and Biological Diversity Conflicts in Urban Wilderness	Issue Awareness	N	S	P/D	LA
Gobster	1999	An ecological aesthetic for forest landscape management	Tool Development	N	S/B	P	LA
Miller	2008	Conserving Biodiversity in Metropolitan Landscapes: A Matter of Scale (But Which Scale?)	Issue Awareness	N	S/B		CB
Opdam and Steingrover	2008	Designing Metropolitan Landscapes for Biodiversity	Strategy/Tool Development	N	B	P	CB
Hunter	2011	Using Ecological Theory to Guide Urban Planting Design: An adaptation strategy for climate change	Strategy/Tool Development	Y	S/B	D	LA/CB
Zeunert	2013	Challenging Assumptions in Urban Restoration Ecology	Issue Awareness	N	S	P/D	LA
Weller	2014	Stewardship Now? Reflections on Landscape Architecture's Raison d'etre in the 21st Century	Issue Awareness	N	n/a	n/a	LA
Mooney	2014	A Systematic Approach to Incorporating Multiple Ecosystem Services in Landscape Planning and Design	Tool Development	N	S/B	P	LA
Sack	2015	A Landscape Neo-Baroque: Design as a Cultural Strategy for the Restoration of Urban Ecosystems	Tool Development	N	S/B	D	LA

(S)=focus on addressing human use/values; (B)=focus on species biology, habitat data, etc.; (P) = Planning focus, (D) = notes specific design considerations or implementation strategies, (LA)=landscape architect or planner, (CB)=conservation biologist, ecologist or natural resources manager

Gobster (1999) addressed the question of how to frame the human relationship with the rest of the natural world through landscape design and use, a conceptual question that also was raised by Merchant (1998) and Heater Jr, Blazej, and Moore (1999). Gobster notes that for the average person, perception of the environment is primarily aesthetic, and that in forest landscapes, management for scenery often conflicts with ecological management. As a result, our current conceptions of landscape aesthetics are an impediment to ecological forest management. He proposed an alternative aesthetic based on ecological principles, and provided planning implications and site-level design guidance for cultivating an ecological aesthetic. These site-level management guides include using design cues to alert visitors to ecological management practices, providing interpretive materials, public involvement, and shaping "conspicuous experiential" spaces to improve the visual and character of areas that are actively managed for example through clearing and fire. In essence, Gobster reconciled human aesthetic use with forest management.

Issues surrounding appropriate human uses of conserved areas were also raised by by Heater Jr, Blazej, and Moore (1999). The authors noted the lack of data to clearly define appropriate and low-impact recreational uses of natural areas in order to limit impacts to biodiversity. Specifically, they raised awareness of the tendency toward racism and other social injustices in defining appropriate human uses of natural areas in the absence of data on impacts to biodiversity.

The literature review identified two articles advancing the modification of human use spaces to support other species – providing early examples of a reconciliation ecology approach.

An early article by Nilon and McPherson (1987) modeled habitat suitability within the urban landscape, to understand core landscape features such as nesting trees and forage necessary to accommodate gray squirrels within a historic urban cemetery. The model was applied to three sites within the cemetery to identify the core habitat requirements for the squirrels. Using this model, the authors derived management guidelines for tree removals and plantings in order to maintain an important urban greenspace as habitat for the species. Due to their recommendations on how to improve the habitat value of an existing human-focused urban landscape, this article by Nilon and McPherson was the first example of reconciliation ecology identified within this review of the landscape architecture literature.

A conservation biologist and ecologist, Richard Miller (2008) provided a second example of urban reconciliation ecology design. Expanding on Rosenzweig's (2003) call for reconciliation of human-dominated spaces, Miller penned an article within *Landscape Journal* advocating for broadening reconciliation ecology to include a greater focus on the relationship between biodiversity and human well-being. In his article "Conserving Biodiversity in Metropolitan Landscapes: A Matter of Scale (But Which Scale?)," Miller suggests that urban design needs to highlight human interdependence with the natural world while including other species in places where people live and work. He bases his argument on the paired facts that biodiversity is threatened yet also plays an important role in quality of life for urban residents. Miller presents landscape architects, among other environmental professionals, as playing "crucial roles in maintaining and increasing biodiversity in the metropolitan landscape, and in fostering a greater awareness and appreciation for biodiversity among the people who live there" (2008, 114). Yet, Miller finds these goals are impeded by several factors including a lack of clear and specific guidance to inform ecological design within urban systems. He cites Perlman and Milder's (2005) book as identifying the conservation biologists' axiom of "It depends," as a general response to requests for specific guidance on the functionality of habitat planning and design decisions. He further notes the lack of research at "appropriate" scales, to provide pertinent data to guide site design within dynamic and complex urban ecological systems.

To derive meaningful solutions in the face of these impediments, Miller echoes the earlier argument by Gobster (1999) that landscape architects need to shift their values, divesting themselves from focusing on aesthetics. Instead, Miller advocates for considering multiple design scales that determine the functional relationship of a site to its surrounding context. Miller notes it is important to identify the "scale of personal experience," which he suggests may be the most important factor in urban biodiversity design because it makes the importance of biodiversity conservation relevant to people's daily lives. To address the lack of research to guide species and site-specific design, Miller suggests an adaptive management approach to biodiversity design that integrates the site within broader ecological processes through a "learning by doing" model. Such an adaptive management strategy takes a phased (incremental) approach to design that is refined through monitoring and defined measures of success.

Miller's article highlights the untapped conceptual linkage between biodiversity and human well-being despite several decades of research documenting the benefits of nature to individuals and communities. Human well-being can be used to make biodiversity conservation relevant to people's daily lives as well as a metric of success for adaptive management. Further, Miller suggests utilizing the popular concept of sustainability to further biodiversity conservation, by broadening the conversation of sustainability beyond energy savings to include biodiversity.

Miller reviews examples of urban biodiversity design to provide two strategies for advancing “metropolitan” biodiversity design: first, he advocates blurring the distinction between human spaces and remnant habitat fragments to ‘grow’ habitat between them; second, he suggests creating “spaces that enhance public appreciation for the interdependence between people and other species” (2008, 122). Miller provides no examples of where such a space should occur or what it would look like.

Landscape architect Kerry Dawson (1988) provided input on what habitat designs should sound like, however. Following her critique that urban residents suffered from a loss of personal experiences with nature as a result of garden design that did not support biodiversity. Focused on the loss of auditory experiences of nature, Dawson discussed the design of nature soundscapes created by including habitat for “sound-making fauna” such as birds and insects.

Merchant (1998) also advocated for design to increase awareness of the natural world, through her discussion of “eco-revelatory” design as a “partnership between people and nature.” Through her review Merchant called for a partnership ethic to guide design toward “the greatest good for the human and non-human community” by acknowledging their interdependence. However, while the experience-based approach to design advocated for by Dawson (1988) and Merchant (1998) provides a more holistic and ecologically-minded approach to site design, they are both focused on enhancing human experience and awareness rather than accommodating the inherent right of native species within the urban landscape.

Opdam and Steingröver (2008) acknowledge the complexity of issues involved in conservation design and the limitations of both available species-specific guidance and ecological knowledge held by planners and urban designers. The authors contribute their expertise as conservation biologists and ecologists to propose a simplified approach to conservation design for local land use planners. The authors find that local planners rarely use scientific knowledge to make land use decisions. To rectify this, they propose an ecosystem network concept to facilitate incorporation of biological and ecological data. Opdam and Steingrover compare the approaches used by ecologists and landscape architects and planners, finding ecologists focus on landscape processes while landscape architects and planners focus on spatial patterns. To bridge the conceptual gap between planners and urban designers, the authors call for ecologists to "develop a step-by-step" method for landscape architects and planners. Opdam and Steingrover acknowledge this will require an "iterative learning process" (77), which they concede will be a challenge. They note the primer developed by Dramstad, Olson, and Forman (1996), but criticize the book as "elegant" but "loosely based on landscape ecology theory" (70). To improve upon the work, Opdam and Steingrover propose creating spatial structures and variables that express ecological processes while being sufficiently generic to include multiple species and a range of scales. They propose that "landscape patterns be designed as a template for biodiversity," and supply ten "building blocks" to use in developing design guidelines: ecosystem patch, patch quality, source and sink patches, ecosystem network, key patch, minimum network carrying capacity, stepping stone, matrix resistance, corridor, stronghold. The authors do not provide guidance on how these building blocks might inform site-level design, or how the generic concepts can be activated for specific taxa or species.

Landscape architect and ecologist Mary Carol Hunter did address the need for site-level design strategies in her 2011 article on establishing climate resilience within urban systems through ecologically-based planting design. Hunter defines plant selection criteria to aid in protecting wildlife corridors and assisting species migration in response to warming climate based on three core ecological concepts: species plasticity, resilience and structural diversity. Focusing on urban gardens as a primary component of green infrastructure and as opportunities for urban habitat creation, Hunter's criteria address core ecological concepts through metrics such as a plant's heat and soil moisture tolerance and utility to wildlife. In addition, Hunter codes plant selections to consider social factors such as aesthetics and financial constraints by including criteria such as bloom color, plant texture, and nursery availability. Consequently, Hunter's approach can also be considered a step toward developing reconciliation ecology design.

To encourage the evolution of aesthetic preference and cultural norms that lead to ecologically degraded and incongruous landscape designs with little habitat value Catharina Sack (2015) that proposed utilizing historical design precedents. Noting the rapid pace of urban development and the limited palette of aesthetic options for designed human-use spaces, Sack proposes Baroque design as a cultural framework for a new design strategy to negotiate contemporary aesthetic preferences and biodiversity preservation in Perth, Western Australia. Sack finds the Baroque focus on "wonder" a good fit for the dramatic textures and forms of indigenous vegetation, providing municipalities and homeowners with a new cultural reference to guide design instead of the popular garden styles that intensively use water and fertilizer and contribute to ecosystem degradation.

While Hunter (2011) Sack (2015) and earlier authors seek to restore native ecosystems or establish a balance between native species habitat and the inherent constraints of existing urban patterns, architect Zeunert (2013) determined urban biodiversity conservation as anachronistic.

Contributing to the literature a scathing critique of urban ecological restoration Zeunert, considered the practice of restoring native systems to be backward-looking and based on false assumptions. Zeunert finds urban habitat restoration only increases the opportunity for wildlife-human conflict, and ignores the value of non-native biodiversity. In addition, he claims that devoting spaces to restoration reduces the area available for addressing what he considers more pressing urban issues such as employment and provision of ecosystem services of food and fiber. Instead, Zeunert closes his critique by advocating for urban agriculture, productive space, and green infrastructure. He specifically takes aim at the proscriptive use of native-only vegetation as a "retrospective and restrictive imposition" rather than using landscape to address present and future systems (239). It is interesting to note that by proposing green infrastructure as an alternative to restoration, Zeunert implicitly defines green infrastructure as a framework for human-centric design that need not consider urban impacts to native species or broader concerns for biodiversity. Contrary to the established literature Zeunert does not acknowledge biodiversity as critical support for the ecosystem services he advocates for.

Mooney (2014) also advocates for an ecosystem service approach to landscape architecture. He proposes an alternate but complementary approach to SITES and the Landscape Architecture Foundation Landscape Performance Series (LPS) to expand the ecosystem services provided within design projects. Mooney distinguishes his approach through a process of public participation to identify ecosystem services of concern. However, Mooney's evaluation and planning method, which he calls the Ecosystem Services Framework for Design/Planning, is based on an evaluation of design to provide utility to human beings and does not target the needs of non-human species, in keeping with a "service" conceptualization of nature.

Critique of Landscape Architecture as Ecological Design Field

The limited literature on biodiversity design within landscape architecture suggests a low rate of knowledge production and general concern for wildlife habitat creation or management within the profession in the past twenty years. This lack of scholarship has met with criticism on several fronts and suggests there may be obstacles to developing reconciliation ecology as an urban design approach.

Landscape architect and academic, Richard Weller (2014) criticized landscape architects for taking very few substantive steps toward proactively addressing global ecological collapse, despite frequently positioning themselves as stewards of the environment. Due in part to a focus on aesthetics and philosophical debates about the relationship of humans to nature, as well as a disconnection between practitioners and the academy, Weller says too little attention has been paid to the ecological implications of our work. Rather, ecology has been limited in consideration to "the symbolic order of things" such that "signification replaced stewardship," while professionals focus on marketing themselves as "purveyor[s] of artful and urbane public space" (Weller, 2014).

Further critiques of the field claim myopic application of environmental design; not adopting an ecosystem approach to design; applying an incomplete understanding of ecological principles; human-centered approach to design; lack of evidence-based decision making; and lack of substantive critique of contemporary urban forms and patterns, including sprawl which contribute to declining biodiversity. Landscape architects have been criticized for limiting their environmental considerations of a design to the site level: wind direction, patches of sun and shade, soil moisture and other local factors. If the goal of design is not purely aesthetic but also to create opportunities for biodiversity, sites need to be connected to their surrounding landscape context (Lovell and Taylor 2013), focusing on a connection to "remnants of native ecosystems" (Beck 2013).

As Beck (2013) clarifies, in order for urban biodiversity design to be "ecologically meaningful" it needs to be "operative" by functionally connecting to the larger landscape, both ecologically and socially. The spatial definition of the "larger landscape" and the functional goals of the site must be determined based on the target species for design work. By promoting biodiversity, incorporation of greenspaces is integral to the design process (McKinney 2010), which improves human communities (Beck 2013) The biggest challenge to creating biodiversity design may be getting urban designers interested in "the ecosystem perspective" (McKinney 2010). However, landscape architecture has a long history of advocating for biome-specific design (Rogers 2001) that can be channeled as we address contemporary challenges. Steiner et al. (2013)

advocate for ecological literacy within landscape architecture, and note the lack of attention to ecological literacy within formal education and accreditation.

Another critique of the profession, leveled specifically against landscape urbanism, is that it adopts concepts and terms from ecology without actually adopting the science of ecology (Thompson 2012). Ian Thompson (2012) further critiques thought leaders within the profession for accepting current trends of sprawl and unmitigated consumption as unavoidable by not critically analyzing the underlying cultural and political structures that drive unsustainable design. In addition, he finds biodiversity is not often a metric of good design; lack of consideration of where wildlife fits into the "functional" urban spaces landscape architects design: and limited acknowledgement of the underlying importance of biodiversity for ecosystem services.

When landscape architecture does seek to engage ecological principles as a means to improve habitat, the profession has been criticized for an incomplete understanding of ecological principles and a lack of consideration for non-human species, resulting in designs that establish or conserve remnant patches of "natural areas" without any consideration of what species they are intended to benefit or how they function (Hostetler 2014).

Roberts (2013) has suggested that the current discourse and practice of ecological design within landscape architecture and urban planning is based on a view of a singular nature that is external to humans, a view that is conceptually flawed and actually contrary to true ecology. According to Roberts, ecology is based on a multiplicity of natures and about relationships between organisms and their environment. Roberts believes truly ecological design must therefore foster democratic relationships between humans and non-human species by including “non-human natures” within the design framework as constituents (stakeholders) with competing interests. Such an inclusive approach may be the only way toward developing the “land ethic” advocated for by Aldo Leopold and effecting real and lasting biodiversity conservation.

In addition to appropriating ecological concepts, landscape architecture has been criticized for lacking a scholarly, scientific approach to the development of landscape designs. For example, Brown and Corry (2011, 327) argued that “much of contemporary practice in landscape architecture is still based on *beliefs* rather than *facts*.” In addition to a lack of reporting on the part of practitioners, Brown and Corry found that little “factual information upon which to base decisions” is generated within the profession. The consequence of this is a repetition of design patterns and forms grounded in precedent, rather than in evidence. This leads to increasing damage to biodiversity, and to natural and social systems. In order to “prevent or solve” these issues “rather than contribute to them,” Brown and Corry advocate for an “evidence-based landscape architecture” (EBLA) based on the model employed by the discipline and practice of medicine. Brown and Corry (2011) define EBLA as “the deliberate and explicit use of scholarly evidence in making decisions about the use and shaping of land.” In order to build a repository of data and best practices, or evidence, to guide the design of landscapes to function for a specific intended effect, landscape architects must look outside the discipline, especially when it comes to designing for non-human species.

At present there are several tools for landscape architects to use in achieving an EBLA: literature within the profession, the Landscape Architecture Foundation (LAF) Landscape Performance Series, and the Sustainable SITES Initiative Rating System. As evidenced above, the landscape architecture literature provides little knowledge production to guide evidence-based urban habitat design. Perhaps more concerning are calls to look past native ecologies to an unequivocally human-centered future (*e.g.*, Zeunert 2013). While the LAF Landscape Performance series provides several case studies identified as biodiversity projects, the case studies provide little information on strategies for habitat design or implementation. Finally, the preeminent program for evidence-based and peer-reviewed assessment of ecological design is the Sustainable SITES Initiative SITES v2 Rating System which provides pre-requisites and evaluation criteria to improve the ecosystem service value of site design. While the rating system provides a framework to guide ecologically-informed and lower impact design, it relegates consideration of wildlife species and habitat design as a component of the goal to "create regenerative systems and foster resiliency" for urban systems (Sustainable SITES Initiative 2014, xii). The only direct assessment of habitat within the rating system is the pre-requisite conservation of habitat for endangered and threatened species.

Conservation biologist Craig Groves (2008) decried the "startlingly" small overlap in methods between landscape architects and planners on one hand and conservation biologists on the other, even when landscape architecture is purported to incorporate ecology within its field of practice. Groves suggests the need for further collaboration between the conservation and land use planning camps, including the need for landscape architects to generate more data, and for conservation biologists to provide more useful and accessibly formatted information. Moreover, he notes the mismatch between the continental and eco-regional scales that predominate within conservation planning, and the municipal and site scales that are typically the concern of landscape architecture and land use planning. Existing patterns of compartmentalized knowledge production slows the pace of progress in addressing the loss of biodiversity.

As Beck (2013) notes, landscape architects can either disrupt or preserve biodiversity. McKinney (2002) suggests the primary effort should be to preserve remnant habitat as cities expand. For landscape architects, this starts with adopting a less destructive approach to native vegetation and topsoil during the construction process (McKinney 2002), which often results in a site being "scraped" to facilitate construction (Sack 2015). While McKinney proposes that intensely developed sites can be improved by revegetating areas with native species and protecting them to allow ecological succession, Rosenzweig (Rosenzweig 2003) proposes landscape architects should more purposefully modify urban sites to incorporate wildlife habitat for specific species.

Social and Cultural Considerations in Urban Wildlife Design

The loss of large patches of remnant habitat forces a consideration of the utility of the urban landscape for biodiversity conservation, and a rethinking of assumptions about these connections. A review of the inherent qualities of urban areas provides some cause for hope and a call to continual assessment, planning, and evaluation by landscape architects. Several features of the urban environment may provide opportunities for biodiversity conservation including proximity to volunteers for management and monitoring, as well as policy infrastructure to fund local projects. However, reconciling the urban landscape for wildlife may also be challenged by such as aesthetic preferences for highly manicured vegetation over the "natural" appearance associated with native forage plants (e.g. Nassauer 1995), as well as the perception and possibility that wildlife pose threats to public health by serving as disease vectors (e.g. Kingston 2016).

Rosenzweig (2003) devotes two chapters in his book to discussing the aesthetic and economic considerations of reconciliation ecology, highlighting these two important areas of concern which relate to broad shifts in decision making and landscape design and management. Instead of a patchwork of momentary efforts to attract species, Rosenzweig calls for large scale approaches to creating "diverse anthropogenic habitats" that give species time and space in which to adapt to new processes. He notes that this will require creating community among people and that the species of interest will dictate the scale of community building (neighborhood, states, nation). Rosenzweig argues that the "secret weapon" of reconciliation is the double-edged sword of human culture, stating, "Human beings can get used to almost anything. And what we get used to, we come to prefer." At present, we are used to an urban environment that degrades biodiversity and human wellbeing, however the hope is that through well-communicated and biologically and socially effective design, humans can get used to more biologically diverse and ecologically functional urban landscapes.

Urban Opportunities

In the United States as well as internationally, most people interact with nature within urban environments and studies have shown that many urban dwellers seek even more interaction with nature than is typically afforded within their immediate environment (Fuller and Irvnie 2010). The desire for increased experience with nature creates greater demand for natural areas, and yet as urbanization spreads, those interactions become increasingly difficult to obtain (Fuller and Irvnie 2010). Human interactions with nature in urban green spaces influences urban biodiversity directly and indirectly. While urban green space is often created and maintained "chiefly for human benefit," it can "directly enhance the ability of an urban landscape to support biodiversity depending on how it is managed" (Fuller and Irvnie 2010). Management can focus on providing aesthetic function, recreation or other uses. The location of urban green spaces often make them within easy access of volunteers and a more focused management approach.

Not only does the extent of urban green space affect the "biological quality" of urban areas but also the disparity in accessibility of experiences in nature between neighborhoods of different socio-economic status (Fuller and Irvnie 2010). In order for urban residents to reap the benefits of human-nature interactions, there not only has to be nature in the local urban environment, but it has to possess certain qualities that create reciprocal effects which "lead to a complex interplay between human activity and biodiversity" such as aesthetic value, and placement of site amenities that provide nature experiences while minimizing disturbances to plants and wildlife. As a result, management for urban biodiversity "should not, and probably cannot, be separated from programmes [sic] to improve human quality of life in urban environments" (Fuller and Irvnie 2010).

Human residents are by default the longterm stewards of any habitat creation or conservation project and they should be engaged and educated about habitat design projects and the importance of their own actions toward wildlife, including managing their homes and neighborhoods in ecologically sensitive manners, for instance, by using pesticides in their gardens, fertilizers on their lawns, or maintaining plants for pollinators (Hostetler (2014). Key to the success of design for biodiversity is communicating the importance of species, habitat, and "scientific knowledge" to urban audiences in a "user-friendly” manner (Frankie, Thorp, Pawelek, et al. 2009, 119). Miller (2008) cites Karasov (1997) as identifying the “scale of personal experience” as being the most important element in creating a design that makes meaningful change for the benefit of biodiversity. By extending natural habitat into the city, environmental designers will be creating spaces for interspecies interaction. The hope is that these experiences will result in a greater desire to preserve natural areas outside the city, and modify human behavior that is detrimental to ecological systems (Miller 2008).

The success of urban conservation projects is not only shaped by their design and management, but also by the attitudes, design practices and management of people who inhabit adjacent spaces (Hostetler 2011). In addition to providing urban residents with greater access to nature experiences, urban landscapes are planned and managed within policy infrastructure and funding systems that can facilitate conservation and other habitat projects. Cities can be used as management units for species conservation because the land area within a municipal city boundary is unified by funding structures, zoning regulations, and integrated land management strategies such as waste removal, right-of-way mowing and invasive species control. Cities also legislate behavior which can be used to modify land management by private landowners to benefit species through incentives or restrictions. The UN Millennium Ecosystem Assessment identified keys steps to reducing the degradation of ecosystem services. It recommended changing “the economic background to decision-making” and improving “policy, planning, and management.” This strategy emphasized knowledge integration to ensure that policy focuses on protecting ecosystems. The MEA authors argued that “natural assets…receive far better protection if their importance is recognized in the central decision-making of governments and businesses, rather than leaving policies associated with ecosystems to relatively weak environment departments." Therefore, cities can develop policy infrastructure to support large-scale habitat conservation practices that link biodiversity to overall economic and social wellbeing. Indeed, a review of urban wildlife conservation by Adams (2005) found it is characterized by a focus on education, the multi-functional use of wildlife habitat and human-wildlife interactions. His review also found that urban conservation initiatives are often undertaken at the city level and typically include a diverse group of non-governmental stakeholders.

