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Wildlife Conservation in Urban Greenways of the Mid-Southeastern United States

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Andrew Schiller

December, 1991

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DEDICATION

This thesis is dedicated to my family and friends. Thanks go especially to my mother, Kathy Kramer, my father, Harvey Schiller, and my step-father, John Kramer. My energy, enthusiasm and courage to pursue this project was possible only because of their support. I will always need them, and be there for them. Thanks to you all.

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ABSTRACT

This research addressed wildlife conservation in urban greenways in the mid-southeastern U.S. in two Parts. Wildlife conservation theory and landscape design information were reviewed in Part one to offer guidelines on how to design and manage urban greenways in the mid-southeast for maximum wildlife conservation value. Part two of this thesis assessed the wildlife conservation value in a selection of six existing urban greenway systems in the mid-southeast in comparison to what is often stated or implied in greenway plans concerning the benefits to wildlife that will accrue with urban greenway development. This assessment concentrated on the presence of red fox, grey fox and/or white-tailed deer (termed "umbrella species") as inferential evidence that ecological and spatial parameters at the site were sufficient for a host of other less sensitive species as well. This presence/absence data was determined by a combination of expert knowledge, visual observation and scent station inventory. In addition to presence/absence data, this evaluation also drew from the information presented in Part one to assess the wildlife-friendliness of natural landscape connectivity, greenway width and vegetation management, and adjacent land uses. This information was subsequently analyzed in an attempt to understand which factors in the landscape are most important for predicting the presence of the umbrella species.

I found that 18 of the 38 surveyed greenway segments in the six urban greenway systems had presence of red and/or grey fox; six had both fox and white-tailed deer. Greenway segments surrounded by less urban adjacent land uses had much better chances of having umbrella species. However, greenway width and vegetation management also tend to be more wildlife-friendly in greenways in these areas. It appears,

therefore, that both adjacent land uses and greenway characteristics work together to promote or limit wildlife conservation value in the surveyed greenways. Wildlife-positive landscape design in surveyed greenway segments is not that common, and purposeful conservation of existing vegetation likewise does not appear to be as frequent or as important for wildlife conservation as fortuitous circumstances of wildlife-positive adjacent land use and incidental preservation of existing natural vegetation in greenway areas. Many areas, in fact, become less wildlife-positive with greenway development because of negative vegetation changes, and the introduction of people and their pets into previously inaccessible lands. In sum, greenway enthusiasts should be more conservative in their statements concerning the wildlife conservation benefits that will accrue as a result of urban greenway establishment.

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Chapter 1

Introduction

Urban greenways -- a recently popularized concept for public open space and conservation -- are developed for a multitude of reasons. These reasons include recreation, floodplain protection, beautification, the provision of alternative transportation routes, buffering of adjacent land uses, neighborhood image improvement and wildlife conservation. Of these, wildlife conservation seems to be the least understood. Nonetheless, it is a frequent justification for urban greenway development. Goals related to wildlife conservation are stated or implied in many urban greenway plans. But are these greenways really contributing to the conservation of wildlife, particularly with respect to the larger, more disturbance- and space-sensitive species that are frequently absent in urban environments? Or, are these greenways only harboring common urban animals that would most likely exist in these environments regardless of the presence of a greenway?

How can we make urban greenways as wildlife-positive as possible? In developing new greenway systems, which locations would be best if wildlife conservation is a prime objective? Once these sites are chosen, how can we best manage the greenway to maximize its value for wildlife conservation?

This thesis is concerned with wildlife conservation in urban greenways in the mid-southeastern U.S. -- both the promise and the reality. The research presented here had two main objectives. The first was to review theories and literature related to wildlife conservation and nature

reserve design, and to draw from this background guidelines for designing and managing greenways to maximize their value for wildlife conservation. These guidelines, and the literature review presented here, should provide useful information to greenway advocates, planners, and managers who are seeking to increase the wildlife conservation value of urban greenways.

The second objective of this thesis was to investigate a series of existing urban greenway systems in the mid-southeastern United States to assess their wildlife conservation value, particularly with respect to selected larger and more sensitive species. These larger and more disturbance-sensitive animals are termed "umbrella" species (Ehrlich and Murphy, 1987). The umbrella species chosen for this study are red fox (*Vulpes vulpes*), grey fox (*Urocyon cinereoargenteus*) and white-tailed deer (*Odocoileus virginianus*). If ecological and spatial parameters at a site are sufficient for these umbrella species, the probability is good that a host of other less sensitive species, such as Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), muskrat (*Ondatra zibethicus*), grey squirrel (*Sciurus carolinensis*) and eastern cottontail rabbit (*Sylvilagus floridanus*), will also exist in the greenway (Sullivan and Shaffer, 1975; Sullivan, 1981; Ehrlich and Murphy, 1987; Shaffer, 1990). As Sullivan and Shaffer appropriately noted:

> For any habitat type.....there are certain range-sensitive species, and if these were properly provided for there would be sufficient room for organisms that demand less space (1975:10).

This field investigation also draws upon the theoretical considerations of nature reserve design and wildlife conservation discussed in the first part of the thesis.

Specifically, this information will be used to help assess the "wildlife-friendliness" of the greenway in terms of its connectivity in the natural landscape, vegetation management, corridor widths and adjacent land uses. Such knowledge will be used in conjunction with umbrella species presence/absence data to evaluate the wildlife conservation value of these selected urban greenways. The wildlife conservation value in these greenways can then be compared to what is often stated or implied in many urban greenway plans concerning the wildlife benefits that will accrue as a result of greenway development. The directive for such an investigation has been provided by Lovejoy and Oren (1981:7):

> As a consequence of the attendant increasing need to protect our biological patrimony, the effect of the fragmentation [of habitat] itself has become a matter of concern. If protection efforts are to be successful and significant, not only must some of the fragments be protected, but also they must be able to maintain their biological integrity over reasonable periods of time - or if not, at least no illusion to the contrary should be operating.

Adams and Dove (1989) reviewed urban wildlife conservation research and found that few studies have examined the success of greenways and other urban wildlife conservation strategies. They concluded that research in this area is badly needed, so that urban wildlife managers and nature reserve designers will have a better idea of what works and what does not.

A Brief History of Greenways

The word "greenway" is derived from a combination of the words "greenbelt" and "parkway" (Grove, 1990; Little, 1990). Many different and divergent elements are included under this heading, including rail beds converted to trails,

recreational corridors in both urban and rural environments, urban river-ways, environmental or conservation corridors of all sizes and even regional systems such as the Appalachian trail. As such, a greenway could range from an urban strip park of less than ten acres to a regional system that threads across more than ten states.

Greenways, or at least the "green-corridor" idea, have been around for a long time. Little (1990) attributes the origin of the idea to Fredrick Law Olmsted. Olmsted is best known as "the father of landscape architecture", and the designer of Central Park in New York City (Little, 1990). In 1865, Olmsted was finalizing his plans for a park and connecting pleasure walkway in Berkeley, California (Beveridge and Hoffman, 1987). Though only small parts of Olmsted's plans for Berkeley were ever implemented, this project, known as the "Park and Piedmont Way", is recognized as the first to incorporate ideas that are today considered to be central elements of greenways (Little, 1990).

Olmsted and his partner Calvert Vaux were subsequently commissioned to design a park in Brooklyn, New York. Here, perhaps borrowing from his plans in Berkeley and his admiration of the broad boulevards of Paris and Brussels (Little, 1990), Olmsted designed the "Linear Park Way", which was to lead visitors to Prospect Park, the central park of the Brooklyn plan. After this project, the Olmsted firm continued to include and enhance the role of "greenway-type" elements in their park designs, including systems in Riverside, Illinois (created in 1869) and the famous "Emerald Necklace" in Boston (developed over several years in the 1880s).

Alfred Marshall's idea (1899) of using greenbelts around cities to keep them from growing together in Britain was also an important precursor to the modern greenway concept. Marshall's plans were similar to the "garden city" ideas of another Englishman, Ebenezer Howard (Little, 1990). Garden cities were built at several scales in Britain and the United States. The design of these cities of gardens, or "cities in a garden" (Little, 1990) were intended to address the philosophical issue of the reunion of city and country (Mumford, 1961).

Following and expanding on the ideas of Ebenezer Howard, Benton MacKaye originated the idea of the Appalachian Trail in 1921. At that time, MacKaye envisioned the trail as a "giant dam and levee system" (Little, 1990) for the metropolitan east coast. The Appalachian Trail was to serve not only as a major hiking and wilderness network, but also as a huge greenbelt capable of stopping the spread of urban America westward from the eastern seaboard.

The origination of the term greenway is still ambiguous. William White's Securing Open Space for Urban America, published in 1959, may have been the first to use the term (Little, 1990). The reference to greenways in White's book was made in regards to a land use plan developed by Edmond Bacon, who, as the text goes, referred to "greenways and parks in between" (Little, 1990:24).

In more recent times, landscape architect Ian McHarg and his famous book Design with Nature (1967) have been responsible for introducing a whole generation of city planners, conservationists and designers to the virtues of greenways and other ecologically-sensitive human settlement patterns, parks and reserves. Though many greenways date to

the 1960s, the first modern comprehensive greenway system in the country was started in Raleigh, North Carolina in 1974. This greenway system was different from its predecessors because it was intended to be a city-wide network, and was designed to help guide future urban growth, and to offer recreational opportunities and urban floodplain protection. The idea for this city-wide system of greenways came from Bill Flournoy, who developed the Raleigh greenway plan for his master's work in landscape architecture at the North Carolina State University in 1972 (Flournoy, 1972; Grove, 1990; Little, 1990).

In 1987, Americans Outdoors: The Legacy, the Challenge (President's Commission on Americans Outdoors) suggested that a green network of trails should crisscross the nation. The commission especially recommended increasing the availability of passive, nature-oriented recreation for the millions of Americans who live in metropolitan areas. This was a direct prescription for the development of urban greenways. Today there are hundreds of greenway projects either completed or planned in the United States, many of which are in the southeastern region of the country.

Linearity and Connectivity in Greenways

Greenways, including urban ones, differ from many other parks, reserves and open spaces in that they are generally linear in shape. Most often a greenway is long and thin with multiple "bulges" in open space occurring every so often along the greenway corridor. These "bulges" are termed nodes (Forman and Godron, 1986), and can be natural open spaces such as parks, fields or woods, points for entrance into the greenway, or places of interest for greenway users such as schools, shopping facilities and neighborhoods. The linear

form of greenways is both their promise and limitation. This linearity allows the greenway to serve as a large and often interconnecting recreation or conservation corridor between larger reserves, while requiring far less absolute land than a conventional reserve and allowing use of areas that have intense land use pressure, such an an urban landscape. For example, flood plains along streams provide suitable locations for greenways, especially in cities where these areas may be the only lands left undeveloped that run from near the center city out towards the less developed suburbs and rural areas. In reality, however, the urban landscape, patterns of property ownership and politics frequently limit the connectivity of urban greenway systems. Even after years of continual land acquisition and greenway development, most urban greenway systems surveyed for this study are simply a collection of individual trails that are administered jointly but are otherwise unconnected.

