Chapter 12
Integrating Wildlife Conservation into Urban Planning

George R. Hess, Christopher E. Moorman, Janette Thompson and Courtney L. Larson

Keywords Chicago Wilderness · Comprehensive plan · Development ordinance · Green infrastructure · Sonoran Desert Conservation Plan · Wildlife zoning · Zoning ordinance

12.1 Introduction and Scope

Urban wildlife conservation has the essential goal of creating, conserving, and maintaining places for species that would otherwise be displaced by people's use of the land. In this chapter, we focus on conserving habitat for native *urban avoiders*—species that typically do not persist in urban and suburban environments—at the scale of cities and metropolitan areas. These species are usually associated with the vegetative communities present prior to development of the city. Examples of displaced vegetative communities include forested habitat along the east coast of the USA, prairies in midwestern America, and desert landscapes in large parts of the American West.

G. R. Hess (✉)
Department of Forestry & Environmental Resources, North Carolina State University, Raleigh, NC 27695-8008, USA
e-mail: george_hess@ncsu.edu

C. E. Moorman
North Carolina State University, 110 Brooks Avenue, Box 7646, Raleigh, NC 27695-7646, USA
e-mail: chris_moorman@ncsu.edu

J. Thompson
Iowa State University, Ames, USA

C. L. Larson
Colorado State University, Fort Collins, USA

R. A. McCleery et al. (eds.), *Urban Wildlife Conservation: Theory and Practice,*
DOI 10.1007/978-1-4899-7500-3_12

For some wildlife species, habitat conservation applied at the local (Chap. 14) or neighborhood (Chap. 13) scale is sufficient. In the case of urban avoiders, where larger areas or the ability to move among areas of patchy habitat are required, planning and coordination are needed at the scale of landscapes covering entire cities or metropolitan areas. Acting at a larger scale can also increase the effectiveness of backyard- and neighborhood-scale activities by coordinating otherwise independent actions and creating connections—both ecological and social—that can further improve conditions for wildlife.

Before describing methods to integrate wildlife conservation into urban planning, we review the landscape-scale effects of urbanization on wildlife, key relevant principles from the fields of landscape ecology and conservation biology, and the process of land development and planning. We present two case studies highlighting different approaches to creating and managing wildlife conservation networks in urban areas before concluding with some thoughts for the future.

We devote significant attention to describing the planning process because this information is generally absent in the teaching of urban wildlife management. Comprehensive plans, zoning ordinances, and development regulations are *de rigueur* in urban America, which is the primary geographic area we cover. By determining in part *what* can be built *where*, these planning tools shape urban landscapes for wildlife in profound ways (Hair 1986). Urban wildlife conservation simply will not happen unless wildlife professionals become familiar with these concepts and involved in these processes.

12.2 Landscape-Scale Effects of Urbanization

Landscape ecology deals with heterogeneous and dynamic mixtures of different types of land cover or ecosystems, and focuses on the interactions among them. There are distinct European and North American conceptualizations of the discipline (Farina 1993). In Europe, landscape ecology emerged from the planning disciplines and therefore has well-developed ties to land use and planning (e.g., Naveh and Lieberman 1984; Zonneveld 1995; Mörtberg et al. 2007). In North America, it emerged from the field of ecology and has focused on the analysis of spatial patterns, flows of energy and materials, disturbances, and pattern-process interactions (e.g., Forman and Godron 1981, 1986; Forman 1995; Turner 2005).

For the purpose of this chapter, we can consider a landscape as the stage on which wildlife exists, comprising a mixture of different types of habitat. A *patch* is a relatively homogenous area that is different from its surroundings. Patches exist in a *matrix*, which is the dominant habitat type in the area. If there is no dominant type, a landscape may be referred to as a *mosaic.* For example, forested patches can exist in an urban matrix (predominantly urban with scattered areas of forest) or forest-urban mosaic (forest and urban in approximately equal amounts). Long, linear *corridors* of similar habitat type can connect patches, such as a riparian forest connecting two larger patches of forest in an urban matrix.

Although the presence and abundance of wildlife species in patches of habitat are influenced by the structure, composition, and distribution of habitat elements within the patch (e.g., food, nest sites), the size and shape of the patch and the matrix in which it is embedded also are important in determining the wildlife community within the patch (Donovan et al. 1997; Rodewald 2003; Shake et al. 2011). Patch size and the matrix surrounding a patch can interact as well. For example, it is likely that increasingly larger forest patches are needed to conserve urban avoiders as the matrix becomes increasingly urban.

The decline of urban avoiders in cities is caused by a series of associated mechanisms, operating at various scales, which can be categorized broadly as degrading habitat condition and disrupting connectivity. Direct loss or degradation of habitat during the urbanization process can increase competition and depredation of urban avoiders by urban adapters or exploiters, and alteration of disturbance regimes can contribute to habitat degradation. Moreover, decreasing permeability of the landscape for wildlife can disrupt connectivity among patches. The cumulative effect of these changes, if unchecked, creates a landscape unsuitable for urban avoiders.

12.2.1 Loss or Degradation of Habitat

Worldwide, urbanization has caused habitat changes leading to the loss of biodiversity (e.g., McKinney 2002, 2006, 2008). As more land is developed, less remains in native vegetative communities, fundamentally altering available habitat. Large patches of remnant native vegetation can offer a mix of elements similar to the predevelopment habitat, provide interior conditions that may be different than conditions nearer to patch edges, and buffer wildlife from potentially detrimental effects of areas adjacent to patches (Donnelly and Marzluff 2004). The quality of urban habitat patches is also influenced by the amount of urban development surrounding the patch. For example, urban avoider bird species are more likely to occur in larger patches further from high density development and closer to other habitat patches or in landscapes with less urban cover (Tilghman 1987; Friesen et al. 1995; Mörtberg 2001). Similarly, the relative amount of forest and urban cover surrounding an urban wetland affects the likelihood that urban-avoiding amphibians are present in the wetland (Findlay and Houlahan 1997; Knutson et al. 1999; Price et al. 2006; Rubbo and Kiesecker 2005).

12.2.2 Increased Competition and Depredation

Habitat fragmentation from urbanization and associated anthropogenic disturbance can affect survival and reproduction of native wildlife in the urban setting (Marzluff and Ewing 2001). Urbanization may increase the density of nonnative predators and competitors. House cat (*Felis domesticus*) densities are greater near human development, and cats are a significant predator of native wildlife (Rottenborn 1999;

Sinclair et al. 2005). Similarly, densities of mesopredators, such as raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), and coyotes (*Canis latrans*), are greater in urbanized landscapes (Chaps. 7, 8). These mesopredators commonly depredate urban avoiders or their young—particularly in small, narrow patches—and may contribute to declines of these species in urban landscapes (Bolger et al. 1997; Marzluff and Ewing 2001; Schmidt 2003). European starlings (*Sturnus vulgaris*), rats (*Rattus* spp.), and other nonnative, synanthropic (human-associated) species often compete with native wildlife for food and cover in urban settings (Kerpez and Smith 1990; Bolger et al. 1997; Marzluff and Ewing 2001).

12.2.3 Altered Disturbance Regimes

Natural disturbance regimes generally are altered in urban landscapes, which can have significant long-term implications for conservation of native wildlife. Naturally occurring fires are suppressed in and adjacent to developed areas, and the ability to use prescribed fire or timber harvest to manage wildlife habitats is limited, especially where remnant patches of natural habitat are small or isolated by habitat fragmentation. Wildlife that depend on landscapes shaped by fire will be rare or absent in these human-altered landscapes unless planning and management actions are taken to conserve them. For example, early successional songbirds that rely on disturbance-created meadow and shrubland landscapes are uncommon in the mature forest patches and greenways typically conserved in North American cities (Mason et al. 2007).

People also create new disturbances that can disrupt nutrient and water cycles in urban landscapes (e.g., Marzluff and Ewing 2001; Bernhardt et al. 2008). For example, in residential and commercial landscapes where some canopy trees remain, leaf litter commonly is removed. This interrupts the normal cycling of nutrients from foliage back into the soil. In addition, the removal of litter eliminates microhabitats for many arthropods and the vertebrates that prey upon them (e.g., birds, salamanders, shrews, small snakes).

12.2.4 Decreased Permeability

Animals may need to move among habitat patches in search of food and cover, to access seasonal life history requirements such as breeding or overwintering sites, to locate available resources, to disperse and establish territories, and to maintain genetic connections with adjacent populations. Landscape permeability is a measure of how easily an animal can move through a landscape. Permeability varies with a species' dispersal ability, the degree of habitat specialization the species exhibits, and the arrangement of habitat across the landscape.

Urban avoiders typically are unable to disperse through areas of urban development, especially areas with high road and traffic densities; landscape permeability declines for these species with increasing amounts of urban land cover (Desrochers and Hannon 1997). For example, Carr and Fahrig (2001) showed the abundance of leopard frogs (*Rana pipiens*), a relatively vagile species, declined with increasing road density, possibly because of high mortality during dispersal. Further, small populations isolated in patches because of low landscape permeability may experience loss of genetic diversity through inbreeding or genetic drift, in turn making these populations less likely to adapt to environmental change through evolutionary processes (Young et al. 1996; Reed and Frankham 2003). The genetic diversity of eastern red-backed salamanders *(Plethodon cinereus*), for example, was lower for isolated urban populations than for populations in continuous habitat that allowed individuals to disperse across larger areas (Noël et al. 2007).

12.2.5 Cumulative Effect

The cumulative effect of these changes is a landscape in which urban avoiders face regional extinction, because they no longer can survive in the remaining patches, move across the landscape to meet their needs, repopulate otherwise suitable patches, or reach patches to establish new territories. Species that are poor dispersers are especially susceptible as habitat patches shrink and the landscape becomes less permeable (Bolger et al. 1997). For example, populations of pond-breeding amphibians tend to have high annual rates of local extinction and depend on repopulation from nearby ponds (Skelly et al. 1999; Green 2003). Most amphibian species are vulnerable to environmental changes that occur with urbanization (e.g., loss of forest cover, road development) and disperse poorly through the urban matrix, commonly resulting in permanent, regional extinctions of these urban avoider species in many urban wetlands (Findlay and Houlahan 1997; Gibbs and Shriver 2005).

Conversely, large patches of remnant habitat with minimal edge are the most likely refuges for urban avoiders in and around cities. Ideally, these patches would be large enough to support natural disturbance regimes (or managed disturbances that mimic them) and connected in ways that allow wildlife to move safely through the urban matrix to meet their resource needs. This is the challenge of urban wildlife conservation.

12.3 Key Principles from Conservation Biology

Conservation biology (and conservation science) focuses on the protection and restoration of Earth's biological diversity at the scales of genes, species, communities, ecosystems, landscapes, and biomes (Soule and Wilcox 1980; Soule 1986; Groom et al. 2006; Kareiva and Marvier 2012). Habitat loss, fragmentation, and degradation are among the main causes of extinction and threats to biological diversity (Wilcove et al. 1998; McKinney 2002) although there are other causes, including over-harvesting and invasive species. Because these are landscape-scale processes, there is substantial overlap among concepts from the fields of landscape ecology and conservation biology.

12.3.1 Island Biogeography Theory, Metapopulations, and Related Concepts

Margules and Pressey (2000) summarized landscape-scale conservation principles that have had profound influence on how we approach conservation (Box A). Taken together, these principles support the "node, buffer, corridor" paradigm that pervades conservation planning at the landscape scale (Harris 1984; Noss and Harris 1986; Noss 1987; Adams and Dove 1989). *Nodes* (also called *core reserves*) of high quality habitat with little or no human activity are surrounded by *multiple-use modules* (also called *buffer zones*) with levels of human activity that decline with proximity to the node; buffered *habitat corridors* connect nodes to create a habitat network. Notice the parallel to terms from landscape ecology, where nodes are patches of habitat in an urban matrix connected by corridors. Benedict and McMahon (2002, 2006) and others have adopted similar terminology when describing green infrastructure in urban contexts, referring to core reserves as *hubs* with *connectors* among them, all *buffered* from intense development by areas of low-intensity human activity.