Social and Cultural Norms

In order to be successful, efforts to improve ecological conditions through the modification of physical form and management of spaces require consideration of social and cultural factors in addition to the underlying ecological function (Warren et al. 2010). This includes regulatory and managing institutions, public policies and cultural values that shape perceptions of wildlife, as well as the role of 'nature' (Hadidian and Smith 2001).

The importance of addressing the social aspects of conservation was outlined by Joan Nassauer (1995) who developed four principles of culture that impact landscape ecology and should be considered by conservation pracitioners. First, Nassauer proposed that human perception, cognition, and cultural values directly affect landscape and are in turn impacted by landscape. Second, cultural conventions influence the pattern of the landscape not just within the built environment, but also areas that are remnant or restored patches of "natural" landscape. Third, Nassauer pushed ecologists to acknowledge that the popular cultural concepts of nature are different from scientific concepts of ecological function. The fourth principle Nassauer posed is that cultural values are communicated through the appearance of landscape.

The appearance of landscape is often discussed through the lens of aesthetics, with authors noting aesthetic considerations are key to establishing social support for projects that may challenge existing cultural norms (Nassauer 1995). Inclusion of wildlife habitat in the urban landscape must address issues such as the aesthetic preferences that many people have for highly manicured vegetation over the "natural" appearance associated with native forage plants (e.g. Nassauer 1995). Aesthetic preference and cultural norms guide not only design decisions (such as turf lawns) but also convenience-based management regimes. As Marzluff and Ewing (2001) note the preference for tidy landscapes guide typically results in removal of ground cover, tree limbs, and standing dead wood that provide forage, nesting and shelter for multiple species. These cultural norms may be due to a lack of understanding and meaningful experience with native ecologies (Casagrande 1997, Gobster 2010). As suggested by Rosenzweig (2003), these preferences may be malleable.

Education may be a tool for expanding the landscape values and aesthetic preferences people hold. Lovell and Taylor (2013) suggest public awareness education focus on the link between biodiverse landscapes and human health and wellbeing as a way of cultivating greater acceptance of altered aesthetics and management regimes associated with habitat improvement projects. McKinney (2002) proposes environmental education efforts begin with edge adapted species that are common within suburban landscapes. As he notes, these species provide "familiar…assemblages and species to promote an understanding of concepts such as ecological succession and the role of native plants in promoting native animal diversity." Further, McKinney suggests that due to the size and the relative wealth and political influence of suburban populations, an "ecologically informed suburban population" would go far to improve social support for species conservation across the urban gradient. Indeed the political and social influence of suburban populations discussed by McKinney (2002) may help to generate constituencies that Gobster (2010) finds necessary to assist in the implementation and maintenance of restoration projects, with success tied to the ability to situate biodiversity projects within broader goals than protecting native biodiversity. This strategy may be particularly important for reconciliation ecology which seeks to bring habitat and wildlife within human use spaces rather than restore spaces that humans are willing to set aside

Beyond educating urban residents about common species, core ecological concepts and the importance of biodiversity, Casagrande (1997) highlights the necessity of establishing a psychological connection between urban residents and native ecologies to ensure the success of restoration projects. Casagrande identifies the need for residents to feel a personal attachment and awareness of the restoration goals, which can be cultivated through demonstration projects and participation.

In addition, successful habitat projects must consider social and psychological scales as well as species scales. Casagrande (1997) focuses attention on adopting a community scale for projects and advancing local participation as a means of capitalizing on the theory of place attachment: people who feel a sense of place within a newly restored or designed ecosystem are more likely to support it and work to maintain it. Similarly, he concentrates on community scale projects to take advantage of an intuitively understood "psychological unit," of bounded space." Without community backing and understanding of the end goal, residents are less likely to accept the temporary inconveniences associated with changing land use or policy related to ecological design projects.

Within urban landscapes people-nature interactions depend on the accessibility of green space and its recreational value, as well as the quality of the green space and available amenities. Despite limited opportunities to interact with nature in urban environments, experiences with nature create a positive feedback loop that stimulates a greater desire to interact with nature (Fuller and Irvnie 2010). However, access to biodiverse green space is a measure of social inequality and socio-economic status is correlated with neighborhood environmental quality (Warren *et al.* in Gaston) and levels of biodiversity awareness and support through landscape management (Luck and Smallbone 2010). In addition, socio-economic status, ethnicity, education, and political context influence the perception of "conflict" between urban wildlife and humans and conservation project outcomes (Soulsbury and White 2015).

Political Barriers to Planning and Implementation

Broad efforts to communicate and engage community members in habitat design also benefits the long-term success of restored or reconciled habitats. While there is limited data to define what elements are necessary to maintain the long-term biological integrity of urban green spaces, it is clear that they are affected by their physical and social matrix (Hostetler, Allen, and Meurk 2011). In a study of urban green infrastructure and conservation areas, Hostetler, Allen and Meurk. (2011) found that 'natural' areas were impacted by nutrient and chemical runoff, invasive plants and non-native animals, and structural damage to soils from adjacent construction – all issues that need to be addressed by urban biodiversity design. The authors identified three key interventions to "maintaining the biodiversity and functionality of urban natural areas and corridors": 1) implement systems-based thinking, 2) remove current regulatory barriers, and, 3) engage built environment professionals and residents in the development of environmental education programs. Hostetler *et al*. argue that systems-based thinking on the part of designers and planners, as well as a general awareness on the part of the public, extends the consideration of design elements beyond the scale of the site to focus on wider ecological and social patterns that affect biodiversity conservation in a particular location. They also contend that regulatory barriers impede conservation activities and that zoning policies should include biodiversity as a goal for projects.

The implementation and management of functional conservation design is further complicated by a tiered system of planning that occurs on at least three levels (Snep and Opdam 2010), which are politically defined, have no inherent relationship to a spatial area, and are not necessarily tied to any biological index. At the site scale, design is guided by "local targets…[and] decisions on how to combine incompatible functions spatially" (Snep and Opdam 2010). At the city scale, decisions are made that affect the pattern and amount of green space, while planning at regional scale involves strategic decisions about infrastructure and building density (Snep and Opdam 2010).

Based on the competing focuses of these three scales of planning, management, and implementation, Snep and Opdam (2010) have identified several challenges to urban conservation design. First, there is the challenge of evaluating the site in terms of its contribution to, and interaction with, the ecological function of the broader landscape. Second, there is the challenge of incorporating “higher-level” interests into local decision-making and design and getting private partners “motivated to invest in public services” (ecosystem services). Finally, there is the challenge of making urban greenspaces “appreciated for their contribution to the economic and social values of the urban system” in order to make local funding sources more available.

As Snep and Opdam point out, the urban landscape is not typically a focus of conservation groups, and local governments are not often equipped financially or politically to establish and maintain urban ecosystems that can be perceived as an added, and perhaps frivolous, expense. This challenge may present an opportunity to seek new ways of managing the urban landscape to provide biodiversity and ecosystem function throughout a city landscape instead of focusing efforts and money on set-aside conservation/green space areas that can be expedient targets of political campaigns and budget concerns.

Given the challenge of making people care about parks for their own obvious benefit suggests added difficulty to get urban residents engaged in habitat design for other species. Snep and Opdam (2010) reiterate that the urban landscape is not typically a focus of conservation groups and local governments are not often equipped financially or politically to establish and to maintain urban ecosystems that can be perceived as added (and perhaps frivolous) expense. This challenge may present an opportunity to landscape architects as we seek new ways of managing the urban landscape to provide biodiversity and ecosystem function throughout the landscape versus focusing efforts and money on set-aside conservation/green space areas that can be expedient targets of political campaigns and budget concerns.

In addition to the suite of challenges for incorporating species habitat and other ecological goals within an urban design project, Steiner *et al.* (2013) acknowledge the rapid pace of design work as another challenge for ecological design. To address urban design timeframes and improve stakeholder and client acceptance of ecological features and processes as design goals, Steiner *et al*. (2013) recommend ways of presenting ecological design to the public:

- a functional asset to the individual site design rather than a feature of the landscape at large;
- a contributor of direct or indirect social and economic benefits;
- an integral part of the design, in conjunction with other design priorities; or
- the provision of multiple benefits (e.g., design for a single performance goal, such as stormwater management, may provide additional benefits, such as improved habitat quality and recreation).

To summarize, designing landscapes that incorporate biodiversity and ecological concerns is a multi-faceted process that involves tackling entrenched patterns of landscape design and management informed by cultural norms and values and complicated by nested regulatory and political frameworks. The trajectory from conception to implementation of such an endeavor may not be smooth or straight, but may require a process of building long-term constituencies to guide the habitat project through implementation and management while education efforts and public perception evolves.

Human Wildlife Interactions and Perceptions of Safety and Benefit

In addition to aesthetic and other values-based considerations discussed above, habitat designs must consider human safety and human perception of safety in them. Management regimes, likewise, have to ensure a habitat functions for other species, while understanding human perception of and the possibility that other species, such as bats, pose threats to public health (e.g. Kingston 2015).

The interactions between "people" and "nature" are two-way relationships that result in measurable changes to both people and the natural environment (Fuller and Irvnie 2010). While human-wildlife interactions within urbanized landscapes can be viewed as positive and beneficial (at least to humans), Hadidian and Smith (2001) of The Humane Society of the United States outlines a disturbing alternate understanding of the primary quality of human-wildlife interaction as grounded in conflict. Based on the implicit and unstated supposition that urban landscapes are solely for the benefit of humans, Hadidian and Smith (2001) provides a review of human-wildlife interactions by summarizing current methods for addressing conflicts. Their review determined that the future of urban wildlife will largely depend "on reform in governance," as well as "on cultural changes that promote greater respect and understanding for wild animals and the biotic communities of which they and we are both a part."

Hadidian and Smith noted in 2001 that if the emergence of urban wildlife as a field of study is measured by the appearance of published texts, then the field "has barely started." They stated that it is related to a similarly emerging discipline, urban ecology, but that there is a lack of biologically-based well-defined terms for urban wildlife. While they may be classified as "inquilines, synanthropes and commensals," urban wildlife species are more often referred to with terms such as "'pest', 'nuisance', and 'vermin'" that are human constructs based on human perception and value rather than "characteristics inherent to animals or their ecology" (Hadidian and Smith 2001). The authors advocated for a more scientifically-based lexicon to set law and policy because vague and subjective terms have potential to desensitize the public and affect professional discourse.

Hadidian and Smith found that studies indicated that most people prefer certain taxa such as songbirds and dislike species groups associated with damage to urban infrastructure, such as mice, rats, or species that are feared such as snakes. People's preferences for other species follow a gradient from urban (moralistic and humanistic views) to rural (practical and utilitarian uses).

He notes that human behavior and orientation to urban wildlife may be disproportionately influenced by fear, misunderstanding and perceived risk. Increased interaction between humans and wildlife can result in misperception within popular literature that species populations are "skyrocketing" and "increasingly becoming threats" and encourage lethal methods of wildlife management. Further, as Hadidian and Smith remarked, "Many urbanites may also still hold to a simple belief that wild animals do not "belong" in cities and have no right to be there, or would certainly be better off if they could be moved to their 'natural' habitat."

Changes in ecological systems and human land uses can create conflicts such as coyote predation on suburban pets, or deer browsing on ornamental landscapes, or raccoons rummaging through trash. These problems can be long-lasting and without easy solutions due in part to their foundation within entrenched social institutions and cultural norms. However, Hadidian and Smith suggest that urban residents can "both benefit from learning what the rules of coexisting" with wildlife are and modify their cultural practices such as not leave small pets outside unattended and better trash management.

In their review of the literature on human-wildlife interaction and conflict, Soulsbury and White (2015) identified four categories of human-wildlife conflict:

1. Aggression/Injury/Death
2. Nuisance/Property Damage
3. Disease
4. Economic Cost

From a wildlife perspective, the urban environment is a significant source of aggression, injury and death. Although attacks on humans are rare, they can significantly impact public perception of wildlife threats. Similarly, regardless of whether they have personally experienced property damage from wildlife, the literature suggests people perceive urban residents as a nuisance due to noise, "fouling," browsing in gardens, and road collisions. While Soulsbury and White point out this type of conflict typically occurs at the individual or local level, perceived nuisance can affect green infrastructure initiatives.

Soulsbury and White determined that 60% of human pathogenic illness is thought to originate in other animal species. With increasing urbanization human populations are more exposed to vector-borne diseases, the propagation and transmission of which are exacerbated by domestic animals. Wildlife species in urban areas often live at higher densities and combined with densities of humans and domestic animals can increase risk of transmitting zoonotic diseases. Transmission to humans typically occurs through pets, with direct transmission to humans rare. However, efforts to increase wildlife populations within urban areas may increase transmission of zoonotic and vector-borne diseases direct contact, infected water run-off, and feral pets.

Most human-urban wildlife conflicts are minor, and there are few proper calculations of their associated economic costs. Direct costs relate to infrastructure repairs and removal of wildlife, along with systematic management approaches, which are rare due to prohibitive expense. The greatest economic impact is likely related to wildlife diseases. The authors note that U.S. expenditures for damage and wildlife control has been estimated at roughly $8.6 billion, equal to estimated expenditure on wildlife feeding and bird boxes.

Noting the potential for conflict within an "increasingly urbanised [sic] and resource-constrained world" Soulsbury and White (2015) advocate for learning to live wildlife and "maximize the diverse benefits that living with wildlife can bring" including to human health and wellbeing (2015, 541). In their review, Soulsbury and White (2015) identify mutual benefits presented by human-wildlife interaction within the urban environment and opportunities for improving the human-wildlife interface.

Soulsbury and White make a case for urban wildlife that extends beyond their intrinsic value. They determine that humans derive tangible and intangible benefits from urban wildlife, which "provide a range of positive values to humans, including opportunities for physical utility, and health, recreational, scientific, ecological and historical values" (2015, 545).

The authors’ review of the literature on urban wildlife coalesces around three key benefits that humans derive from urban wildlife:

1. Keystone Species and Ecosystems
2. Provisioning, Regulating, and Supporting Ecosystem Services
3. Cultural Ecosystem Services

When ecosystems lose keystone species, there is “a disproportionately large effect on ecosystem processes” and overall biodiversity of the urban landscape. Fortunately, urban residents are beginning to recognize and value ecosystem services of wildlife as evidenced by popular discussion of pollinator decline.

There is also growing evidence that the “presence and viewing of urban wildlife are beneficial for mental health and [that they] bring psychological benefits” to humans. Urban wildlife also give aesthetic pleasure and interactive enjoyment, with feeding wildlife being the most commonly cited one. Soulsbury and White (2015) note that positive experiences with wildlife may motivate conservation action and increase the “value and appreciation of the urban landscape.” Soulsbury and White also suggest that the “potential role of urban wildlife in promoting mental wellbeing may be one area in which the value of urban wildlife is very significant.” They note that “mental ill-health” is estimated to account for roughly fourteen percent of the global disease burden and is a problem associated with increased urban living (2015, 545).

Soulsbury and White (2015) conclude that we need to accept wildlife as part of urban ecosystems and that we should adopt a more ‘holistic’ and inter-disciplinary approach to researching and managing urban wildlife, including improving conceptual frameworks for understanding human-wildlife interactions. As Warren *et al.* (2010) note, most land management decisions that affect urban ecosystems - and therefore the survival of disturbance-sensitive native species - occur at the household scale. These decisions include feeding wildlife, killing or removing ‘nuisance’ species, or managing vegetation through herbicides and pesticides, which can change the trophic structure of a local urban environment and species composition. Education, individual and community site design and management regimes, and supporting local regulation may all provide a set of tools to frame and guide urban design and to shift human actions toward greater inclusion and benefit to wildlife species.

<u>Framework Review and Design as an Interdisciplinary Conservation Approach</u>

Conservation planning became increasingly popular during the late 1990s and 2000s and was guided by two fundamental questions formulated by Redford et al. (2003): “where should conservation take place, and how should conservation get done?” (Groves 2008, 83). As Groves notes, determining where conservation should take place has received more attention and methodological development than how to implement conservation strategies in human-dominated landscapes. A search in the journal *Conservation Biology* for “conservation framework” (n=226) yielded more results than “design guidelines” (n=5) “management guidelines” (n=42) or “planning guidelines” (n=19) suggesting that research focus remains on reserving areas for biodiversity conservation rather than defining methods to reduce the impact of development and other land uses on wildlife species.

An early and enduring concern within conservation planning is maintaining habitat connectivity by establishing wildlife ‘corridors’ that physically or functionally connect remnant habitat patches in order to sustain local populations (Fleury and Brown 1996, Hilty et al. 2006). Other research topics within landscape planning include greenways (Dawson 1995) and concepts for reducing the impact of new development, such as the conservation subdivision (Hostetler and Drake 2009, Hostetler and Reed 2014, Freeman and Bell 2011). While these topics remain central to inquiries about ways to improve the ecological function of development and reduce fragmentation impacts on wildlife, the literature also suggests a recent research shift toward assessing community values and human-wildlife interactions (Kretser, Sullivan, and Knuth 2008, Zheng, Zhang, and Chen 2011), and innovations in data dense analysis methods such as Geodesign (e.g. Perkl 2016) to plan landscapes expected to serve multiple functions (e.g. Slotterback et al. 2016). In addition, the recent landscape planning literature presents a greater focus on implementation and local and site scale interventions to improve habitat value within human dominated landscapes through development of conservation frameworks and design guidelines (e.g. Hudson and Bird 2009, Jackson, Kelly, and Brown 2011, Fontana et al. 2011). This shift in focus may speak to the acknowledged need for evidence-based decision-making within rapid decision-making cycles that characterize design and development within the urban gradient (Brown and Corry 2011).

Common limitations of conservation design frameworks

Despite a growing number of studies that attempt to “translate” current understanding of the relationship between land use change and biodiversity into ecological guidelines, as well as growing recognition of the positive impact local planning can have on biodiversity, Gagne et al. note there has been little “on-the ground change” in land use planning (2015, 13). Rather, they find that landscape planners rarely incorporate “science-based information” into the planning process due to the often impractical nature and low feasibility of ecological guidelines, limited ecological knowledge held by planners, and limited consideration of biodiversity within municipal planning (Gagné et al. 2015, 14).

In their review of select ecological land use planning guidelines, principles and recommendations, Gagné et al. (2015) identified several important limitations to incorporating ecological planning frameworks within municipal settings. These limitations include the necessity of species-specific information, which is often unavailable, costly or time-consuming to obtain. Further, species data may conflict with planning scales. When data is available, Gagne et al. found the frameworks were complex, and did not provide a clear sequence of actions to perform. Finally, the authors found that published conservation planning methods did not consider socioeconomic constraints to locating conservation actions. Gagne et al. propose their own framework of five sequential steps based on commonly available land use data for regional conservation planning. However, their framework applies to selection of sites for conservation and does not extend to guidelines for site level decision-making.

A small selection of other frameworks for site selection and design were reviewed to gain a basic understanding of the different approaches taken for framework construction within ecological design (Table 2.7). Categorization of the framework components (discussed in Chapter 3), revealed important commonalities of approach. Common framework features shown on Table 2.6 include: the necessity for defining project goals; understanding site qualities and context; involving or otherwise identifying needs and concerns of human stakeholders; and monitoring project success

The framework proposed by Fleury and Brown (1997) provided a simplified approach to corridor design for use by landscape architects. The authors used sections and plans to communicate ideal landscape structure and elements for each species-focused corridor - a unique graphic strategy that is well-suited to designers. In addition, Fleury and Brown addressed the challenge of designing in the face of limited data for individual species by collecting data for species "guilds" or a group of species that use the landscape in a similar way. Using this broader approach enabled them to identify habitat needs and necessary corridor components for a range of species.

The Nature Conservancy Conservation Action Plan (CAP) provided the most comprehensive framework for project definition, implementation and adaptive management, including stakeholder involvement in the process. Authors placed lead designer roles within their own fields of expertise, with most specifying ecologists or conservation biologists lead site selection, assessment, and definition of design actions. Pickett and Cadenasso (2008) took a multi-disciplinary approach with ecologists identifying the conservation actions, and landscape architects selecting sites for green infrastructure project implementation based on stakeholder inputs and review of the built environment.

None of the five frameworks reviewed considered ways to incorporate species with compatible human uses. While Lovell and Taylor (2009) clearly defined an approach to match social and cultural values with ecological landscape practices, their framework addressed ecosystem services rather than species habitat..

Table 2.7. Conservation Frameworks for Site Selection or Design

Author	Article Data	Year	Journal	Title	Framework Data	Select/Design /Both	Set Goal	Site Description	Site Context	Species Target	Biodiversity/Eco Svc	Policy Review	Human use/value	Human Stakeholder	Identify Threats	Life-cycle Habitat	Monitor/Adapt Mgmt.	Design Lead
Brown & Fleury		1997	LU	A framework for the design of wildlife conservation corridors with specific application to southwestern Ontario		D	X	X	X	X	B					X		P
Groves		2008	LJ	The Conservation Biologist's Toolbox for Planners		D	X	X	X	X	B			X	X		X	E
Pickett & Cadenasso		2008	JE	Linking Ecological and Built Components of Urban Mosaics: An Open Cycle of Ecological Design		B	X	X	X		ES	X	X	X			X	E
Lovell & Johnston		2009	FE	Creating Multifunctional Landscapes: How Can the Field of Ecology Inform the Design of the Landscape?		D	X	X	X		ES		X	X			X	E
Gagne et al.		2015	LU	A simple landscape design framework for biodiversity conservation		S			X		B			X				P

Journal: (LJ) Landscape Journal, (LU) Landscape & Urban Planning, (JE) Journal of Ecology, (FE) Frontiers in Ecology and Environment

Design as an Interdisciplinary Approach to Biodiversity Conservation

Despite the “wicked” problems posed by urbanization, ecologist Michael McKinney (2010) finds there is cause for hope. For McKinney, the fact that cities have such a large negative impact on the global environment implies that any reduction in those impacts can lead to gains in sustainability. According to Dramstad *et al*. (1996) landscape architects, like planners, are “uniquely poised” to address the new issues society faces as a result of resource scarcity. This is because the profession focuses on land function and adopts an approach of problem-solving through synthesis and holistic programing. As a profession situated at “the intersection of society and nature” landscape architects develop “a three-dimensional ‘dialectic’ of experiential form” (Diamond 2002) that mediates the interaction of humans and non-human species through physical and symbolic form. Therefore, through landscape design and management, landscape architects can tackle the “double-edged sword” of culture (Rosenzweig 2003), helping to reshape cultural norms and perceptions necessary to generate positive relationships between humans and wildlife and cultivate greater levels of biodiversity stewardship necessary for reconciliation ecology.

Addressing the complexity of designed human-wildlife interactions within urban landscapes clearly requires a trans- or multi-disciplinary approach, as advocated by both landscape architects and conservation scientists (e.g. Musacchio 2008, Lovell and Johnston 2009).

Knowledge, interest, and communication gaps limit the efficacy of transdisciplinary efforts to urban reconciliation ecology design. Despite incorporating discussion of metrics for “ecologically-based” design within landscape architecture discourse, few authors have provided details for how that is to be achieved. Furthermore, there remains little discussion within landscape architecture about biodiversity and the place of other species urbanized landscapes. Similarly there are questions within conservation biology about the field's ability to meet its mission to protect biodiversity. In addition to debate about whether the field is asking and answering appropriate questions, Meine (2010) wonders if the field is performing its core function of providing reliable and useful scientific information about biodiversity conservation in the most effective manner. Further, Meine (2010) questions whether the information generated and disseminated by conservation biologists is making a difference, and what constituencies conservation biologists need to engage and more fully involve in the task of conserving biodiversity?