Connectivity, though difficult to achieve, remains a key goal of greenway design. Such connectivity is believed to make greenways attractive to both people and wildlife. If this connectivity is present, an urban resident may be able to enter a trail in the city and travel out to the country or even into a large regional park without coming into direct contact with houses, streets and cars. Likewise, it is believed that wildlife can and will use these greenways to travel to different areas seasonally and daily with much less disturbance than they would normally encounter when moving through a populated area (Elton, 1958; Higgs and Usher, 1980; Gilpin, 1981; Harris, 1981, and pers.comm., 1991; Higgs, 1981; Mathiae and Sterns, 1981; Swingland and Greenwood, et al., 1983; Houte de Lange, 1984; Forman and Godron, 1986; Soulé and Simberloff, 1986; Dendy, 1987; Dickman, 1987;

Rohling, 1988; Adams and Dove, 1989; Lines and Harris, 1989; Little, 1990).

Though the linear shape of greenways makes them attractive for many reasons, it also has drawbacks. Reserve patches that have a high proportion of edge to interior space are far more susceptible to outside disturbance (Forman and Godron, 1986; Lines and Harris, 1989). Disturbances can affect wildlife directly (noise, pollution, predation by domestic dogs and cats, mortality from automobiles; Fahrig and Merriam, 1985), or indirectly through their effect on vegetation. Light penetration into the interior of narrow, forested corridors may limit habitats for plants that require filtered light, and for the animals that depend upon these plants. Pollution from industries and automobiles, competition from exotic ornamentals, and trampling by people and their pets may also affect plant distributions, and in this way the distributions of dependent wildlife species.

Island biogeographic theory (MacArthur and Wilson, 1967) and studies of mammal home-range shapes and sizes (Koepl, Slade and Hoffmann, 1975; Mathiae and Sterns, 1981; Forman and Godron, 1986) suggest that reserve area and distance from the source of primary dispersal to the reserve will limit wildlife colonization and survival in greenways (Diamond, 1976; Simberloff and Abele, 1976; Davis and Glick, 1978; Fahrig and Merriam, 1985; Lines and Harris, 1989). Some authors (Sullivan and Shaffer, 1975; Sullivan, 1981; Adams and Dove, 1989), in fact, regard distance from the area of dispersal and reserve size as the most influential variables.

Another drawback related to greenway linearity involves limitations in habitat owing to reserve placement. Many greenways follow streams, and are located entirely on

floodplains that may be inundated every year or every few years. Plant communities here include only species adapted to moist environments, a set of species that may not include all plants needed by wildlife for food or shelter.

Wildlife species in urban greenways are also limited by corridor widths and total reserve area. Some species, such as the black bear (*Ursus americanus*) which have large home ranges, simply will not be found in or near large urban areas along a conservation corridor of less than several thousand acres, barring some severe disturbance in the bear's natural territory or an occasional bear who is simply passing through. Grey squirrels (*Sciurus carolinensis*), on the other hand, have much smaller range requirements. They live comfortably in small patches of woods, and in parks, suburbs and even inner city areas. The squirrel will usually be found in and around cities regardless of the presence of a conservation greenway.

Organization of the Thesis

This thesis is divided into two parts. The first part (Chapter 2) reviews theories and literature in urban wildlife conservation and nature reserve design that are applicable to the development and management of urban greenway systems for maximum wildlife conservation value. This section focuses on the inherent problems of wildlife conservation in fragmented habitats (particularly in urban areas), and the contributions of island biogeographic theory, landscape ecology, and landscape design to wildlife conservation in such environments. It includes specific guidelines for increasing the wildlife conservation value of urban greenways that can be used by greenway planners, designers and managers.

The second part of the thesis (Chapters 3-6) focuses on the wildlife conservation value of selected urban greenways in the mid-southeastern U.S. Chapter 3 describes the urban greenway systems that were investigated. Here I describe how the greenways were chosen, qualities and characteristics of the greenway systems, and the cities in which they are located. Research methods are explained in the following Chapter.

In Chapter 5 I present research results for each greenway system and section within the system. Finally, in Chapter 6, I discuss the results of the greenway inventories and the lessons that these results provide for urban wildlife conservation in the southeastern U.S.

PART I

Designing and Managing Wildlife-Positive Urban Greenways

Chapter 2

Maximizing Wildlife Conservation in Urban Greenways: Theory and Application

How can we maximize the wildlife value of urban greenways in the mid-southeastern U.S.? Which characteristics are ideal, from a wildlife conservation perspective, and which disastrous? How can we improve existing greenways, and what can we do better next time?

From my first conversations and correspondence with greenway advocates, designers, and managers in the mid-southeastern U.S., it became clear that few ready answers existed for such questions. While occasionally professing an interest in wildlife conservation, most of the people who design and manage greenways have little or no experience with wildlife, and few ideas for improving the wildlife value of their greenways. Furthermore, the growing literature on greenways has yet to provide substantial help in this area. There are books and articles on greenways (for example, Rohling, 1988; Grove, 1990, Little, 1990), but few offer direct prescriptions for wildlife friendly design and management.

A key objective of this research thus became to develop guidelines that could be used to maximize wildlife value in urban greenways of the mid-southeastern U.S. To develop these guidelines, I turned to the literature in island biogeography, landscape ecology, and landscape design. I examined this literature in the context of wildlife conservation, and drew upon my own experiences assessing wildlife conservation in existing greenways (Chapter 3-6 of this thesis). This chapter reviews key themes from the

literature that are relevant to wildlife conservation in urban greenways of the mid-southeastern U.S., and presents specific guidelines drawn from this literature.

Wildlife in Fragmented Habitats

Wildlife conservation strategies are presently focusing on the problem of fragmentation of habitat and not just on the absolute loss of habitat area. This focus is well founded. With the increasing human population of the planet, larger areas are being altered for the needs of people, leaving smaller and continually more isolated fragments of unaltered habitat patches for other species (for example, Kendeigh, 1974; Grossman, 1977; Houte de Lange, 1984; Wilson, 1988; Saunders et al., 1991). Urban greenways, as a popular conservation strategy, are thought to help wildlife by providing absolute habitat within the greenway itself and by serving as a corridor for the potential movement of species between otherwise isolated habitat fragments (Forman and Godron, 1986; Adams and Dove, 1989; Lines and Harris, 1989; Little, 1990; Harris, pers. comm., 1991). For a greenway to serve these two functions well, it must be designed for maximum habitat connectivity, and managed for optimum habitat value. An understanding of the ecology and dynamics of connected and isolated fragments of natural vegetation -- which can affect both habitat value and connectivity -- is therefore central to the design and management of urban greenways for maximum wildlife conservation value. Such an understanding is also useful in assessing the success of urban greenways in wildlife conservation.

Urban areas are among the most fragmented of habitats and offer an especially rich laboratory for the study of conservation in habitat remnants (Urban, et al., 1987). Not

only is the natural landscape severely altered and fragmented in the urban environment, but (unlike many other areas with habitat fragmentation) the surrounding landscape is often overtly hostile to nearby wildlife populations. If wildlife conservation strategies can be successful in urban places, then perhaps we will be better able to conserve wildlife on larger habitat fragments surrounded by less hostile environments elsewhere. Urban wildlife conservation research, then, can act as an experiment for wildlife conservation strategies in less hostile areas, hopefully making these projects even more successful than they would be otherwise.

As habitats are fragmented, many ecological changes take place. Studies of fragment dynamics, such as Lovejoy's "Minimum critical size of ecosystems project" in the Amazon (Lovejoy and Oren, 1981; Lovejoy, et al., 1983), have shown that after fragmentation some species will decline and others will increase, and that the timing of these fluctuations varies considerably depending on many individualistic, mutualistic and community interactions between both plants and animals. Lovejoy's study of different sizes of tropical rain forest fragments is a relatively new research project. It will be some time before many of the observations are analyzed and the underlying reasons for such changes begin to be known. Other researchers have worked on fragment dynamics in mid-latitude regions and even in urban environments. These studies of post-fragmentation may be of critical importance to wildlife conservation efforts in urban greenways, which are themselves often on highly fragmented lands.

Island Biogeographic Theory and the Species-Area Relationship

MacArthur and Wilson's Island biogeographic theory (1967) has become one of the most hotly debated theories in conservation today. The theory was originally meant to serve as a model for species diversity and rates of colonization and extinction on oceanic islands. Since its introduction, the theory also has been applied (with varying degrees of success) to continental habitat islands.

Island biogeographic theory consists of two principle ideas (Shaffer, 1990). The first is that the size of an island and the distance to a source area for species will strongly affect the speed of colonization and total number of species that can inhabit the island. To this basic original model, we can add that the inherent species richness of a source area will also influence the potential species richness of the island (Cox and Moore, 1985). The second principal idea of the theory is that the opposing forces of immigration and extinction will eventually lead to an equilibrium species turnover rate for a particular island, and an equilibrium number of species in residence on the island. This equilibrium model is what distinguishes island biogeography from earlier theories concerning biotic diversity and dispersal on islands and island-like habitats (Shaffer, 1990).

The theory of island biogeography predicts that larger islands that are closer to a species-rich source area (a mainland, in the case of oceanic islands) will have both higher rates of immigration and larger total numbers of species in residence. Smaller islands that are farther from a source area and for which the source area itself is

relatively species-poor will have slower rates of immigration and lower total numbers of species in residence. These variables, excepting species richness of the source area, are illustrated in Figure 1.

The relationship between island size and the potential total number of species that may inhabit a particular island is called the species-area relationship. The species-area relationship, which pre-dates island biogeography (Shaffer, 1990), is one of the central theories for conservation on true oceanic islands as well as in isolated habitat fragments on land, including insular natural areas surrounded by urbanization. (for example, Arrhenius, 1921; Higgs, 1981; Houte de Lange, 1984; Bennett, 1987). The species-area relationship is therefore of importance for wildlife conservation in urban greenways.

In agreement with island biogeographic theory, there is a proven general positive correlation between increasing area and species diversity for a variety of true islands and island-like habitats (for example, Frankel and Soulé, 1981; Merriam, 1984). But, unlike the predictions of island biogeographic theory, it is not steady and continuous. In fact, the demonstrated relationship shows smaller increases in species numbers with a continued increase in area, after a certain point (Figure 2). This concept is at the heart of the current debate about using several small reserves or a single large one of equal area for biological conservation.