Box A

These principles have guided thinking about defining conservation targets and the design and management of conservation networks (Margules and Pressey 2000).

Spatial autecological requirements. It is important to recognize the amount of space and different habitat types needed by species to satisfy the full needs of their life cycles.

Effects of habitat modification. As other habitat types (e.g., agriculture, urban) surround remnant natural habitat, *edge effects* can lead to changes in microclimate and species composition, altering the value of the remaining natural habitat for local wildlife. Once remnant patches shrink below a certain size in an urban setting, they become "all edge" and have no value to urban avoiders. This principle leads to "larger-is-better thinking" for patch size, as well as a desire for more circular patches to reduce edge.

Biogeographic theory. Posited by MacArthur and Wilson (1967), the theory of island biogeography states that the number of species on an island is a balance between the rate at which new species colonize the island and the rate at which species go extinct. Large islands will harbor more species and have lower extinction rates than small ones; islands closer to a mainland source will have higher colonization rates than more distant islands. These concepts lead to rules of thumb including "larger reserves are better than smaller," "closely-spaced reserves are better than distant," and "reserves linked by corridors are better than unlinked."

Metapopulation dynamics. Levins (1969) coined this term to mean a network of populations linked by dispersal. Local populations go extinct from time to time, but dispersing individuals from other populations can recolonize areas of local extinction. Metapopulations start the slide to extinction when the rate of local extinctions exceeds the rate of recolonization. Like biogeographic theory, this leads to calls for maintaining larger patches connected by corridors.

Source-sink dynamics. Reproduction exceeds mortality in source habitat; in sink habitat mortality exceeds reproduction (Pulliam 1988). Differentiating source from sink habitat is not always easy because individuals can move between them. A species can appear viable in sink habitat because of continuous immigration from nearby source habitat; this might not become apparent until connections to source habitat are severed. During the planning process, it is important to differentiate source from sink habitat and focus conservation efforts on source habitat.

Source-pool effects and successional pathways. Species composition in any place changes through time—this is called succession. Periodic disturbances in natural landscapes typically result in a distribution of successional stages, often needed for wildlife populations to persist. The distribution of successional stages is different when people suppress disturbances (e.g., fire suppression) and must be restored to conserve some wildlife species. After a disturbance, the vegetation that regenerates depends on the pool of seeds available, which, in turn, affects the animals that can use the area. This principle mandates practices that preserve the seed bank and mimic natural disturbance regimes.

12.3.2 Alpha, Beta, and Gamma Diversity

Regional approaches to conservation also have been influenced by the concepts of alpha (local), gamma (regional), and beta (spatial) diversity (Box B). Noss (1983), reflecting on measures of diversity at different scales, identified the importance of thinking regionally to conserve the widest range of biodiversity. Because many game (i.e., hunted) species are edge-adapted and wildlife management is often constrained by property boundaries, wildlife managers long focused on creating edge habitat to maximize local (alpha) game diversity for individual property owners (Leopold 1933). If everyone worked to maximize alpha diversity for game species without considering gamma diversity, edge habitat would be created everywhere to the detriment of species that require large areas of interior habitat. This would regionally homogenize species composition with consequent reduction of gamma and beta diversity. Regional knowledge, collaborative planning, and management across ownership boundaries can prevent such scenarios.

Box B

Alpha, beta, and gamma diversity measures relate to planning and management at different scales. Whittaker (1972) documented and examined three measures of biological diversity that are used commonly by ecologists.

- *Alpha diversity* is the number of species within a single habitat or small area (e.g., a backyard or neighborhood).
- *Gamma diversity* is the number of species in a large geographic region or landscape (e.g., a city or region). If all habitats in a region are similar, gamma diversity tends to be similar to alpha diversity.
- *Beta diversity* is a measure of the change in species composition across a landscape—it reflects the differences in species composition as one moves from one small area to another. Although various formulations have been proposed, beta diversity is most simply calculated as gamma diversity divided by average alpha diversity for the region. If all habitats in a region are similar, gamma diversity is similar to alpha diversity and beta diversity is low (close to 1).

12.3.3 Conservation Planning and Implementation

The essential steps for conservation planning and implementation have been presented in various forms (e.g., Adams and Dove 1989; Margules and Pressey 2000; Groves et al. 2002; Conservation Measures Partners 2007; Groom et al. 2006). In an adaptive management framework (Holling 1978), they are:

- Identify conservation targets and establish measurable goals for them.
- Map and prioritize the habitat needed to attain those goals.
- Create an implementation plan to secure needed habitat and carry out required management actions.
- Monitor and evaluate the results and adjust plans and management as needed.

In the remainder of this section, we will focus on identifying targets and mapping and prioritizing habitat.

12.3.4 Identifying Conservation Targets

Noss (2003) categorized three types of conservation targets; they are applicable in urban settings.

- *Special element* targets are rare, unique species and locations, such as remnant populations of plants, important nesting areas, large undeveloped areas, and wetlands.

Table 12.1 Urban avoiders typically have specific traits or life history requirements that make individuals, and thereby populations, vulnerable to the landscape-level change commonplace in urbanizing areas

Trait/requirement	Examples	Disruptive landscape-level change
Wide-ranging organisms	Large and medium-sized carnivores, some raptors, and some grazers	Habitat loss and fragmentation—conversion of habitat to urban uses
Species that disperse seasonally	Amphibian dispersal to and from breeding pools, turtle dispersal out of ponds to lay eggs in uplands, and northern bobwhite that disperse each spring	Decreased permeability—roads, parking lots, and buildings destroy or disrupt movement corridors—leads to increased patch-level extinctions
Species that benefit from interior habitat	Ground-nesting, forest-interior birds preyed on by urban adapters and exploiters such as domestic cats and raccoons	Habitat degradation and fragmentation—patches become smaller and more elongated—leads to increased competition and depredation
Ecosystems and associated wildlife species that require disturbances not tolerated by people	Fire-dependent ecosystems such as longleaf pine (red-cockaded woodpecker), ponderosa pine (white-headed woodpecker), chaparral (red diamond rattlesnake)	Suppression of fire to protect property
Species that require aquatic habitats for all or portions of their life cycle	Amphibians, pond turtles, freshwater mussels	Draining and filling of wetlands, loss of travel corridors among wetlands, and increased impervious surface in watersheds that leads to reduced water quality

- *Representation* targets are designed to capture ecological gradients by including areas representing the full range of biotic and abiotic conditions typically associated with an ecosystem.
- *Focal species* targets are chosen to serve as surrogates for a wider range of species and habitats (including representation targets). The notion is that conserving habitat for focal species—which usually have large home range requirements—will conserve habitat for many other species with similar needs (Lambeck 1997).

Urban avoiders are the focus of most urban conservation efforts. They typically have specific traits or life history requirements that make individuals, and thereby populations, vulnerable to landscape-level change common in urbanizing areas (Table 12.1).

These targets can be identified using data documenting occurrences of species of conservation concern, but often rely on expert opinion and local knowledge. Hess and King (2002), for example, described a Delphi survey approach in which 28 local experts selected representation and focal species targets for the Triangle Region of North Carolina through a set of structured surveys. They elicited responses

Table 12.2 Final list of landscapes and focal species for conservation planning in the Triangle Region of North Carolina. (Modified from Hess and King 2002)

Landscape	Focal species	Rationale
Extensive undisturbed habitat	Bobcat	Requires large area of habitat with relatively low levels of human activity, and preferably few roads
	Eastern box turtle	Roads disrupt connectivity between breeding habitat and other resources
Riparian and bottomland forest	Barred owl	Nests in mature, large trees and forages in bottomland. Occurs at relatively low densities
	Beaver	Keystone species that creates wetlands
Upland forest	Ovenbird	Ground nesting, interior species in mature upland forests with dense canopy
	Broad-winged hawk	Requires extensive upland forest
Mature forest	Pileated woodpecker	Requires mature forest interior habitat and breeds in large, dead trees
Pastures and grassy fields	Loggerhead shrike	Needs agrarian habitat with a mixture of open fields, scattered trees and hedgerows, forest edge, and thickets
Open and early successional forest	Northern bobwhite	Needs abandoned fields, thickets, and woodland margins. Sensitive to development

from experts, synthesized their responses, and then required them to examine and reevaluate the synthesized results. Although the process started by requesting focal species targets, the respondents suggested a combined landscape-species approach; the landscapes essentially were representation targets selected based on the needs of focal species (Table 12.2). The panel was confident that a conservation network developed around these targets, plus known locations of special element targets, would provide habitat for most species of conservation concern in the region.

In Pima County, Arizona, a Science Technical and Advisory Committee comprising scientists and local citizens developed a list of species to be used in the role of focal species targets (see case study below). They identified 55 "priority vulnerable species," across a range of taxa, for which habitat would be mapped as a step in defining a conservation network. In the case of Pima County, this activity was part of a much larger process to develop a holistic conservation plan for the Sonoran Desert ecosystem in and around the City of Tucson, Arizona.

As these examples suggest, selecting conservation targets is a social as well as a scientific process. The citizens living in urban areas may have strong opinions about what should be conserved. These ideas often conflate biological conservation goals with recreation, aesthetics, sense of place, and other environmental objectives. It is best to recognize these differences explicitly during the planning process and attempt to formulate solutions that use them in mutually reinforcing ways (Benedict and McMahon 2002, 2006; Lafortezza et al. 2013).

12.3.5 Mapping and Prioritizing Habitat

Once conservation targets are selected, their locations must be mapped to identify potential core habitat, buffer zones, and corridors.

The locations of special element targets are sometimes cataloged, but the extent of habitat needed for their conservation may require further study and definition. In the Western Hemisphere, Natural Heritage Programs are a primary source of consistent data about known locations of species and ecosystems of special concern in geographic information system databases (NatureServe undated). Every US state, most Canadian Provinces, and many Latin American countries and states have a Natural Heritage Program. Local universities and naturalists may also have knowledge of special element targets and should be consulted.

Mapping representation targets requires explicit definitions of the gradients to be included and their identification on the ground. Typical representation targets include elevation gradients, gradients of soil and geology, and plant communities. Representation targets are often the critical habitat for focal species, as in the example for the Triangle Region of North Carolina described previously (Hess and King 2002).

Mapping the habitat for focal species targets requires defining and modeling habitat needs and finding suitable areas in the region, including core areas and corridors (e.g., Lambeck 1997; Rubino and Hess 2003). Modeling species habitat requires information about what a species needs (e.g., food, home range size, cover, affinity for edge or interior environments) and attributes of the landscape that may help satisfy those needs (e.g., elevation, geology, vegetative cover, wetlands). These data are often available in a GIS format and combined, using information about species requirements, to create potential habitat maps.

Once potential habitat has been identified, there are a variety of procedures to select the set that likely would conserve the maximum level of diversity for the least cost, in area or dollars (see Sarkar 2012 for a brief history of these algorithms). Most of these analyses rely on some combination of several basic principles (e.g., Margules and Usher 1981; Pressey et al. 1993):

- Complementarity: selecting conservation areas with minimum overlap in targets contained
- Completeness: total number of conservation targets captured
- Irreplaceability: selecting areas containing targets not contained in any other areas
- Naturalness: selecting areas that are the most natural
- Rarity: selecting areas containing the rarest elements
- Representation: capturing each conservation target at least once
- Size: selecting the largest areas of habitat

For example, one might start with the conservation hub that contains the largest number of species and select next the hub that contains the largest number of *different* species, repeatedly, until full representation is achieved. Connectors can be prioritized using algorithms derived from graph theory that allow one to determine which set of corridors provides maximum network connectivity and which connectors, if severed, will isolate large portions of the landscape (e.g., Urban and Keitt 2001; Minor and Urban 2007).

Hubs and corridors can be further prioritized for conservation based on the threat of human interference—areas most likely to be developed typically are accorded higher priority for acquisition than areas unlikely to be developed. Pressey et al. (1993), however, stressed the need for flexibility to respond to the availability of land for purchase and changing conditions. Meir et al. (2004) performed simulations that suggested strict adherence to a plan may be less effective than flexible responses to changing conditions and opportunities to protect land: sometimes it is better to protect lower priority areas when they become available rather than waiting for the highest priority areas, which might never become available.