Additional considerations for bridging the gap between biodiversity conservation and urban land use planning and design include issues of scale, conservation thresholds, competing mandates, conflicting terminology and access to biological data (Groves 2008). Groves (2008) identifies a mismatch between the scale of ecological processes and species movement, and the scale of planning and design within fragmented urban and ex-urban landscapes. Despite the challenges, he notes the possibility for success through situating local design within municipal/regional planning goals. What is an obstacle to such success, Groves suggests, is that landscape architects and land use planners are often in search of "short-cuts or one-stop shopping for answers to complicated ecological issues" in the form of "principles, guidelines, and thresholds" to apply at the site or project level. Groves notes, however, that in reality there are few if any clearly defined thresholds for creating functional habitat. Rather, the conservation design, such as a riparian buffer width and the size and configuration of habitat features, must be based on the element of biodiversity that is targeted for conservation.

The complexity of ecological systems the dynamic character of urban landscapes characterized by rapid change can create challenges to translating research documenting the effects of urbanization on species to creation and implementation of best practices. This is often referred to as the " 'It depends' problem" in conservation biology and ecology (Musacchio 2008). The conceptual conflict between conservation science and modes and timeframes for landscape architecture practice guides the desire for something like a "Time Savers Standards for Ecology," to guide decision-making within rapid time frames in a fee-for-service profession. Such a numerically driven basic approach is cautioned against by Rosenzweig (2003) who suggests it may be too generic to be useful for individual species. To resolve the conflict in scopes and mode of practice, Musacchio proposes adopting "translational" research for collaborative knowledge generation, an approach from the medical field that involves merging theoretical and applied approaches.

Nassauer and Opdam (2008) propose design as a tool and product to form a link between the scientific community and landscape practitioners. They suggest that design provides a mutually beneficial process of knowledge innovation that will ultimately lead to sustainable landscape change that balances biodiversity and social values. Building on the paradigm of *pattern: process* they find in landscape ecology, Nassauer and Opdam propose an altered paradigm of *process: pattern: design* to provide the conceptual basis for interdisciplinary work, with design as research and pattern providing sustainable landscape change (Figure 2.1).

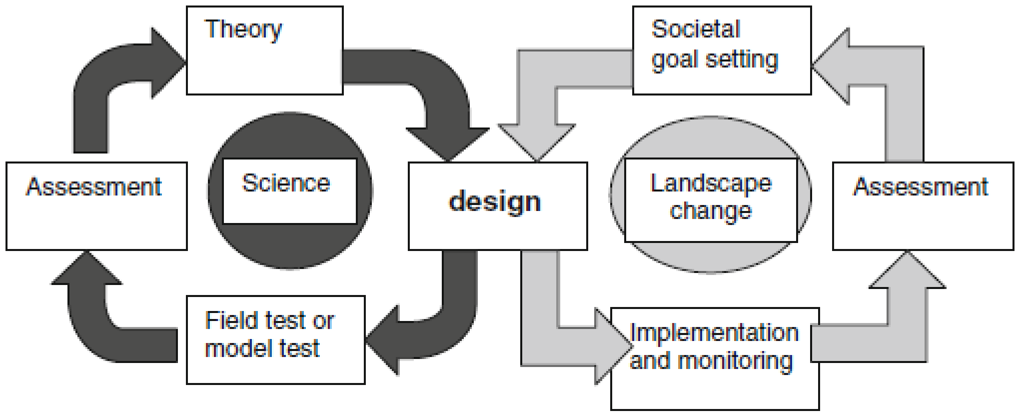

Figure 2.1. Nassauer and Opdam (2008) Diagram of *Process: Pattern: Design* Paradigm.

Nassauer and Opdam (2008) propose an iterative three-phase process to activate this paradigm. The phase is first informed by disciplinary science. The second phase is informed by stakeholder knowledge and "anticipatory societal knowledge" to derive a "generalizable pattern rule," which is applied to a sample site and assessed. The third stage involves collaboration between professionals and stakeholders to implement specific landscape change, based on site goals crafted in response to local characteristics. This stage acknowledges factors often overlooked in design and implementation and by ecologists – scientific data or good design may not be used because scientists and practitioners do not have social support for their work. There are social, cultural, historical, and political factors and community differences that have to be considered when crafting a link between science and landscape change - one size does not fit all.

The synthetic and applied nature of landscape architecture and conservation biology and compatible holistic approaches to landscape study across spatial and temporal scales, suggests the possibility of building collaborative constituencies for species conservation within the urban gradient. While Nassauer and Opdam (2008) propose that design can be both an iterative tool to facilitate this collaboration as well as a product to assess design, other authors note the lack of common terminology as an impediment to interdisciplinary collaboration within the urban landscape (e.g. Tarsitano 2006, Hostetler 2014).

Without establishing a common language based on understanding of core biodiversity principles and design within the built environment, the opportunities for interdisciplinary collaboration are greatly reduced. However, by utilizing principles and terminologies from ecology and conservation biology in an informed manner rather than as design devices, landscape architects can engage in ecological design that seeks to establish functional habitat at a range of scales within the urban gradient.

Hostetler (2014) also calls for a design-based collaboration between ecologists and 'built environment designers' to create "doable' wildlife conservation goals for a site." He notes this will require putting management on the "same pedestal as design" in order to for the process and the design to function ecologically. Hostetler (2014) advocates for landscape architects to apply ecological concepts to construct relationships that facilitate ecological functions and receive training in ecological management practices. He provides key conceptual categories for habitat design that bridge the conceptual and practice gap between conservation biology and landscape design, focusing on concepts frequently misused by built-environment designers: patches; habitat edges; wildlife corridors.

Patches

- Patch definition is species dependent and relates to the scale at which each species responds to and utilizes landscape geometry and spatial objects
- Spatial objects include trees, fields, water that animals use to fulfill their daily need for sustenance and cover

- Species life history informs what spatial objects a species responds to, and at what scale
- Species needs may change dramatically during the course of its life cycle
- Urban sites may not be able to provide all the different types of habitat necessary for a species, especially migrating or far-dispersing species. However, urban sites may provide ‘stopover’ areas along dispersal or migration routes

Habitat Edges

- Edge habitat does not inherently create habitat value or improved ecosystem function.
- Within projects, designers should advocate for “larger, circular patches” of habitat in planning and design to reduce disturbance along edges
- Consider the impacts of landscape structures on generalist vs specialist species.
- Edge habitat poses potential direct and indirect threats including human disturbance, increased competition with generalist species, and higher levels of predation.
- The extent of edge effect disturbance is also species specific – for example, disturbance zones for varied thrushes (*Ixoreusn aevlu*) extend up to 140 meters into a habitat patch.

Wildlife Corridors

- Corridors serve two purposes: connecting diverse habitat areas within a home ranges and permitting movements between populations.
- Corridors are only effective if designed for the functional requirements of a target species.
- Scale matters: design at species scale including unique distances required for protection from disturbance
- Utilize metapopulation theory
- Stepping stones may facilitate movement and linear corridor may be unnecessary.

Reconciliation ecology design requires new patterns of collaboration between landscape architects and other urban designers and the conservation community (Rosenzweig 2003). As advocated by Nassauer and Opdam (2008) design provides not just a product but also a tool for framing new modes of collaboration to generate data and knowledge and generate new urban forms that are more responsive to wildlife needs. However, as noted by Hostetler (2014), successful collaboration is predicated on a shared understanding of core ecological concepts, which landscape architects may lack.

Overview of Bat Biology and Conservation Status

Bats belong to the order *Chiroptera* which includes over 1300 extant species, making it the second largest order of mammals. All 18 extant families of Chiropterans are thought to have been evolved by about 37 million years ago (Voigt and Kingston 2016). Bats are unique among mammals for having evolved the ability for powered flight (Voigt and Kingston 2016) thanks to a thin membrane webbing extending from the elongated bones of their forearms and fingers. Most bats are also able to echolocate due to the modification of three bones in the ear and throat including an enlarged cochlea (Currie 2017).

Bats exhibit an impressive range of trophic and geographic diversity, inhabiting all continents except for Antarctica and including nectavores (nectar feeders), frugavores (fruit feeders), sanguinivores (blood feeders), piscivores (fish feeders) and carnivores, while the majority of bat species are insectivores (insect feeders) (Voigt and Kingston 2016). Due to this wide variation in trophic diversity, bats play important roles in the ecology of the landscapes in which they are found, including helping to manage insect populations, pollinate plants, and disperse seeds. Bats assist in nutrient distribution and soil fertility through dispersal of guano during flight, as well as providing primary nutrient input into cave ecosystems. They also provide hosts for parasites and serve as prey for larger vertebrates including raccoons, raptors, fish, reptiles and amphibians (Kasso 2013).

Insectivorous bat species have been estimated to provide $1 billion (US) in pest control services to agroecosystems worldwide (Maine 2015). These services extend beyond direct predation of pest species to influence the ecology of agricultural fields through direct influence on crop pests and interactions between bats and other pest predators including birds and spiders (Maine 2015, Karp 2014). In the case of corn fields, research has found bats to suppress corn pest-associated fungi, a globally significant crop (Maine 2015).

Globally 29% of bats depend at least in part on plants as a food source, with bats having co-dependent relationships with at least 858 plant species in the Neotropics. These plants rely on bats for pollination or seed dispersal, which has been found to be very important for forest regeneration following 'slash-and-burn' agriculture (Rojas).

Due their important roles in maintaining ecological systems, as well as key common factors of their life histories, including size, longevity, and high degree of mobility, bats also serve as indicators of habitat quality providing evidence of short and long term effects of physical and chemical disturbance (Kasso 2013) and (Jones 2009)and the broad and likely non-linear effects of climate change on ecological systems (Jones 2009).

In response to seasonal reductions in available food, bat species may either hibernate or migrate, while some species adopt both strategies. In general, tree roosting bats migrate to warmer clines of their range to survive the winter, while hibernating species may also travel long distances to overwinter in hibernation habitats known as hibernacula. Little brown bats are known to travel between 200 km to 800 km between summer and winter roosts. Migrating to hibernacula or other winter habitat is energetically costly and increases the risk of injury, illness or death through increased exposure to predators, impacts with buildings, wind gusts, pesticides and other chemicals they are exposed to along their journey (Organization for Bat Conservation 2017).

Unable to build their own shelters, bats rely on existing roost structures, suggesting roosts are a limiting resource. Perhaps for this reason, bats have long association with human settlements, and are thought to have coevolved with humans, occupying the earliest human structures. Some species are considered synanthropic, meaning that they have a “strong ecological association with humans” that can confer direct benefits to bats through protection from predators, and reduced energy expenditure due to available warm roosting habitats (Voigt et al. 2015).

Despite their diversity, bats exhibit a fairly consistent pattern of vulnerability to anthropogenic change due to their life history. Unique among small mammals, bats reproduce slowly (only one to two live births per year) and are relatively long-lived. Despite this bats have high metabolism and consequently high food requirements (Voigt and Kingston 2016). In addition, bat species are social, and urban-adapted species often aggregate at key times during the year in human structures. When gathered in large aggregations, they experienced heightened risk to catastrophic events such as structure collapse, predation and disease (White 2017). Threats to bat populations at the global level include land use change, urbanization, persecution and general intrusions on bat habitats. In addition, bats face the added disadvantage of being nocturnal (Voigt and Kingston 2016). Voigt and Kingston (2016) note, humans are “driven by our visual system and therefore tend to neglect the dark side of conservation, i.e., the protection of nocturnal animals.”

Global review of bat conservation status finds that 15% of bat species are threatened by extinction, while 18% are identified by the IUCN as being “Data Deficient” showing the lack of ecological study to support assessment of conservation status (Voigt and Kingston 2016).

Threats to and from Bat Species

Urban Threats to Bat Species

Despite posing a significant threat to global biodiversity and being commonly "viewed as the most ecologically damaging change to land use worldwide" urbanization may not result in uniformly negative impact to all bat species, which may be "the most diverse group of mammals remaining in urban areas" (Jung and Threlfall 2016). As humans have grown increasingly urban, some bat species have maintained a functional connection to human settlements and are classified as synurbic, suggesting that they tolerate or favor opportunities for foraging or roosting within the urban environment. Many other bats species are very sensitive to the degradation or loss of natural habitats (Russo and Ancillotto 2015).

Urbanization appears to affect species diversity and abundance differently in international studies but all studies on the effects of urbanization on bat species reviewed by Russo and Ancillotto (2015) presented "altered species assemblages" with one or two species dominant. In their review, Russo and Ancillotto identified three key opportunities that some bat species are able to exploit in urbanized environments: roosting areas; increased temperatures that enhance daily rest periods and seasonal hibernation; and shelter from large non-human predators. In addition to some natural roost opportunities found in urbanized landscapes such as trees and rock faces, urban environments provide numerous artificial roosts such as bat houses, common in residential areas, and unintended roosting areas such as tunnels and buildings. Urban environments may also provide important sources of drinking water to replenish moisture lost through respiration and the wing membranes (Russo and Ancillotto 2015).

Despite the opportunities for warm and protective shelter bats may find within the urban environment, Russo and Ancillotto (2015) suggest the literature shows that urban landscapes may actually present conservation “sinks” or spaces that attract bats but are unable to support breeding populations, a finding supported by (Coleman and Barclay 2011) Coleman and Barclay Coleman and Barclay (2011). In a global meta-analysis of urbanization effects on bats, Jung and Threlfall (2016) found bats favored natural areas over urban areas and that intensity of urbanization negatively affected bats. Their meta-analysis of urbanization suggests that the effect of intensity of urbanization on bat species is better explained by individual species behavioral and morphological traits than functional ecology or phylogenetics. This finding is also supported by a meta-analysis by Russo and Ancillotto (2015) which reviewed a host of impediments to bat species success in urbanized landscapes and noted that not all species are able to take advantage of these opportunities, but those that were, typically presented greater “phenotypic plasticity or evolutionary processes” allowing them to alter the timing of breeding, foraging patterns, and their individual response to the stresses of the urbanized landscape.

Jung and Threlfall (2016) also tested the effect of intensity of urbanization on bat species using simple categories of low, medium, high, finding that family, genus, forage and foraging mode (i.e. aerial forage versus gleaning) were not useful in predicting the persistence of bats within each development category; however “narrow space forages” were more strongly associated with natural areas and less likely in urban areas (Jung and

Threlfall 2016). Similarly, “open space” foragers are more persistent in urban areas, perhaps due to having morphological traits associated with increased mobility that allow them to commute long distance between roosting sites and foraging areas (Jung and Threlfall 2016).

Jung and Threlfall found bats used habitats in “intermediate” urban landscapes much less that adjacent natural areas, a finding they call “alarming” given the general presumption that “small towns and suburban landscapes could potentially provide suitable habitat for a wide range of species…including bats.” Despite that, there appears to be regional differences in bat response to intensity of urbanization based on the broader landscape contexts (Jung and Threlfall 2016). It is possible that within broader natural landscape contexts with limited tree cover (such as prairies), cities provide more attractive habitat due to street and yard trees, parks, and other artificial vertical structures such as buildings (Coleman and Barclay 2011). Within urban landscapes bats have been found in higher abundance and species richness in mature landscapes that may include remnant vegetation such as parklands, riparian areas, and older residential neighborhoods (Jung and Threlfall 2016). In a study of Little brown bats in the urban gradient of Calgary Canada, Coleman and Barclay (2011) found the prairie species exhibited the greatest fitness in transition zones, which they defined as having a mean distance between houses of 4.3+/-1.72 km (roughly 1.5 to 3.5 miles). Despite having the lowest insect availability, the transition zones provided riparian foraging zones and mature native trees to serve as root habitat.

The habitat opportunities urbanized landscapes provide may be outweighed by threats inherent in common design and management strategies. Even for bat species able to colonize urbanized landscapes, their density may be misleading. The review by Russo and Ancillotto (2015) suggests the urban landscape is composed of threats to bat species. Despite finding that urban bats exhibited high fidelity to roost sites, Jung and Threlfall note the literature suggests species have differential success in foraging insects within the urban matrix based on differences in their flight characteristics and sensitivity to artificial light.

Russo and Ancillotto (2015) evaluated urbanization as affecting three key habitat requirements: roosting, foraging and commuting. They begin by noting that roosts play "a central role to the natural history of bats" (Russo and Ancillotto 2015). The roost provides a safe place for bats to rest, and bats may use several roosts throughout the year, including maternity and hibernation roosts (Bat Conservation Trust). The availability, structure, microclimate and amount of protection the roost provides "critically" influences "survival and reproductive success." Structures within the urbanized landscape are known to provide roosting spaces. It is possible that urban buildings provide greater warmth, larger colony spaces and greater protection from predators. However, not all bat species may benefit from artificial roosting areas, particularly species that are strictly cave-dwelling or tree-dwelling (Russo and Ancillotto 2015). The construction of the urban environment may also pose threats to bats by introducing toxins in building materials where urban bats roost. The use of breathable roofing membranes can entangle bats who roost in buildings and smooth surfaces inside buildings can lead to infant mortality due to their inability to cling tightly to the surface when their mothers leave the maternity colony to for daily forage (Russo and Ancillotto 2015). Artificial and human-altered roost environments are associated with larger social group size (White 2017), which has been found to be an important predictor of parasitism, with larger aggregations of individuals typically hosting more parasites and lowering the overall fitness of individuals (Rifkin, Nunn, and Garamszegi 2012).

Natural roosts such as trees confer benefits to foraging, by attracting the insects on which many bat species feed (Bat Conservation Trust). Bat species that successfully roost in urban environment may not have as much success with foraging and may have to travel longer distances to reach suitable foraging areas. Russo and Ancillotto (2015) found the literature suggests three general effects urbanization has on bat foraging. First, they found that foraging activity “declines as urban density increases.” Second, they note that street lamps deter most bat species, although some are able to capitalize on street lamp lighting for foraging. Third, Russo and Ancillotto note that “natural or semi-natural habitat within urban areas” support increased bat activity, however, this is likely dependent on whether these urbanized areas are able to support prey species, such as nocturnal moths which may particularly sensitive to urban environments. In addition to presence of vegetation able to support insect populations, the urban form itself may influence urban foraging success.

The wing morphology, flight patterns, and echolocation design of bat species affect their success with urban foraging and ability to navigate urban structures and lighting patterns. Species such as pipistrelle bats which typically forage in woodland edge habitats frequently forage in urban areas, suggesting a similarity in form. Large artificial ground planes can be confused for calm water bodies, disrupting foraging and causing fatigue or collisions for slower, lower flying species which forage by gleaning. Artificial lighting may favor species that are more tolerant, allowing them to outcompete light sensitive species. Studies from less urbanized landscapes suggest that a diverse insect community may be more important to understanding bat diversity than tolerance to artificial lighting (Russo and Ancillotto 2015). As urbanization and impervious land cover increases, taxonomic diversity of insects decreases and overall abundance has been shown to decrease (e.g. Bennett and Gratton 2012, Avila-Flores and Fenton 2005). Ambient noise within the urban landscape may also affect foraging success, well as the increased competition for available food sources (Russo and Ancillotto 2015). Finally, the urban landscape due to the prevalence of artificial light may act as a sink for nocturnal insects, reducing the diversity and overall abundance of forage resources for insectivorous bat species (Rowse et al. 2016).

Commuting is the third key habitat requirement Russo and Ancillotto (2015) reviewed to understand effects of urbanization on bat species. Vegetated commuting habitats such as tree lines and hedgerows provide bats safe passage from roosts to foraging areas providing landmarks to help bats navigate and protection from predators (Bat Conservation Trust). Urbanization has been found to interfere with commuting by reducing connectivity of vegetated areas, and may also provide "structural constraints" such as artificial surfaces that affect the ability to navigate, communicate over long distances during commuting, and hunt using echolocation (Russo and Ancillotto 2015). Busy roads can also sever commuting routes directly and indirectly through car collisions and fragmentation of the "acoustic landscape." (Russo and Ancillotto 2015). Large and tall vertical surfaces as well as large horizontal surfaces can also interfere with echolocation, confusing navigation and thwarting communication among the social animals. Large vertical and horizontal surfaces are energetically costly and can result in collisions (Russo and Ancillotto 2015).

In addition to the impacts to three key habitat types, Russo and Ancillotto (2015) identify multiple further threats urbanized landscapes pose to bat species. Among these are increased exposure to opportunistic predators such as cats and dogs; competition for roosts from exotic species such as parakeets; and pollutants and pesticides. Incompatibilities between human uses and bat habitation create conflicts resulting in bat exclusions from buildings, which Russo and Ancillotto note may "represent a serious conservation issue." The displacement of colonies from buildings can disrupt social organization, decrease reproductive success and increase individual mortality. This is particularly dangerous for pregnant females and flightless nursing pups which may suffer high mortality due to poorly-timed evictions or exclusions for buildings during the spring and summer rearing season. Even small scale disruptions part of the urban landscape, including construction, artificial light sources and patterns (not celestial), and pervasive and obtrusive sound patterns can alter behavior and species ecology. Disrupted patterns of roost switching combined with increased urban colony sizes may elevate disease risk, providing additional threats to urban bats (Russo and Ancillotto 2015).

Roads

Road networks are pervasive in cities and beyond, with the literature indicating that only 17% of the landscape in the United States is more than 1 km (or six-tenths of a mile) from a road (Riiters and Wickham 2003 in Altringham and Kerth 2015). Road development has three direct impacts on wildlife, and two associated effects. Direct impacts include destruction of habitat due to construction of roads and associated structures; mortality from traffic impact; degrade habitat quality through intrusions of light, noise and chemicals. Indirect impacts include fragmentation of remaining habitat that can restrict movement and accessibility of adjacent habitat areas; increased landscape accessibility provided by road networks accelerates further development and other types of human disturbance (Altringham and Kerth 2015).

Research into effect of roads on bats is relatively recent despite evidence of their "profound effects" on other wildlife species (Altringham and Kerth 2015). Similar to other urban characteristics, the impacts of roads on bats appears to be species specific (Altringham and Kerth 2015), with roads either acting as general barriers to movement (Kitzes and Merenlender 2014) or not, depending on a tangle of factors including adjacent habitat and species traits (Fensome and Mathews 2016). However, whether roads restrict movement across a broader landscape or not, meta-analyses conducted by Fensome and Mathews (2016) suggests that roads do threaten bats.

As a barrier to movement, roads break the canopy cover which bats use as landmarks and protection from predators along commuting routes (Altringham and Kerth 2015). In addition, the open space and light put them at risk of predation, while the noise and movement along roadways may be perceived as a threat. Further, the noise can mask the sound of insects, and impact foraging for insectivorous bat species. Chemicals from roadways have also been shown to impact the abundance and diversity of arthropods along roadways, affecting foraging. The light, noise and chemical pollution along roadways can extend up to 1.6 kilometers from roadways, and bats may expend energy seeking 'safe' crossing across roadways while trying to maintain original commuting lines. Research identified by Altringham and Kerth (2015) has found that roads act as barriers to foraging and commuting between day roosts in summer habitat, which may have effects on genetic diversity and reproductive success. Other studies have found bias toward male bats killed during road crossings, suggesting relationships between roads, adjacent habitat quality and species-specific dispersal patterns (Fensome and Mathews 2016).