Some studies have demonstrated (for example, Dickman, 1987; Loman and Von Schantz, 1991) that more species will exist on a combination of several small reserves than on one large reserve of equal area. If maximizing species diversity were the principal goal of conservation biology, these

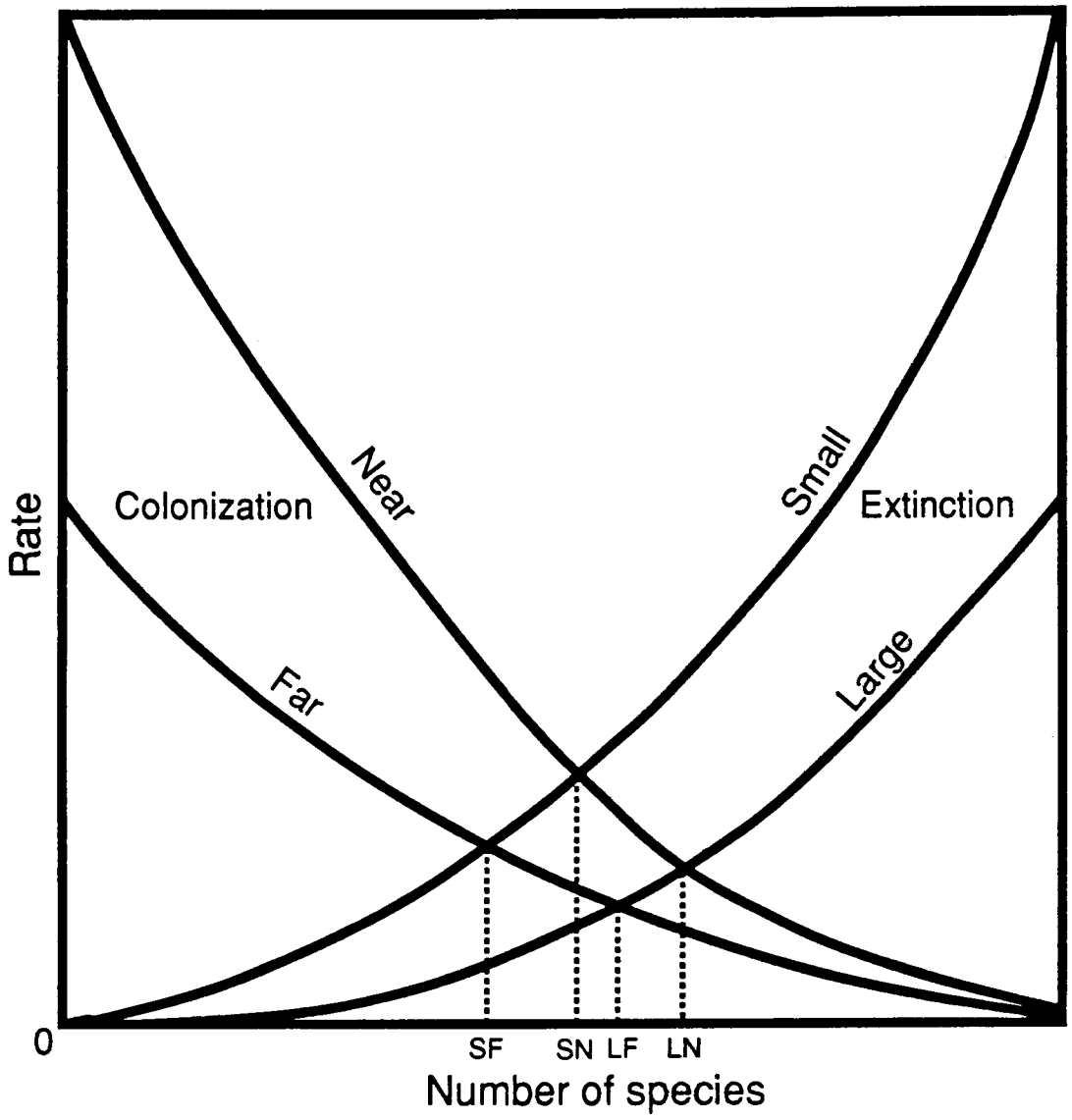


Figure 1 The equilibrium model of island biogeography. This figure shows the number of species projected to inhabit islands of different size and distance from a species source area (such as a mainland). The figure highlights the theoretical number of species resident on a small island far from a source area (SF), a small island near a source area (SN), a large island far from a source area (LF), and a large island near a source area (LN). Adapted from: Wilcox, B.A. 1980. Insular ecology and conservation. In Soule' and Wilcox (eds.), Conservation Biology: An Evolutionary-Ecological Perspective. Pp. 95-117. Sinauer Associates, Inc., Sunderland, MA.

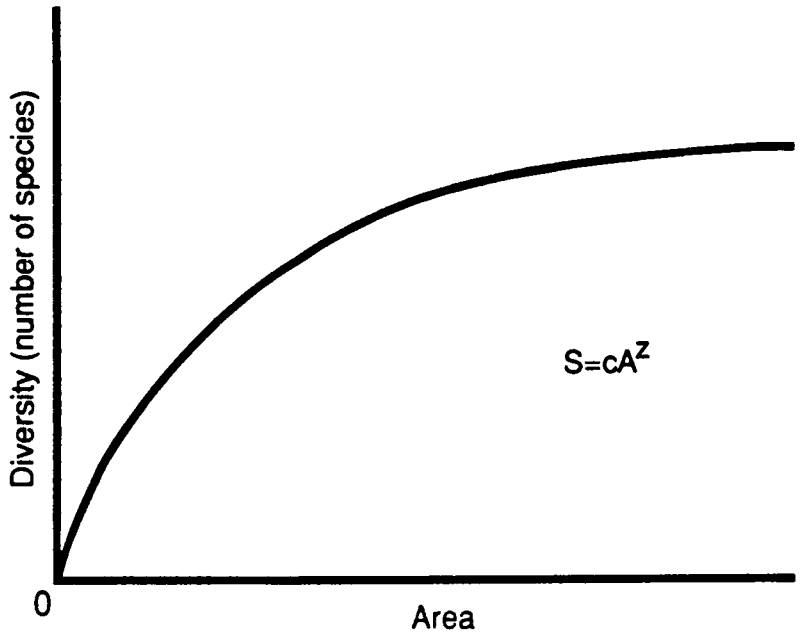


Figure 2 A schematic representation of the relationship between fragment size and species diversity. S=species richness, A=fragment area, and c and z are constants. Source: Adams, L. and L. Dove. 1989. Wildlife Reserves and Corridors in the Urban Environment. U.S. Fish and Wildlife Service, Washington, D.C.

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studies would provide a clear mandate for multiple, small wildlife reserves. But other studies have shown that single large reserves are more apt to conserve larger numbers of species, or that either strategy can be equally valuable.

One of the problems with these studies, according to Margules and Usher (1981) and Dickman (1987), is that many researchers have mistakenly assumed that maximizing species diversity is the principal goal of conservation biology. Instead, the goal of conservation biology is (or should be) to conserve the biological integrity of an ecosystem, not simply to maximize species diversity.

Species diversity may be maximized at the expense of some of the larger and more sensitive species in an ecosystem (Bennett, 1987; Harris, pers. comm., 1991). These species

are frequently of importance as keystone species. Keystone species are defined as ecologically significant species whose roles in ecosystems are such that their loss would precipitate a cascade of extinctions or faunal collapse (Ehrlich and Murphy, 1987:203). Strategies directed at increasing localized diversity may potentially reduce regional or global diversity by limiting the larger and more disturbance-sensitive species (Noss, 1983; Harris, pers. comm., 1991), whose loss can in turn negatively affect many other species in the community.

Maintaining species diversity should be an intermediate goal en route to conserving ecosystem integrity as close as possible to its natural state (termed "characteristic diversity" by Lovejoy and Oren, 1981 and Lovejoy, et al., 1983). This characteristic diversity must necessarily include the larger and more sensitive species of the ecosystem. The goal, then, is to preserve an ecosystem's characteristic diversity, not simply to maximize diversity *per se*. All things being equal, one large reserve is preferable to several small ones of combined equal area for conserving an area's characteristic diversity. Several large reserves are even better (Shaffer, 1990).

There is much debate concerning the applicability of island biogeographic theory, both for true islands and for island-like habitat fragments. Gilbert (1980) critically examined studies that supported the application of island biogeographic theory. He concluded that applying the theory to nature conservation is premature and that most of the studies supporting it are flawed in some way. Others have concluded that the theory, though imperfect in the face of real world complexity, includes general principles that hold true and are of considerable value in nature reserve design

(Adams and Dove, 1989; Shaffer, 1990). I agree with Shaffer (1990) and others that the theory can provide useful guidelines for nature reserve design in both urban and non-urban areas. In fact, according to Adams and Dove:

> Island biogeography theory has emerged as the conceptual focal point in the design of habitat corridors and reserves for wildlife (1989:10)

Guidelines From Island Biogeographic Theory for Maximizing Wildlife Conservation in Urban Greenways

The following points should be particularly useful for guiding wildlife conservation strategies in urban greenways. These points are derived from island biogeographic theory itself, the findings of the researchers mentioned above, and my own interpretations of the theory as it pertains to nature reserve design. The list is modeled after a similar Table in Shaffer (1990).

- A larger reserve will have more species than a smaller one, all else being equal.

- A single large reserve will be better able to conserve the more sensitive and often rarer species in a community than a series of smaller reserves with the same total area.

- If a reserve is close to a species rich source area, it will contain more diversity and have lower rates of species extinction than a reserve that is far removed from such an area, all else being equal.

- Continued fragmentation of a reserve is likely to reduce species population sizes and overall species diversity.

- Fragmentation or negative alteration of a source area for a reserve's species should have a similar effect on species dynamics in the reserve proper as direct reserve fragmentation, but the process will be slower.

In sum, a large greenway should contain more species than a smaller one, including some of the rarer and more sensitive species of the community. If the greenway is close to a large natural area, it should have more species diversity than a similar sized greenway further from such an area. Both the greenway area itself and any natural areas that serve as a source of species should be protected from fragmentation and/or degradation. Negative alterations to either can significantly limit the wildlife conservation value of the greenway.

Landscape Ecology

Landscape ecology is a science that is applicable to wildlife conservation in urban environments along with island biogeography (Shaffer, 1990). It is also frequently used as a perspective where landscape conservation and management strategies are analyzed, directed and evaluated. Like island biogeographic theory, landscape ecology uses mathematical extrapolation and generalizations to build a framework useful in guiding landscape level ecological understanding and biological conservation strategies. Unlike island biogeography, landscape ecology looks beyond simple measures of area and distance, and includes many other spatial and non-spatial parameters in its study of nature. Landscape

ecology incorporates some of the basic premises put forth by island biogeography (Forman and Godron, 1986).

Landscape ecology, in one form or another, has been around for a long time. As a discipline, its roots are in northern and eastern Europe (Shaffer, 1990), where it has been used for years as a land planning and land management strategy. Landscape ecology has recently attracted much attention as a useful tool and perspective for biological conservation throughout the world. This attention is warranted, for analysis at the landscape level is useful for planners, conservationists and nature reserve designers due to the scale of ecological investigation. Forman and Godron defined the term "landscape" as:

> a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout. Landscapes vary in size down to a few kilometers in diameter. Aerial photography is often useful in portraying the ecosystems composing a landscape as well as its boundary, which is usually relatively distinct, especially in vegetation structure. Localized areas of a few meters or hundreds of meters across are at a finer scale than a landscape (Forman and Godron, 1986:11)

In a broad sense, landscape ecology is a further refinement of the discipline of physical geography as it applies to biological conservation. Landscape ecology is also derived from studies of biology and ecology, but is specifically focused at the landscape level. Here I will concentrate on the elements of landscape ecology most relevant to the design of urban greenways for wildlife conservation.

The primary focus of landscape ecology is on the ecological elements of structure (the geographic and spatial

arrangement of landscape level components that together form heterogeneous landscapes), the function, or interactions of exchange among these spatial elements (the movements of energy, earth, water, plants and animals) and the changes in these properties through time (Forman and Godron, 1986).