12.4 Urban Development and Planning in the USA

Development of US cities occurs within the context of private property, is usually initiated locally by corporations and individual property owners, and is subject to a variety of interwoven planning controls established by local governments. These planning controls may be constrained by state and federal laws. People interested in wildlife conservation in and around cities must become familiar with the land development process, if they expect to influence the use of land for conservation purposes. This requires local knowledge, because the process and the cultural and political contexts in which it is embedded vary. Further, there is often a choice between fighting for conservation every time a land development project is proposed and working within the planning process to establish long-term policy that recognizes the importance of ecologically sensitive lands and creates mechanisms to avoid their development. This is a thorny issue, because excluding development typically reduces the economic value of land, which has real and significant effects on the property owners that must be considered.

12.4.1 Private Property

Most land in US urban areas and their surroundings is private property, owned by people and corporations. Within some limits, owners may use and develop their property as they see fit. These limits are defined by municipal (city) legislation that typically takes the form of comprehensive plans and zoning and development regulations. Development is often driven by the concept of *highest and best use*, which usually translates to the greatest profit that can be made by developing a parcel of land. As areas become more developed, the size of properties tends to decrease and the number of different owners increases, making it difficult to reach any kind of consensus about conservation. This phenomenon also occurs at the edges of heavily developed areas, as property owners (e.g., farmers, foresters, ranchers) anticipate development and begin splitting and selling their properties.

12.4.2 All Development is Local, Mostly

Land development is a broad term for the process of changing the landscape to meet human needs or wants, and includes everything from creating agricultural fields to city-building. Within urban and surrounding areas, development usually refers to building on lands that are currently covered by natural communities or farm fields. *Land developers,* usually referred to simply as *developers,* conceive projects and assemble parcels of land on which to build them. For example, a commercial development company might recognize an opportunity to build a large shopping center in a particular location. They will attempt to purchase property in the area and, if successful, oversee the conversion of the land to the shopping center they envisioned.

Decisions are not always solely at the discretion of developers and property owners. Some local governments attempt to control the development of cities using a variety of planning mechanisms, as authorized by citizens through local legislative bodies. These controls are codified in comprehensive plans, zoning maps, development ordinances (regulations), and transportation plans, among other documents (McElfish 2004; Duerksen et al. 2009). Where numerous cities are adjacent or close to one another, each with its own governing and planning bodies, there is often political fragmentation and insufficient coordination among them. This can complicate efforts to conserve wildlife habitat that spans multiple jurisdictions.

Local government control of land development might also be constrained by regulations at higher levels of government. For example, the US Endangered Species Act is federal law and applicable anywhere threatened and endangered species are found; local governing bodies have no choice but to work within the Act (for example, Miller et al. 2008; Stokes et al. 2010). In Washington, for example, the state's Growth Management Act established a framework, goals, and timelines that local governments must adhere to when planning for growth; decision-making is not centralized, but there are requirements and constraints within which local governments operate (Washington State Legislature 1990).

12.4.3 Overview of Urban Planning

In jurisdictions that do plan, there are numerous planning documents describing desired development within the jurisdiction and the processes through which development occurs. Land developers, who have a strong economic interest in understanding them, are well-versed in the process of creating and using these documents and are present at almost all public meetings related to them. Meetings tend to be lightly attended by others, including those with conservation interests. Advocates for the conservation of wildlife and associated habitat need to learn about these documents and processes to participate effectively (Broberg 2003; Hamin et al. 2007; Murphy and Noon 2007).

Broadly, there are *comprehensive plans* that describe the desired future for a community, *zoning ordinances* that divide the community into districts and describe the kinds of development allowed in each, and *development ordinances* that enumerate the process by which development occurs and the detailed rules and regulations for development in each zone. There may also be separate plans, integrated to various degrees, for transportation; parks, recreation, and open space; storm water control; cultural affairs; economic development; and so forth.

12.4.4 Comprehensive Planning

Comprehensive plans provide a broad perspective of the desired future for a community and a framework for arriving there (McElfish 2004; Hamin et al. 2007). They may cover a large range of issues relevant to the growth of a community, including housing, infrastructure, transportation, economic development, recreation, historic preservation, open space, and conservation (Box C). These issues are usually addressed in separate comprehensive plan *elements* that document existing and desired conditions, opportunities and obstacles to change, and recommendations and strategies for moving forward. Comprehensive plans can be sprawling documents with many inter-related, cross-referenced elements, all written in the discipline-specific language of planners. It can take significant time to understand a community's comprehensive plan and associated ordinances.

Box C

Table of Contents from the 2001 Pima County Comprehensive Plan Update, Regional Plan Policies, as Amended June 2012 (Pima County 2012a).

This document, Regional Plan Policies, is one of three working documents of the Pima County Comprehensive Plan; see also Land Use Intensity Legend and Rezoning and Special Area Plan Policies. The complete Comprehensive Plan is available in the office of the Planning Division, Pima County Development Services Department.

1. Land Use Element Regional Plan Policies
    A. Administration
    B. Cultural Heritage
    C. Site Design and Housing
    D. Public Services and Facilities
2. Circulation Element Regional Plan Policies
3. Water Resources Element Regional Plan Policies

4. Open Space Element Regional Plan Policies
5. Growth Area Element Regional Plan Policies
6. Environmental Element Regional Plan Policies
   A. Water Quality
   B. Natural Resource
7. Cost of Development Element Regional Plan Policies
8. Military Airport Regional Plan Policies
   A. Findings of the Board of Supervisors
   B. Pima County Policies
   C. Joint Land Use Study Implementation Program Plan Introduction
   D. Joint Land Use Study Implementation Strategy Policies

12.4.5 Zoning Ordinances

Implementation details are rarely included in comprehensive plans, and are found instead in zoning and development ordinances (regulations). *Zoning* is the process of dividing a community into districts and prescribing the type of development permitted in each, typically presented in a map and accompanying land use tables (Box D). Common zoning districts include commercial, industrial, manufacturing, residential of various densities, and rural agricultural. The primary purpose of zoning is to separate land uses that are thought to be incompatible and to prevent new development from harming people already using areas nearby.

Overlay zones are districts that supplement the underlying zoning with additional requirements to meet a stated goal. They are particularly useful when the goal spans multiple zoning districts, because it unifies those districts to meet that goal without the need for incorporating detailed language into each underlying zone. For example, an historic downtown overlay district might contain special provisions related to the desired character of a city's core area.

Within a zoning district some uses are allowed *by right*, which typically means that approval is in the hands of a technical committee that reviews the project to ensure that it meets all requirements for the district. Other uses, such as those that are often considered objectionable (e.g., tattoo parlors, sex shops) or that have a potentially adverse effect on surrounding properties (e.g., large shopping centers, heavy manufacturing), require public review, hearings, and approval by the local elected body.

Box D

Development zones for Pima County, AZ (Pima County undated-a)

Rural Zones
IR—Institutional reserve
RH—Rural homestead
GR-1—Rural residential
SR—Suburban ranch
SR-2—Suburban ranch estate
SH—Suburban homestead

Residential Zones
TH—Trailer homesite
ML—Mount Lemmon
CR-1, 2, and 3—Single residence (different lot sizes)
CR-4—Mixed dwelling type
CR-5—Multiple residence
TR—Transitional zone
CMH-1 and 2—Country manufactured and mobile homes

Business
MR—Major resort
RVC—Rural village center
CB-1—Local business
CB-2—General business

Industrial
MU—Multiple use
CPI—Campus park industrial
CI-1—Light industrial/ warehouse
CI-2—General industrial
CI-3—Heavy industrial

Overlay
AE—Airport environs and facilities
BZ—Buffer overlay
GC—Golf course
H-1 and 2—Historic
HD—Hillside development

12.4.6 Development Ordinances

Development ordinances are the rules and regulations providing detailed specifications and limitations for building in each zoning district. The regulations prescribe such details as how far buildings must be from the street and adjacent property lines (setback), how tall buildings can be, how roads must be designed, and whether or not sidewalks are required. *Unified development ordinances*, which include zoning maps and development regulations, are becoming increasingly common.

If permitted by state law, development ordinances may require exactions or impact fees for the public good in exchange for project approval. *Exactions* are required mitigation of anticipated effects of a development. For example, the developer of a very large housing subdivision might be required to build a new school building or widen a roadway in or near the subdivision. *Impact fees* are direct payment to local governments for mitigation of an anticipated effect. For example, developers of smaller subdivisions might be required to pay a per-housing-unit fee into a fund that will support the building of a new school or the widening of a roadway once a certain number of new homes are built in an area.

Exactions and impact fees must be designed carefully so that they are not considered takings, which must be compensated, under the Fifth Amendment of the US Constitution. Advocates for property rights have challenged the use of impact fees and exactions, considering them a taking. For example, the Saint Johns River Water Management District in Florida demanded impact fees for wetland mitigation in exchange for a building permit. In June, 2013, the US Supreme Court ruled their demand "extortionate," calling into question the use of impact fees and exactions nationwide (Doyle 2013).

12.4.7 Voluntary Approaches

Strong property rights sentiment exists in many parts of the US along with a philosophical opposition to zoning and development controls that force landowners to set aside land for conservation purposes. Voluntary approaches avoid these issues by attempting to develop conservation networks through the purchase of land or conservation easements from willing sellers. As of 2010, some 1700 local land conservancies in the US had taken this approach and had protected more than 190,202 km^2 (47 million acres), which is nearly twice the area of all of the National Parks in the conterminous 48 states (Land Trust Alliance 2010). Such voluntary efforts integrated into an overall, regional plan can significantly increase the capacity for conservation in urban and metropolitan areas.

12.5 Integrating Wildlife Conservation into Urban Planning

In urban areas, there is tremendous need for regional thinking, planning, and action that conserves habitat patches large enough for urban avoiders and disturbance dynamics, buffers habitat from the effects of the surrounding urban matrix, ensures that habitats are connected for life cycle requirements and metapopulation persistence, and maintains the necessary ecological processes and disturbances.

Provisions for wildlife and natural resources conservation can be included in comprehensive plans, zoning ordinances, and development ordinances. This approach is more proactive than attempting to sway decisions during development approval hearings; by then developers have already made significant expenditures on surveys and engineering and are reluctant to make substantial changes. Each step in the planning and development process provides opportunities and obstacles for people interested in wildlife conservation. In this section, we introduce opportunities for creating plans that favor wildlife conservation. There are many resources for those interested in more in-depth information (Box E).

Box E

Resources for conservation-friendly urban planning.

Environmental Law Institute (http://www.eli.org/) has numerous relevant books and research reports freely available. Their work focuses on the legal frameworks and mechanisms supporting biodiversity conservation in the US. One of the most valuable for wildlife professionals is *Conservation Thresholds for Land Use Planners* (2003), a literature review-based compendium of information about patch sizes, edge effects, corridor widths, and other design guidelines to help land use planners design viable green infrastructure.

Green Infrastructure: Linking Landscapes and Communities, by Mark Benedict and Edward McMahon (2006) is currently the definitive resource for green infrastructure development. Benedict and McMahon describe the importance of green infrastructure; key principles; the integration of ecological, social, and economic concerns; and tools available to acquire and manage green infrastructure.

In ***Natural Experiments: Ecosystem-based Management and the Environment***, Layzer (2008) presents in-depth case studies of seven attempts to conserve biological diversity in the US. Although not all are in urban settings, they all provide insights into the difficulties faced by anyone working on large-scale conservation projects. This is a must-read for wildlife professionals interested in participating in the planning or political processes; Layzer does not mince words.

Nature-Friendly Communities, by Duerksen and Snyder (2005) presents more than a dozen case studies of communities that have integrated habitat protection into their land use planning activities. They cover comprehensive plans, zoning and development ordinances, educational campaigns, and mechanisms to finance conservation.