Roadways are not always found to restrict bat commuting, for example due to their placement with a high quality habitat, however, this is linked to greater risk of collision with traffic (Fensome and Mathews 2016). When bats do cross roadways, they do so at heights of three to twenty feet, putting them in direct conflict with traffic (Altringham and Kerth 2015).

Additional research is needed to clarify the contributions of various roadway attributes such as lighting, sound and clearing that influence the barrier effect of roads (Fensome and Mathews 2016, Kitzes and Merenlender 2014). Despite the incomplete understanding of roadway effects on bat biology, the literature proposes measures to minimize the impact of roads on bat species. A preliminary approach may be to monitor the effects of new roads compared to baseline assessment (Fensome and Mathews 2016).

Ideally roadways should avoid known commuting and migrating routes. Efforts to mitigate the effects of roads include gantries (overpass structures), road underpasses, lighting reduction, and habitat improvement and landscape-scale planning to increase woodland cover, and replace lost or degraded water bodies. The overall effectiveness of mitigation measures is unclear, although highway underpasses along historic commuting routes are promising as ways of maintaining an overall ‘connected’ landscape that provides a high density and broad extent of “interconnected linear features” including hedgerows and tree lines that are particularly important for woodland adapted species such as *Rhinolophus*, *Plecotus*, and *Myotis* (including Little Brown bats), than larger open-air species such as *Eptesicus* (big brown bats). Underpasses are particularly important on banked highways (Altringham and Kerth 2015).

Artificial Lighting

Artificial light at night is an important aspect of urbanization at a global scale (Rowse et al. 2016), with nearly one-fifth of terrestrial earth impacted by light pollution (Cinzano 2001 cited in Rowse et al. 2016). Bats as nocturnal species are likely affected by light pollution although with taxon specific effects on physiological processes, either attracting or repelling bats depending on the wavelength of the light (Rowse et al. 2016).

Artificial street and building lights may be incandescent or high or low pressure gas discharge varieties, each with a unique wavelength signature. Incandescent bulbs output lights mostly within the near infrared spectrum, creating more heat and less light visible to the human eye. High and low gas discharge lamps such as mercury vapor lamps, high-pressure sodium, and LED provide more visible light, with greater longevity and energy efficiency.

In addition to light pollution which affects the visibility of the celestial sphere, artificial night lighting results in ecological light pollution manifested as glare, over-illumination, light clutter, light trespass, and sky glow. The evolution of energy efficient lighting has exacerbated ecological light pollution through a shift to broader spectrums able to emit more blue light which scatters more easily in the atmosphere, contributing more to sky glow. Technological advances are also lowering costs, leading to more nonessential usage of lighting such as advertising and architectural detailing (Rowse et al. 2016).

The biological effects of ecological light pollution include disrupted circadian rhythms and circannual cycles which impact individual species and intra- and inter-species interactions, including establishing no-analog instances of interspecies competition between nocturnal and diurnal species. Artificial lighting reduces immune function and metabolism, and can interfere with seasonal behaviors triggered by natural variations in the timing and quality of light. Nocturnal navigation is also impacted by artificial lights during dispersal, migration, or foraging. Migratory birds have been known to get confused, or “trapped” in a sphere of light that interferes with their magnetic compass, which may also affect bats. Insects are also differentially attracted to artificial lights depending on type, swayed from following the moon which provides their point of orientation (Rowse et al. 2016). The impact of artificial lighting on insect species can be far-reaching resulting in a “vacuum-cleaner” effect that draws nocturnal insects from relatively long distances and ultimately leading to local extinctions (Rowse et al. 2016, 194). Resultant insect biodiversity loss further reduces bat foraging potential within urban areas.

Artificial light results in species-specific impacts to bats, also depending on light type. Fast-flying bat species adapted to aerial hawking in open landscapes are drawn to feed around street lights, while slower species adapted to more dense terrain are averse to lights. *Myotis* and *Rhinolophus* are two genus adapted to be “clutter-tolerant” whose commuting activity is reduced by high-pressure sodium and LED lights and avoid LED lights even when they are dimmed. For light averse species, experimental research has shown that lighting can delay the start of evening commuting and foraging activity, causing them to miss the peak of insect abundance and causing them to expend additional energy to avoid lighting (Rowse et al. 2016).

There are many knowledge gaps on the effects of artificial lighting on bats, including acceptable spectral range and intensity thresholds for species, and the effects of light pollution on individual fitness and community health. Several mitigation efforts exist, without evidence of efficacy in reducing impacts on bat species. These include “intelligent lighting” that uses motion sensors to turn on as needed; lowering lighting intensity; limiting the amount of trespass through directional lighting (using shields); and engaging in “Part-Night Lighting” as utilized in the UK to turn off road lights between midnight and 5:30 am (Rowse et al. 2016). A most effective approach may be to limit lighting by restricting unnecessary installation and removing lighting from areas already saturated. Adding tree canopy can also help to decrease light trespass into the night sky (Rowse et al. 2016).

Rowse et al. (2016) have called for a transdisciplinary approach to minimize the impact of artificial light on biodiversity. In addition to devising a common metric to measure and specify light in a way that is meaningful to wildlife (it is currently measured in lux defined as units perceived by the human eye), Rowse et al. (2016) advocate for modes of broadening “awareness of light pollution and its ecological impacts” to encourage public acceptance of light pollution mitigation efforts.

In addition to specifically urban elements, bats are threatened by additional anthropogenic factors such as wind energy development; hibernacula disturbance (Tinsley 2016); environmental contaminants within urban, industrial and agricultural landscapes (Tinsley 2016, Williams-Guillen et al. 2016); climate change and the spread of exotic pathogenic disease (Tinsley 2016).

White-Nose Syndrome

In addition to these habitat threats, bat species in the United States have been heavily impacted by White-Nose Syndrome. First discovered in 2006 in New York the fungal infection has since spread rapidly across the east coast and west as far as Washington. The syndrome is named for a white fungus (*Pseudogymnoascus destructans*) which coats the muzzle and wings of hibernating bats. The fungus disturbs hibernating bats causing them to arouse more frequently than normal during the hibernation period, depleting precious fat reserves. White-Nose Syndrome (hereafter WNS) has been blamed for the loss of 90 to 100 percent of bats in some hibernacula (White-Nose Syndrome).

The invasive European fungus thrives in the cool moist environment of caves and mines where many North American bat species hibernate (Bat Conservation International 2017). While the “mechanisms underlying mortality” are not yet completely understood the effect of increased arousal caused by the fungus results in emaciated individuals (Wilcox 2016, 2). Those individuals able to survive to spring often suffer from immune reconstitution inflammatory syndrome which results in overall deteriorated body condition, and potentially mortality (Wilcox 2016).

White-Nose and related effects is estimated to kill over one million bats annually (Bat Conservation International 2017). Over half of the 47 bat species living in the US and Canada hibernate to survive the winter season, and of these, seven bat species are confirmed to show evidence of WNS and three of these species are nationally listed as endangered or threatened. Based on contemporary research, predictions have been made that by 2030, the little brown bat, once a common species "will be reduced to just 1%" of pre-WNS population numbers (Bat Conservation International Bat Conservation International 2017).

Though not specifically an urban issue, White-Nose Syndrome presents the leading cause of bat population decline and current research suggests design interventions may assist in aiding the conservation of bat species through this deadly disease. The process of healing from WNS, related illness, and wing-damage is thought to require a large energy expenditure through often harsh spring weather and into summer It is possible that providing "warm roost microclimates could help survivors make it through potentially harsh spring conditions and initiate reproduction earlier in summer, improving survival of their offspring." Further, this management strategy may "facilitate evolution of WNS-survival traits in threatened populations" (Wilcox 2016, 2). Experimental research has shown a preference among little brown bats (*Myotis lucifugus* – hereafter *MYLU*) for artificially heated bat roosts, particularly those recovering from WNS. The heated roosts may minimize energy expenditure for thermoregulation during cool weather, particularly important for pregnant and lactating females. Potential negative consequences to providing artificially heated roosts include preventing torpor during spring when forage insects have not yet emerged, and altering social behavior related to group roosting as a method for thermoregulation (Wilcox 2016).

Research has supported the theoretical link between local population size and extinction rate due to WNS, with the "probability of local extinction from a given hibernaculum" decreasing as population size increases. This research suggests that aggregations of hibernating bats and their social behavior provides “flexibility to cope” with population decrease, helping to maintain population levels above critical extinction thresholds (Webber 2016, 126). This information helps to situate the role of urban areas to provide adequate roosting habitat, and in particular using the opportunities presented by the urban landscape such as access to electrical power and monitoring to assist bat species recovery from WNS through artificially heated roosts.

Potential Threats of Bat Species to Human Health and Wellbeing

In their review of the literature, Kasso and Balakrishnan (2013) identify several threats to human health, wellbeing and economy posed by bats. These include transmission of diseases to humans and their livestock such as rabies through bites inflicted in self-defense or predation (in the case of vampire bats); airplane strikes resulting in equipment damage and accident. Aggregations of bats in buildings and other built infrastructure can result in accumulations of waste, staining surfaces and posing the risk of fungal disease transmission such as histoplasmosis. In addition, the visual evidence of bat presence, sounds of bats roosting within buildings and odors may cause human distress (Kasso 2013), thereby affecting their wellbeing.

<u>Little Brown Bat Life History</u>

There are six subspecies of MYLU, however, this review focuses on one, *Myotis lucifugus* (MYLU-LU) whose distribution extends from Georgia north to Alberta, Canada and extending from New Foundland along the east coast of America to the Dakotas and stretching beyond through Canada to Alaska (Tinsley 2016).

Physical Description

A diminutive species, MYLU-LU weigh between 0.2 to 0.4 ounces as adults (Tinsley 2016), approximately the weight of two quarters. The females are slightly larger than males, especially in weight during the winter. Their fur coloration ranges from pale yellow or olive brown to golden brown or dark sooty brown (Tinsley 2016).

Life History

MYLU-LU are nocturnal insectivores. Following the fall of darkness in spring through fall, MYLU-LU forage on small insects belonging to several orders: Diptera (flies), Lepidoptera (butterflies and moths), Coleoptera (beetles), Trichoptera (caddisflies), Ephemoptera (mayflies), Cicadellidae (leafhoppers), Delphacidae (planthoppers), Neuroptera (net-winged insects). Using echolocation to find prey, MYLU-LU engage in two or more rounds of foraging per night, using night roosting areas to rest and digest between hunts. Night roosting is a communal activity among reproductive females and may be linked to temperature, with communal roosts providing important social thermoregulation for pregnant females on colder nights (below 41 degrees F) (Barclay 1982). Night roosts may be a limiting factor of bat conservation for temperate insectivorous species, serving as an integral component of primary foraging areas (Knight 2009). Bats may utilize several night roosts (Knight 2009) and are often human structures such as bridges, and building eaves and awnings, providing protection from predators and warmth relative to ambient temperatures (White 2017).

MYLU-LU typically feed between three and 20 feet above the ground or calm water surface, using a variety of habitats to forage: over open water, margins of water bodies, over fields and agricultural areas, woodland areas, as well as urban areas (Tinsley 2016).

Within the course of a night, pregnant females can cover over 74 acres of forage land, with ranges often occurring within 600 meters of a roost during lactation, on average consuming roughly half their weight in insects (Tinsley 2016).

As nocturnal creatures, MYLU require roosting habitat during the day that provides them dark and safe spaces to rest. MYLU are also a migratory species traveling between summer roost areas to overwintering sites. Their range of migration and their habitat choices depend on the season and suitability of available structures, with distance traveled likely determined by the availability of suitable sites for overwintering.

Prior to overwintering, and as part of their annual migration, MYLU engage in swarming behavior in the Autumn characterized by large congregations of individuals gathered at hibernacula entrances after dusk. Swarming occurs in stages with a later stage involving polygamous mating. While there appears to be high fidelity of swarm sites, low rates of individual recapture suggests swarming occurs while bats are migrating to winter hibernacula, with individuals visiting more than one swarming site along their journey. Swarming may involve the organization of the population hibernating in a particular site each year, and may play a role in maintaining genetic diversity of MYLU-LU populations (Tinsley 2016). Following mating during the swarming period, MYLU females delay fertilization until the following spring, allowing females time replenish fat reserves without further expending energy to mate prior soon after emerging from hibernation (Tinsley 2016).

As with other bat species in temperate zones, MYLU are unable to feed across much of their range in winter when insects are inactive, with swarming occurring during the peak buildup of fat reserve. MYLU have adapted to survive the season through a prolonged hibernation which is characterized by long cycle of torpor (typically two to three weeks) punctuated with short periods of arousal (Tinsley 2016). During torpor, MYLU exhibit lower metabolic rates and reduced body temperature and immune function. During arousal MYLU eliminate waste, groom, rehydrate, and move to new roosts. Arousal is energetically costly, accounting for over 75% of energy expenditure during hibernation, and draws down fat reserves. MYLU ideally regulate arousals to conserve fat deposits until spring when insect reemerge and pups are born. The inability to regulate arousals results in premature emergence from hibernation and depletion of fat reserves. If MYLU-LU deplete fat reserves by February or early March when forage insects have not emerged, they die of starvation (Tinsley 2016).

The triggers for arousal are unclear, although it appears to be influenced by changes in ambient temperature. Ideal hibernation temperature is 36 degrees, with arousals becoming three times more frequent with temperatures 5 degrees lower or 10 degrees higher than ideal (Tinsley 2016).

In the spring, reproductive females leave hibernacula first, forming maternity colonies to collectively birth and rear pups. Following a 50-60 day gestation, mothers typically birth one pup in late spring or early summer and provide sole care for them until they are weaned and able to forage on their own, typically three to four weeks after birth. Mothers forage for shorter distances (approximately 600 meters) from their maternity colony location during the lactation period in order to accommodate periodic nursing (Tinsley 2016). During lactation mothers may consume 75% to over 100% of their total body weight in insects each night (Williams-Guillen et al. 2016). After young reach independence, the maternity colony disperses to utilize other summer day and night roosts, building fat reserves before fall swarming and winter hibernation (Tinsley 2016).

Individual Resource Needs

The fitness (or ability to survive and complete reproduction) of MYLU individuals is related to meeting key requirements of food and shelter. Foraging habitat requirements may be further dissected to meet the needs of MYLU at different life stages. Tinsley (2016) identified studies showing correlation between bat age and wing length with forage habitat qualities, with the youngest and shortest winged bats found foraging in more open, uncluttered habitats while older bats with longer wings were found utilizing more diverse and often more cluttered habitats.

In addition to daily forage, in order to fulfill their individual biological needs little brown bats need three habitat types during an annual cycle: summer roosts, swarming habitat, and over-wintering sites. Little brown bats are a “highly versatile” species able to exploit diverse natural and human structures for roosting habitats.

Summer habitat includes day and night roosts as well as maternity colony sites for breeding age females. Day roosts within natural landscapes include tree hollows, spaces under rocks, and occasionally, caves. Within anthropogenic landscapes common day roosts include wood piles, inside buildings and under awnings and shutters (Tinsley 2016). Night roosts may be located in ecologically different areas located near foraging grounds.

Reproductive females form “gregarious” and often large maternity colonies in the early spring that may hold several females to over a thousand. Depending on the habitat used, maternity colonies may also include solitary males, although they place themselves apart from the clustered females. Maternity sites commonly include human-made structures such as house attics, barns and bridges, as well as natural areas such as tree cavities and rock crevices. MYLU require maternity roosts to provide stable warm temperatures (ideally between 86-130 degrees Fahrenheit), shelter from the weather, darkness, protection from predators, and potential to create microclimates to adjust to changing weather conditions throughout the day. MYLU-LU often use social thermoregulation to modify roost temperature and humidity which are important to successful reproduction and pup rearing. Maternity colony sites are often established in areas along lakes or forested regions (Tinsley 2016), which may facilitate easier access of foraging areas, particularly important during lactation. The species have a strong fidelity to maternity colony sites, which can increase the risk of conflict with humans through eviction from houses and other human use spaces (Tinsley 2016). Unfortunately, when pregnant or lactating females are evicted from maternity colony sites, they may not return to "known nearby maternity roosts" unlike other species, such as big brown bat (*Eptesicus fuscus*) of which reproductive females will join existing maternity colonies nearby. Due to the importance and specificity of MYLU-LU maternity colonies, this habitat type may be a limiting factor in the species distribution and abundance in any particular area.

There is little known about MYLU-LU preferences for swarming habitat, although there is a correlation between swarming site and proximity to hibernation locations, as well as greater abundance of bats at more isolated cave hibernation sites (Tinsley 2016).

MYLU hibernation habitats are known as hibernacula. These are typically underground caves, but may also be sites that mimic rocky substrate caves, such as abandoned mines. Hibernating bat species are also known to hibernate in tunnels, dams, and boulder fields. Despite the variety of structural typologies, MYLU-LU require hibernacula to maintain high humidity (70 to over 99 percent) with stable temperatures between 34 – 41 degrees Fahrenheit in order to promote efficient hibernation that reduces water loss and heart rates (Tinsley 2016).

Population Resource Needs

Research suggests that maternity colony habitat may be a limiting factor in MYLU abundance and distribution (Tinsely 2016) and that roosts in general are limiting resources for many bat species, due to their inability to construct their own shelter (Voigt et al. 2015). Hibernation sites are also possible limiting factors to species who use them, including MYLU, particularly hibernacula large enough to accommodate natural population fluctuations (Tinsely 2016).

Conservation Status

Prior to the 2006 discovery of White-Nose Syndrome, MYLU was considered a common species and received little monitoring during annual bat surveys. As a result, there is limited data against which to assess current population levels and overall conservation status. The historical range for the species covered 34 states including Vermont, with the range thought to be constrained by the availability of hibernacula (Tinsley 2016). In his status review of the species, Tinsely (2016) found that the species range has not altered significantly, however the abundance of the species has sharply declined and the overall low numbers combined with increasingly isolated local populations may put the species at greater risk from stressors other than WNS as well as stochastic events. Across their range, MYLU populations have suffered a median decline of 95% across 165 winter hibernacula following discovery of White-Nose Syndrome (Tinsley 2016).

Identified Threats and Potential Stressors

There are a suite of past, current and potential stressors that Tinsely (2016) has identified as directly or indirectly threatening the long-term viability of MYLU-LU. Primary among these are stresses related to *Pseudogymnoascus destructans*, the fungus causing White-Nose Syndrome, and the loss or degradation of key habitat resources (Tinsley 2016). In addition to these are stressors known to impact individual and population ability to complete annual life history stages and events. These include general bat diseases, wind energy, environmental contaminants, climate change, and colony persecution (Tinsley 2016).

Little Brown Bats in Vermont

The largest historically known concentrations of MYLU-LU occurred in the Northeast and Midwestern United States, with large hibernating populations found Vermont and seven other northern states. Vermont MYLU populations have suffered 90% population declines due to White-nose syndrome, reflecting comparable or greater losses at the regional scale (Vermont Wildlife Action Plan Team 2015), resulting in the species being listed as a state endangered species in 2015. Prior to WNS, the Little Brown Bat was the most common bat in Vermont, comprising approximately 73% of all bats surveyed (Tinsley 2016).

Vermont may play an important role in supporting regional populations, providing winter hibernacula for populations migrating from as far away as Cape Cod Massachusetts (Tinsely 2016). The Aeolous cave in Vermont, one of the largest in New England was recorded to support as many as 300,000 hibernating MYLU-LU prior to WNS (Tinsely 2016). Since discovery of WNS in Vermont maternity colonies appear clustered in the greater Champlain Valley norther Taconic Mountains of NY, with a few in the Southern Vermont piedmont. Acoustic data suggests males and non-reproductive females occur sate-wide (Vermont Wildlife Action Plan Team 2015). Despite “drastic declines” in the species population in Vermont, it is noteworthy that a concentration of MYLU-LU maternity colonies has been observed in the relatively populous Champlain Valley. Most significant is the fact that these colonies appear relatively stable, with population estimates ranging from 50-100 individuals while two colonies have populations approaching 500-700 individuals (Tinsley 2016).

In Vermont, MYLU-LU are associated with several natural habitat types including northern hardwood, spruce-fir northern hardwoods, hardwood swamps, and fluvial and lacustrine landscapes. In addition, the species is associated with habitats that have cultural landscape components, including: marshes and sedge meadows; subterranean; grasslands, hedgerows, old-field, shrub or orchard; lawns, gardens and row crops; wet swales and ditches; shrub swamps; buildings or other structures; mines;

powerlines, railroads, roadsides; and man-made waterbodies (Vermont Wildlife Action Plan Team 2015).

Threats to MYLU identified within the State Wildlife Action Plan include conversion of habitat, habitat alteration, and incompatible recreation. MYLU are heavily dependent on human dwellings for maternity sites, and eviction from human buildings and structures and removal of historic barns or other structures costs Vermont bat species hundreds of possible roosts every year (Vermont Wildlife Action Plan Team 2015). In addition Vermont Fish & Wildlife identifies direct killing as threat due to concerns over rabies and histoplasmosis. Other non-habitat threats include pesticides and broad spectrum insecticides.

Climate change is expected to further stress MYLU which forage primarily on aquatic insects in the larval stage, the availability of which can be greatly affected by changing precipitation patterns and reduced soil moisture. However, it is possible that a warmer, wetter climate could result in a direct benefit to the species (Vermont Wildlife Action Plan Team 2015).

Efforts to address these threats at the state level include three strategies: training wildlife control operators and homeowners on proper building exclusion techniques; maintain at least twenty maternity colony sites and a minimum of 10,000 adult females; protect hibernacula containing 100 or more little brown bats (Vermont Wildlife Action Plan Team 2015).

Opportunities for Improving Urban Bat Habitat

Insectivorous bat species such as little brown bats are considered good candidates for a habitat-enhancement approach to conservation (Wilcox 2016). Current efforts to improve the survival rate of urban bats primarily focus on roost habitat, through the construction of bat houses and education programs to mitigate the impacts to bats from efforts to remove bats from living spaces. Depending on the legal and conservation status of bat species, state agencies may promote or require the sensitive removal of bats from human spaces outside of hibernation or maternity seasons (Vermont Fish and Wildlife Service , Wisconsin Department of Natural Resources 2016). Organizations such as Bat Conservation International and the Bat Conservation Trust promote the construction of bat houses as alternative habitats.

However, as the meta-analysis by Russo and Ancillotto (2015) suggests, despite providing housing opportunities, the urban landscape does not fulfill all bat habitat needs. In addition, the type, quality, and location of roosting habitat greatly affects the ability for bats to successfully navigate the urban environment. Despite these limitations it is possible the urbanized landscape can be formed and maintained in a manner that improves the conservation outlook for little browns and other bat species.

Coleman and Barclay (2011) studied the effects of urbanization on little brown bats along a gradient from natural prairie to urban Calgary Canada. They found that urban populations of little browns in Calgary "exhibited decreased body condition and smaller production of juveniles," which they hypothesized could be attributed to any or all of a suite of urban threats including greater foraging competition, disease, noise pollution and stress. However, they also found that individuals had the greatest fitness within the urban transition zones defined as roughly one-half mile between human residences, despite having the lowest insect availability. They suggest that the transitional zones conferred some benefits of the natural open prairie and the greater roosting opportunities, protection from natural predators, and warmth of the city. However, the urban transition zone also provided less competition for forage and a morphological improvement for the little browns, allowing them to navigate a reduced number of human structures with greater ease (Coleman and Barclay 2011).