Landscape ecology recognizes three basic types of structural landscape elements: patches, corridors and the surrounding matrix (Forman and Godron, 1986:24). These are discussed below.

Patches in the Landscape

A patch is an area in a landscape that differs from its surroundings, and, although often elongated, is not linear in form (Forman and Godron, 1986). Patches vary considerably depending on size, shape, type, boundary characteristics, age and origin (Forman, 1981; Forman and Godron, 1986). Primary types of patches are ones created by disturbance in an otherwise undisturbed area, remnants of natural habitat surrounded by disturbance, naturally occurring discrete habitats (like a wetland -- termed an "environmental resource" by Forman and Godron, 1986), and introduced or planted patches, such as a garden. Remnant habitat patches are the ones that concern us most in regards to wildlife conservation in urban greenways. Such remnant patches are actually habitat fragments and are often treated similarly to islands in the ecological literature.

Patch size and shape are critically linked to habitat type, diversity, and overall habitat extent within the patch (Forman, 1981; Forman and Godron, 1986). Patch size is directly related to the general species-area relationship, as discussed above (Bennett, 1987). Patch shape affects habitat

type, specifically the ratio of edge to interior species in the patch (Figure 3), and susceptibility to habitat-altering disturbance from outside the patch. A perfectly round patch will have the greatest amount of its area characterized as interior and the least amount as edge. A longer and thinner patch will have a larger proportion of its area characterized as edge at the expense of the interior environment (Figure 4). Round patches will be less susceptible to outside disturbance, but will have lower rates of species immigration from outside. In contrast, thinner and longer patches will be more susceptible to disturbance, but will be more likely to receive immigrating species from outside of the patch (Forman and Godron, 1986). Additionally, a small patch, no matter the shape, will consist purely of an edge community (Figure 4). These considerations are particularly important for the preservation of plant and animal communities on remnant patches embedded in urban environments.

The characteristics of boundaries between patches of different types, or between a patch and the surrounding matrix, vary considerably. Wildlife species respond differently to various ratios of edge to interior, and to differences in the structure of the edge itself in remnant patches (Patton, 1975; Harris, 1981; Ranney, et al, 1981). Harris (1981) suggested that edge type, especially edge density and the difference between characteristics of the edge community and the patch interior and adjacent land areas, are what bring about higher wildlife values, not simply "edge" *per se*.

Patch distribution in the landscape and individual patch isolation are also of importance, because the geographic arrangement of like patches may allow them to act as species source areas for one another, or simply as "stepping stones"

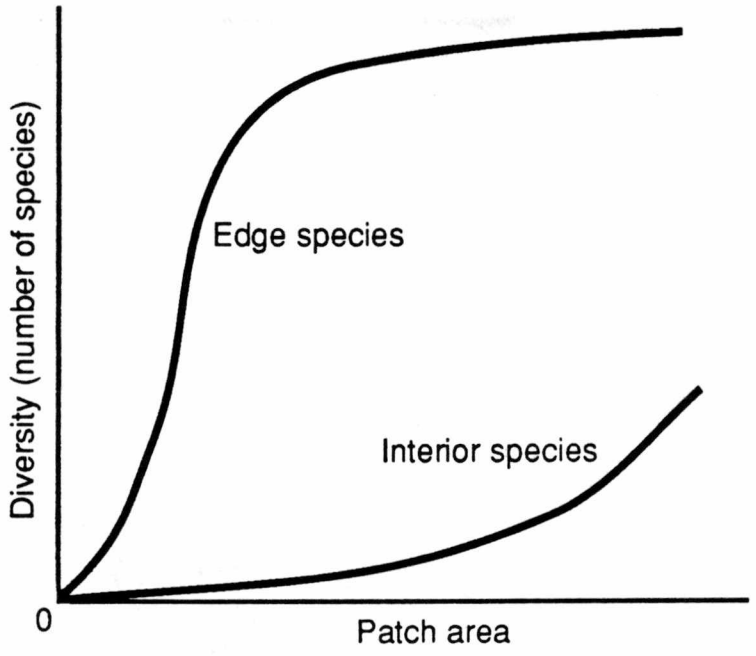


Figure 3 Hypothesized effect of patch size on edge and interior species. Adapted from Forman, R.T.T. and M. Godron. 1986. Landscape Ecology. John Wiley & Sons, New York.

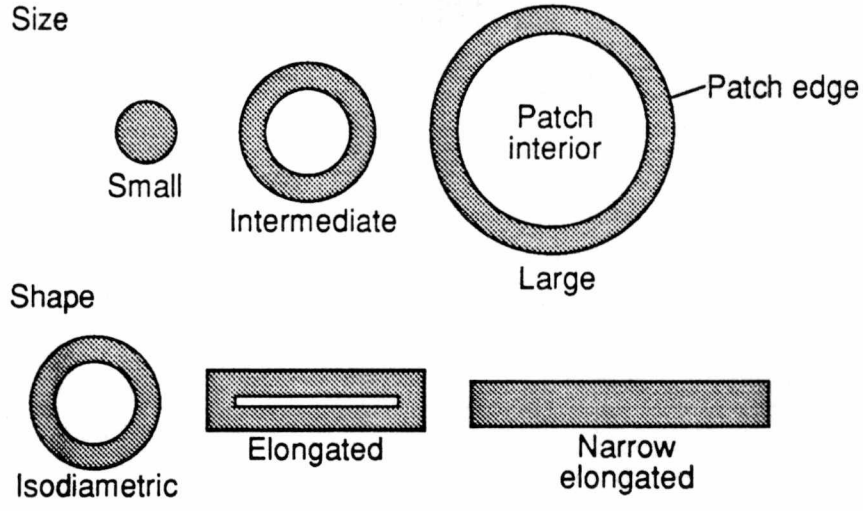


Figure 4 The effect of patch size and shape on interior and edge areas. Source: Forman, R.T.T. and M. Godron. 1986. Landscape Ecology. John Wiley & Sons, New York.

of habitat across a landscape dominated by a substantially different matrix (Forman and Godron, 1986). The closer like patches are to each other, the more interaction will occur between them, all else being equal. If these same patches were widely dispersed in the landscape, isolation would take its toll on individual species survival and eventually on overall species diversity because flows of species would be hindered between the fragments, effectively reducing individual species' populations (Gottfried, 1979; Houte de Lange, 1984; Merriam, 1984; Forman and Godron, 1986; Soulé, 1986; Friend, 1987).

Patch dynamics -- both within individual patches and between patches of like and different habitat structure -- are of critical concern for wildlife conservation in urban greenways (Leedy et al., 1978; Dickman, 1987; Adams and Dove, 1989; Shaffer, 1990). Freedom for choosing the shape, size and distribution of patches to be preserved is often missing in urban greenway projects. However, knowledge of patch dynamics is valuable for understanding how patch size and distribution can affect wildlife conservation, and how patch structure can change through time due to influences from the urban matrix, and by the extent and character of potential fragmentation.

A greenway, as mentioned in Chapter 1, is a reserve area that is predominantly linear in form. Thus, greenways are characteristically more related to the structural landscape component known as a corridor than they are to patches. Patch dynamics and conservation strategies are, however, very applicable to greenway systems -- both because the ecological dynamics of greenways and other corridors are similar to those of patches, and because the greenway systems investigated for this study all contained patches (termed

"nodes"; Forman and Godron, 1986) linked to the more linear greenway corridors.

Corridors in the Landscape

A corridor is a linear landscape feature that connects to a habitat patch of similar characteristics on one or both ends and functions as a route of exchange and movement between the corridor itself and associated patches. (Merriam, 1984; Harris, pers. comm., 1991).

Corridors are created in the landscape in the same ways that patches are created: disturbance in a line that produces the corridor itself, a linear remnant of natural vegetation surrounded by a disturbed matrix, an environmental resource corridor (such as a stream) and planted corridors, like a hedgerow (Forman and Godron, 1986). Corridors differ from patches due to their more linear form and because of the primary ecological functions they perform: the connection of similar habitat types and the exchange of energy and species between these habitats in a landscape (Forman and Godron, 1986; Lines and Harris, 1989).

In the mid-southeastern U.S., urban greenway corridors are both remnant and environmental resource corridors, for they frequently include a stream (environmental resource) and an urban gallery forest (remnant) component. Additionally, urban greenways often have a "linear lawn" component. This feature is sustained by continued anthropogenic disturbance as is the urban matrix, but differs considerably from the largely built and paved urban environment.

The principle elements of corridors that will be focused on here are ecological gradients within a corridor, true

connections between similar habitat types at either end of a corridor, within corridor interruption or fragmentation, and corridor widths.

Corridors are a curious element, for they can at once connect and divide a landscape (Forman and Godron, 1986:123). Roads, which are corridors for automobiles, are effective barriers to both wildlife and pedestrians if they are sufficiently wide and busy. Streams are corridors for the movement of fish and other aquatic animals, but are barriers to the movement of small terrestrial animals and people if the stream is wide and swift. To a lesser degree, corridors of forest, or conversely, corridors of open meadow or field can act as partial barriers to the movement of organisms that are adapted to the alternate environment.

To act as a thoroughly effective corridor between habitats, an individual corridor should maintain a thread of connectivity of similar habitat types throughout its length, and connect to similar habitat patches or larger habitat environments at either end. The longer the corridor, the more difficult it is to maintain this continuity (Harris, pers. comm., 1991). This is especially true at the continental or regional scale. At this scale, ecological gradients often exist that a corridor must cross. Examples include gradients in rainfall, temperature, altitude, soil, and land-surface form. The latter two are also factors at the landscape level.

Many of the habitat changes that occur along the length of a corridor may be due to the orientation of various habitat types in relation to the directional heading of the corridor itself. Often corridors have several habitat types represented within them, both in successive order appearing

in a cross-grain fashion perpendicular to the corridor's long axis, and as continuous bands along the corridor's length, as is the case in the La Selva Protection Zone in Costa Rica (Figure 5). There would obviously be some overlap between types that would make the real world situation more complex than this schematic representation. But, these perpendicular habitat types may reduce or stop the linear landscape element from serving as a corridor for many wildlife species, because axis-oriented habitat connectivity may not exist.

Changes due to ecological gradients along the length of a corridor on a regional or continental scale are important to understand. However, simple continuity of habitat types such as forest or meadow through conservation corridors at the scale of the landscape also needs to be maintained for linear landscape elements to function as true corridors for many species of wildlife (for example, Forman, 1981; Forman and Godron, 1986; Dendy, 1987; Shaffer, 1990). Continuity in habitat types at this scale is of critical importance for wildlife conservation in urban greenways. The habitat types of principal concern for connectivity in urban greenway corridors in the mid-southeastern U.S. are the components of 1) forest edge, 2) forest interior, 3) stream and stream bank, 4) meadow or field, and 5) upland forest. These habitats should run along the full length of the corridor, or reoccur frequently enough in the corridor so that they function as a continuous habitat for wildlife from one patch to another (Forman and Godron, 1986).