Nature-Friendly Ordinances, by McElfish (2004) contains detailed guidance about developing comprehensive plans, zoning ordinances, and development regulations that can help local communities conserve biodiversity. Numerous examples and case studies are included. Although written primarily for planners, wildlife professionals interested in becoming active in their community planning processes will find this book accessible.

Preserving and Enhancing Communities: A Guide for Citizens, Planners, and Policymakers, by Hamin et al. (2007) is not specific to wildlife or conservation. Instead, it is a guide for people interested in participating in the various processes through which local communities govern themselves and is designed to help readers navigate those processes.

The Green Growth Toolbox (http://www.ncwildlife.org/greengrowth/), coordinated by the North Carolina Wildlife Resources Commission, is one of a growing number of technical assistance tools for communities, local governments, planners, planning-related boards, and developers. The toolbox provides mapping data, planning techniques, recommendations, and case studies for conservation of priority wildlife habitats that can be used in local land use planning, policy-making, and development design. The approach is to train interested communities in priority areas about the need for and benefits of wildlife conservation, the priority wildlife and habitats in their area, the principles of conservation biology, and how to achieve "green growth." The information is intended to provide communities with a menu of step-by-step methods and strategies to choose from to suit their needs. Recommendations center on the conservation thresholds of priority wildlife species. A model overlay district ordinance for priority natural resource conservation based on the conservation thresholds and intended for highly sensitive areas is included. (Contributed by Kacy Cook, NC Wildlife Resources Commission)

12.5.1 Wildlife-Friendly Comprehensive Planning

All US states have planning enabling statutes that *allow* biodiversity conservation to be included in comprehensive plans (Environmental Law Institute and Defenders of Wildlife 2003; McElfish 2004). Not all states, however, *require* local government to create a comprehensive plan or to include a conservation element. A comprehensive plan element for conservation might include conservation goals, provisions for developing inventories and maps that define conservation areas (e.g., core, buffer, corridor), development guidelines that respect conservation areas and allow types of development that can accommodate conservation goals (e.g., cluster or conservation subdivisions), and provisions for funding conservation.

Wildlife conservation might be included under elements for conservation, habitat, natural resources, or open space. However, information in other elements may have implications for conservation, particularly: transportation (transportation corridors fragment habitat but also provide opportunities for connectivity (e.g., greenways)), stormwater (streams and riparian areas are important conservation corridors), recreation (parks and greenways can be part of an open space network), and infrastructure (sanitary sewer lines often run along stream corridors).

McElfish (2004, pp. 34–35) suggested that a comprehensive plan's biodiversity element should (1) recognize the ecological context of the plan (e.g., ecoregion, watershed), (2) use all available data or include a requirement to collect data,

(3) provide for core habitat, connectors, and buffers, (4) address quality of life issues associated with biodiversity, (5) call for city-wide conservation measures (e.g., tree canopy, water use, native plants) that affect biodiversity, (6) address funding issues, and (7) establish accountability.

12.5.2 Wildlife-Friendly Zoning Ordinances

Because zoning ordinances control what can and cannot be developed in each zoning district, they can have a profound effect on wildlife conservation. For example, one could define conservation zones that coincide with the location of ecologically important habitat and wildlife species of conservation concern. Such actions, however, can conflict with a city's economic development goals and residents' property rights concerns. Creating a conservation zone is particularly problematic if land is already in a zone that allows development; such an action is considered *downzoning*, which is immensely unpopular with affected landowners because it diminishes the economic value of their land.

Another approach is the use of conservation overlay zones or conditional use zones that apply additional regulations and oversight to ecologically sensitive areas within the underlying zoning districts. A conservation overlay zone might, for example, span a variety of residential and commercial zones in a forested area that is home to neotropical migrant songbirds. Within the overlay zone, conservation subdivisions (Chap. 13) might be required or encouraged to retain forest overstory and leave forested corridors intact. This approach avoids the need to zone the land as open space and allows development with constraints that should not significantly reduce a developer's or property owner's return on investment.

To be effective, zoning districts intended for conservation should (1) have clearly stated conservation goals, be it for biodiversity, water quality, or wildlife habitat; (2) show clear links between conservation requirements and zoning regulations; (3) conserve as much contiguous habitat as possible; (4) include maps with defined conservation lands, buffers, and connections; (5) be supported with evidence that the zone can meet its conservation goals; and (6) be well-connected with any adjacent conservation zones (McElfish 2004, pp. 40–41).

12.5.3 Wildlife-Friendly Development Ordinances

Development ordinances detail the procedures and requirements for obtaining approval for and completing a development project, providing another opportunity to consider wildlife conservation. Development ordinances may require the developer to collect and present information about natural resources as part of the approval process. Local government can use this information to make decisions about design requirements, exactions, impact fees, mitigation, and other actions to conserve natural resources. For example, the documented presence of important wildlife habitat might trigger a requirement for a conservation subdivision on the site. Development ordinances can also include requirements for open space, recreation, or conservation land on the site of the development or in the form of an impact fee to purchase such land elsewhere for the benefit of the community.

Important legal requirements must be met when creating effective conservation-oriented development ordinances, including demonstrating a *rational nexus* (essentially a cause–effect relationship) between the development and the claimed impact, clearly stating the goals for the actions required of developers, documenting how the required exactions or impact fees are calculated based on the impact, and detailing how collected fees will be spent (McElfish 2004).

12.6 Wildlife Zoning and Green Infrastructure: A Way Forward?

In his seminal paper on ecosystem development, Eugene Odum (1969) suggested two approaches to people's use of land: compromise and compartmentalization. In a compromise approach, people maintain all land somewhere between completely production-oriented and completely natural. In a compartmentalized approach, landscape units are separated and managed for different goals, such as agriculture, cities, industry, and wilderness. Compartmentalization has long been a dominant strategy for conservation in the US (Noss and Cooperrider 1994). As has been emphasized throughout this chapter, while a compromise approach will be effective for urban adapters, urban avoiders likely need compartmentalized zones (McKinney 2002).

Here we consider how wildlife zoning may be integrated with the emerging framework of green infrastructure to address wildlife conservation in urban areas. *Wildlife zoning* organizes landscapes in terms of use by wildlife rather than people (Linnell et al. 2005). Because planners are already steeped in the nuances of zoning, using their language may improve chances for wildlife conservation—think "wildlife overlay zones." In addition, terms like *green infrastructure* (network of green space conserving natural functions for the benefit of people in cities) have potential to draw many ecologically friendly components, including wildlife conservation, into the machinery of urban infrastructure development, financing, and management (Benedict and McMahon 2002, 2006).

12.6.1 Wildlife Zoning

Wildlife zoning is the spatial delineation of wildlife conservation goals as designated zones that vary in their desired wildlife density, wildlife management techniques, or the level of protection afforded to wildlife and their habitat. Wildlife management plans typically do these things, but do not describe their management system as "zoning," a term understood by urban planners. Wildlife zoning can be used to manage wildlife across entire landscapes, from protected areas to urban centers, by integrating well-accepted zoning practices with additional zoning for wildlife that could be implemented as overlay zones.

The scale of a wildlife zoning system must correspond to the ecologically relevant scales of the species being managed (Linnell et al. 2005). Important ecological data to consider when developing a zoning strategy include species' range size, current distribution, population size and density, habitat suitability, and dispersal distance. In an urban area, information about the human population is equally important, including size and density, housing density, land use, and rates of population growth and land development.

Two special cases of wildlife zoning involve species that are hunted and species that are sometimes considered pests. *Game species zoning* is used to manage wildlife through hunting. Regulations are already common in which certain areas (zones) are opened or closed to hunters and the number and types of permits issued varies based on management goals, wildlife population sizes, and the number and density of people living in the area. *Nuisance species zoning* can be used to minimize the harm done by wildlife to people and their property (Chap. 17). In many cases, this means reducing the species' population in areas with high rates of damage.

Different zones can be created for the same species within a single city or region, depending on goals and conditions. For example, Boulder, Colorado's management plan for the black-tailed prairie dog (*Cynomys ludovicianus*) uses a nuisance species zoning approach (City of Boulder 2006). Although black-tailed prairie dogs are an important component of the prairie grassland ecosystem, they can damage landscaping and buildings, transmit infectious disease, and create roadway hazards. Following an inventory of prairie dog colonies, zones were delineated for long-term protection, interim protection (in which prairie dogs will be allowed to remain unless problems arise), and near-term removal (where prairie dogs are currently causing damage).

Wildlife zoning can be used to manage multiple species, most commonly by creating protected areas. The classic UNESCO biosphere reserve model is a form of multiple species zoning that is used worldwide. It has a well-protected core zone, a buffer zone, which accommodates limited human activity such as research and ecotourism, and a transition zone, which permits a broader range of human activity (Batisse 1982). Creating a network of protected areas linked by corridors, as described in this chapter (nodes, buffers, corridors; hubs and connectors), is an expansion of the most basic multiple species zoning strategy and is advocated by many, because it allows for increased animal movement and gene flow (Beier and Noss 1998; Hilty et al. 2006).

12.6.2 Green Infrastructure

Within the past two decades, the term *green infrastructure* has been coined and promoted when referring to interconnected open spaces that provide ecosystem services and wildlife habitat, and contribute to healthy communities and people; the approach recognizes and respects the sociological context in which conservation in cities occurs (e.g., Benedict and McMahon 2002, 2006; Lafortezza et al. 2013). The basic precepts for green infrastructure harken back to Ian McHarg's (1969) *Design with Nature*, emphasizing that development should occur after ecological conditions are evaluated and green infrastructure planned. The term is intended to resonate with planners and local government officials and put it on par with the "gray" infrastructure—such as communications, sewer, transportation, and water networks—which they are accustomed to planning, financing, and building. In the US, the concept is being applied at the scale of city (Pitsford, NY), county (Montgomery County, Maryland), metropolitan region (Chicago Wilderness), state (Maryland and Florida Greenways), and continent (Yellowstone to Yukon) (see Benedict and McMahon 2002, 2006 for these case studies).

Benedict and McMahon (2006, p. 37) stated ten principles of green infrastructure, grounded in concepts from landscape ecology, conservation biology, and urban planning. The principles emphasize well-connected, ecologically functional green space as the framework in which development should occur. Green infrastructure is described as a critical, long-term investment in a healthy community that benefits people and nature, and is created with respect for the desires of the community and individual landowners. Explicitly stated relationships among green infrastructure, ecosystem services, and human well-being are seen as crucial to the success of efforts to further develop green infrastructure in urban contexts. As with wildlife zoning, one could argue that this is simply good wildlife conservation and management repackaged, but the connections made between habitat conservation and human well-being when promoting green infrastructure are central to convincing an urban populace and governing bodies to fund its design and protection (Lafortezza et al. 2013).

12.6.3 Moving Forward

Open space in urban contexts—land that does not contain buildings and pavement (Ahern 1991) —generally occurs in parks and nature preserves that serve as core habitat for wildlife, with greenways along streams acting as corridors connecting the core habitat patches. Application of green infrastructure principles to existing open spaces in urban settings would buffer these areas from additional urban development to protect their function. Furthermore, planning for future development would occur only after core habitat and corridors for species of interest have been identified clearly (Benedict and McMahon 2006). Moreover, including such designations explicitly in comprehensive plans, zoning ordinances (including wildlife zoning), and development regulations will lead to purposeful integration of wildlife management in urban planning process and practice.

Although green infrastructure is intended to emphasize ecological function over recreational and other uses, open spaces in urban areas are often promoted as serving multiple uses that may conflict with their function as wildlife habitat, including recreation, improving human health, and transportation. Despite these potential conflicts, the multiple-use aspects of green infrastructure are important to building public support for investment in their acquisition and management. Charlotte-Mecklenburg, NC, has addressed this issue by developing parallel systems of parks and nature preserves, often adjacent to one another, but managed by distinct agencies for different uses (Mecklenburg County undated). Thus, application of wildlife zoning principles within this system could separate core habitat with little human disturbance from buffer zones with opportunities for human-wildlife interaction around the periphery of the core areas and in corridors between them. In addition to protecting core habitat for wildlife conservation, this approach encourages positive interactions between humans and wildlife along edges and corridors that will lead to important public support for additional conservation efforts (Miller 2006; Stokes et al. 2010).