The complexity of the urban form and the diversity of bat species make determining the causal relationships between urbanization and species fitness difficult, prompting calls for further research into behavioral and morphological traits to describe differential responses to urbanization (Jung and Threlfall 2016). Regardless of disparate responses of species to diverse urban patterns, suburban and urban transition zones seem to support greater species diversity and fitness than urban zones (Russo and Ancillotto 2015, Coleman and Barclay 2011). As Jung and Threlfall (2016) note, this may be truer for urbanized areas surrounded by agricultural areas or natural prairies that have lower structural heterogeneity than cities surrounded by forested landscapes. This implies that urban trees and artificial vertical roosting areas can be implemented and managed to benefit bat species, particularly in relationship flat homogenous agricultural landscapes that frequently surround urban cores. While efforts to date have focused on roost availability, there are likely other ways in which to augment the three dimensional form of urban public spaces to confer benefits and buffer threats to bat species.

The Bat Conservation Trust, an organization in the United Kingdom has produced a book of urban design guidelines titled, *Landscape and urban design for bats and* *biodiversity* that synthesizes ecology and landscape architecture to improve the function of urbanized landscapes for bat species. In addition to general guidance to improve urban biodiversity and ecological function, the authors, Gunnell et al. (2012) provide specific recommendations for three key habitat requirements: foraging, roosting, and commuting. This design guidance is provided in Table X below.

In addition to improving day and night roosting habitat within the urban landscape, opportunities exist for providing hibernacula within human dominated landscapes as well. Gunnell et al. (2012) note that man-made hibernation sites can include structures that are no longer used, including cellars abandoned mines. Horizontal grilles may be installed to protect hibernacula within natural caves, abandoned mines and other spaces humans can enter and disturb bats during the overwintering period. Artificial hibernacula are also options, and may be as simple as artificial caves created by burying a large-bore concrete pipe (Gunnell, Grant, and Williams 2012). Larger scale artificial hibernacula also exist, including a pre-cast concrete bunker, the size of a single-wide trailer buried in a hillside in Tennessee. Constructed by The Nature Conservancy in 2012 next to a natural cave, the artificial cave provides biologists the opportunity to easily monitor the population and disinfect the habitat following identification of *P. destructans*, the fungus causing White-Nose Syndrome (Kingsbury). Guidance for designing artificial hibernacula include: high humidity (approaching 100%); stable winter temps; suitable crevices to hide in or surfaces to hang from; protection from predators and people (Gunnell, Grant, and Williams 2012). Additional considerations include human access points for monitoring, bat entrance points, and ventilation (The Nature Conservancy).

To address two key urban threats, artificial lighting and roadways, Gunnell, Grant, and Williams (2012) provide additional guidance for design interventions. Design recommendations for reducing the disturbance impact of artificial lighting in urban landscapes focus on limiting the use of artificial lighting, reducing light spill through siting choices, and using low impact wavelengths. These recommendations from Gunnell, Grant, and Williams (2012, 20, 28-29) are listed below:

- Provide unlit areas in and around bridges, roadways, and within and around parks and other urban greenspaces
- Limit outdoor lighting to meet safety requirements
- Limit lighting times to provide dark periods
- Minimize light spill by eliminating bare bulbs and upward pointing lights.
- Utilize flat cut-off lanterns to keep light spread at or below the horizontal
- Use narrow spectrum bulbs and those peaking higher than 550 nm, or install glass lantern covers that filter UV light. While white LED lights do not emit UV they may disturb slow-flying bat species
- Limit the impact to insects by using sources that emit minimal ultra-violet light; avoid white and blue wavelengths that attract insects
- Reduce the height of lighting columns
- Provide directional pedestrian lighting below 3 lux at ground level and preferably below 1 lux
- Consult lighting engineers to predict and avoid light spill
- Avoid reflective surfaces below lights
- Shield sensitive areas from lighting until screening vegetation matures

The authors present two options for assisting bats across roadways: underpasses and overpasses. Underpasses such as culverts and tunnels are more readily accepted by slow and low-flying bat species than fast-flying hawking species, and the height of underpasses is more important in determining their success than the length of the tunnel, with a preferred height to width ratio of one. To aid bats in navigating the underpass, the authors suggest planting the entrances to create a “funnel” effect at both ends, which will encourage their use over the roadway above. The underpass should remain unlit. Culverts may also serve as underpasses for riparian species. Overpasses can be “hop-overs” or green bridges. Hop overs use canopy framing to connect two side of a road. Green bridges provide a fully or partially vegetated elevated surface to help wildlife disperse across roadways. The critical element for successful design of green bridges for bat dispersal is removing lighting from the bridge itself and traffic below. Providing solid bridge walls reduces light spill, while linear vegetation features are preferentially used in navigating across green bridges (Gunnell, Grant, and Williams 2012, 26-27).

Trees are important landscape structures for bat species including little browns. Bats utilize trees for navigation, roosting, protection from predators, and as a source of forage. For insectivore species, vegetation provides habitat for insect prey as larval host and shelter. Gunnell, Grant, and Williams (2012) define a typology for urban trees to aid in selecting species for different human use areas. These types include:

Signature trees - a visual landmark and may serve roost trees
Avenue trees - linear features for flight paths and foraging, may provide roost trees
Street trees - pollution tolerant trees with roost potential; provide linear features to guide flight paths and foraging
Ornamental feature trees – provide insect source for foraging
Belts and groups – landscape structures and foraging sources
Courtyard trees – fruit and flowering trees that provide insect sources for bat foraging

Relating Gunnel, Grant, and Williams’ urban tree typology to their habitat creation and management guidance provides greater conceptual clarity on the relationship between tree types (e.g., Signature), tree species selection and placement within different types of urban sites (e.g., live, work, play) (Table 2.8).

Table 2.8. Design Guidance for Three Key Bat Habitat Requirements with Tree Types and Vermont Species Added. Adapted from Gunnell, Grant, and Williams (2012).

Habitat Type	**Urban Tree Type**	**Potential Native Vermont Species**	**Design Guidance**
Foraging Habitat	Ornamental Trees; Courtyard Trees; Belts and Groups	Ornamental: White Birch (Betula papyrifera), Red Maple (Acer rubrum) Courtyard Trees: American Hornbeam (Carpinus caroliniana) American Mountainash (Sorbus americana) Roundleaf dogwood (Cornus rugosa)	Create and enhance features that attract nocturnal flying insects
			Plant mixtures of flowering plants, trees, shrubs and vegetables to encourage insect diversity
			Provide areas of unmaintained woodland as insect habitat
			Retain dense understory with at least 50% cover
			Retain standing and fallen dead wood
			Use native and veteran trees to support insect diversity
			Increase feeding opportunities in open areas through inclusion of flower rich meadows, scrub and tree clusters
			Leave unmown areas
			Create or maintain freshwater sources including ponds, canals, ditches, rivers
			Create pond complexes with a range of types and sizes
			Retain bankside trees and encourage aquatic plants
			Incorporate rain gardens, swales and green roofs to attract insects and provide stepping stone habitat
			Enhance vertical urban surfaces with climbing plants and living walls
Roosting Habitat	Signature Trees and Avenue Trees	Signature Trees: Shagbark Hickory (Carya ovata); American Beech (Fagus grandifolia) Eastern Hemlock (Tsuga Canadensis) Avenue Tree: White Ash (Fraxinus americana)	Retain mature trees as roosting habitat
			Clearly mark any trees that have high potential for or exhibit signs of bat roosting
			Maintain a buffer of trees and understory vegetation around known or potential roost trees at least 1.5 times the diameter of the roost tree
			Work to create or maintain woodland patches in urban areas – most bat roosts tend to be found within 440 meters of woodland patches
			Design and construct new buildings to provide roosts for bats in appropriate location and size for specific bat species
			Utilize bat boxes to enhance habitat, placing them in warm areas at least 2 meters above the ground, provide more than one aspect to ensure enough solar gain
			Construct artificial hibernacula to provide cool stable microclimate with high humidity
Commuting Habitat	Belts and Groups; Avenue Trees; Street Trees	Belts and Groups: Northern Red Oak (Quercus rubra), Balsam Fir (Abies balsamea), Chokecherry (Prunus virginiana) White Cedar (Thuja occidentalis) White Pine (Pinus strobus) Street Trees: Northern Red Oak (Quercus rubra) American Elm (Ulmus americana)	Retain and enhance known commuting routes
			Avoid creating gaps in linear features including tree lines and hedges
			Provide tall, wide continuous hedgerows with vegetation planted at the base
			Install or maintain hedgerow trees within hedgerows Provide unlit linear or linking features within urban areas through trees, hedges, tall shrubs, woodlands, parks, railway lines, waterways and green roofs
			Protect street trees and riparian areas as important corridors for urban wildlife and ensure they are not artificially lit

In addition to providing some insight into the intersection of human use spaces and bat uses that trees provide, this typology may provide a useful tool for identifying groups of tree species that may be specified for different urban land uses. This approach speaks to the concept of reconciliation ecology.

Stilley (2017) has identified the importance of shagbark hickory trees (*Carya ovata*) as roost trees for Indiana bats and little brown bats. Placing the shagbark within the “Signature trees” cultural tree category defined by Gunnell, Grant, and Williams (2012) above, can facilitate consideration of how these important little brown bat habitat trees can be incorporated into the urban gradient.

In addition provide habitat and cultural services as living specimens, snags provide roosting cavities and support insect populations. Research on Indiana bats within the southern Appalachian forest has identified a preference for yellow pine snags, with preference for taller snags protected within a cluster (Farmer 2017). Existing snags can be surrounded by living trees to buffer them from the wind (Farmer 2017). University of Vermont Department of Plan and Soil Science professor, Dr. Leonard Perry writes in the “Green Mountain Gardner” website that snags can be created by girdling live trees, particularly to allow sun where a living tree is providing shade. Dr. Perry notes that soft wood tree species such as firs are beneficial for supporting insects, while hardwood species such as maples may provide better nesting cavities. In addition, Perry notes that the bat roosting value of snags can also be provided or enhanced by cutting a slit in the south facing side of the trunk, at least fifteen feet off the ground, eight inches deep and angled upward (Perry 2017).

Conclusion

The future of Earth's living beings "depends on how effectively plants and animals can be maintained in fragmented landscapes dominated by agricultural and urban land uses" (Bennett and Saunders 2010, 99). Due to the severity of our ecological crisis and the unrelenting demand for resources posed by urbanization, we need to reconceive the city as not simply a source of environmental problems, but as an opportunity to provide solutions for those problems (Lovell and Taylor 2013). As Kunstler (1994) noted, for our own benefit, we must transform the "physical setting for our civilization" by "remaking the places where we live and work." Michael Rosenzweig (2001, 2003) echoed this sentiment in his call for a reconciliation ecology that will include non-human species in a bold new "remaking."

Michael Rosenzweig summarizes reconciliation ecology as a process of determining the "critical components" of species survival and "reassembling" (Rosenzweig 2003) them within the social and physical infrastructure of the urban environment to construct "new" ecosystems (Rosenzweig 2016). There is no blueprint for how to do this, so this chapter embarked on a literature review to identify the range of considerations for successful habitat incorporation within the urban landscape along two tracks: biological requirements of wildlife species, and social and cultural components of urban design and human-wildlife interaction.

As identified within the conservation literature, species conservation requires identifying and reducing direct and indirect disturbances to species. In addition, providing habitat requires understanding the unique needs of target species, including the landscape objects they require (e.g., shrubs, rivers, tall grasses) and the scale at which species interact with those objects. Conservation actions should be informed by data on the presence, abundance of species and an understanding of how the species are interacting with the existing landscape. Finally, habitat must accommodate the full life-cycle of the target species.

Social and cultural components were identified as critical to the success of traditional conservation and restoration projects, and it is likely they will be at least as important within reconciliation ecology design. The literature review determined that engaging human stakeholders requires a level of conservation literacy on the part of the public to understand the importance of species habitat and the role a proposed project plays in broader concepts and biodiversity conservation strategies. Further, reconciliation design must acknowledge that landscapes hold different use and other values and social barriers to wildling inclusion in urban landscapes including aesthetics, fear, concepts of wildlife as nuisances, and normative values of the function and purpose of the urban landscape.

A review and categorization of nine habitat certification programs operating at both the city and backyard scales provided insight into habitat implementation strategies. The review noted the importance of communicating the intentionality of habitat, as well as the need to expand stakeholders in species conservation through community education and promotional events. More importantly to species, the certification programs required consideration of life cycle habitat design to ensure the habitat can provide more than one resource (e.g., forage and shelter), preferably throughout the species life cycle. This consideration was not clearly stated within the conservation planning literature. Finally, several programs were noted for using human use typologies to evaluate and maximize the habitat potential of each site type.

As the profession of landscape architecture grows increasingly interested in addressing the sustainability of urban environments through reconceptualization of urban form, it must also advocate for designing to conserve and promote biodiversity. A limited review of the literature identified an overall lack of interest and knowledge production regarding biodiversity conservation within landscape architecture. Further, the profession has been criticized for a narrow focus on ecosystem services and adopting ecological terminology rather than a scientifically-grounded use of ecological concepts.

To inform the creation of a framework to guide reconciliation ecology site design, the chapter reviewed selected conservation frameworks and categorized them to identify factors considered necessary for successful habitat planning or design. The framework review identified the importance of ecological knowledge to guide decision-making and the need to consider social and economic aspects of design to ensure habitat projects are successful and managed into the future.

This chapter concluded with a detailed overview of bats and their conservation status as well as a more focused discussion of little brown bat life history and conservation status within the United States and Vermont. The review identified White-Nose Syndrome as the primary threat to the species as well as other threats to the species unique to the urban landscape, including lighting and roadways, and identified opportunities for minimizing and avoiding these effects. In addition, this chapter identified the importance of trees in structuring the landscape for bats and for their use for three different habitat values: commuting, foraging, and roosting.

The information on species requirements and social components of conservation design will be synthesized and logically organized in chapter 4 to create a framework for reconciliation design. The framework will then be used in chapter 5 to propose a reconciliation design for an urban park in Burlington, Vermont.

CHAPTER 3

METHODS

This thesis utilizes four methods to answer the central question of how landscape architects can design urban public spaces for little brown bats: literature review, categorization, logical systems and projective design. These methods were used to address the following sub-questions:

1. Do urban landscapes hold opportunities for greater inclusion of native wildlife species?
2. How does reconciliation ecology differ from previous approaches to wildlife conservation?
3. How does landscape architecture as discipline and practice address urban wildlife conservation?
4. What considerations must be addressed to reconcile urban sites?
5. Does research or practice provide guidance on reconciling human use spaces for other species?
6. Are little brown bats compatible species for reconciliation within urban public space and what are their habitat requirements?

Definitions

This study advocates for the use of reconciliation ecology as an approach to including wildlife species as stakeholders in urban design. Used in a general sense, "stakeholders" is intended to identify parties with an interest or "stake" in the outcome of urban design. For wildlife, an "interest" in urban design relates to the effects the design has on individual fitness and population health.

This study also addresses the "urban" landscape. The question of how exactly to define an urban area is difficult and the answers are often context dependent. Within the biological sciences, the urban landscape is a gradient frequently defined by the percentage of impervious land cover (e.g. McKinney 2006, Bennett & Gratton 2012), or by identifiable processes (Gaston 2010). According to the US Census Bureau, urban areas are identified *ex post facto* based on the number of people, population density and land use types. Acknowledging this range of definitions, this thesis uses "urban" in a colloquial sense to include the gradient of dense urban cores to suburban fringe historically connected by patterns or resource extraction from the surrounding landscape (Taylor 2012).

<u>Description of Methods</u>

Chapter 2: Literature Review, Categorization, Logical Systems

In Chapter 2, a broad literature review informs a basic understanding of how urbanization impacts wildlife species; what place wildlife hold within urban landscapes, both physically and culturally; and established modes of biodiversity conservation, including a brief review of the Endangered Species Act, the main legal frameworks for protecting individual species. The literature review sought to identify the range of urban site reconciliation considerations for both human and wildlife stakeholders. To determine the interest and ability for landscape architects to function as reconciliation ecology designers, biodiversity conservation was reviewed within the landscape architecture literature which identified a critique of the field for not fully engaging biodiversity design. The role of design to address the biodiversity crisis and knowledge gaps was then reviewed, followed by in-depth research to understand the conservation status and life history needs of little brown bats, and their relevance to urban wildlife reconciliation.

The literature review for these lines of inquiry was primarily conducted through the UGA Libraries Multi-Search which includes a wide range of science and humanities journals. UGA Libraries Multi-Search also used to locate articles on the effects of urbanization on bats and identify the life history and habitat needs of little brown bats that must be addressed through reconciliation design. Categorization was employed in four instances as a strategy for synthesizing information and identifying patterns among sources:

First, categorization was used to parse the narrative of Rosenzweig's (2003) examples of "hard core" (intentional) reconciliation within *Win-Win Ecology*. Given the thesis purpose of developing a basic framework for actively considering little brown bats as stakeholders in urban public spaces, these examples were selected for analysis and categorization, while other examples considered in the book as "happy accidents" were not.

Through an iterative process of combing the narrative examples for key information repeated among the examples, six categories were found to be descriptive of reconciliation ecology success. A subsequent analysis of the "reconciliation design" category identified the three types of reconciliation action to address root human causes: new design, modification of existing form, and altered management regimes.

Categorization 1: Reconciliation Ecology Examples (Table 2.4)

Category	Definition
Species	The species identified as being impacted
Site Type	A description of the landscape and human use, further categorized according to Rosenzweig's typology of live, work, play
Threat	Source of disturbance to individual or population survival
Critical Biology	The most limiting factor for species survival
Root Human Cause	Human action that caused threat – may be land use, design elements, or management strategies
Reconciliation Design	Action found to successfully reconcile species in site by removing threat. These were further categorized as new design, modification of existing design, and change in land management.

Second, to understand the implementation strategies employed by urban habitat organizations, an internet search was conducted to identify habitat certification programs. The search utilized multiple search engines and search terms such as "habitat certification" and "backyard habitat" as well as taxon specific searches such as "bird habitat certification."

Nine programs were identified and categorized to identify strategies for habitat success held in common by the habitat certification programs and strategies that were unique to individual programs. The categorization was largely driven by elements of each program, but also included pre-defined categories specific to reconciliation ecology such as target species or groups; whether the programs utilized human site typologies to identify the habitat protection of sites; and whether the programs considered human use values in defining site habitat potential.

Categorization 2: Habitat Certification Programs (Table 2.5)

Category	**Definition**
Name	Name of certification program and organization
Certification/ Design	Whether program provides certification or habitat design guidance
Scale	City Scale or Site
Target species/ group	Implied or Stated
Site Typologies	Checked if they define site types based on human use and value such as residential yard or place of worship
Human use/value	Clearly indicates human use/value of site considered in determining habitat opportunities
<u>Requirements</u>	
Legal Protection	If program requires habitat be legally protected; requires municipal resolution
Designate Managing Org	Certification requires designation of long term management authority
Ownership	Program certifies public land (U), Private land (R) or Both (B)
Life Cycle Habitat	Life cycle habitat is required
Architecture	Whether the program includes site architecture in determining habitat opportunities, e.g., mounting bat houses on buildings
No/Low Chemical	Certification requires no or low herbicide and pesticide use for management
Promote Habitat	Signage, or other elements to identify the habitat and inform residents of purpose
Public Education	Events to raise awareness of species conservation, teach habitat design, sustainable management, or other environmental education
Locally native plants	Program requires use of locally native plants
Domestic Predators	Requires efforts to exclude cats dogs and other domestic predators
Monitoring	Requires monitoring species abundance to determine habitat function
Invasive Species Control	Requires invasive species removal, including invasive wildlife
Other	(A)=Aesthetic considerations such as edge treatments, focal points like bird baths, structure and screening elements

(C)=conservation measures such as rainwater harvesting, composting
(F)=community forest management
(P)=park planning incorporates habitat

Next, a targeted review of the landscape architecture literature was categorized to understand the state of biodiversity conservation within the field, as both a topic of inquiry and focus of practice the literature. The review was limited to articles published within *Landscape Journal*, the primary scholarly journal for landscape architecture research in North America *Landscape Journal.* A search seeking to gather articles related to habitat creation or species conservation using the following string identified twenty-five articles:

"biodiversity OR habitat OR wildlife AND urban AND design"

Of these twenty-five results, twelve were selected for review based on inclusion of biodiversity or habitat within their keywords. Articles pertaining to agricultural landscapes, soil or storm water management were not included, nor were book or conference reviews.

Relevant articles were analyzed to determine their focus on either social or biological aspects of biodiversity conservation, and whether they include actionable recommendations for design. Further, the categorization tracked whether the authors were contributing expertise from within the field of landscape architecture or a conservation science field. It is possible that a similar search within the international Journal of Landscape Architecture would reveal a greater breadth of interest in biodiversity conservation and depth of knowledge creation regarding habitat design. However, the goal of the literature review was to take the pulse of U.S. landscape architecture scholarship and practice.

Categorization 3: Urban biodiversity conservation in Landscape Architecture (Table 2.6)

Category	**Definition**
Year	publication year to understand chronological development of knowledge production
Title	
Purpose	Raise awareness of general or particular issue related to biodiversity conservation including knowledge gaps (Issue Awareness); contributes tools to conservation design (Tool Development); provides conceptual approach to inquiry or practice (Strategy)
Habitat Guidance	Provides specific guidance for conservation of a species or community
Social/Biological	Article is focused on human components of biodiversity conservation (Social) or wildlife components (Biological)
Planning/Site Design	article addresses conservation planning or provides guidance on site design
Author Discipline	author background in conservation sciences such as conservation biology (CB) landscape ecology (LE), or landscape architecture or planning (LA)

Finally, categorization was used to gain a basic understanding of conservation frameworks using articles identified through targeted literature review. These strategies sought to inform the development of a framework for reconciliation ecology site design that would guide incorporation of human and wildlife considerations for successful design within broader contexts. To identify relevant frameworks that held conceptual relevance to urban habitat design, the search was limited to the journal *Landscape and Urban Planning* (LUP) using the following search terms:

"biodiversity conservation OR habitat OR wildlife AND framework"

The search returned over 1,200 articles, the majority of which focused on identifying the effects of land use change on species and ecological processes and providing explanatory models for species occurrence. Based on title, keyword and abstract review, a very limited subset of this extensive list of results was selected for review and classification. Articles chosen were design-focused, and proscriptive rather than descriptive. Articles that described plans but did not articulate a framework were not selected either. Framework evaluations were not selected nor were articles that focused on data-dense GIS-based habitat modeling, in order to acknowledge limited availability of species data limitations as well as to avoid frameworks that sought to prioritize habitat conservation areas away from human centers – in short, the opposite of a reconciliation ecology approach. Using these very loose criteria, only four articles were selected. To expand the review articles were included that had been identified through searches for ecological design and the previous search within *Landscape Journal*, yielding one additional article for review.

The Framework categorization utilized both predefined criteria and those identified through article review. Predetermined criteria included whether the framework addressed site design, if the framework considered human values-based site typologies, and the degree to which the framework included species as stakeholders through life cycle design and threat reduction.