Directly related to habitat connectivity within corridors is the concept of corridor interruption and fragmentation. A linear landscape element can be a multiple corridor, that is, a corridor for several distinct habitat types, or a single corridor, for only one kind of habitat.

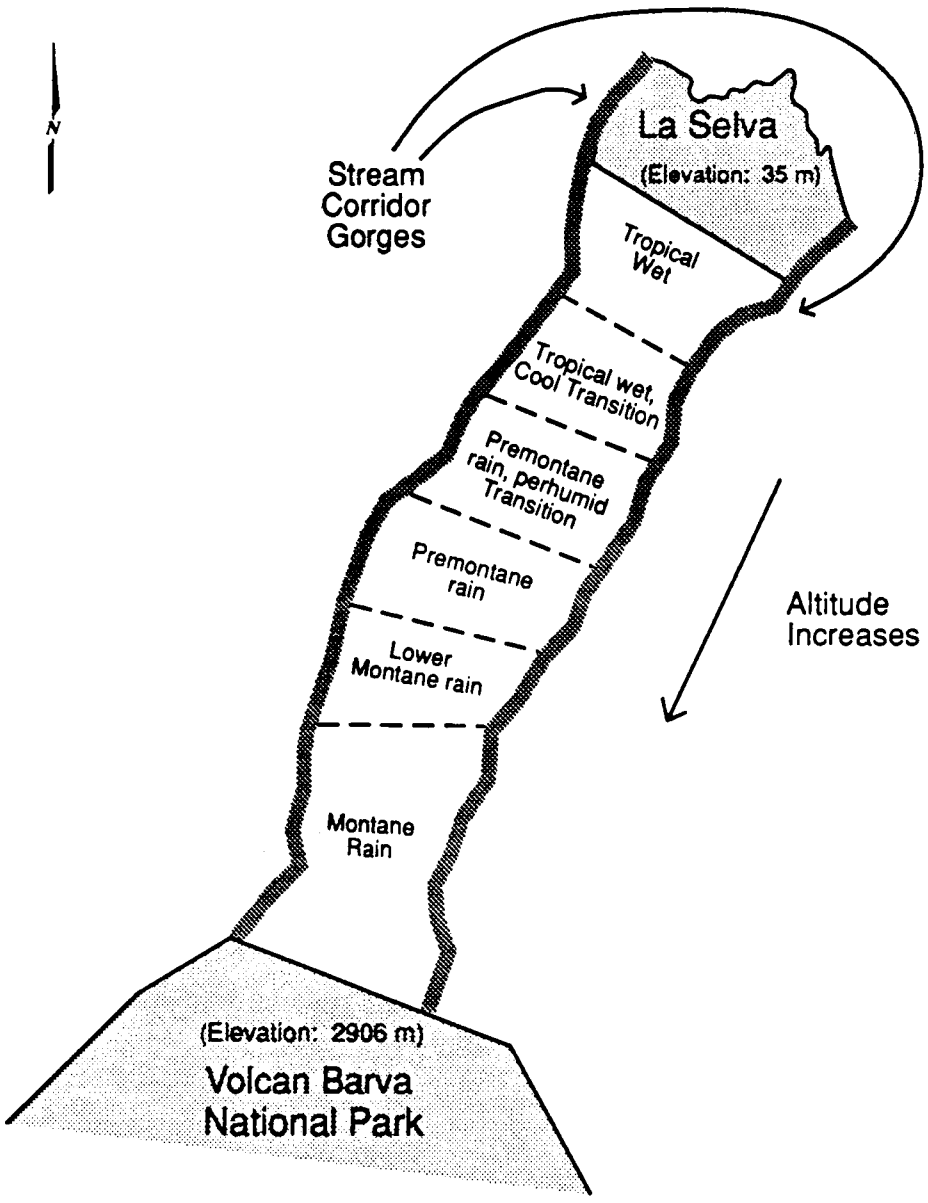


Figure 5 Schematic representation of perpendicular orientation of habitat types through the Zone of Protection, Costa Rica. Notice the more continuous habitats along the stream corridors on either side of the zone of protection. Altitudinal changes are the cause of perpendicular habitat bands. Habitat types refer to "Holdridge Life Zones". La Selva is a biological reserve in natural rainforest vegetation. Besides the Zone of Protection, La Selva is nearly surrounded by agricultural and pasture lands. Drawn using data from 1) Hartshorn, G. & R. Paralta. 1988. Preliminary description of primary forests along the La Selva-Volcan Barva altitudinal transect, Costa Rica. In Tropical Rainforests: Diversity and Conservation. Almeda, F. & C.M. Pringle, eds. California Academy of Sciences, San Francisco; and 2) Pringle, C.M., et al. 1984. Natural history observations and ecological evaluation of the La Selva Protection Zone, Costa Rica. Brenesia 22: 189-206.

Interrupted corridors may be fragmented for one or several of the habitats represented in the linear feature, or can be fragmented across the entire feature so that all habitats are interrupted.

Repeated fragmentations of habitats within a corridor, and the width and character of such interruptions, are among the critical elements to be considered in quantifying loss of corridor value (Forman and Godron, 1986). To illustrate, the fragmentation of a forested corridor that is interrupted by a super-highway is different than the same corridor being fragmented by a five foot wide meadow. However, quantification of existing exchange values of a corridor, and assessing the loss of such value, is difficult because there are other factors to be considered. These factors include corridor width and length, habitat extent and habitat character within the corridor, connected patch size and patch characteristics, the nature of the surrounding matrix, and the wildlife species of concern. For maximizing wildlife conservation value in urban greenway systems, care should be taken to preserve all of the above mentioned critical habitat types in continuous fashion through the greenways, and have the greenways link to patches of like habitat at either end.

Landscape connectivity is not simply a measure of within-corridor fragmentation. It can also be a measure of the network of corridors that cross a landscape and the number and types of patches that are linked together by the corridor system (Merriam, 1984; Fahrig and Merriam, 1985; Forman and Godron, 1986; Bridgewater, 1987). According to principles of landscape ecology, the higher the connectivity of otherwise isolated patches, the better the chances are for large-scale, long term wildlife conservation (Harris, 1984; Merriam, 1984; Forman and Godron, 1986; Bridgewater, 1987;

Dendy, 1987; Lines and Harris, 1989). Merriam's research on white-footed mice and chipmunks in fragmented woodlots outside of Ottawa, Ontario (1984:10) showed that increased connectivity actually lowered the frequency of local extinctions, increased the patch population growth rate and overall population size, and decreased the coefficient of variation of patch population size. This study showed that the number of patches connected was more important than the number of connections between the patches. As a general principle, greenways should link as many habitat fragments together as possible.

The final element of corridors to be considered is width. Width is important in the structure and function of corridors very much like size is for patches. Width controls the amount of edge to interior habitat that is found in the corridor and also affects the penetration of outside disturbances (noise, light, airborne pollutants, etc.) into the corridor (Forman and Godron, 1986). Because of the effect of corridor width on habitat type and habitat proportion in a corridor, conserving the width of natural corridors can often be useful for assuring that a particular corridor contains habitat types for several principle wildlife species throughout its length.

Landscape ecology recognizes three types of corridors that are related to width and function. The three corridor types are line, strip and stream (Forman, 1981; Forman and Godron, 1986). A line corridor is a thin corridor that is purely an edge in structure. The references to "single element" corridors above were referring to line corridors. Examples are a hedgerow for a forested line corridor and a gas pipeline right of way for a cleared line corridor.

Strip corridors are wider than line corridors. In essence, a strip corridor is wide enough to contain an interior element running down the center of the corridor, in addition to an edge on either side. Forman and Godron (1986) eluded to the fact that strip corridors do not have to be very wide to contain an interior element. In fact, their illustrations of apparent widths for a corridor to contain an interior element appeared to be less than 30 meters from one outside edge of the corridor to the other. It seems that Forman and Godron (1986) are assuming that edge is limited to the very border of a landscape element -- like the few meters that are composed almost entirely of young and shade intolerant species on a forest boundary. It is possible that many strip corridors similar in width to those Forman and Godron (1986) diagrammed would not contain a truly functional interior, or be capable of sustaining this interior over a long period of time. Ranney (et al., 1981), while studying remnant wooded patches in southeastern Wisconsin, concluded that edge effects generally penetrate into a forest fragment 10-15 meters from the forest fragment's boundary on the north, south and east sides, and 30 meters into the fragment on the west. This would mean that a wooded corridor would have to be at least 30 to 60 meters wide to contain an interior forest element, depending on individual site conditions. It would seem logical to use widths closer to 60 meters for long term maintenance of the interior. Ranney's findings, then, should be used as a guideline for corridor width planning and design for wildlife conservation in urban environments.

A stream corridor follows a linear waterway and functions to control runoff of water and nutrients, which in-turn governs flooding and erosion (Forman and Godron, 1986), and contributes to water quality downstream. Stream

corridors vary in width depending on stream size (Forman and Godron, 1986) and local topography (Hupp, 1982, 1988; Harris, 1986). Because of these differences, a stream corridor can allow the movement of edge species and, if wide enough, may contain an interior habitat element for the movement of wildlife dependent on that habitat type as well. Stream corridors are primarily conduits for wildlife that use floodway and floodplain habitats and may act as partial barriers to wildlife that do not, particularly upland adapted species. Generally speaking, edge adapted wildlife species use floodplain habitats more extensively than many interior adapted wildlife species. Many urban greenways are at least partial stream corridors with a line corridor component. On occasion a strip corridor interior habitat is also present.

Corridors are often lauded as the number one way to maintain connections in habitat patches or reconnect fragmented habitats so that biological conservation efforts will be successful (for example, Forman, 1981; Noss, 1983; Harris, 1984; Merriam, 1984; Fahrig and Merriam, 1985; Forman and Godron, 1986; Bennett, 1987; Bridgewater, 1987; Dendy, 1987; Adams and Dove, 1989; Lines and Harris, 1989; Grove, 1990; Little, 1990). However, Shaffer (1990), Simberloff and Cox (1987) and others have cautioned against blindly applying corridors and connectivity concepts to all fragments in hopes that they will work conservation miracles. Though most ecologists agree that maintaining or enhancing natural connectivity in the landscape is a sound ecological principle for wildlife conservation, there are some examples where corridors have been detrimental. For example, I was made aware of a situation in Raleigh, North Carolina where a bobcat, moving along a riparian corridor from a large state park into the city, was killed by an automobile as it tried to cross a highway that bisected the corridor. In essence,

the corridor had led the bobcat down a path that did not truly connect to a patch of appropriate habitat, and thus the cat was killed (Connors, pers. comm., 1990).

Other reasons for using caution in maintaining or adding corridors, especially in an urban landscape, are that they have such a high edge to interior ratio that predation by people and their pets and between wildlife species is enhanced, disturbances such as noise and pollution are drastically increased, and mortality from automobiles becomes almost overwhelming where corridors are constructed near, across or under busy roads.

It should be stressed that what looks like a corridor is not always a true corridor in function. Some linear landscape elements in a greenway system that look like corridors may actually be functioning like peninsulas. Forman and Godron (1986:113) define a peninsula as a narrow extension or lobe of a patch. Truncated corridors are peninsulas as well (Forman and Godron, 1986) -- they have lost their corridor-like function of energy and species exchange avenues between other landscape elements because there is no connection to a similar habitat at the peninsular end. Thus, the above example of a bobcat mortality in Raleigh, North Carolina may have occurred because the riparian corridor acted like a peninsula for that particular animal species.