As an element of this approach, greenways along streams and utility rights-of-way are an efficient conservation strategy because they are protected, provide multiple benefits (e.g., buffer water sources, provide recreational opportunities, offer aesthetic views), and often are not developable. Research in North Carolina, USA, showed that wider greenways and those surrounded by lower density development provided the greatest benefit to urban avoider songbirds (Sinclair et al. 2005; Mason et al. 2007). There are, however, potential conflicts among the various uses for which greenways are promoted. For example, Mason et al. (2007) found that forest-interior birds were more common along wide greenways with narrow trails that retained continuity of the forest canopy. Recreational users tend to prefer greenways containing wider trails with mowed, grassy shoulders because they provide more capacity for cyclists, runners, and walkers as well as longer sight lines that confer a feeling of increased safety. Greenway planners must balance competing uses carefully, if greenways are to serve conservation purposes.

12.7 Strategies for Regional Urban Wildlife Conservation: Case Studies

Here, we present case studies of two approaches to regional wildlife conservation. The Sonoran Desert Conservation Plan for Pima County, Arizona, is a holistic, landscape-scale plan with the preeminent goal of conserving biological diversity. Chicago Wilderness is a regional conservation alliance comprising some 300 organizations that coordinates efforts to study, sustain, restore, and expand remnant natural areas and engage local residents with their natural heritage in a multi-state area around Chicago, Illinois.

12.7.1 The Sonoran Desert Conservation Plan: A Biodiversity-Centered Approach

The Sonoran Desert Conservation Plan, adopted as part of its comprehensive plan by Pima County, Arizona, in 2001, was a landscape-scale approach to conserving biological diversity. It relies on a Conservation Land System that includes a set of maps and prescriptions for guiding the purchase of public protected areas and protecting biological diversity during the development process. Layzer (2008) provided a detailed account of the social and political conflicts surrounding the plan's creation, adoption, and implementation. Here, after providing brief contextual background, we focus on three aspects of the plan:

- The scientific underpinning of the plan's biological element
- The plan's insertion into the urban planning and development process
- The conditions that supported the plan's creation and implementation

Pima County, Arizona, is an arid landscape of broad plains and high mountains covering 23,800 km^2 (9190 mi^2) of land in southcentral Arizona, bordering Mexico. Approximately 305 mm (12 in.) of rain falls each year, mostly during summer monsoons. Much of the county is part of the Sonoran Desert, which has high levels of endemism and biodiversity. In 2012, Pima County was home to approximately 1 million people (US Census Bureau 2012), most living in the Tucson metropolitan area. Much of the land in Pima County is in Native American or government ownership, with approximately 14 % privately held.

12.7.1.1 Events Leading to Creation of the Sonoran Desert Conservation Plan

During the 1960s–1970s, there was little consideration of the cumulative environmental consequences of authorizing rezoning requests to accommodate construction (Layzer 2008). Relatively uncontrolled growth around Tucson sprawled into Pima County's jurisdiction, mostly toward the foothills in the northwest. New housing subdivisions often blocked access to public recreation areas; this and objections to the aesthetics of housing developments extending up the hillsides led to some of the first rumblings against this style of development (M. Livingston, personal communication). In 1972, public reaction was strong and negative when Rancho Romero, a 17,000-home, 1620-ha (4000-acre) housing subdivision, was proposed for the foothills of the Santa Catalina Mountains northwest of Tucson. Opponents, who ultimately prevailed, argued the site was better suited for conservation and recreation (Eatherly undated). Similar battles unfolded elsewhere around the edges of Tucson as environmentalists and developers became adept at blocking one another's plans (J. Fonseca, personal communication).

Several events during the 1980s let to increased natural resource protection activities. In October, 1983, Tropical Storm Octave dumped some 330 mm (13 in.) of rain in 24 h, causing major floods, significant damage of property along rivers, and visible changes to the riparian areas throughout Tucson (National Weather Service undated). In response, the Transportation and Flood Control District became active in acquiring flood-prone lands to remove buildings from the floodplain and allow for overbank flood storage and infiltration (Duerksen and Snyder 2005). Through time, focus shifted to riparian conservation linked to recreational opportunities; the river banks have become the backbone of Pima's river park and greenway system.

Pima County adopted a Hillside Development Overlay Zone (1985) to minimize damage by development and a Buffer Overlay Zone (1988) to address aesthetic concerns within one mile of designated public preserves (Duerksen and Snyder 2005). Finally, the University of Arizona's William Shaw led a small group of graduate students in creating the first comprehensive habitat map for Pima County (Shaw et al. 1986). This Critical and Sensitive Wildlife Habitats map was destined to be "just a class project" until County Supervisor Iris Dewhirst had the document adopted as a policy guideline, asking developers to voluntarily comply with its recommendations (W. Shaw, personal communication).

Despite this activity, there was no comprehensive approach to land protection, and development continued to sprawl into the desert. During the late 1990s, Pima County's citizens began electing pro-environment candidates to the Board of Supervisors; by 1998 the Board's makeup had changed from 4–1 pro-development advocates to 4–1 pro-environmental (Layzer 2008). This shift fundamentally shaped Pima's reaction to the 1997 listing by the US Fish and Wildlife Service of the cactus ferruginous pygmy owl (G*laucidium brasilianum cactorum*) as an endangered species. The owl occupied habitat in the areas north of Tucson that were under heavy development pressure. In 1998, owl sightings halted ongoing construction of a housing subdivision near the Tortolita Mountains and led to an injunction blocking construction of a high school (Layzer 2008). With development brought to a standstill, something had to be done.

County decision-makers decided to approach the challenge holistically within Section 10 of the Endangered Species Act by creating a multi-species habitat conservation plan rather than seeking a permit for the pygmy owl alone (Pima County Office of Sustainability and Conservation 2012); a Section 10 permit allows the "incidental take" of endangered species and their habitat, so long as a viable conservation plan is in place. In mid-1998, the Board of Supervisors voted in favor of this approach, noting the high financial cost of sprawl relative to more compact development and the contribution of sprawl to the destruction of the natural environment. They also adopted a Native Plant Preservation Ordinance, agreed to limit rezoning of environmentally sensitive land during the planning process (to avoid a development rush to circumvent the plan), and passed regulations allowing development rights to be transferred from sensitive lands to other areas (Layzer 2008).

12.7.1.2 Creating the Plan

The ecological centerpiece of the Sonoran Desert Conservation Plan was its Critical Habitat and Biological Corridors element. Under the leadership of County Administrator Chuck Huckelberry and Assistant County Administrator Maeveen Behan, the County recruited a Science and Technical Advisory Team, led by Bill Shaw, to develop an assessment of the region's biodiversity and a plan to conserve it. Huckelberry declared that implementation of the Board of Supervisors' directives would be based on science, that the conservation of biological diversity was the primary goal, and that the science team would be insulated from political and economic pressures and should proceed without regard to land ownership patterns and political boundaries (Layzer 2008). Public input would occur, but it would occur after creation of a plan based on conservation tenets. This action avoided a phenomenon common among stakeholder-driven biodiversity planning processes—the persistent dilution of conservation goals by political and economic considerations, such that a plan to fully conserve biodiversity is never put forth for discussion (Layzer 2008). But it also created significant tensions between County decision-makers and property-rights advocates, the real estate development industry, and other jurisdictions that they left out of that part of the planning process.

Identifying Conservation Targets The Science and Technical Advisory Team called for ensuring the long-term survival of plants and animals indigenous to Pima County through an ecosystem-based approach and established six consonant goals: recovery of federally listed and candidate species, reintroduction of extirpated species as feasible, improving conditions for species of conservation concern, reducing threats from invasive species, mitigating damage to ecosystem functions, and promoting long-term viability of species valued by people in the region (see Layzer p. 183). The team surveyed and interviewed biologists and local experts to develop a list of 55 *priority vulnerable species* to serve as focal species for habitat mapping including amphibians, birds, fish, invertebrates, mammals, plants, and reptiles (Fonseca 1999; Huckelberry 1999, 2000b; Layzer 2008). Habitats of concern were also identified for mapping and conservation action (Fonseca 1999).

Mapping and Prioritizing Habitat The team developed habitat models for each of the 55 priority vulnerable species using occurrence data (Arizona Game and Fish records plus any available state and federal records), literature accounts, and expert opinion (Huckelberry 2000a, b). All available information about the past and present distribution, life history, demography, habitat needs, and potential habitat within Pima County was compiled for each species by consulting firms under the oversight of the Science Technical and Advisory Team.

Using this information and detailed maps of vegetation, topography, geology, hydrography, and other environmental variables, the team created habitat maps for each species (Huckelberry 2000a) and combined them to create species richness maps for the County (Huckelberry 2001). Locations in which five or more vulnerable species could occur were designated as biological core areas. Areas suitable for fewer species were considered sensitive, but appropriate for multiple uses. Patches less than 405 ha (1000 acres) in size were eliminated from the reserve design, as were areas that already had been developed. “Special elements” (*sensu* Noss 1983) not otherwise captured were added to the reserve system (Huckelberry 2002). The team also developed broad areas in which connections could be made between reserves (Fig. 12.1).

12.7.1.3 Implementing the Plan

The resulting map of Biological Corridors and Critical Habitat and associated guidelines form the core of the Sonoran Desert Conservation Plan (Fig. 12.1). Important riparian areas were given highest priority with a goal of conserving 95 % as undisturbed open space; the goal for the 2125 km^2 (525,000 acres) of biological core land

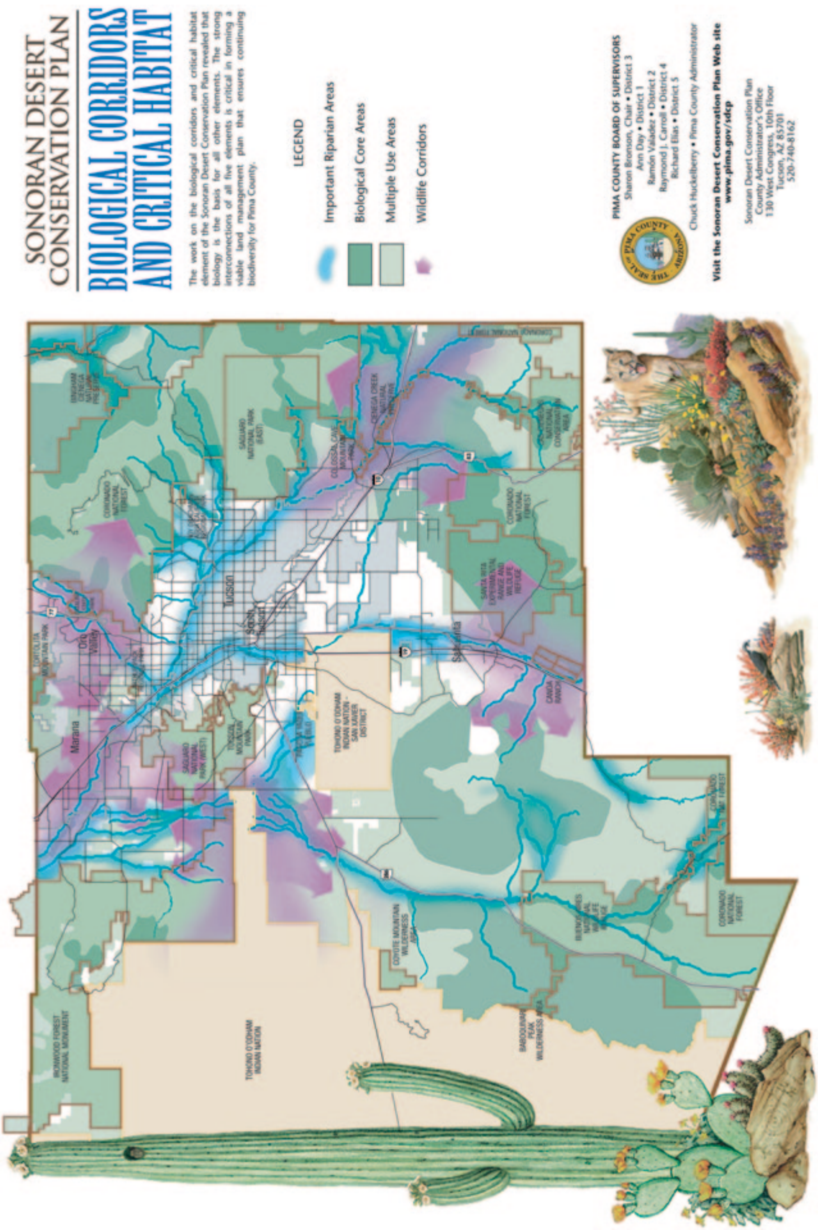

Fig. 12.1 The map of biological corridors and critical habitat for the Sonoran Desert Conservation Plan shows the biological core areas (five or more vulnerable species), the multiple use areas intended to buffer them, and areas for wildlife corridors to provide connectivity among them (Huckelberry 2000b; Pima County 2009)

was 80% undisturbed; and for 2023 km^2 (500,000 acres) of multi-use land, 66%. Six critical landscape connections were defined as areas where connectivity for wildlife could still be maintained or restored (Pima County 2009). The plan also included four other overlapping elements important to Pima County's citizens, providing a holistic approach to conservation: Riparian Restoration, Mountain Parks, Historical and Cultural Preservation, and Ranch Conservation (Pima County 2012b).