Categorization 4: Conservation Frameworks (Table 2.7)

Category	**Definition**
Select/Design	Framework guides selection of conservation properties to prioritize biodiversity protection (S=select) or design (D) for habitat, (B) Both
Journal	FE-Frontiers in Ecology & Environment LJ-Landscape Journal

	LU-Landscape & Urban Planning
	JE-Journal of Ecology
Goal	Framework requires clear description of project and goal
Site Description	Physical and/or Human attributes inventoried
Site Context	Physical and/or Social context identified
Biodiversity/Eco Svc	Framework for Biodiversity Conservation (B) or Ecosystem Services (ES)
Species Target	Framework specifies a conservation target, either a species (S), guild (G), community (C), unstated (X)
Policy Review	Review of policies guiding land use/shaping
Human use/value	Considers human use and value of the site
Human Stakeholder	Engages human stakeholders in planning/design process including through educational efforts
Identify Threats	Requires identification of threats on site or context
Life-cycle Habitat	Plans/designs for life-cycle habitat for target species
Monitor/Adapt Mgmt.	Incorporates monitoring and adaptive management
Design Lead	Professional background of design lead, either ecologist (E), or planner (P)

The selection of articles on bat conservation were identified through academic journal searches and online searches to identify materials published by bat conservation organizations. A very recent and unpublished status review on little brown bats prepared for the U.S. Forest Service was provided through personal communication with bat biologist, J. Paul White, indicating the importance of consultation with conservation biologists. The Vermont Wildlife Action Plan developed by the Vermont Department of Fish and was also consulted to understand little brown bat status in the state of Vermont. The literature review sought to identify information on little brown bats to enable their inclusion as stakeholders in site design. This included: threats to their individual and species survival, with a focus on sources of urban disturbance; critical components of little brown bat life history and habitat needs.

A Logical Systems strategy was employed to organize key lessons from the literature review. Logical systems include decision-making frameworks that attempt to place ideas in a “coherent system or order” (Deming and Swaffield 2011, 223). The framework sequentially guides the site design process to find compatibilities between species habitat needs and existing site programing and the site existing cultural norms and use values.

Central to the framework is a SWOT analysis which is a matrix tool used for planning, typically within business. The acronym stands for strengths, weaknesses, opportunities, and threats and assists in identifying qualities (good and bad) inherent in a place, product, or organization. This analysis is used to define and achieve goals. A core component of the SWOT analysis is identifying the characteristics of the surrounding context that can assist or deter from achieving those goals. Due to this organization, the SWOT analysis provides a useful tool for assessing the threats to species and habitat opportunities within the site and context.

Chapter 4: Literature Review, Projective Design

To test the reconciliation framework for conceptual clarity, ease of use, and ability to guide meaningful habitat interventions, the framework was applied to a sample site. Following the proposed framework, the site was assessed and design interventions proposed to reduce threats and improve habitat value for little brown bat.

The projective design process provides a strategy to explore the utility of the framework and opportunities for incorporating little brown bat habitat within the project site. Unlike the development of design guidelines, projective design enables a synthesis of opportunities and constraints and their spatial relationships. Further, it provides a method for communicating design ideas with conservation biologists or other species experts to judge the habitat value of the proposed design prior to implementation.

Selection of a projective design site, Schmanska Park, was guided by three criteria. First it is a public site. Second it provides a clear example one of Rosenzweig's three site typologies, in this instance "play." Finally, it was a site known to the author and easily accessible. The reconciliation projective design sought to improve an existing site as it is currently managed and used, rather than propose guidance for new site development. In keeping with the concept of incorporating wildlife species as stakeholders in urban design, only public landscapes were considered in selecting the site. Reconciling public spaces for wildlife species explicitly acknowledges the rights of wildlife to exist within the urban landscape. Therefore, the act of reconciliation broadens the municipal role of providing beneficial, safe and functional public landscapes to include wildlife as a class of urban residents. To understand this municipal policy context for the project site in Burlington, Vermont, the city website was searched for relevant policy documents. The search located the following resources:

1. 2014 Municipal Development Plan
2. City of Burlington, VT Comprehensive Development Ordinance (2014)
3. City of Burlington Open Space Protection Plan (2014)
4. City of Burlington Parks, Recreation & Waterfront Department Tree Database
5. City of Burlington Outdoor Lighting Design Review Guide (1999)

These resources provided limited information on policies for landscape management. Most useful was information located on the Parks, Recreation & Waterfront

Department website on the semi-annual tree inspection and ordinances included in the Comprehensive Development Ordinance permitting removal of “dead” trees or those posing “danger to life or property.”

Delimitations

This study did not undertake a thorough or exhaustive approach to answer any sub-questions listed above. Rather, the study goal was to cultivate a basic understanding of US species protection and conservation practice and their limitations for achieving broader goals for biodiversity conservation in the face of rapid habitat loss, climate change, and human cultural norms that drive land use and resource consumption.

As discussed above the literature review was delimited in specific instances to specific search terms within standard journals. These delimitations helped to narrow the review of large bodies of literature to provide a more focused overview of key lines of inquiry related to urban habitat design. In addition, the projective design component was delimited to application within one urban site as discussed above.

The framework did not include a traditional GIS-based habitat suitability analysis, as is commonly done within conservation planning. This research strategy and planning tool was omitted for several reasons. First, the goal of the thesis is not to guide land use planning, but rather to guide site-level design by incorporating target wildlife species as stakeholders in site programming, design features, and management plans. Second, while GIS-based habitat suitability analysis seeks to identify sites away from humans to provide wildlife habitat, this study explores reconciliation ecology as a way of bringing select wildlife species into human use spaces. This study focuses on exploring ways to expand existing site programs and aesthetic /use values to include wildlife. Finally, the study sought to create a framework that more closely replicates the contemporary practice in which landscape architects are tasked with finding design solutions to accommodate programming within a client-identified site, rather than a site selected by the architect.

A further delimitation regarded engagement of human stakeholders as part of the design communication strategy rather than prior to design selection. While the literature review in Chapter 2 indicates the need for public support and engagement in the design process, such an exploration was beyond the scope of this study which sought to focus on the species side of reconciliation. Therefore, questions of whether human stakeholders *want* wildlife in their spaces or if they *agree* with altered mowing or planting regimes were not considered outside of the framework discussion of species selection (Framework item 2.a.). Rather, the thesis assumed the right of selected species to coexist in compatible urban public spaces and discusses efforts to engage human stakeholders as strategies to educate human site users and guide their appropriate behavior on site.

Limitations

The study is limited by the author's knowledge of conservation biology principles and practice gained through the literature review, and available information on human-wildlife interactions. The study is further limited by available data on little brown bat life history. To fill knowledge gaps in the impacts of urbanization on little brown bats, the literature review sought more general information on urbanization impacts on bat species, focusing on other insectivorous cave bat species when available.

CHAPTER 4

SCHMANSKA PARK RECONCILIATION FOR LITTLE BROWN BATS

This chapter proposes a preliminary reconciliation ecology framework to help landscape architects and other urban designers consider the needs of wildlife species within site design and programming. The framework is grounded in the core elements for successful habitat implementation and management determined through literature review and analysis of habitat certification programs.

Following description of the proposed reconciliation ecology design framework, the chapter begins the projective design portion of the thesis, by introducing little brown bats as a target species for urban reconciliation design within Schmanska Park in Burlington, Vermont.

Reconciliation Typologies

Urban Site Typologies

In his call for reconciliation ecology, Michael Rosenzweig (2003) advocates for urban designers to incorporate non-human species into the human-dominated spaces he classifies as “live,” “work” and “play.” This approach to classifying human-dominated landscapes by human use values and then advocating for them to be more inclusive of other species is also advocated by other conservation scientists (e.g., Miller and Hobbs 2002, Goble, Scott, and Davis 2006). Contrary to classifying the human environment, most efforts to define urban habitat typologies have focused on structural classifications to describe the qualities and the scales at which the habitat operates, including housing density, percentage of impervious pavement, and categories of land use (e.g. Hadidian and Smith 2001, Bennett and Gratton 2012, Xie, Qiu, and Chen 2013). While these approaches allow for the urban gradient to be categorized according to its structure and basic composition, they do not address the underlying use values that humans ascribe to these sites. The process of site design is informed by cultural expectations of appearance and utility, which may be specific to different types of sites. As discussed in chapter 2, successful habitat interventions must anticipate and address cultural expectations and aesthetic preferences that may be contrary to habitat goals.

Rosenzweig's call for reconciliation suggests utilizing human-value based typologies to parse the habitat potential of the urban landscape according to spaces where people live, work and play. An overly simplistic typology requiring further development and nuance, Rosenzweig's approach introduces an important consideration about how people perceive different urban site types, what they expect them to look like, their ideas of safety within each site, and their expectations of what functions and amenities each site should hold. The values ascribed to different urban site types impact the species and habitats that may be compatible with each site type.

Development of site typologies is beyond the scope of this thesis. However, consideration of an urban typology of spaces based on human use and associated values may help to identify points of intersection between urban site types and species reconciliation. Typologies that describe the ways in which people use distinct types of urban landscapes, and their cultural expectations for them, guide management decisions and speak to the willingness of urban residents to incorporate wildlife species habitat within them. The following is an exploration of the uses, values, and characteristics that could be associated with the typologies of live, work, and play:

> Live: These landscapes are idealized as 'safe' places, with infrastructure and institutions that are established to facilitate family and community. In addition to residential landscapes ranging from single-family homes to multi-family housing complexes, 'living' landscapes may include community spaces that can accommodate multiple users, and provide a sense of comfort, such as schools, municipal buildings, libraries and community gardens, places of worship and cemeteries. Functionality and aesthetics are important aspects of living spaces.
>
> Work: Economic function is paramount for this category, while aesthetics may be less important. These sites facilitate movement of people, goods, services, and production. Work landscapes are not conceived primarily as social gathering places and open space may be less minimal and less intensively managed, with a limited plant palette. Sites within this category range from commercial shopping centers to industrial sites. Roadways and railroads are also included in this category.
>
> Play: These sites exist along a continuum of vegetation management and perceived control and safety. They range from urban children's playgrounds to rustic gathering sites within large peri-urban parks. Aesthetics play an important role in play sites, which are associated with recreation and activities that support human wellbeing. Play sites accommodate individual or group use, and may be

multi-functional in programming. Examples include neighborhood walking trails, arboreta, sport complexes, city parks, and pet exercise areas.

The type and frequency of human use for different urban landscapes also may help to inform what species and types of habitat interventions are compatible. For example, historic cemeteries may accommodate larger or more disturbance-sensitive species because they receive less frequent usage and often utilize naturalistic plantings for spiritual benefit. Similarly, the use of patterns that are common at school grounds, where a sense of safety and ease of management is paramount, may preclude reconciliation of species that are perceived as threats, or that create an additional burden on maintenance.

The uses and values associated with live, work, and play sites should be considered within reconciliation design to improve the species habitat compatibilities within human use spaces.

Preliminary Framework for Reconciliation Design

This section proposes and explains a preliminary framework to activate ecological reconciliation at the site scale (Figure 2.2). The framework is informed by the biological and social considerations for species conservation identified in Chapter 2, and from the review and categorization of conservation planning frameworks. The framework, guides a sequence of seven major steps and associated tasks to understand how the site functions for humans, the landscape and policy context, and the requirements and threats to the species targeted for reconciliation on site. These tasks focus on identifying compatibilities between human use and the needs of wildlife species, addressed through a

SWOT analysis to identify the strengths and opportunities for species habitat on site, as well as the weaknesses and threats to species in the site and surrounding physical and management context. The seven steps are described in order below, along with potential methods and resources to facilitate each stage of the process.

The SWOT informs design that seeks to incorporate as many habitat elements as possible, while minimizing or removing threats, developing a management strategy that protects and enhances the design viability and limits chemical and physical disturbance to species. In addition, the framework considers the opportunity to monitor species on the site, addressing the need for data on urban habitat, and also encourages a communication strategy to educate visitors or other stakeholders on the habitat design and target species.

Finally, the framework was developed to be used within often rapid design timeframes by landscape architects who may have limited conservation literacy. Responding to a call within the conservation planning literature for greater collaboration between designers and scientists (e.g. Pickett and Cadenasso 2008, Lovell and Johnston 2009) , the framework identifies key stages for collaboration or consultation with conservation biologists: 1) identifying species to reconcile; 2) assessing site context; 3) defining a design and management strategy; and 4) establishing monitoring needs and methods. These points of consultation/collaboration are shown with a dashed outline on Figure 4. An interdisciplinary approach is more likely to result in more functional, manageable and appropriately sited habitat, with greater longevity in the urban matrix.

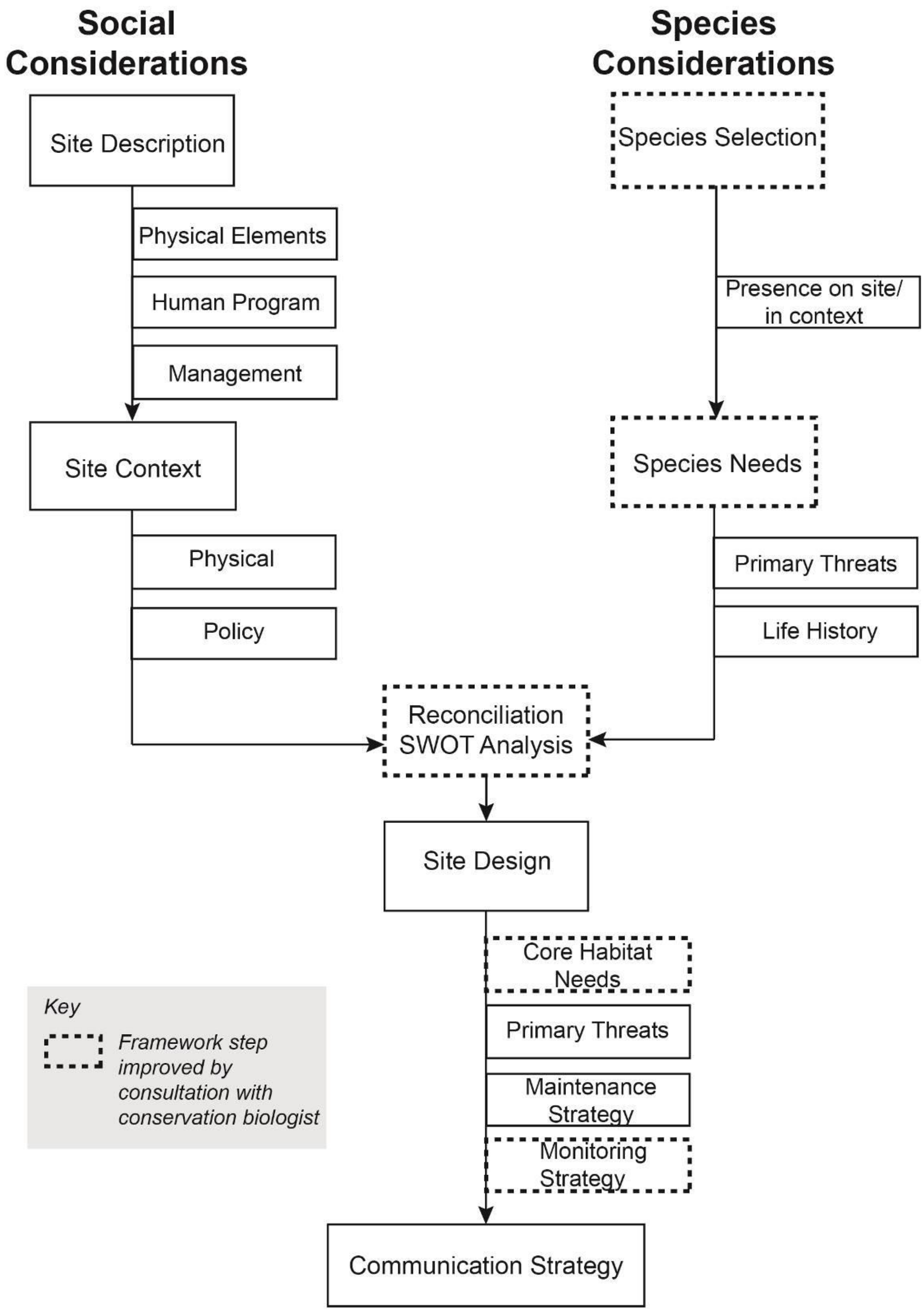

Figure 2.2. Proposed Framework for Reconciliation Ecology Design. Dashed outline indicates key points of collaboration with conservation biologist or ecologist.

1) *Site Description*

a. *Physical Elements*

Begin with an inventory of site physical features including hydrology (e.g. surface water, seeps, wetlands, vernal pools), soils, caves or rock outcroppings, slope and site aspect. If data is available identify what native species animal utilize the site or adjacent areas, and what native plant species exist on site.

Following site inventory, establish the landscape context by evaluating adjacent parcels to identify key habitat resources including native vegetation patches, water sources, or known nesting or breeding locations. Determine the presence of species within the broader city context, and map the physical relationship between known or potential habitat areas and the design site.

b. *Human Program*

While Step 1a considers the site based on habitat attributes and landscape context, this step explores the site based on human programming. Key questions include: how do people use this site? What are primary and unintended activities? How often are people present on the site? What physical structures are required to facilitate human use (e.g., paved/unpaved paths, lighting, large gathering areas)? How do people perceive and value this space? What aesthetic expectations might they have? These questions seek to capture aspects of human use, including values and associated aesthetic and safety considerations. A human use typology, as suggested by calls to incorporate species where humans live and work (Miller and Hobbs 2002) and play (Rosenzweig 2003) may aid in identifying the compatibilities, as well as possible points of friction between human uses and wildlife uses.

c. *Management*

Identify existing management strategies through site inventory, including evidence of mowing, chemical spraying, tree limbing and removal, and irrigation features.

2) *Species Needs*

a. *Species Selection for Reconciliation*

As previously discussed, the creation or preservation of "green space" does not necessarily entail the creation of good-quality habitat. Rather, the habitat value of a site or area dependents on the availability and utility of a suite of resources that are needed by a particular species (Hostetler 2014). The selection of a target species should be based on presence within the broader landscape context of the site. Habitat creation of habitat is not meaningful if the species that it intends to help are not able to access the site (Rosenzweig 2003). Narrowing the selection of species requires a basic assessment of the site structural and compositional attributes (e.g., birds and insects are better candidates to include in rooftop reconciliation than frogs and other amphibians). Additional approaches to refining the selection of species to reconcile may include matching the species scale to the site scale, public interest, and level of perceived threat to humans.

The species selection process is based on presence within the site or adjacent areas, but should be guided by physical and cultural attributes of the site. To ensure compatibility between habitat and site uses, user expectations and management regimes, species selection should follow and be informed by site physical inventory and analysis of human site program.

Groves (2008) notes that landscape architects and planners face challenges related to obtaining and interpreting biodiversity data to make decisions and calls for better collection and sharing of information in accessible formats. In recognition of limited data available on requirements for many species and biotic communities, Grove notes that conservationists often employ a “course and fine filter” to selecting conservation targets. While coarse filters opting to preserve communities are expected to encompass many associated species, it is possible for rare or sensitive species not to be supported by these coarse level efforts (Groves 2008).

<u>Urban Inhabitants</u>

Begin with species that are already known to use or inhabit the site, but that may be rare or sensitive to the effects of urbanization. This criterion looks at improving the habitat quality for existing from vulnerable species. Note that the presence of species may not indicate that the habitat is good quality habitat – an urban landscape could be a sink for a local meta-population (e.g., Russo and Ancillotto 2015), in which case the habitat is actually functioning in a way that is detrimental to the species’ survival. States or local municipalities may publish lists or maps of species presence within urbanized landscapes, which may inform species selection. An additional consideration may be to capitalize on species that are receiving public attention either because they are tied to the concept of ecosystem services (such as native insect pollinators) or due to perceptions of threat (such as urban coyotes).

Specific Species or Guilds

In proposing reconciliation ecology, Rosenzweig (2003) calls for design that addresses the needs of each species. However, Brown and Fleury (1997) suggest taking a "guild" approach to habitat design that utilizes generalized criteria for groups of similar animals (e.g., small mammals, insects). Selecting a single species may be useful if the species is unique or recognizable and there is data available to guide habitat design.

Scale

As Hostetler (2014) notes even small patches hold potential to provide habitat, especially for smaller species, including insect groups, amphibians, plants, soil biota. Small sites can also serve as stopover sites for migrating and dispersing species.

Select species that have habitat needs that are commensurate with the urban spatial context of the design. Small species such as native bees typically have smaller ranges for foraging and dispersal than larger animals, such as birds or mammals. As shown by monarch butterflies which migrate from Central Mexico to Canada over their lifecycle, this is not always the case. Nonetheless, smaller species generally can be accommodated within the urban matrix more easily that larger species (e.g., moose, bear, lynx), which typically are also associated with greater conflicts with human inhabitants.

Scale also refers to the design site and the site context and how the target species will respond to the spatial structure and composition of the design site (Hostetler 2014). Depending on their size and life history, species interact differently with the landscape and the presence of intrusions (e.g. roads) or absence of key elements (e.g., snags and hedgerows) can create barriers to movement and individual and species success.

Threat

The type, size, and landscape context of a site may guide the selection of species with regard to the ability of the site to minimize threats to species. The site and context is also important in absorbing the level of threat potentially posed (or perceived to be posed) by particular species or taxa. While less threatening species such as birds, butterflies and arthropods may be more readily accepted within the social norms of densely urban landscapes, species such as deer, coyotes and other predators may be better reconciled within suburban and urban fringe landscapes that provide greater buffer between humans and wildlife.

Identify common concerns that neighbors or city residents may have related to human interaction with the species, and commonly held misconceptions. These may be portrayals of the species as disease vectors, as agents of property damage, or as threats to the safety of humans or pets.

Decision Making Guides: review local publications, existing species and habitat inventories, to identify what species are present on site, or within a broader landscape context. Consult conservation biologists or ecologists to guide the selection of appropriate species.

b. Life History

As determined in Chapter 2, the life history of the target species must be understood in order to create functional habitat interventions for the species throughout its life cycle. Functional habitat must provide landscape objects at the appropriate scale (Hostetler 2014). The Endangered Species Act refers to these essential landscape objects as "primary constituent elements" of critical species habitat that must be provided as part of a complete habitat:

- Space for individual and population growth and normal behavior
- Cover or shelter
- Food, water, air, light, minerals, or other nutritional or physiological requirements
- Sites for breeding and rearing offspring
- Habitats that are protected from disturbances or are representative of the historic geographical and ecological distributions of a species

It is important to note that reconciliation focused on adding habitat value to existing site types and reducing the disturbance. While these reconciled spaces may not be fully representative of the species historic habitat conditions, design modifications should strive to provide basic structural components that enable their use of the site and continued existence across their range.

Decision Making Guides: Identify available resources outlining life history of target species; list species requirements guided by the above outline. Life history and habitat needs may be located online from conservation organizations, literature review, or consultation with conservation biologists. As Brown and Fleury (1997) note, in the absence of data on a specific species, conservation designers can adopt a "guild" approach that utilizes life history and habitat data on similar species to approximate the needs of the target species. Data limitations within this step and 2.c. "Threats to Species" may help in selection the target for reconciliation (e.g. species, guild, community).

c. *Threats to Species*

Identify threats to the species, focusing on urbanization impacts to species. This can be derived from best practices for species design, targeted literature review of urbanization impacts to the species or similar species, or determined through consultation with conservation biologists. If this information is not available, threats to species may be determined based on understanding of the species' behavior and life history needs, coupled with exploration of urban characteristics that can be impair species ability to function in the urban landscape. Evidence from species which possess similar life histories may help inform the threat identification process.

Decision Making Guides: List threats, tied to elements of life history, if possible, according to habitat and non-habitat categories.

3) Site Context

A review of landscape policies and management requirements for the study site should be conducted along with the identification of nearby habitat patches. To be successful, habitat design and management must consider adjacent land use, chemical runoff, sources of disturbance, invasive exotic species and natural disturbance regimes such as prescribed burns (Hostetler 2014).