Corridor integrity must be maintained for successful urban wildlife conservation, or the corridors may instead function as peninsulas, siphoning wildlife away from a reserve or a larger population, rather than acting as connections between otherwise isolated habitat patches (Figure 6). It would appear better to have no corridors than

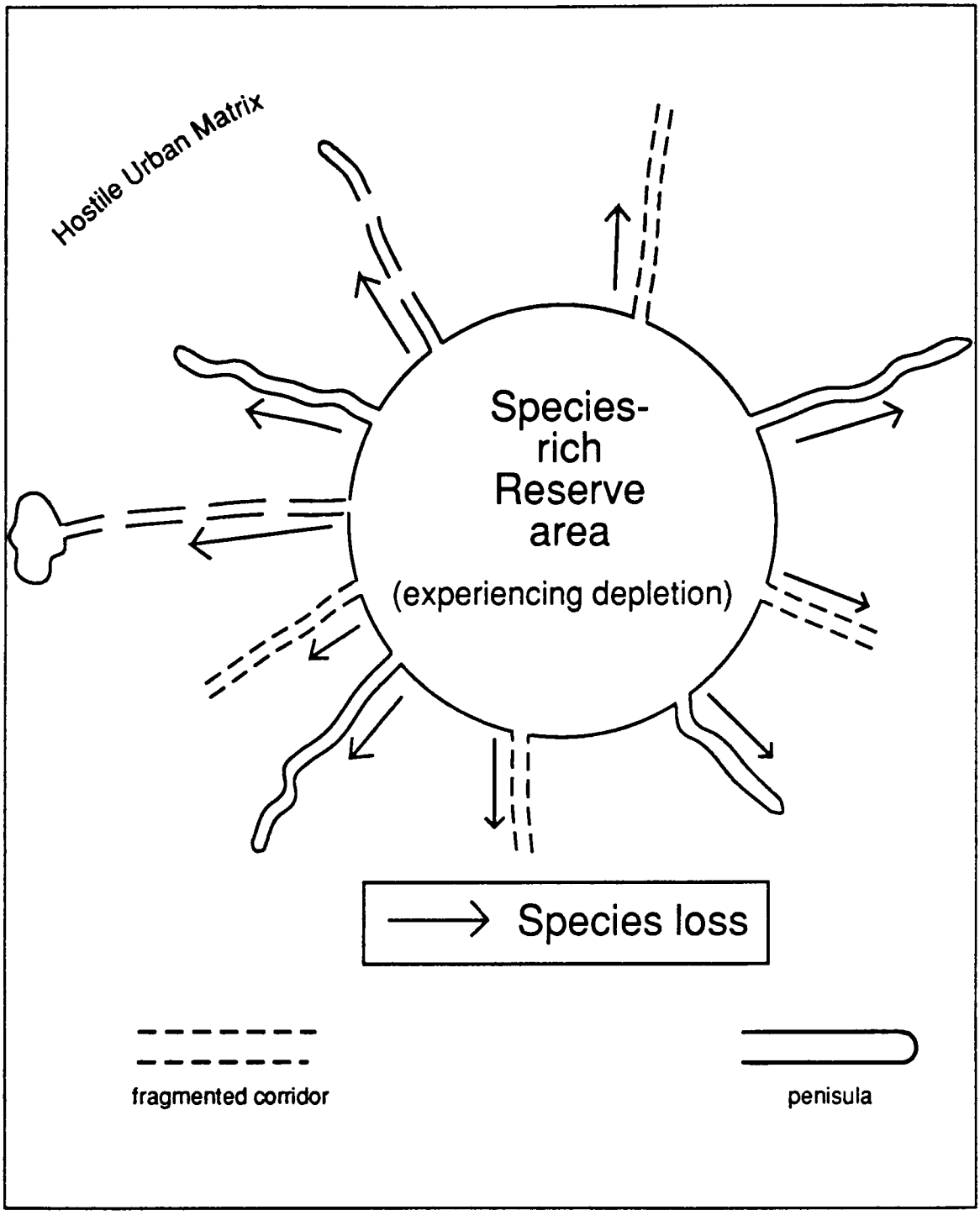


Figure 6 Schematic representation of projected species loss due to the siphoning of individuals away from a source area by peninsulas and fragmented corridors. Subsequent mortality within the peninsulas and fragmented corridors is the reason for the hypothesized siphoning effect.

to have a collection of highly fragmented corridors and peninsulas connected to a central reserve, though I am not aware of any research that tests this hypothesis. Keeping these cautions in mind, the conservation of natural landscape corridors is the best way to maintain linkage between otherwise isolated landscape patches and their associated wildlife populations. As a landscape is fragmented, it is the remaining corridors of natural vegetation that continue the exchange functions that are critical to maintaining a balanced wildlife community (Merriam, 1984; Fahrig and Merriam, 1985; Forman and Godron, 1986; Bridgewater, 1987; Dendy, 1987; Lines and Harris, 1989; Shaffer, 1990). In general, corridors should be preserved and enhanced on a case by case basis between remnant habitat patches in an urban greenway system.

Much of the caution concerning the potential detrimental affects of corridors is related to the degree that the surrounding matrix is inhospitable to various wildlife species (Merriam, 1984), as discussed below.

The Landscape Matrix

The matrix is the most extensive and connected element in the landscape and is ecologically dominant over the other landscape elements (Forman, 1981; Forman and Godron, 1986). Other landscape elements derive their identity in relation to the matrix. For example, an unbroken forest in a particular landscape would be the matrix of that landscape. A stream flowing through the forest would be a corridor. If a logging operation were to clear an area in the forest, this area would be a patch: an area of different structure in relation to the forested matrix.

With ongoing logging, the few remaining, uncut forested areas that were once part of the matrix would now be isolated remnant patches. The matrix would no longer be forest. Instead, the matrix would be composed of clearings which had coalesced: now the dominant element in the landscape. In a similar way, this is the process leading to an urbanized landscape with remnants of urban gallery forest and forest patches embedded in a landscape that is dominated both spatially and functionally by humans and their built environment.

The character of the matrix is very important for interactions between all landscape elements. This is especially true for wildlife interactions and movements between habitat patches and their connecting corridors. On an oceanic island, the colonizing species from a source area must traverse a matrix of water to arrive at the island (which acts like a patch in this case). The character of the water, in regards to the survival needs of the various dispersing animals and plants, plays a key role in how successful the dispersal and subsequent colonization of the island will be. A matrix of agricultural fields surrounding a remnant patch of forest will have a different effect on dispersing organisms (Merriam, 1984). Thus, it may be hypothesized that the hostility of the matrix to a particular dispersing species, and not just the distance from one island or patch to another, acts as a controlling agent for rates of colonization and number of species that may exist on the patch at a theoretical state of equilibrium.

The principle components of an urban matrix are roads, cars, buses and other machines, parking lots, houses, industries, offices, shops and other buildings, and people and their pets. The urban matrix, with these characteristic

elements, acts upon dispersing species in a much different way than an ocean or an agricultural field. These differences should affect wildlife movements, population dynamics, and ultimately the survival of resident wildlife in an urban area. Thus, the special character of the urban matrix (and its associations with remnant patches and corridors of natural vegetation) should be given consideration when designing urban greenways for wildlife conservation. In particular, greenways should be wider near areas of the urban environment that are particularly disruptive to wildlife, or removed from such areas all together if increased widths are not possible. Special vegetative plantings and built walls can also be employed as buffers between the urban matrix and the greenway in such areas (Lyle, 1985).

Habitat Juxtaposition, Diversity and Individual Habitat Extent

Habitat juxtaposition and diversity are addressed by landscape ecology (Forman and Godron, 1986). Individual habitat extent, however, is not. The ecological role that individual habitat extent plays at the landscape level is, however, included here for discussion because I believe that it is an under recognized element in the landscape that directly contributes to species survival rates and in the future should prove useful in measuring minimum areas of conservation reserves on a species by species basis. Thus, an understanding of all three of these concepts is important for urban wildlife conservation efforts. These three measures of habitat -- juxtaposition, overall diversity and individual extent -- will now be discussed briefly as they relate to maximizing wildlife conservation in urban greenways.

It has long been recognized that areas where a collection of habitat types come together are of special value for wildlife (for example, Martin, Zim and Nelson, 1951; Kareiva, 1982). This is called habitat juxtaposition. In these areas, many species of wildlife can meet their needs for food, water and shelter without having to traverse great distances. For urban wildlife conservation, areas where a multitude of habitats come together should be given preservation priority.

The number of different habitats in a landscape is termed habitat diversity. Measures of habitat diversity are essentially independent from habitat juxtaposition. Habitat diversity is one of the key measures of overall landscape value for wildlife conservation. Landscapes with low habitat diversity generally have lower species diversity, and conversely, landscapes with more habitats usually have a higher diversity of species. This broad generalization is particularly applicable to the small-scale areas that are of concern in this thesis.

Numerous state and federal wildlife agencies base their game management strategies on projects that increase local habitat diversity. Many research projects have studied various strategies for increasing wildlife diversity in a particular area by artificially enhancing habitat diversity (for example, Gullion, 1977; Sullivan, 1981; Marcot and Meretsky, 1983). Some studies of fragmented habitats (Bennett, 1987; Noss, 1983), however, have shown that increasing diversity at the local level may decrease diversity at a larger scale. And, as noted above, often times artificially high local habitat diversity increases the amount of insensitive "weed" species at the expense of larger and more disturbance sensitive species that are in greater

need of protection on a regional or global scale. There is much controversy concerning the value of artificially increasing local habitat diversity through purposeful manipulation of a site's terrain and vegetation.

For urban wildlife conservation, this argument takes on a slightly different twist. In the small remnant patches of natural vegetation that do exist in the urban environment, there is little chance of preserving habitat for the most sensitive and far ranging wildlife species because the required habitat of these species has long since been altered and fragmented. It may, therefore, be a good strategy to increase habitat diversity on a local scale in an urban wildlife conservation reserve, while keeping in mind that any individual species will probably require a minimum amount of a particular habitat type to continue to survive in that area. This required minimum individual habitat extent should not be sacrificed for habitat diversity *per se*.

Guidelines From Landscape Ecology for Maximizing Wildlife Conservation in Urban Greenways

Landscape ecology has much to offer to biological conservation efforts, including those in urban environments. For maximizing wildlife conservation in urban greenways, it would be wise to include the premises of the discipline. Primary points derived from landscape ecology, the associated research cited above, and my interpretations of this information as it specifically relates to wildlife conservation in urban greenways are highlighted in the following list.

- Remaining non-urbanized habitat patches should be conserved and buffered against negative outside influences where possible.

- The ecological dynamics related to patch orientation, size, shape, isolation, and general geographic distribution should be taken into account when decisions are made as to which wildland habitat areas are to be protected. These same ecological dynamics should be considered in choosing urban patches for ecosystem restoration projects.