The County released a final reserve plan for public review in February, 2001, some two years after the Science Technical and Advisory Team began work. During that planning period, the County released numerous technical reports, held hundreds of public meetings, and assembled an open Steering Committee of more than 80 people (Layzer 2008; Davis 2009). Although they participated in presentations, the science team was insulated from political pressures and allowed to develop a plan that satisfied its mission. Once the plan was released, protests from property rights advocates, ranchers, municipalities (which had not been consulted during the process), and the real estate industry began in earnest. County leaders repeatedly discredited arguments against the plan and shifted the argument from the cost of implementing the plan (the cost had not been nailed down) to the cost of *not* implementing the plan (Layzer 2008). Despite continuous pressure from opponents of the plan, in December, 2001, the Board of Supervisors voted 4–0 to adopt the plan as part of the County's updated comprehensive plan. They also passed numerous other regulations to protect the environment from uncontrolled development (Layzer 2008, p. 192).

Land conservation occurs in several ways under the Sonoran Desert Conservation Plan's Conservation Land System. First, developers are required to demonstrate adherence to the plan's guidelines during the development approval process. Although compliance is technically voluntary, almost all development in Pima County requires a change in zoning; the Board of Supervisors is not required to agree to requests for zoning changes and rarely do if conservation conditions are not met. Second, the County raises bond funds to purchase conservation lands. The public has been supportive of bonds for open space and greenways for conservation, recreation, and economic development reasons. Third, the County has entered into agreements with ranchers in which the County purchases private ranch land and eliminates development rights on the land while allowing ranchers to continue to use the land in an environmentally sensitive manner (Layzer 2008). Fonseca and Jones (2009) reported an increase in protected land from about 182 km^2 (45,000 acres) in 2001, when the Sonoran Desert Conservation Plan was adopted, to 939 km^2 (232,000 acres) in 2009.

12.7.1.4 Keys to Success for Pima County

The Sonoran Desert Conservation Plan has long been cited as a plan with a high probability of success (Adams and Dove 1989; Duerksen and Snyder 2005; Layzer 2008). Factors contributing to this success include:

- A consistent focus on large-scale conservation efforts with biodiversity as the primary goal. Rather than focusing narrowly on obtaining an incidental take permit for the Pygmy owl, County leaders opted to create a much broader plan that galvanized public support.
- Creation of a Science Technical and Advisory Team that was insulated from political and economic pressures. This allowed the team to focus on creating for public discussion the best conservation plan rather than a plan on which everyone could agree.
- A fortuitous confluence of events and a catalyst to "force the issue." With an environmentally supportive Board of Supervisors, strong leadership from County Administrator and other staff, and a public supportive of conservation, the discovery of a federally endangered species catalyzed creation and implementation of the Sonoran Desert Conservation Plan.
- Integration of biodiversity concerns into a holistic plan covering other conservation issues important to people in Pima County: riparian areas, ranch conservation, mountain parks, and cultural heritage. For example, riparian protection is supported in part by associating it with the riverwalk and greenway system that is a popular recreational amenity.
- Leadership emerged from within the community of environmental organizations that focused their efforts. This took the form of the Coalition for Sonoran Desert Protection, which helped create a unified voice for environmental concerns. The Coalition comprises some 40 organizations that continue to support funding and implementation of the Sonoran Desert Conservation Plan.

12.7.2 Chicago Wilderness: A Regional Conservation Alliance

Chicago Wilderness is a public-private alliance among some 300 organizations (as of 2014), including civic groups, federal, state and local governmental entities, non-governmental organizations, educational institutions, associations and clubs, faith-based groups, and corporations (L. Hutcherson, personal communication). The alliance coordinates efforts among its members to study, sustain, restore, and expand remnant natural areas and engage local residents with their natural heritage in a crescent-shaped region wrapped around the southern tip of Lake Michigan. This encompasses approximately 31,565 km^2 (7.8 million acres) extending from Milwaukee, WI, through the greater Chicago metropolitan area, eastward across the dunes and rustbelt area of northwestern Indiana, and northward into the southwestern part of Michigan's lower peninsula near Benton Harbor, MI (Fig. 12.2).

More than 2206 km^2 (545,000 acres) are under protection within this region, in parcels that range in size from 0.2 ha (0.5 acres) to 77 km^2 (19,000 acres). These lands include federal and state parks and preserves, county forest preserve and conservation districts, park districts, municipal holdings, land trusts, and other public and privately protected areas (C. Mulvaney, personal communication). The alliance serves as a collective voice for conservation efforts across a complex metropolitan region encompassing a matrix of urban, suburban, and rural landscapes. The

Fig. 12.2 Chicago Wilderness "Green Infrastructure Vision" showing the regional boundary, land that is already protected, and land recommended for protection. (Courtesy of Chicago Wilderness)

Chicago Wilderness alliance provides a structure for interaction and communication among a large number of participants by coordinating activities of their teams and task forces, and by hosting regional forums, a biennial "Chicago Wilderness

Congress," as well as other collaborative events that help advance goals for the alliance's major strategic initiatives.

12.7.2.1 Early History

Chicago Wilderness emerged from discussions during 1993–1996 among a group of conservation and planning professionals who had a vision of conserving biodiversity by managing the scattered natural remnants of prairies, forests, savannas and wetlands in the rapidly urbanizing Chicago region *as a single landscape* (Ross 1997). Prior to these discussions, beginning in the 1970s, there had been strong public awareness of and engagement with natural areas throughout the region, including a growing grassroots movement of volunteer stewardship and restoration (Gobster 1997). Thus, local energy and enthusiasm buoyed the early work of these partners as they developed a structure, assembled resources, and created a common vision and mission. Chicago Wilderness was launched officially at an event hosted by The Field Museum in April 1996. The buy-in and strong leadership by local and national environmental and conservation organizations provided a firm foundation for the future work of the alliance. These organizations included the Forest Preserve Districts, the Chicago Botanic Garden, The Field Museum, The Morton Arboretum, the Chicago Zoological Society/Brookfield Zoo, Openlands, the US Environmental Protection Agency, The Nature Conservancy, the US Fish and Wildlife Service, and the USDA Forest Service.

12.7.2.2 Activities

Early in the formation of what became Chicago Wilderness, participants identified five overarching goals for their work: (1) documenting and mapping the region's natural communities, (2) preventing loss of critical habitat and promoting planned development, (3) restoring natural communities on public and private land, (4) informing and engaging decision-makers and the public about the valuable natural resources in the region and the need for their management, and (5) providing opportunities for citizen involvement in conservation efforts (Ross 1997).

These goals continue to be reflected in Chicago Wilderness' work assessing and monitoring the status of natural areas and restoration activities, conducting and coordinating planning among other organizations involved in acquisition and management of natural areas (Ruliffson et al. 2002), orchestrating a strong public relations program highlighting the region's unique and valuable natural areas, and providing resources for projects and initiatives that support conservation of biodiversity in the region. They currently do so within a framework that includes a leadership group and four teams: Natural Resources Management, Science, Education, and Sustainability. The work of these teams is further organized by their efforts in support of four *Strategic Initiatives*: Climate Action, Greening Infrastructure, Leave No Child Inside, and Restoring Nature. Research is a central component of the work of the

Science team, which has recently been successful in attracting significant grants from sources such as the National Science Foundation for work combining social and ecological approaches to examining conservation and restoration decisions and activities in the region (Heneghan et al. 2012).

The alliance's approach to conservation has been strongly oriented toward identification and protection of critical areas identified as endemic, rare, or endangered plant communities (Chicago Wilderness 2011). These plant communities include 55 "subcategories" of endemic forest, savanna, shrub, prairie, wetland, cliff, lakeshore, and cultural vegetation communities (e.g., Moskovits et al. 2002). Conservation of wildlife biodiversity emanating from their work is mostly through wildlife that co-occur in these ecosystems of interest, although it is certainly made very "wildlife-friendly" by the regional framework in which this work is conducted. They have also documented wildlife diversity in some instances, including birds (Brawn and Stotz 2001), invertebrates (Panzer et al. 2010), and coyotes (Gehrt et al. 2009).

Engagement of member participants with planning expertise and representatives of local and regional planning agencies has contributed to Chicago Wilderness' effectiveness in adoption of biodiversity conservation in local and regional planning processes. For example, principles from the Green Infrastructure Vision have been integrated in the *GOTO 2040 Plan* of the Chicago Metropolitan Planning Agency, and the *2040 Comprehensive Regional Plan* of the Northwestern Indiana Regional Planning Commission (Hutcherson 2013).

12.7.2.3 Helping Create a Regional Conservation Network

The alliance has consistently conducted their work as a collaborative that effectively integrates the participation of scientists, educators, planners, policy-makers, and land managers with a regional-scale focus (Moskovits et al. 2002). Chicago Wilderness was instrumental in providing resources for the creation of an *Atlas of Biodiversity* of the Chicago Region (1997) and a *Biodiversity Recovery Plan* (Chicago Region Biodiversity Council, 1999), both geared to broad audiences. These serve as the foundation for land protection and management efforts in the region. Both documents have been updated recently, the Atlas in 2011 (Chicago Wilderness 2011) and the Biodiversity Recovery Plan Climate Change Update (Chicago Wilderness 2012), with elements added to address potential effects of climate change on biodiversity in the region.

Although Chicago Wilderness does not "own" natural areas, its work has provided strong support for the efforts of entities that do own and manage lands. Chicago Wilderness has undergirded planning, acquisition, and restoration efforts of its members by educating citizens and generating strong public support for the protection, restoration, and management of natural areas (P. Gobster, personal communication), by providing information on spatial distribution and connectivity of natural areas (e.g., Wang and Moskovits 2001), by supporting the work of restoration in those areas (e.g., Heneghan et al., 2009, 2012), and by providing information and guidance for local and regional planning agencies (Chicago Wilderness 2004;

Retzlaff 2008). In addition, Chicago Wilderness has been instrumental in development of the Metropolitan Greenspaces Alliance, a relatively new organization of several similar urban conservation coalitions, and has provided support for the Practitioner's Network for Large Landscape Conservation. Thus, Chicago Wilderness has been successful in "putting the pieces together" by identifying and mapping critical habitat, affecting acquisition and management of habitat, providing opportunities for human interactions with nature in a variety of settings, and by planning at a regional level to protect and promote biodiversity.