Investigate the site context to identify the relationship between the reconciliation site and regulations on land use (broad scale) and land development that inform landscape structure broad and smaller scales (Hostetler 2014). Identify municipal laws and management policies that inform these broader patterns of land use and site structure and management, as these may guide or thwart attempts to provide habitat. Policies may include design guidelines such as ordinances that prohibit 'wild' or 'edible' residential landscaping, or municipal management practices such as regular mowing along roadways.

In addition, identify the site ecological context, such as hydrological and nutrient flows, adjacent or other conservation areas within functional distances for the target species.

<u>Decision Making Guides</u>: Many cities, counties or regional planning authorities publish online Geographic Information Systems data viewers that provide data on hydrology, soils, land use, including habitat areas. Identify broader patterns of connectivity of open space or other landscapes types with habitat value that is commensurate with species scale. If available, utilize species metrics such as average foraging range, to define appropriate scales for context assessment. Identify the land

managing agency to determine what policies may be helpful or harmful to habitat creation and management.

4) *Reconciliation Analysis*

Landscape architects can use the SWOT method to identify a site's potential to provide habitat by tabulating attributes that address site structure, management, human use, and landscape context. The analysis structures data accumulated through the previous steps to assess the site habitat value for the target species. In addition, a site must be evaluated for disturbance to target species as identified during review of conservation biology literature. Potential interferences include light, sound, and patterns of human use that could interfere with species function. Finally, the site should be evaluated to identify points of intersection or discord between human use values and non-human species use.

Decision Making Guides conduct SWOT analysis for design site, using the seven assessment categories listed above to evaluate the site potential to provide habitat and possible disturbance, as well as additional evaluation of the site physical qualities and human use/value determined through Step 1 above. Figure 4.3, provides a SWOT guide to incorporate this review.

	Helpful To achieving the objective	Harmful To achieving the objective
Internal Origin (attributes of the site)	Strengths (habitat)	Weaknesses (site structure, human use)
External Origin (attributes of context)	Opportunities (site structure and human use)	Threats (population threats, connectivity, adjacent human uses)

Figure 4.3. SWOT Analysis Explanatory Chart

	Habitat Features	Disturbances To achieving the objective
Site Attributes	☐ Species present on site ☐ Forage Sources ☐ Shelter ☐ Water ☐ Scale of site ☐ Breeding area ☐ Beneficial relationship & orientation of key resources (e.g. south facing slopes) ☐ Areas undisturbed by humans ☐ Stability of form and material (e.g. trees appropriately sited for full growth)	☐ Lighting, noise ☐ Pets ☐ Management Regimes to support existing human program (mowing, chemical use, tree removal) ☐ Patch is isolated ☐ Human use patterns conflict with species active periods/shelter areas ☐ Non-native plant palette ☐ Scale of site inadequate to provide undisturbed resource use
Landscape Context Attributes	☐ Nearby Forage Sources ☐ Nearby Shelter ☐ Nearby Water ☐ adjacent to potential habitat patch ☐ Stable ownership and management regimes in adjacent parcels ☐ Human stakeholders available for management/monitoring ☐ Humans value site for natural character ☐ Flyways, dispersal corridors ☐ Local/Regional habitat management and design guidelines exist	☐ Local vegetation management guidelines ☐ Roads bound site ☐ Competition/predation from urban exploiters ☐ Disease or other known threats to population health ☐ Invasive species ☐ Rapid development patterns ☐ Human perception of threat

Figure 4.4. Reconciliation Ecology Habitat SWOT. This rubric is designed to aid in evaluating site habitat potential according to site attributes, sources of disturbance and surrounding context.

Site Design Strategy

The goal of this step is to consider the species as a stakeholder in the site design in order to devise strategies that reduce disturbance to the species while aiming to improve or create life-cycle habitat. As noted above, these habitat spaces include forage, shelter/nesting spaces, migration/dispersal, and mating/raising young. Utilizing the SWOT analysis of the site, the designer should identify specific design, management, or programming interventions that can improve the habitat quality of the site. This includes designing buffers to reduce penetration of disturbing elements, and acknowledging that human activity is not compatible with interior habitat conditions (Marzluff and Ewing 2001). Marzluff and Ewing also caution habitat designers to anticipate and address urban expansion including ways to increase habitat patches and collective management.

Focus on vegetation as a core element of design and management. As noted by Tallamy (2011) native plants are important primary producers that establish food webs supporting native species. The design strategy should therefore maintain native vegetation and extend native plants to support forage as well as plants that provide shelter. Planting areas should be designed to allow space for trees to fully mature, without risk of being trimmed or removed due to perceived safety risk so that they can be retained as deadwood (e.g.,Ikin 2015, Marzluff and Ewing 2001). This can be accomplished through buffering "habitat islands" around large trees, permitting a "centuries" approach to the management of trees on site – a perspective that permits trees to achieve full maturity and engage the fullest range of biotic relationship possible during life and after death (Ikin et al 2015). When native plants and full life-cycle approach to planting is limited, supplement these habitat features with artificial nest boxes or other functional substitutes such as fence posts installed in place of coarse woody debris (Ikin et al 2015).

Consider the management requirements of existing human use of the site, and identify ways of altering management regimes or site programming to put habitat management "on the same pedestal as design" in order to support the long-term function of the reconciled site (Hostetler and Reed 2014). This includes snow/ice removal, mowing, herbicide application, and other site-specific management needs.

Decision Making Guides: Review species life history to identify forage plants; for insectivores and carnivores, review available literature to identify plants that support lower trophic levels. Utilize native planting guides from municipal or conservation agencies to identify appropriate plant species, including optimal spacing to ensure full growth. Attend to the structure of the site to ensure species have appropriate roost, nesting sites and other elements and that the species can move through the site unimpeded, to reach different habitat objects (such as forage sources and water). In the absence of species specific data, utilize design guidelines for similar species, and ensure that conservation best practices are met. If necessary utilize a systematic review to extract design guidance from the academic literature (e.g. Reynolds 2013).

5) Monitoring Strategy

This step does not directly relate to habitat design, but can be incorporated to guide additional design elements that facilitate assessment of the habitat function. Felson and Pickett (2005) have proposed the concept of "designed experiments" that incorporate monitoring within ecological landscape design in order to generate data on design function. Several frameworks and species conservation organizations such as the North American Pollinator Protection Campaign include monitoring to assess habitat value of existing and designed landscapes. However Hostetler and Reed (2014) propose that monitoring be addressed during site design, which could conceptually expand beyond material selection to include designing features that facilitate human monitoring of species on site. Including monitoring as a mode of urban habitat intervention can also serve objectives of educating urban residents about native species, and thereby improving interspecies interactions.

State and federal agencies often have limited staffing and budgets to collect data to monitor the health of wildlife populations, making citizen science an important and useful tool. In addition, due to the large percentage of land in private ownership, state agencies may be spatially restricted in their population monitoring efforts. For example, Tinsley (2016) notes South Carolina state wildlife personnel have not been able to access and monitor a known little brown bat population since the 1990s. Turner (2003) suggests a more robust data set on the presence and persistence of native bird species within urban areas will help address gaps in scientific understanding of how ‘metropolitan landscapes” can be designed to better accommodate native bird species. After a second annual volunteer-based city-wide bird count in Tucson, Arizona, Turner reported that the method provided a “high visibility, efficient means to acquire data unobtainable by other methods, presenting great potential to advance ecology and conservation” (Turner 2003, 149). Turner notes the importance of studying species populations longitudinally (i.e., over relatively long periods of time), because "urban ecology is – for the foreseeable future at least – a study of change" (p151). The study conducted as a modification of the North American Bird Count (which does not survey in urban areas) lasted for one month using skilled observers to count birds at predefined locations across the urban gradient. While not included in Turner's discussion, it is possible that urban sites designed for reconciling birds can incorporate landscape features that aid in this type of survey work.

Decision Making Guides: Identify common metrics and methods for surveying the target species to explore how this management tool can be supported through the site design.

6) Communication Strategy

An important component of most of the habitat certification programs reviewed in chapter 2 was the communication or promotion of the habitat intervention. This included strategies from Migratory Bird Day celebrations to simple yard signs identifying residential yard pollinator gardens. Ikin *et al.* (2015) also emphasized the overarching need to educate and engage local residents about native species and ecological processes, while Lovell and Johnston (2009) proposed site design reveal ecological functions. As part of the site reconciliation design process, this framework requires designers to determine a strategy for communicating the purpose and importance of the design. Strategies may include physical interpretive elements (e.g., signs, informational kiosks, and symbols representing plants and animals within paving materials); providing site managers or owners with management guidance that clearly states the importance of the site interventions and clearly describe management actions that are needed to support species, and generating publicity through news media or the designer's website.

The communication strategy is intended to promote citizen awareness and engagement with biodiversity design. This includes clarifying for site visitor what appropriate behaviors are within reconciled sites, to reduce disturbance to non-human species. A corollary goal is to improve awareness of biodiversity design within the landscape architecture and urban planning communities. As Trombulak et al. (2004) argue, all levels of society need to be conservation literate in order for humans to live harmoniously with nature. Communication efforts are particularly important for neighbors and residents who are, by default, the long-term stewards of designed areas (Hostetler 2014).

Project Area Overview

Burlington is located in northern Vermont near the Canadian border. It is the most populous city in Vermont, with a municipal population of slightly over 42,500 people estimated in 2015 (Wikipedia 2017). It is located in the ecological region called Adirondack-New England Mixed Forest, Coniferous Forest, Alpine Meadow Province (The Pollinator Partnership). Burlington has an average annual temperature range from 18 degrees to 70 degrees Fahrenheit, with annual precipitation of approximately 37 inches throughout the year (Wikipedia 2017). The city was founded on the eastern shore of Lake Champlain, in roughly the center of the Champlain Valley. The broader metropolitan area is bounded on the east by the Green Mountains.

The city is bounded to the north by the Winooski River and along the south and east by major transportation corridors. Burlington is home to the University of Vermont, and the local population recognizes seven neighborhoods including the Intervale, an area containing organic farms and nature preserves along the Winooski River.

Burlington, like the rest of Vermont, is known for efforts toward sustainability, and in 2015 it became the first U.S. city to use entirely renewable energy (Wikipedia 2017). The city has an Open Space Plan that states protection of "Ecological Integrity & Social Well Being" as one of its core goals. Twenty-two pre-settlement natural communities are recorded for the city; based only on soils data, the plan notes the potential for all 22 communities to remain, although in fragmented state, when the plan was written in 2013.

Wildlife receives scant mention in the plan, other than noting a general desire to maintain urban forest as corridors for humans and wildlife. Among the land use classifications recorded, none is dedicated to conservation or wildlife habitat. However, the open space plan records that the city covers 6,784 acres and contains six urban wilds and 49% open space, suggesting the general value the city places in natural areas and open space.

<u>Schmanska Park Reconciliation</u>

1. Site Description: Schmanska Park
    1.1. Human Program: The site is a former farm deeded to the City of Burlington in 1942 by Pearl Schmanska in memory of her husband, Frank. The park retains evidence of its agricultural past, most obviously through the small red barn that

marks the western edge of the park. Managed by the Burlington Department of Parks and Recreation, the rehabilitated site is graded to hold four terraced use areas, two tennis courts, a basketball court and adjacent ball field, a smaller level grassy gathering area, and a playground along the street (Figure 4.5).

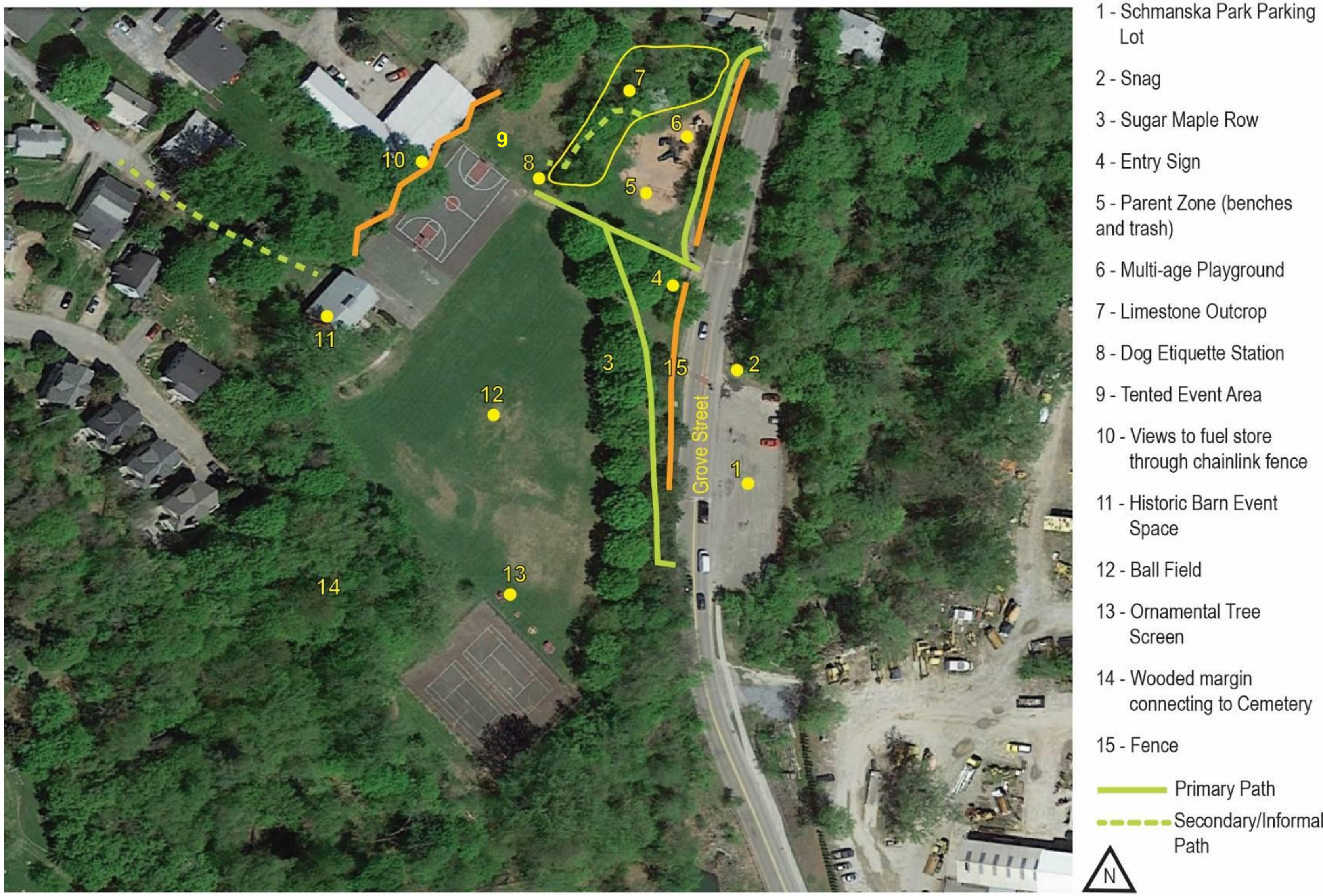

Figure 4.5. Schmanska Park Existing Conditions Plan

Two paved paths provide access into the site from the street, while an additional path connects the site to the playground, running perpendicular to Grove Street. There is no other programmed internal circulation. An opening in the vegetation along the rock outcrop shows a relict metal fence post and an informal duff path created by people (likely children) climbing across this un-vegetated area (figure 4.6). A low metal fence lines the eastern edge of the park, providing containment for children and toys.

In addition to the playground, there are two programmed activity spaces: a tennis court and a basketball court. A large concrete pad extends southward from the basketball court to connect to the barn. Two mown grass areas (including a ball field) provide a level gathering space. While a historic bank barn is maintained near the highpoint of the site, it does not appear to be used for regular events. The Burlington Parks Department website lists no reservation information and indicates there are no restrooms.

Parking is provided in a small lot across the busy residential street. The lot is bounded on the east by the steep Centennial Brook ravine that runs north to the Winooski River. Neither the park nor the lot have lighting, suggesting that the area has no night programming.

Site furnishings within the park are focused around the playground and are limited to a bench, trash bins and recycling bins. A dog etiquette station provides bags for dog waste cleanup. Aside from the barn, there are no interpretive elements on the site, nor are any provided on the Burlington Parks Department website.

Based on site observation, most park visitors are families with small children, who utilize the playground area. Larger groups were also observed congregating in the tennis court area, with some using the basketball court. No dog walking or field sports were observed. Online aerial mapping shows that the park can be used for events, with a large tent set up north of the basketball court, and local event calendars indicate that a local wildlife observation group meets semi-annually at the park.

1.2. Physical Elements:

The approximately 6.5 acre park is situated on a hilly prominence with an east aspect overlooking the Winooski River. The hillside has been graded into four level areas, while a rock outcrop creates an "amphitheater" around the playground (figure 4.6), providing evidence of the underlying geology and historic terrain. The site slopes east toward the steep ravine of Centennial Brook, which drains north to the Winooski River. Following heavy rain or rapid snow melt, eastward drainage across the site causes erosion of the ball field slope and the curving entry path (Figure 4.7).

Figure 4.6. Rock outcrop at Schmanska Park. Unmanaged vegetation growing out of the rock outcrop that frames the playground at west, March 2017. Photo by author.

Figure 4.7. Turf slope Erosion, Schmanska Park. Snow melt draining northeast to the Winooski River causes erosion to grassed slope above the entry path below a line of sugar maples, March 2017. Photo by author.

Site features and clearings are oriented roughly northeast-southwest. Areas receiving full sun along a southern aspect are limited. Open sunny areas are in the central sports field and in the small clearing west of the rock outcrop.

According to the Burlington 2013 open space plan, the area has the potential to support a maple-ash-hickory-oak forest community. The City of Burlington Open Data Tree Map and site review indicates the park includes green ash and sugar maples among the planted trees. Trees exist primarily along the park perimeter, while a row of sugar maples is planted to define the curving entry path. Young trees also grow in the rock outcrop zone, along with sumac and other unplanted herbaceous material. Several ornamental trees (e.g., service berry and crabapple) mark the eastern entry to the barn and line the northern edge of the tennis courts. Ground cover is limited to turf, and understory vegetation only occurs within the southern perimeter where the park connects to the Green Mountain Cemetery.

A parking lot, constructed in 2016, is fenced along the park's eastern edge to prevent pedestrian and vehicle access to the Centennial Brook ravine. Vegetation along the western edge of the parking lot directs pedestrians to cross Grove Street at the designated point. "Knock-out" roses line the planting strip, while the northwestern corner is planted with young pine trees. A tall snag remains at the parking lot northwestern corner between the existing woodland and the newly planted pines, providing potential habitat if retained.

2. Species Needs

2.1. Species Selection:

Little brown bat (*Myotis lucifugus*)

2.2. Life History Key Elements:

Literature review identified five habitat requirements for little brown bats: forage habitat, commuting habitat, roosting places, maternity habitat and hibernacula to overwinter. Common forage for this insectivorous species are soft-bodied insects such as crane flies, moths, wasps, gnats, mosquitoes, and aquatic species such as mosquitoes and midges (Wisconsin Department of Natural Resources 2013). Little brown bats require warm day and night roosting spaces that provide protection from predators such as raptors, snakes, raccoons, and domestic cats.

2.3. Threats to species:

Currently, the primary threat to little brown bat populations is White Nose Syndrome. Aside from this disease, habitat loss and degradation resulting in limited access to forage and roost resources are core population threats. Within urban landscapes, additional threats to individuals come from humans killing or removing little brown bats from roosting sites, traffic collisions, acoustic and light disturbance, predation from domestic animals, pesticides, and other pollutants.

3. Site Context

3.1. Landscape

The park is bounded along the north, west and south by a moderately dense, mixed single- and multi-family residential neighborhood with some commercial uses, containing approximately 2200 dwelling units per square mile. Grove Street, a two-lane residential road marks the eastern boundary of the park. A feeder road, Grove Street is a common route for motorists traveling to and from the airport. Although largely unlit, Grove Street receives frequent nighttime use. While industrial activity and residential development exist farther east of Grove Street, the Centennial Brook ravine encompasses a noteworthy patch of woodland. This relatively undeveloped strip of land extends southward to the Centennial Woods Natural Area, and northward to the Winooski River and the Cassavant Woods Natural Area, a riparian woodland across the river in the City of Winooski.

The broader site context is further defined by dense urban and residential development, with the meandering Winooski River providing important patches of undeveloped land extending westward to Lake Champlain and eastward toward less developed areas in the Green Mountain range. The park is located south of the National Guard Base and lies in the general flight path for the Burlington International Airport, which is located southeast of Schmanska Park.

The Chittenden County Regional Planning Commission provides an online data viewer called the ECOS GIS map that records useful data on sensitive habitat areas, including rare and endangered species occurrences, wildlife linkage ratings for road crossings, and priority habitat blocks. The ECOS data viewer shows Schmanska Park within an area of protected conservation lands, significant wetlands connected by the Winooski River. Data on rare, threatened, and endangered species shows occurrences of plants, animals, and natural communities within the parks broader context. The park connects south to the significant white pine-red oak-black oak forest in the protected land in Centennial Woods. Northeast of Schmanska Park is a Silver Maple-Ostrich Fern Riverine Floodplain Forest in the City of Winooski Cassavant Natural Area.

Using the most limited foraging range approximated for lactating females, a roughly 600 meter buffer was mapped around the park center to identify the range of potential existing habitat areas available to little brown bats (Figures 4.8 and 4.9). This exercise shows the opportunity for Schmanska Park to supplement and increase connectivity among existing potential habitat areas.

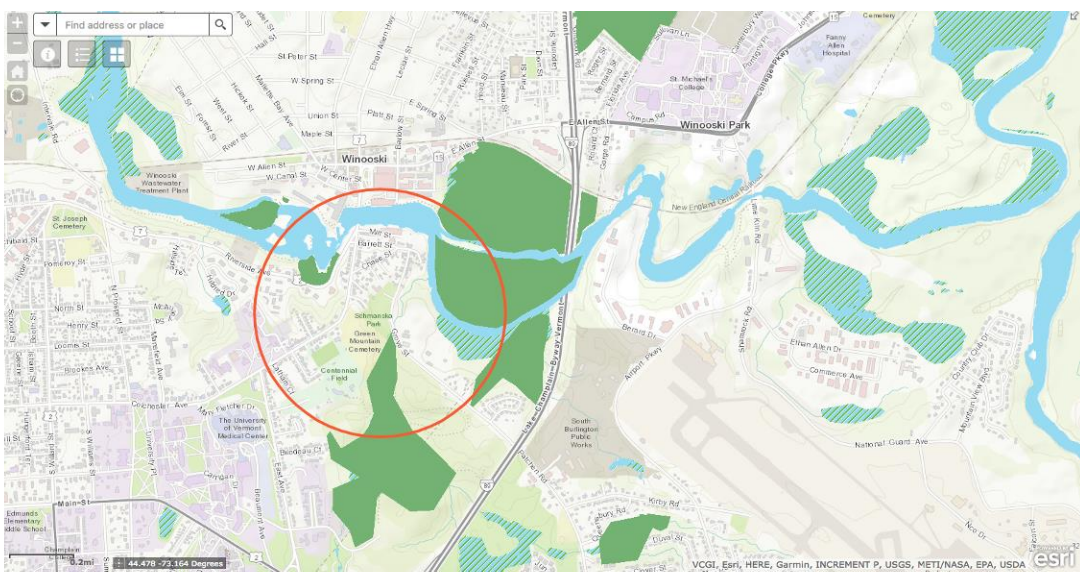

Figure 4.8. Schmanska Park Conserved Land Context. Conserved lands shown in dark green. A 600 m MYLU maternity foraging buffer is shown in red.