- Patch connectivity is critical and should be preserved and enhanced on a case by case basis. To preserve patch connectivity, there should be as many alternate routes (corridors) and patches connected together in a landscape structure as possible.

- Corridors should be as wide and continuous as possible.

- Corridors should maintain continuous habitat types throughout.

- Corridors should be functionally (and not just visually) connected to other patches of similar habitat so that they can perform efficiently as routes for species and energy exchange.

- A poorly connected or overly fragmented corridor will function like a peninsula, possibly siphoning species populations away from a reserve by increasing mortality along these fragmented or peninsular routes.

- Within-corridor fragmentation should be avoided. Where it is excessive, analysis should be done to determine if it is best to "disconnect" the corridor where it diverges from a principle species source area.
- Corridors should provide a system with ecological connections for all of the principle habitat types that are required for a diverse and characteristic wildlife community.

- Negative effects from the urban matrix should be reduced where possible. Strategies for reducing these negative effects include actual reserve siting, buffer easements, zoning, plantings, fences, and even walls where necessary.

- Habitat juxtaposition should be preserved. Special plantings and landscaping can also positively increase this juxtaposition.

- Habitat diversity should be maintained and enhanced without reducing individual habitat extent below critical levels.

Landscaping for Urban Wildlife Conservation

Though reserve size, isolation and connectivity play an important and often overriding role in wildlife conservation, proper landscape management can preserve and even enhance the wildlife value of the area. Specifically, maintaining as much of the natural vegetation as possible should be given precedence. Where this is not possible, or where the natural vegetation had been removed prior to the area becoming a greenway and it is not practical to let it regenerate to its natural state, plants that are good for wildlife should be

given planting priority over ones with ornamental value only. In addition, native plant species should be given priority over exotics. Choosing native plants will help maintain a truly functional plant community. Such a plant community is considered better for wildlife than using exotic plants that are individually good for wildlife, but do not together form a natural community (Lyle, 1985). This type of landscape management in an urban greenway may increase population numbers of several species, and even help additional species reside in the greenway if the area is close in size and connectivity to that which is required by that particular species.

Plants are frequently added to urban parks and greenways for aesthetic reasons. It is therefore practical to consider choosing trees, shrubs, vines, ground covers and other landscaping designs that are good for wildlife as well as attractive to people. In this way, the limited amount of land available for conservation in an urban greenway system can provide the maximum possible benefit for wildlife.

Animals need food, water and shelter to survive. If we design nature reserves to provide easy and plentiful access to these resources there should be an increase in species populations and perhaps even in species diversity, as mentioned above. Though the land available for wildlife conservation may be limited by a multitude of factors, there is much that can be done to increase the wildlife value of the land that is available. The principle way to do this is to add selected plants and accessible sources of water to the landscape that will benefit wildlife. Plants can be useful by directly providing food and shelter for wildlife (Leedy and Adams, 1984), and can be planted to create a buffer between the reserve and the urban matrix (Lyle, 1985).

Chosen food plants should provide sustenance for a variety of wildlife and collectively be available for use throughout the year. There are many plants to choose from that are good wildlife food sources. Some, however, are better than others because they not only make up a large portion of the diet of an individual animal, but are used extensively by many species (Martin, Zim and nelson, 1951).

Two of the primary food trees for wildlife are oaks and pines (Martin, Zim and Nelson, 1951). Many animals make extensive use of acorns, from black bears to chipmunks. Likewise, pine trees are used extensively by numerous wildlife species, though it is believed that pines are used as a food source more due to their availability than because of their palatability (Martin, Zim and Nelson, 1951). Small mammals and many birds use the pine seeds, whereas several larger animals like deer, bear and beaver eat the twigs, foliage and bark. Pines and oaks of one species or another are nearly always found naturally on urban greenways of the mid-southeastern U.S. Therefore, it is not essential to add them to the environment in every situation. Where these trees are absent or few in number, they should be given planting priority. Where pines and oaks are abundant, however, additional wildlife positive vegetation should be planted to complement them.

If lists of good plants for wildlife are cross-referenced with a list of plants that are aesthetically pleasing and often used in landscaping, a compact Table emerges that can serve as a guide for plantings in urban greenways (Table 1). The list provided in Table 1 is for the mid-southeastern U.S., and focuses on trees. Plants in the Table were chosen because of their intensive and extensive use by wildlife and their aesthetic values for landscaping.

TABLE 1. Some Suggested Plantings for Both Wildlife Habitat Improvement and Aesthetics in Urban Greenways of the Mid-Southeastern U.S.

Plants	Principal Wildlife Species that Benefit	Of Principal Food Value	Of Principal Cover Value	Notes
Alternate leaf and Flowering Dogwood (*Cornus alternifolia*) and (*Cornus florida*)	Many birds; cottontail rabbit, fox, white-tailed deer	Yes	No	Fruit persists into winter.
Wild Cherry (*Prunus serotina*)	Many birds, black bear, fox, cottontail rabbit, squirrel, raccoon, chipmunk, white-tailed deer	Yes	No	Fruit, twigs, foliage and bark are all used by wildlife.
Persimmon (*Diospyros virginiana*)	Many birds, raccoon, opossum, squirrel, fox, white-tailed deer, beaver	Yes	No	Fruit sometimes persists into winter.
Black Tupelo (*Nyssa sylvatica*)	Many birds, black bear, fox, raccoon, opossum, squirrel, white-tailed deer, beaver	Yes	No	Fruit, twigs and foliage all used by wildlife. Fruit falls from tree soon after it is ripe.
Red and Suger Maple (*Acer rubrum*) and (*Acer saccharum*)	Many birds, beaver, fox, squirrel, chipmunk, white-tailed deer	Yes	No	Birds and small mammals use seeds, buds and flowers. Twigs, bark and foliage used by deer and beaver.
Hackberry (*Celtis laevigata*)	Many birds, fox, opossum, squirrel, white-tailed deer	Yes	No	Fruit persists into winter, when it is extremely important to many birds

TABLE 1 (CONTINUED)

Plants	Principal Wildlife Species that Benefit	Of Principal Food Value	Of Principal Cover Value	Notes
Beech (*Fagus grandifolia*)	Some Birds, squirrel, chipmunk, black bear, fox	Yes	No	Nuts are of most value.
Eastern Hemlock (*Tsuga canadensis*)	Many birds, squirrel, white-tailed deer	Yes	Yes	Exceptional cover, less important as food. Plant in groves for best results.
Greenbriers (*Smilax* spp.)	Many birds, cottontail rabbit, squirrel, white-tailed deer	Yes	Yes	Important winter food source. Great wildlife cover.
Virginia Creepers (*Parthenocissus* spp.)	Many birds, fox, squirrel	Yes	No	Berries persist into winter. Very important to birds and rodents.
American Holly (*Ilex opaca*)	Many birds, raccoon, fox, rodents, white-tailed deer	Yes	Yes	Beautiful evergreen tree. Offers cover and food. Berries persist into winter.
Eastern Redcedar (*Juniperus virginiana*)	Many birds, black bear, fox, rodents, white-tailed deer	Yes	Yes	Great cover.Berries, foliage and twigs are all eaten.
Red and White Clover (*Trifolium pratense* and *Trifolium repens*)	Many birds, black bear, white-tailed deer, cottontail rabbit, fox, squirrel, chipmunk	Yes	No	A favorite of many species, from rodents to bears. Beautiful when in bloom.

Notes: This table lists plants that are good for improving wildlife habitat and have ornamental value. Such a combination should prove useful for application in urban greenway situations, where both people and wildlife can benefit. Trees and other woody species dominate this list. These plantings were selected by cross referencing plants of exceptional wildlife value with lists of attractive ornamental plantings. Data Sources: 1) Little, E.L. 1989. The Audobon Society Field Guide to North American Trees: Eastern Region. Alfred A. Knopf, New York. 2) Martin, A.C., H.S. Zim and A.L. Nelson. 1951. American Wildlife and Plants. Dover Publications, Inc., New York. 3) Powers, V.S. 1981. A lot for wildlife. Tennessee Wildlife Magazine, March/April.

Please note that there are many other plants that could be included in this list. Some examples are American Elder (*Sambucus canadensis*), Carolina Buckthorn (*Rhamnus carolinia*), Hickories (*Carya* spp.), Redbud (*Circis canadensis*), Sumacs (*Rhus* spp.), Sweetgum (*Liuidambar styraciflua*), Wild Plums (*Prunus* spp.), and many berry bushes as well.

Plants can also be added to the landscape to increase wildlife cover. Most plants serve as cover for some form of wildlife, but some plants work better than others because they are denser, shroud the ground more fully, persist as a visual shield all year, or serve as cover for more animals. Many of the plants in Table 1 are good for cover in addition to being a wildlife food source. Of these, Hemlock, Eastern Redcedar, American Holly and Greenbrier offer the best cover. Cover is needed for denning and safety from predation when an animal is eating, sleeping or traveling. If cover is enhanced near natural crossings and places where wildlife stop to eat, sleep or build a home, it will be of most value. In general, cover near the ground is of paramount importance for many species of wildlife.

Landscape plantings can also buffer the reserve from outside negative disturbances. Planted rows of vegetation can reduce noise and pollution, and restrict indiscriminate entrance into the greenway by people and their pets. Evergreen trees and shrubs can reduce light into a thin strand of forest (Ranney, et al., 1981). This may allow a small amount of forest interior environment to exist where it otherwise would not.

There are several other general considerations for managing vegetation for wildlife habitat enhancement. One of

these is the maintenance and creation of vertical vegetation structure. Allowing the vegetation to grow up in certain areas adds habitat diversity by providing vertically stacked zones of different light and humidity levels, which in turn allows various animals to make use of these environments (Merriam, 1984; Forman and Godron, 1986). Increased vegetation verticality also improves cover for wildlife.

As mentioned above, habitat juxtaposition and overall habitat diversity are of value. Designing and arranging plants in the landscape to maximize both, while retaining individual habitat extent above minimum levels, is a good urban wildlife conservation strategy. For example, managing areas for meadows and old fields through periodic mowing, and managing other areas as mature, uneven aged forest by girdling a few trees to create snags and cutting others down to produce fallen logs and small openings in the canopy for new growth, is a preferred strategy for improving habitat diversity and quality. Once the initial snags, downed trees and clearings are produced, the forest environment will naturally perpetuate the uneven age stand for many years.

Aside from plantings, the most common landscape design for wildlife is to add a permanent water source to the environment (Leedy, et al. 1978; Leedy and Adams, 1984; Adams and Dove, 1989). Water in a landscape -- be it a pond, lake, stream or wetland -- is extremely valuable for wildlife. Usually, the addition of water to the urban landscape is by way of a created pond, storm drainage containment basin, or wetland. Water is so important to wildlife that these strategies have received a lot of positive recognition -- and it is deserved. It should be noted, however, that storm runoff from urban surfaces contains many contaminants. There is great concern that ponds made with this runoff water will

concentrate these contaminants and that they will move up the food chain. There has been little research concerning the detrimental effects of contaminant concentration in man-made water containments for wildlife, but it is needed. If contamination can be kept in check, the addition of permanent water reservoirs in a greenway where they are scarce is highly recommended for wildlife habitat improvement.