12.7.2.4 Keys to Success for Chicago Wilderness

Chicago Wilderness has been touted as an example of great success in urban conservation. Many factors have contributed to the alliance's ability to lead effective efforts in the region, including:

- Early and strong participation by local leaders in most cases from respected and place-based institutions including both governmental and nongovernmental organizations
- A full-court press on public relations and public education and engagement with a clear message focused on biodiversity
- Purposeful integration of biodiversity and habitat protection in planning at multiple scales (e.g., over time from Forest Preserves to multi-county and now multistate geographic scope)
- A broad range of conservation partners
- The organization's positive approach to tackling challenges, both old (e.g., habitat degradation) and new (climate change), to biodiversity conservation in a large, heavily urban-influenced landscape

Conclusion

The integration of wildlife conservation into urban planning processes provides an opportunity to protect elements of biodiversity in the landscapes where people live, work, and play (e.g., Miller and Hobbs 2002). In the absence of specific planning to conserve wildlife, the landscape-scale effects of urbanization on wildlife populations are generally negative through degradation or elimination of habitat, increased competition with and depredation of sensitive wildlife species by generalist species, alteration of natural disturbance regimes, and decreased permeability of urbanized landscapes that inhibits the movements of urban avoider species.

Key principles from landscape ecology and conservation biology can be used to devise wildlife conservation strategies that counteract negative effects or urbanization. In an urban context such strategies must fit within well-established planning processes that include the development and application of comprehensive plans, zoning ordinances, and development regulations. These planning tools shape urban landscapes for wildlife, whether or not wildlife are considered explicitly. The emerging framework of green infrastructure provides an opportunity for wildlife conservation to become a standard element in local and regional planning efforts, and an integral part of local and regional comprehensive plans. For this to occur, wildlife professionals must become involved in these processes, either directly or through strategic alliances with people and organizations who are.

References

Adams, L. W., and L. E. Dove. 1989. *Wildlife reserves and corridors in the urban environment*. Columbia: National Institute for Urban Wildlife.

Ahern, J. 1991. Planning for an extensive open space system: Linking landscape structure and function. *Landscape and Urban Planning* 21:131–145.

Batisse, M. 1982. The biosphere reserve: A tool for environmental conservation and management. *Environmental Conservation* 9:101–111.

Beier, P., and R. F. Noss. 1998. Do habitat corridors provide connectivity? *Conservation Biology* 12:1241–1252.

Benedict, M. A., and E. T. McMahon. 2002. Green infrastructure: Smart conservation for the 21st century. *Renewable Resources Journal* 20 (3). http://www.sprawlwatch.org/greeninfrastructure.pdf. Accessed Aug 2013.

Benedict, M. A., and E. T. McMahon. 2006. *Green infrastructure: Linking landscapes and communities*. Washington, DC: Island Press.

Bernhardt, E. S., L. E. Band, C. J. Walsh, and P. E. Berke. 2008. Understanding, managing, and minimizing urban impacts on surface water nitrogen loading. Year in Ecology and Conservation Biology 1134:61–96.

Bolger, D. T., A. C. Alberts, R. M. Sauvajot, P. Potenza, C. McCalvin, D. Tran, S. Mazzoni, and M. E. Soule. 1997. Response of rodent to habitat fragmentation in coastal Southern California. *Ecological Applications* 7:552–563.

Brawn, J., and D. Stotz. 2001. The importance of the Chicago region and the "Chicago Wilderness" initiative for avian conservation. In *Avian ecology and conservation in an urbanizing world,* ed. J. Marzluff, R. Bowman, and R. Donnelly, 509–522. Norwell: Kluwer Academic.

Broberg, L. 2003. Conserving ecosystems locally: A role for ecologists in land-use planning. BioScience 53(7):670–673.

Carr, L. W., and L. Fahrig. 2001. Effect of road traffic on two amphibian species of differing vagility. *Conservation Biology* 14:1071–1078.

Chicago Region Biodiversity Council. 1999. *Atlas of biodiversity*. Chicago: CRBC.

Chicago Wilderness. 2004. Chicago wilderness green infrastructure vision. http://www.chicagowilderness.org/files/8513/3020/2252/Green_Infrastructure_Vision_Final_Report.pdf. Accessed May 2013.

Chicago Wilderness. 2011. Atlas of Biodiversity. 2nd ed. http://www.chicagowilderness.org/files/6813/3053/7702/1_Atlas_of_Biodiversity_Introduction.pdf. Accessed May 2013.

Chicago Wilderness. 2012. Introduction-changing landscapes in the Chicago wilderness region: A climate change update to the biodiversity recovery plan. http://climate.chicagowilderness.org/index.php?title=Introduction. Accessed June 2013.

Chicago Wilderness. n.d. Ecological planning and design directory. http://www.chicagowilderness.org/index.php/what-we-do/protecting-green-infrastructure/epdd-resources/. Accessed 12 May 2013.

Chicago Wilderness. Undated. Introduction-changing landscapes in the Chicago wilderness region: A climate change update to the biodiversity recovery plan. http://climate.chicagowilderness.org/index.php?title=Introduction. Accessed June 2013.

City of Boulder. 2006. City of Boulder urban wildlife management plan: Black-tailed prairie dog component. http://www.bouldercolorado.gov/files/Wildlife/p_dog_component.pdf. Accessed May 2013.

Conservation Measures Partners. 2007. Open standards for the practice of conservation, version 2.0. http://www.conservationmeasures.org/wp-content/uploads/2010/04/CMP_Open_Standards_Version_2.0.pdf. Accessed June 2013.

Davis, T. 2009. Desert protector Maeveen Behan dies: County's maestro behind conservation plan earns last honor. Arizona Daily Star, Tucson, AZ. 2009 Nov 4. http://www.pima.gov/cmo/sdcp/Memorial/AZstar.html. Accessed August 2013.

Desrochers, A., and S. J. Hannon. 1997. Gap crossing decisions by dispersing forest songbirds. *Conservation Biology* 11:1204–1210.

Donnelly, R., and J. M. Marzluff. 2004. Importance of reserve size and landscape context to urban bird conservation. *Conservation Biology* 18:733–745.

Donovan, T. M., P. W. Jones, E. M. Annand, and F. R. Thompson III. 1997. Variation in local-scale edge effects: Mechanisms and landscape effect. *Ecology* 78:2064–2075.

Doyle, M. 2013. Private property advocates cheer Supreme Court ruling. *Miami Herald*. 2013 June 25 http://www.miamiherald.com/2013/06/25/3469864/private-property-advocates-cheer.html. Accessed Aug 2013.

Duerksen, C., and C. Snyder. 2005. *Nature-friendly communities: Habitat protection and land use planning*. Washington, DC: Island Press.

Duerksen, C. J., C. G. Dale, and D. L. Elliott. 2009. *A citizen's guide to planning*. 4th ed. Chicago: American Planning Association.

Eatherly, C. R. undated. History of Catalina State Park. http://azstateparks.com/Parks/CATA/history.html. Accessed 30 Aug 2013.

Environmental Law Institute & Defenders of Wildlife. 2003. Planning for biodiversity: Authorities in state land use law. http://www.elistore.org/reports_detail.asp?ID=10917. Accessed July 2013.

Farina, A. 1993. Editorial comment: From global to regional landscape ecology. *Landscape Ecology* 8:153–154.

Findlay, C. S., and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. *Conservation Biology* 11:1000–1009.

Fonseca, J. 1999. Determining vulnerable species within Pima County, Arizona: A discussion paper for the Sonoran Desert Conservation Plan. http://www.pima.gov/cmo/sdcp/reports/d9/002DET.PDF. Accessed July 2013.

Fonseca, J., and C. Jones. 2009. Progress report: Measuring effectiveness of open space land acquisitions in Pima County, Arizona in relation to the Sonoran Desert Conservation Plan. http://www.pima.gov/cmo/sdcp/reports/d52/Acquisition_Analysis.pdf. Accessed July 2013.

Forman, R. T. T. 1995. *Land mosaics: The ecology of landscapes and regions*. Cambridge: Cambridge University Press.

Forman, R. T. T., and M. Godron. 1981. Patches and structural components for a landscape ecology. *BioScience* 31:733–740.

Forman, R. T. T., and M. Godron. 1986. *Landscape ecology*. New York: Wiley.

Friesen, L. E., P. F. J. Eagles, and R. J. Mackay. 1995. Effects of residential development on forest-dwelling neotropical migrant songbirds. *Conservation Biology* 9:1408–1414.

Gehrt, S. D., C. Anchor, and L. A. White. 2009. Home range and landscape use of coyotes in a major metropolitan landscape: Conflict or coexistence? *Journal of Mammalogy* 90:1045–1057.

Gibbs, J. P., and W. G. Shriver. 2005. Can road mortality limit populations of pool-breeding amphibians? *Wetlands Ecology and Management* 13:281–289.

Gobster, P. 1997. The other side: A survey of the arguments. *Restoration and Management Notes* 15:32–37.

Green, D. M. 2003. The ecology of extinction: Population fluctuation and decline in amphibians. *Biological Conservation* 111:331–343.

Groom, M. J., G. K. Meffe, and C. R. Carroll. 2006. *Conservation biology*. 3rd ed. Sunderland: Sinauer Associates.

Groves, C. R., D. B. Jensen, L. L Valutis, K. H. Redford, M. L. Shaffer, M. Scott, J. V. Baumgartner, J. V. Higgins, M. W. Beck, and M. G. Anderson. 2002. Planning for biodiversity: Putting conservation science into practice. *BioScience* 54:499–512.

Hair, J. D. 1986. Cooperation between conservation advocates and corporate interests. Pages 2–7 In Stenberg, K. and W.W. Shaw (eds.). Wildlife Conservation and New Residential Developments: Proceedings of a National Symposium on Urban Wildlife. School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Hamin, E., P. Geigis, and L. Silka. 2007. *Preserving and enhancing communities: A guide for citizens, planners, and policymakers*. Amherst: UMass Press.

Harris, L. D. 1984. *The fragmented forest: Island biogeographic theory and the preservation of biotic diversity*. Chicago: University of Chicago Press.

Heneghan, L., L. Umek, B. Bernau, K. Grady, J. Iatropulos, D. Jabon, and M. Workman. 2009. Ecological research can augment restoration practice in urban areas degraded by invasive species—examples from Chicago wilderness. *Urban Ecosystems* 12:63–77.

Heneghan, L., C. Mulvaney, K. Ross, L. Umek, C. Watkins, L. Westphal, and D. Wise. 2012. Lessons learned from Chicago wilderness—implementing and sustaining conservation management in an urban setting. *Diversity* 4:74–93.

Hess, G. R., and T. J. King. 2002. Planning open spaces for wildlife 1: Selecting focal species using a Delphi approach. *Landscape and Urban Planning* 58:25–40.

Hilty, J. A., W. Z. Lidicker, and A. M. Merenlender. 2006. *Corridor ecology: The science and practice of linking landscapes for biodiversity conservation*. Washington, DC: Island Press.

Holling, C. S., ed. 1978. *Adaptive environmental assessment and management*. Chichester: Wiley.

Huckelberry, C. 1999. Determining species of concern in Pima County, Arizona: A discussion paper for the Sonoran Desert Conservation Plan. http://www.pima.gov/cmo/sdcp/reports/d9/001DET.PDF. Accessed July 2013.

Huckelberry, C. 2000a. Priority vulnerable species habitat data analysis. http://www.pima.gov/cmo/sdcp/reports/d16/051PRI.PDF. Accessed July 2013.

Huckelberry, C. 2000b. Priority vulnerable species: Data compilation and synthesis. http://www.pima.gov/cmo/sdcp/reports/d15/046PRI.PDF. Accessed July 2013.

Huckelberry, C. 2001. Reserve design process. http://www.pima.gov/cmo/sdcp/reports/d17/068RES.PDF. Accessed July 2013.

Huckelberry, C. 2002. Special elements: Sonoran Desert Conservation & Comprehensive Plan. http://www.pima.gov/cmo/sdcp/reports/d9/012SPE.PDF. Accessed July 2013.

Hutcherson, L. 2013. *Chicago pioneering large landscape conservation*. Press Release, Chicago Wilderness, issued 5 April 2013.

Kareiva, P., and M. Marvier. 2012. What is conservation science? *BioScience* 62 (11): 962–969.