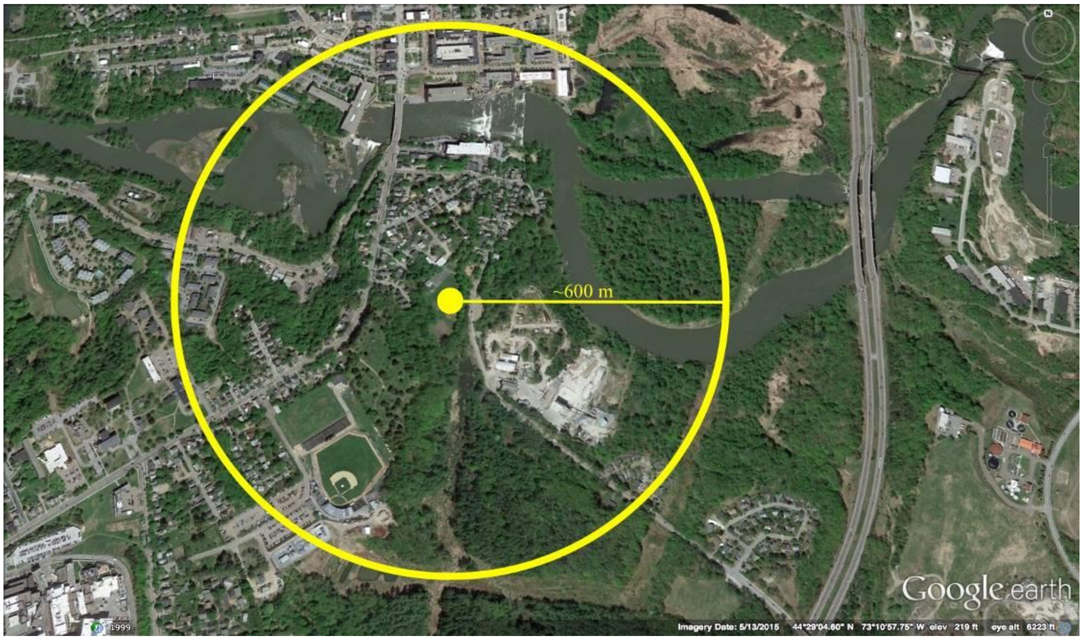

Figure 4.9. Schmanska Park 600m Buffer Context. A Google Earth aerial shows woodland patches of conserved and other adjacent land within the 600 m MYLU maternity foraging buffer, shown here in yellow.

3.2. Policy

The Burlington Parks department website states that Burlington Trees and Greenways staff conducts a biannual inspection of street trees in the right-of-way to identify dead or hazardous trees that should be removed or potentially replaced. No other policy documents were identified relating to vegetation management or use.

4. SWOT Analysis

As discussed in Chapter 6, a *SWOT* analysis (alternatively *SWOT* matrix) is an acronym for strengths, weaknesses, opportunities, and threats and is used to structure planning and assessment of projects, organizations or businesses. It is applied to assess bat habitat at Schmanska Park (Figure 4.10).

	Habitat Features	Disturbances To achieving the objective
Site Attributes	☐ Human use appears limited to day events, no lighting ☐ native trees may support forage ☐ Rock outcrop may provide roosting habitat ☐ Site topography helps to define distinct use areas ☐ Topography may support artificial hibernacula ☐ Site is large enough to support mature vegetation and limited separation of human and bat use areas ☐ Stability of form and material (e.g. trees appropriately sited for full growth) ☐ South facing wall on barn, a potential roosting site ☐ Snag in parking lot for roosting and insects	☐ Noise from daily use and large gatherings may disturb roosting bats ☐ Dogs are allowed in the park, and permeable park edges allow entry to neighborhood pets ☐ Vegetation management includes lawn mowing and hazard tree removal ☐ Large mown area, limited groundcover and understory plantings ☐ Scale of site inadequate to provide undisturbed resource use
Landscape Context Attributes	☐ Centennial Brook provides water source, and woodland cover likely supports forage ☐ Adjacent to additional potential habitat patches for roosting and forage (cemetery, Centennial Woods) ☐ Stable ownership and management regimes in adjacent parcels ☐ Human stakeholders available for management/monitoring ☐ Humans value site for natural character ☐ Centennial Brook ravine may provide commuting corridor	☐ Road bounds site ☐ Potential for competition or predation from urban exploiters, such as, raccoons ☐ Development of adjacent and nearby parcels ☐ Neighborhood residents may perceive threat from bats, particularly when visiting park with children or pets

Figure 4.10.Schmanska Park Little Brown Bat SWOT Analysis.

5. Site Design Strategy:

The SWOT analysis reveals that the primary disturbances on the site are during daytime hours, and planting palette and management pose the greatest barriers to habitat improvement. In addition to roaming cats in the neighborhood, traffic on Grove Street presents a more enduring threat to bat commuting to and from the Park. Despite these threats, the size of the park and the availability of adjacent riparian and woodland areas, means that Schmanska Park is likely able to provide foraging and roosting habitat. In addition, the park can provide an opportunity for public awareness about bats and urban habitat needs. In addition, the park could possibly support an artificial hibernaculum within the ball field hill.

Overarching goals for site reconciliation include establishing a safe roosting location, improving site foraging potential, and increasing public awareness about the species. The site reconciliation design seeks to separate roost and human use spaces, particularly with respect to spaces that are actively used by children, who could be exposed to bat guano. In addition, the design seeks to maintain opportunities for group gatherings, while limiting the disturbance that these events may cause for roosting bats. Finally, informal pedestrian paths through the rock outcrop and animal motifs used to decorate the existing playground equipment suggest the desire on the part of people to interact with, and interpret "natural" in the landscape

Design Areas and Elements

The reconciliation design for Schmanska Park focused on addressing potential threats to little brown bats and maximizing habitat potential for three key little brown bat habitat needs: roosting, forage and hibernation. A fourth, commuting, was less easily addressed during the design process.

As a reconciliation design, habitat elements were included in a manner that would not disrupt current human site uses and be compatible with values for the site. In addition to habitat elements, the plan addressed social elements through communication and monitoring strategies. The Schmanska Park Reconciliation Plan (Figure 4.11) depicts these habitat and social elements, which are discussed below.

Figure 4.11. Schmanska Park Little Brown Bat Reconciliation Plan

Roost – Bat House Meadow and Beech Tree

The bat house meadow is the core habitat zone within site. As identified in Chapter 2, roosts may be a limiting factor for little brown bats and other bat species, all of which rely on existing structures. To provide immediate roost habitat on site, a large bat house is proposed for the seldom-used open space west of and uphill from the Limestone Outcrop (Area 7 on the Schmanska Park Existing Conditions Plan, Figure 7). The roost is located 9 feet above the ground to limit predation from neighborhood cats. Dark wood construction ensures maximum solar gain to warm the roost. Design for the roost house may be modified to ensure it functions for a maternity colony, which research suggests may be a limiting factor for population viability (Tinsely 2006).

The bat house is located at the highest elevation of the site, and provides southern exposure necessary to warm the roost. A meadow buffer planting establishes a 'safe' zone around the bat house – providing a visual cue for humans not to disturb the roost and helping to limit pet and small child interaction with bat guano that can collect at the base of the bat house. The meadow forbs and grasses is intended support a more diverse and abundant insect assemblage than does the existing turf grass (Figure 4.12).

An analysis of the site in relationship to the tree typology developed by Gunnell, Grant, and Williams (2012) suggests the inclusion of a "signature" or "ornamental" tree in order to support roosting and forage. A signature American Beech tree is proposed for the open corner of the park southeast of the barn, to provide a potential roosting, interpretation, and space-shaping element near the western entry to the park.

The tree serves as a "Signature" tree and when mature can provide a natural roost. The beech is placed in a location to frame, but not obscure views to the historic barn while taking advantage of the shelter provided by the woodland edge.

Figure 4.12. Proposed Roost. Meadow planting to provide a buffer and support forage.

Forage – Maple Row Shade Garden and Courtyard Trees

The slope above the curving entry walk presents opportunities for improving forage by providing moth and other soft-bodied insect habitat. The garden bed may also help to address site erosion, and the plant selection enhances the entry aesthetic. A shade tolerant native garden is proposed to include plants such as wild ginger, white wood aster, wild geranium, cardinal flower and sedge species to aid in holding the slope (Figure 4.13). The line of existing sugar maples (*Acer saccharum*) may provide protection for foraging bats from aerial predators.

Figure 4.13.Proposed Maple Row Shade Garden. Garden supports bat forage by providing insect habitat as do Courtyard trees and unmown grass areas at back of picture

Two lines of "Courtyard" trees are proposed along the east edge of the tennis court and along the north edge of the basketball court to further support moths and other forage insects, providing vertical structure to the site and potential night roosts.

Hibernate – Artificial Cave

It is possible that due to the site soil moisture and large existing topography, an artificial hibernaculum could be incorporated beneath a portion of the ball field lawn, near the tennis courts, where the site is less actively used. Unmown areas and ornamental trees are proposed to buffer a bat entry flue, while a human maintenance entry along Grove Street could be set within the eastern slope near the curving entry path (Figure 4.14). Artificial hibernacula may prove critical in efforts to combat

White-Nose Syndrome by enabling more consistent population monitoring and sanitization. The fields receive little activity in the winter and likely present little disturbance to bats within an artificial cave.

Figure 4.14. Concept Sketch for Gated Artificial Cave Maintenance Entry along Grove Street. View from parking lot near the entry to the park.

Management Plan

Management strategies developed in combination with the habitat plan are focused on limiting disturbance to core habitat areas, enhancing insect diversity to support forage, and reducing chemical and energy inputs.

Roost and forage areas along the ball courts, and the hibernaculum entry flue are protected by unmown “habitat islands” to allow forage trees and the roost beech tree to reach full maturity and ecological relationships, including as they decline. These no-mow buffers shown on Figure 12, establish life-cycle habitat zones and establish a safe perimeter around the beech tree to allow it to reach “hazard” tree conditions.

In consideration of the city’s limited capacity for site maintenance, plantings for habitat improvement are proposed to be contained and maintained through mowing. Groundcover plants along the Maple Row Shade Garden and the Bat Meadow are added in two well-defined beds in order to accommodate mowing of adjacent turf. Rocks and stump features protect the line of planting beds and provide structure to enhance habitat value. These structures also maintain the integrity of the no-mow habitat islands proposed under the beech roost tree and in the southeast corner near the tennis courts.

Once it is established, the bat meadow like the no-mow areas can be maintained with annual mowing in early spring prior to the start of growing and roosting season. Prescribed burning is not recommended as a management strategy due to the small size of the meadow and proximity of residential and commercial buildings, including a propane vendor.

6. Monitoring Strategy:

Common methods for surveying little brown bat populations include mist-netting and harp traps, winter hibernacula surveys, bat house/maternity colony evening exit counts, and acoustic survey. In addition to methods that seek to determine bat presence and population health on a site, monitoring can also include efforts to ensure that the bat habitat is well-managed and that bats are not being harassed or endangered by visitor or management actions.

The inclusion of a bat house, makes evening exit counts a good strategy to support through site design. Site furnishings are proposed to facilitate monitoring, and daytime appreciation of the augmented habitat. Benches placed near the bat house, particularly angled to the west, invite park visitors to count the bats dark silhouettes against the brighter western sky as the animals leave their house to forage each evening (Figure 4.15). Site visitors can be invited to report counts and habitat observations through informational kiosks, as discussed further in section 7, below.

The site's proximity to two small colleges and the University of Vermont, as well as the fairly dense urban neighborhoods that surround it (or are near it) suggests opportunities to cultivate a volunteer base for additional types of monitoring.

Figure 4.15. Proposed Monitoring Bench. Benches placed near the bat house facilitate monitoring through evening exit counts.

7. Communication Strategy:

Located near the park entry, the playground area provides the opportunity for expanding existing site furnishings to include an information kiosk on the bat habitat reconciliation (Figure 4.16). The kiosk will provide reading material for a captive audience of parents and provide opportunities to engage children in learning. The kiosk can also host information about monitoring goals and procedure, and provide reporting forms for summer exit counts. The kiosk can also educate visitors on bat biology and ease concerns over human and pet safety when visiting the park. Resources for further education and stewardship opportunities can also be posted on the kiosk to invite community engagement.

Figure 4.16. Proposed Information Kiosk. Placed near existing site furnishings at the park entry.

To further awareness of the habitat project and guide visitor behavior, additional etiquette signs are placed at secondary entry points and near habitat areas. Signs are placed near the barn, the hibernaculum unmown area, and the bat meadow.

Many communities within Vermont utilize a social networking platform called "Front Porch Forum," through which municipal governments and residents announce events, request assistance for projects, and notify neighbors of potential problems. Front Porch Forum and the existing Parks and Recreation website give the city at least two digital options establish dialogue about bat habitat, communicate progress and recruit volunteers to aid in monitoring and habitat management.

Conclusion

This chapter synthesized the literature reviewed in Chapter 2 to propose a framework that provides landscape architects with a checklist for site-level habitat design that seeks to reduce disturbance to wildlife species, while meeting nine core habitat components. As urban landscapes continue to develop and habitat continues to be lost, landscape architects must make meaningful use of ecological concepts and work within a framework to guide their inclusion of wildlife species as stakeholders within urban design. To assess the utility of the proposed framework, it was applied through projective design to a public park in Burlington, Vermont. The result was a series of habitat improvement measures and communication strategies to engage human stakeholders to increase their conservation literacy and expand the values they hold for the park.

CHAPTER 5

RECONCILIATION DESIGN DISCUSSION & CONCLUSIONS

Discussion of Framework Demonstration

Despite the limitations urbanization may pose to bat species, the fact that there are species such as little brown bats drawn to urbanized landscapes suggests the possibility of improving urban habitat value exists. While reconciliation ecology proposes incorporating species within human use spaces, there is no framework for operationalizing the theory. Current efforts to improve bat habitat are often limited to bat house installation and do not address the complete life history of bats or the breadth of challenges the urban landscape poses.

The proposed framework was created to guide site design through a targeted assessment of habitat requirements, social and cultural expectations, and management, to generate successful urban habitat interventions. The goal of the framework is to promote urban reconciliation design within short schematic design timeframes and despite incomplete knowledge of urban ecosystems and species life history. In that regard, the framework was found to be a useful tool for organizing the design process on what information to collect and what elements to consider in reconciling the park for little brown bats. The SWOT matrix was found to be particularly helpful in organizing data on the site and little brown bat habitat needs. The SWOT also facilitated selection of interventions to address each of the potential threats to little brown bats posed by the site and activate each potential opportunity.

While the thesis question asked how to incorporate little brown bats as stakeholders in urban public sites, generally, the projective design used a park as the study site. It is possible that parks as a site type, or Schmanska Park in particular, are so different from other public site types that the lessons learned from the projective design may not be translatable to other types of urban public space. Further projective design applications will not only help to refine the framework, but also answer the question of the range of reconciliation actions possible within urban public spaces.

In addition, the literature review took a broad approach to understand the range of reconciliation designs considerations as well as to establish the need for reconciliation as a complementary approach to existing modes of species conservation. However, the review did not explore characteristics of public spaces that may hold unique considerations for reconciliation design. This includes an exploration of opportunities public spaces hold for common management regimes, their relative stability within dynamic urban landscapes, and the potential for implementing similar little brown bat reconciliation projects in other Burlington parks.

The projective design application provided an iterative approach to finding spatial compatibilities between current human uses and historic and cultural values the site holds and the goal to maximize habitat value for little brown bats. While it was not peer-reviewed, the approach can provide an opportunity for framing collaboration with and assessment by conservation biologists prior to implementation.

Without being implemented, it is unclear how successful the little brown bat reconciliation for Schmanska Park would be. While the projective design enables site review by conservation biologists to understand the potential impartments that can be made, it is necessary to define possible metrics of success to evaluate implemented designs. Because reconciliation design addresses both species and human needs the success of the design must be evaluated in terms of how it functions for both humans and little brown bats. For both lines of evaluation, success must be evaluated against baseline data.

Establishing baseline data is particularly important for judging the success of reconciliation for little brown bats. Little brown bats are presumed to exist within the study site context based on habitat potential and observation of other bat species in adjacent areas. No data was obtained to determine whether little brown bats are currently using the site. To assess the effectiveness of the proposed design, baseline data would need to be collected to identify the presence and abundance of bats on site, so that this data could be compared with little brown bat abundance on site following design installation. Acoustic monitoring is often used to identify the presence of bats on site – recording their echolocation calls and providing a measurement of the number of bats passing the monitoring equipment.

It is possible that due to White-Nose Syndrome or other threats to little brown bat populations, no matter how well-designed the habitat improvements are, little brown bat population numbers in the Champlain Valley are too low to register a significant increase in site monitoring data. In this situation, alternative measures of success can be used to evaluate the design including the increase in diversity and abundance of little brown bat forage species such as moths, gnats and crane flies.

Social metrics of success can include increased community involvement in site monitoring and maintenance, greater levels of awareness about little brown bats, and increased conservation literacy based on an understanding of the role of the Schmanska Park reconciliation in broader ecological processes.

Adding a project definition step to the framework may assist in setting actionable goals for site design that will inform monitoring strategies and permit adaptive management. Establishing baseline data on site species richness and little brown bat presence as well as visitor satisfaction with the site would help to define goals possibly altering the reconciliation design.

Conclusion

This thesis speaks to the cumulative effects incremental design and management actions have on biodiversity, and how landscape architects can reframe our individual actions to consider wildlife. The hope is that by taking a biodiversity focused approach to site design, landscape architects can aid in broader efforts to slow or stop the loss of species. Habitat loss driven by urbanization and agricultural production is the biggest threat to most species, therefore it is important to devise simple, consistent, and scientifically informed methods to guide urban designers and planners whose daily decisions can have incremental effects on broad landscape patterns for decades to come. Tarsitano (2006) warns against "a dangerous *decline in the quality of life"* if cities are not "tailored to their inhabitants." And as Hadidian and Smith (2001) and Soulsbury and

White (2015) indicate, wildlife species are urban inhabitants and we must address the sources of conflict between humans and wildlife while promoting the benefits of cohabitation. Little brown bats are just one species of resident urban wildlife which deserve to be included as stakeholders in urban design.

The primary research question this thesis sought to answer is “how can landscape architects reconcile urban public spaces to benefit little brown bats?” Answering this question was limited by available data on how little brown bats interact with and are impacted by the urban landscape, as well as a lack of design guidance on how to support bats through design.

While the conservation and planning literature review found a well-developed body of research on how to select and prioritize areas for conservation, guidance on how to design sites for biodiversity was noticeably lacking. As noted by Mussachio (2008), the complexity of conservation decisions and the multiplicity of factors threatening species has further limited published efforts to establish species guidance. Efforts to make evidence-based design decisions that limit impacts on biodiversity are further thwarted by the fact that conservation biologists and ecologists have historically limited their research into and consideration of urban wildlife. As a result, the literature search conducted in Chapter 2 identified few articles with guidance on reducing the threat of urbanization on individual species.

Systematic review has been proposed as a method for ensuring landscape architects and planner’s biodiversity design decisions are informed by the best available evidence (Reynolds 2013). However it is a time-consuming process, and requires sufficient scientific background to assess each article identified through the scoping review and then comprehensively derive guidance through statistical or other analysis (Reynolds 2013). While this is a methodologically sound approach, it likely does not reflect the aptitude, interests, and motivations of the average landscape architect. In addition, based on the limited design guidance presented within the professional literature, a systematic review method may not directly inform design strategies to reconcile sites for wildlife species. Therefore, alternate methods for designing in the face of limited data is required.

The reconciliation ecology design framework developed and demonstrated in Chapter 4 may provide a useful tool to guide urban habitat design based on available evidence and guided by consultation or collaboration with conservation scientists. Further, the simplicity of the framework, particularly the SWOT checklist, may enable landscape architects without conservation backgrounds to engage in reconciliation ecology design with or without comprehensive systematic reviews or collaboration with conservation scientists.

While the reconciliation framework may hold promise as a tool to establish a new conceptual approach to urban design, it will certainly benefit from additional development and refinement. In addition the framework and ability to successfully design for little brown bats will be improved by resolving underlying obstacles to urban habitat design. Suggested areas of future research and development include:

1. *Refine the framework by applying it to additional sites for little brown bats (and other species)*

2. *Explore and refine the urban site typologies of live, work play as a culturally-based approach to pairing species habitat with ubiquitous human-dominated landscapes*

   Refine these typologies to clarify their associated aesthetic and use values that can be used to guide appropriate habitat interventions. This process will help to identify which types of sites are capable of holding species habitat and which are better suited to promote awareness.

3. *Explore opportunities for data collection within reconciliation projects*
4. *Identify modes of collaboration between landscape architects and conservation scientists that can facilitate reconciliation design development within short time frames*
5. *Assemble little brown bat regional forage and plant species lists to serve as preliminary guidelines*
6. *Extend the human use typology to other elements of habitat design, such as vegetation*

   The literature review identified planting design as a vector for biodiversity loss or conservation (e.g. Tallamy 2011, Ikin 2015, Sack 2015, Hunter 2011). Planting design provides a point of intersection between species habitat needs and human cultural values and land uses (e.g. Hunter 2011, Gunnell, Grant, and Williams 2012). The functional categorization of trees for both bats and humans provided by Gunnell, Grant, and Williams (2012), and the rubric for aesthetic and food web value of plants generated by Hunter guided the selection of plantings for the Schmanska Park little brown bat reconciliation as provided in Table 2.8.

Following Hunter (2011), these species and categories were reviewed for food web value, selecting tree species associated with the eight invertebrate orders identified in chapter 2, such as Lepidoptera (butterflies and moths), which serve as major food sources for little brown bats. This type of analysis could be completed for little brown bats in the Northeast and developed for other regions and species to provide a preliminary reconciliation guideline for species.

Additional obstacles to reconciliation ecology design include low levels of conservation literacy among landscape architects, a disconnection from the scientific community; the challenge of translating data into form; and the lack of data to guide urban habitat design.

As discussed previously in this chapter, in order to be successful, reconciliation design must be functional for species. However, as noted in Chapter 2, there is often a disconnect between the site scale, the scale at which the species interacts with the landscape, and the broader scales at which species populations merge and mix as described by meta-population theory. It is possible that reconciliation ecology design at the site scale does little more than create ecological traps – attracting species to resource-filled sites set within otherwise dysfunctional matrixes devoid of habitat resources and full of threats. While this possibility must be acknowledged, it should not limit efforts to provide habitat and remove potential threats through site level design. Just as habitat is degraded and lost through site level actions, there may be opportunities to reduce these impacts through a reconciliation approach.

Rosenzweig (2003) suggests that true reconciliation will require the creation of community at multiple scales to reflect the many scales at which species operate. It is possible that through collaborative approaches and common platforms for knowledge generation and sharing, landscape architects, biologists, and conservation organizations can address species reconciliation from multiple scales and approaches.

Ultimately, the goal of this thesis is to encourage landscape architects to consider wildlife at the beginning stages of design projects, identify threats to species and considering opportunities for improving habitat quality and species awareness. By proposing a preliminary framework, this thesis hopes to begin fruitful exploration of strategies for reconciliation ecology design. Urban wildlife species are implicit stakeholders in design because they are impacted by design decisions. As stakeholders they deserve to be incorporated into the fabric of human dominated landscapes through site programming and design that makes sites function for them – or at least reduce threats.

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