Kerpez, T. A., and N. S. Smith. 1990. Competition between European starlings and native woodpeckers for nest cavities in saguaros. *The Auk* 107:367–375.

Knutson, M. G., J. R. Sauer, D. A Olsen, M. J. Mossman, L. M. Hemesath, and M. J. Lannoo. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, USA. *Conservation Biology* 13:1437–1446.

Lafortezza, R., C. Davies, G. Sanesi, and C. C. Konijnendijk. 2013. Green infrastructure as a tool to support spatial planning in European urban regions. *iForest* 6:102–108. http://www.sisef.it/iforest/contents/?id=ifor0723-006. Accessed Aug 2013.

Lambeck, R. J. 1997. Focal species: A multi-species umbrella for nature conservation. *Conservation Biology* 11:849–856.

Land Trust Alliance. 2010. 2010 National land trust census report. https://www.landtrustalliance.org/land-trusts/land-trust-census/national-land-trust-census-2010/2010-final-report. Accessed Aug 2013.

Layzer, J. 2008. *Natural experiments: Ecosystem-based management and the environment*. Cambridge: MIT Press.

Leopold, A. 1933. *Game management*. New York: Scribner's.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. *Bulletin of the Entomological Society of America* 15:237–240.

Linnell, J. D. C., E. B. Nilsen, U. S. Lande, I. Herfindal, J. Odden, K. Skogen, R. Andersen, and U. Breitenmoser. 2005. Zoning as a means of mitigating conflicts with large carnivores: Principles and reality. In *People and wildlife, conflict or co-existence?*, ed. R. Woodroffe, S. Thirgood, and A. Rabinowitz. 162–175. New York: Cambridge University Press.
Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. *Nature* 405:243–253.
Margules, C., and M. B. Usher. 1981. Criteria used in assessing wildlife conservation potential: A review. *Biological Conservation* 21:79–109.
Marzluff, J. M., and K. Ewing. 2001. Restoration of fragmented landscapes for the conservation of birds: A general framework and specific recommendations for urbanizing landscapes. *Restoration Ecology* 9:280–292.
Mason, J., C. E. Moorman, G. R. Hess, and K. Sinclair. 2007. Designing suburban greenways to provide habitat for forest-breeding birds. *Landscape and Urban Planning* 80:153–164.
MacArthur, R. H., and E. O. Wilson. 1967. *The Theory of Island Biogeography*. Princeton: Princeton University Press.
McElfish, J. M. 2004. *Nature friendly ordinances*. Washington, DC: Environmental Law Institute.
McHarg, I. L. 1969. Design with Nature. Wiley, New York.
McKinney, M. L. 2002. *Urbanization, biodiversity, and conservation*. *BioScience* 52:883–890.
McKinney, M. L. 2006. Urbanization as a major cause of biotic homogenization. *Biological Conservation* 127:247–260.
McKinney, M. L. 2008. Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystems* 11:161–176.
Mecklenburg County. Undated. Mecklenburg county nature preserves. http://charmeck.org/mecklenburg/county/ParkandRec/StewardshipServices/NaturePreserves/Pages/default.aspx. Accessed Aug 2013.
Meir, E., S. Andelman, and H. Possingham. 2004. Does conservation planning matter in a dynamic and uncertain world? *Ecology Letters* 7:615–622.
Miller, J. R. 2006. Restoration, reconciliation, and reconnecting with nature nearby. Biological Conservation 127:356–361.
Miller, J. R., and R. J. Hobbs. 2002. Conservation where people live and work. Conservation Biology 16:330–337.
Miller, J. R., M. Groom, G. R. Hess, T. Steelman, D. L. Stokes, J. Thompson, T. Bowman, L. Fricke, B. King, and R. Marquadt. 2008. Biodiversity conservation in local planning. *Conservation Biology* 23 (1): 53–63.
Minor, E. S., and D. L. Urban. 2007. Graph theory as a proxy for spatially explicit population modeling in conservation planning. *Ecological Applications* 17 (6): 1771–1782.
Mörtberg, U. M. 2001. Resident bird species in urban forest remnants; landscape and habitat perspectives. *Landscape Ecology* 16:193–203.
Mörtberg, U., B. Balfors, and W. Knol. 2007. Landscape ecological assessment: A tool for integrating biodiversity issues in strategic environmental assessment and planning. *Journal of Environmental Management* 82:457–470.
Moskovits, D, C. Fialkowski, G. Mueller, and T. Sullivan. 2002. Chicago wilderness: A new force in urban conservation. *Annals of the Missouri Botanical Garden* 89:153–163.
Murphy, D. D., and B. R. Noon. 2007. The role of scientists in conservation planning on private lands. Conservation Biology 21:25–28.
National Weather Service. Undated. Tropical storm octave 1983. http://www.wrh.noaa.gov/twc/tropical/Octave_1983.php. Accessed Aug 2013.
NatureServe. Undated. The NatureServe network of member programs. http://www.natureserve.org/visitLocal/. Accessed 11 Aug 2013.
Naveh, Z., and A. S. Lieberman. 1984. *Landscape ecology theory and application*. New York: Springer.
Noël, S., M. Ouellet, P. Galois, and F.-J. Lapointe. 2007. Impact of urban fragmentation on the genetic structure of the eastern red-backed salamander. *Conservation Genetics* 8:599–606.
Noss, R. F. 1983. A regional approach to maintain diversity. *BioScience* 33:700–706.
Noss, R. F. 1987. Protecting natural areas in fragmented landscapes. *Natural Areas Journal* 7:2–13.

Noss, R. F. 2003. A checklist for wildlands network designs. *Conservation Biology* 17:1270–1275.
Noss, R. F., and A. Cooperrider. 1994. *Saving nature's legacy: Protecting and restoring biodiversity*. Washington, DC: Island Press.
Noss, R. F., and L. D. Harris. 1986. Nodes, networks, and MUMs: Preserving diversity at all scales. *Environmental Management* 10:299–309.
Odum, E. P. 1969. The strategy of ecosystem development. *Science* 164:262–270.
Panzer, R., K. Gnaedinger, and G. Derkovitz. 2010. The prevalence and status of conservative prairie and sand savanna insects in the Chicago Wilderness region. *Natural Areas Journal* 30:73–81.
Pima County. 2009. Maeveen Marie Behan conservation lands system. http://www.pima.gov/cmo/sdcp/memorial/Behan_CLS.pdf. Accessed July 2013
Pima County, AZ. 2012a. Pima county comprehensive plan update, regional plan policies. http://www.dsd.pima.gov/Documents/planning/ComprehensivePlan/PDF/Policies_Legend/REGIONAL_PLAN_POLICIES-Jun2012.pdf. Accessed Aug 2005.
Pima County, AZ. 2012b. Sonoran desert conservation plan. http://www.pima.gov/cmo/sdcp/. Accessed Aug 2012.
Pima County, AZ. Undated-a. Zoning classifications summary. http://www.pimaxpress.com/Planning/plan4c.htm. Accessed Aug 2013.
Pima County, AZ. Undated-b. About Pima County. http://www.pima.gov/areainfo/area.html. Accessed Aug 2013.
Pressey, R. L., C. J. Humphries, C. R. Margules, R. I. Vane-Wright, and P. H. Williams. 1993. Beyond opportunism: Key principles for systematic reserve selection. *Trends in Evolution and Ecology* 8:124–128.
Price, S. J., M. E. Dorcas, A. L. Gallant, R. W. Klaver, and J. D. Willson. 2006. Three decades of urbanization: Estimating the impact of land-cover change on stream salamander populations. *Biological Conservation* 133:436–441.
Pulliam, H. R. 1988. Sources, sinks, and population regulation. *American Naturalist* 132:652–661.
Reed, D. H., and R. Frankham. 2003. Correlation between fitness and genetic diversity. *Conservation Biology* 17:230–237.
Retzlaff, R. C. 2008. Planning for broad-based environmental protection: A look back at the Chicago Wilderness Biodiversity Recovery Plan. Urban Ecosystems 11:45–63.
Rodewald, A. D. 2003. The importance of land uses within the landscape matrix. *Wildlife Society Bulletin* 31:586–592.
Ross, L. 1997. The Chicago Wilderness: A coalition for urban conservation. *Restoration and Management Notes* 15:17–24.
Rottenborn, S. C. 1999. Predicting the impacts of urbanization on riparian bird communities. *Biological Conservation* 88:289–299.
Rubbo, M. J., and J. M. Kiesecker. 2005. Amphibian breeding distribution in an urbanized landscape. *Conservation Biology* 19:504–511.
Rubino, M. J., and G. R. Hess. 2003. Planning open spaces for wildlife 2: Modeling and verifying focal species habitat. *Landscape and Urban Planning* 64:89–104.
Ruliffson, J., P. Gobster, R. Haight, and R. Homans. 2002. Niches in the urban forest: Organizations and their role in acquiring metropolitan open space. *Journal of Forestry* 100:16–23.
Sarkar, S. 2012. Complementarity and the selection of nature reserves: Algorithms and the origins of conservation planning, 1980-1995. *Archive for History of Exact Sciences* 66:397–426.
Schmidt, K. A. 2003. Nest predation and population declines in Illinois songbirds: A case for mesopredator effects. *Conservation Biology* 17:1141–1150.
Shake, C. S., C. E. Moorman, and M. R. Burchell II. 2011. Cropland edge, forest succession, and landscape affect shrubland bird nest predation. *Journal of Wildlife Management* 75:825–835.
Shaw, W. W., J. M. Burns, and K. Stenberg. 1986. Wildlife Habitats in Tucson: A Strategy for Conservation. School of Renewable Natural Resources, University of Arizona, Tucson, AZ.
Sinclair, K. E., G. R. Hess, C. E. Moorman, and J. H. Mason. 2005. Mammalian nest predators respond to greenway width, landscape context, and habitat structure. *Landscape and Urban Planning* 71:277–293.

Skelly, D. K., E. E. Werner, and S. A. Cortwright. 1999. Long-term distributional dynamics of a Michigan amphibian assemblage. *Ecology* 80:2326–2337.

Soule, M. E. 1986. What is conservation biology? *BioScience* 35:727–734.

Soule, M. E., and B. A. Wilcox, eds. 1980. *Conservation biology: An evolutionary-ecological perspective*. Sunderland: Sinauer Associates.

Stokes, D. L., M. F. Hanson, D. D. Oaks, J. E. Straub, and A. V. Ponio. 2010. Local land-use planning to conserve biodiversity: Planners' perspectives on what works. *Conservation Biology* 24:450–460.

Tilghman, N. G. 1987. Characteristics of urban woodlands affecting breeding bird diversity and abundance. *Landscape and Urban Planning* 14:481–495.

Turner, M G. 2005. Landscape ecology in North America: Past, present, and future. *Ecology* 86:1967–1974.

Urban, D. L., and T. H. Keitt. 2001. Landscape connectivity: A graph-theoretic approach. *Ecology* 82 (5): 1205–1218.

US Census Bureau. 2012. State and county quick facts. http://quickfacts.census.gov/qfd/index.html. Accessed Aug 2013.

Wang, Y., and D. Moskovits. 2001. Tracking fragmentation of natural communities and changes in land cover: Applications of Landsat data for conservation in an urban landscape (Chicago Wilderness). *Conservation Biology* 15:835–843.

Washington State Legislature. 1990. Growth management. http://apps.leg.wa.gov/rcw/Default.aspx?cite=36.70a&full=true. Accessed Aug 2013.

Whittaker, R. H. 1972. Evolution and measurement of species diversity. *Taxon* 21:213–251.

Wilcove, D., D. Rothstein, J. Dubow, A. Phillips, and E. Losas. 1998. Quantifying threats to imperiled species in the United States. BioScience 48(8):607–612.

Young, A., T. Boyle, and T. Brown. 1996. The population genetic consequences of habitat fragmentation for plants. *Trends in Ecology and Evolution* 11:413–418.

Zonneveld, I. S. 1995. *Land ecology: An introduction to landscape ecology as a base for land evaluation, land management, and conservation*. Amsterdam: SPB Academic.