Finally, all of the above recommendations must take into consideration the base state of the greenway environment and its attendant limitations. Soils, slope, aspect, water resources and the wildlife and plants that already exist should be inventoried and play a role in guiding habitat improvement projects.

The Design Process

The process of designing urban greenways for maximum wildlife conservation value should begin with choosing which natural areas in the urban environment are to be preserved, and deciding on ideal widths for greenway corridors. The larger and closer preserved areas are to one another, the better they will be for wildlife conservation. When some choice exists as to which areas are to become part of a conservation greenway system, the natural areas that are concentrated geographically and largest should be selected over smaller and more isolated ones. This way, connectivity between the patches is more likely and there is also a better chance of preserving larger areas of habitat, including interior forest environments (which may be absent in smaller remnant patches). In addition to size, patch shape can affect habitat composition and susceptibility of disturbance from the urban matrix. The more connected are preserved areas, both to one another and to larger natural areas

outside of the greenway, the better the chances that the system will have greater species diversity, and include the larger and more disturbance- and space-sensitive animals that are typically absent in the urban environment.

For best connections between patches, urban greenway corridors should be wide enough to contain all of the most important habitats for wildlife. These include forest edge, forest interior, stream and stream bank, meadow or field, and upland forest. These habitat types should run the full length of the corridor or reoccur frequently enough so that they function as a continuous habitat from one area of the greenway to another. The forested part of the greenway corridors should be at least 60 meters wide for an interior forest to be present. Ideally, the greenway corridors should be even wider so as to include a meadow area, and even an upland forest if the local floodplain isn't too wide for its inclusion.

Habitat connections within preserved corridors, and connections between corridors and patches should be protected and enhanced. Corridors that do not functionally connect to patches or to other corridors will not serve well as routes for animal movement. On the contrary, such unconnected areas can become traps for wildlife: where unsuspecting animals can be killed by automobiles, domestic pets, or other predators. If a poorly connected or overly fragmented corridor is found to be more detrimental than beneficial to wildlife, it is best to "cut-off" the corridor (from the point of view of the more disturbance- and space- sensitive wildlife species) from the rest of the greenway system. This can be done by reducing vegetative cover in the area where the fragmented corridor diverges from the rest of the system, erecting a fence, or using the large area where the forest was removed

for a parking lot and/or services such as restroom facilities for greenway patrons.

Within this ideally wide and interconnected greenway system, habitat juxtaposition and diversity should be preserved and enhanced without reducing individual species-centered habitat extent below critical levels. For example, if there is sufficient interior forest along the corridor but no fields or meadows, it may be wise to cut some of the forest and allow meadow succession to occur. Mowing every several years will maintain the meadow.

This newly created forest boundary, and the meadow itself, are ideal locations for adding wildlife positive plantings. Eastern Hemlock, Persimmon, Dogwood, Wild Cherry and Black Tupelo trees (among others from Table 1) are all good choices of plantings to add to urban greenways in the mid-southeastern U.S. for wildlife. Areas in the newly created meadow can be sown with red and white clover (and native wildflowers), which are enjoyed as food by many species of wildlife and are also quite beautiful when in bloom. Even in greenways that are much more manicured than the idealized one being discussed here, plants from Table 1 should be selected from when adding plants for aesthetic reasons.

As discussed in the landscape design section, special vegetative buffers may be beneficial to add to the border of corridors and around preserved patches in greenways that abut particularly disruptive areas of the urban environment. Combinations of evergreen trees and shrubs are useful as visual and auditory screens, filters for pollution, and also restrict indiscriminate entrance into the greenway by people and their pets.

In greenways where water (or clean water) is scarce, the addition of a permanent water source in the landscape is of paramount importance for wildlife. When doing so, these impoundments should be designed to have a gradual bank with swampy environs on at least one side. Such an arrangement facilitates the growth of aquatic vegetation, which is itself valuable as habitat for many fishes and amphibians, and is used as food for many land dwelling animals. An artificial water source should also be deep enough, at least in one spot, so that water will always be available, even in the coldest or driest times of year. Furthermore, there should be good plant cover (such as an extension of the forest, or a planted stand of trees with thick undergrowth) to the margin of the pond in at least one place to offer cover and facilitate animal movement to the water's edge. All of the above landscaping strategies -- from plantings to water impoundments -- can increase wildlife value in even small and isolated reserves.

I concede that the urban environment is not always as conducive to designing a wildlife-positive greenway system as is depicted here. When it is not, the ideals set forth in this section should still be used as guiding principles with which decisions can be made regarding greenway design and management. Protect patches and corridors from further fragmentation or degradation. Preserve corridors to be as wide as possible. Protect and enhance connectivity throughout the greenway system. When a corridor is thin, make sure that as much of it as possible is forested. Add wildlife-positive plantings along the greenway trail's edge, while leaving natural vegetation in place on either side. Add small ponds and vegetative buffers. Do not let greenway or urban structures (such as bridges and trails, roads and parking lots) degrade the preserved areas, or limit what

natural landscape connectivity does exist. These principles, if followed diligently, will preserve and enhance the wildlife conservation value of the greenway system. This is how to design and manage an urban greenway system for maximum wildlife conservation value.

PART II

Assessing the Wildlife Conservation Value of Urban Greenways in the Mid-Southeastern U.S.

Chapter 3

Study Areas

The second part of this thesis is concerned with assessing the wildlife conservation value of a selection of urban greenway systems in the mid-southeastern U.S. The surveyed greenway systems can then be compared to what is often stated or implied in many greenway plans concerning the benefits to wildlife that will accrue with the development of an urban greenway system. Some of the information covered in the first part of the thesis will be used to evaluate the "wildlife-friendliness" of greenway connectivity, vegetation management, corridor widths and adjacent land uses. The presence or absence of chosen umbrella species will be considered the final measure of whether the individual greenway segment is contributing to wildlife conservation. The second part of the thesis begins with a discussion of the study sites surveyed for this research.

I have chosen six urban greenway systems in the mid-southeastern United States as representative of urban greenways throughout the region (Figure 7). These urban greenway systems were chosen for investigation because of the characteristics of the individual systems, the types and sizes of the cities in which they are located, and the general promise of at least some wildlife conservation value inherent in these greenways.

This was either stated in the individual greenway master plan, specified by the greenway planner or other official when discussing the greenway with me, or mentioned in a public relations oriented pamphlet. The amount of wildlife conservation promise and the relative obligation for the

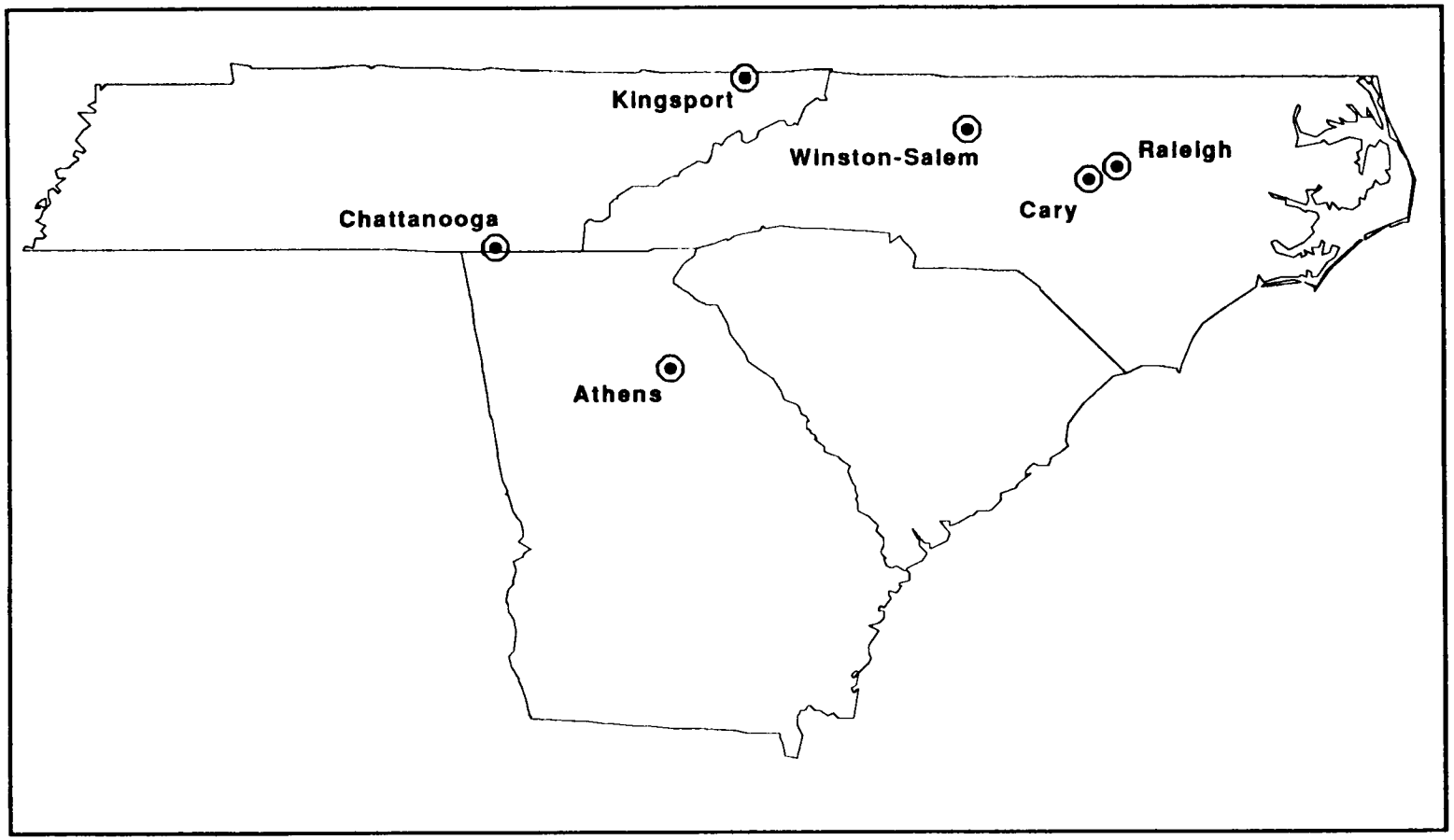


Figure 7 Locations of Studied Urban Greenway Systems

inclusion of wildlife-needs varies considerably among the surveyed greenways.

I believe that the surveyed greenway systems are fairly representative of urban greenways in the mid-south, covering much of the expected variation in greenway design and size. The Capital Area Greenway System in Raleigh, North Carolina consists of 27.95 miles of trail spread among 19 different segments throughout the city. In contrast, Chattanooga has one trail with a length of about 1.5 miles. The other greenway systems fall somewhere in between these two in regards to length and number of trails. Some of the greenway segments are manicured like a golf course, others are left in natural vegetation. Some trails are wide and paved, and punctuated with workout stations and playgrounds, while others more closely resemble hiking trails, and offer views of secluded swamps and diverse forests.

The sizes of the cities in which the greenway systems are located vary considerably. Kingsport, Tennessee, with a population of 36,365, is the smallest city with a greenway included in the study. Raleigh, North Carolina, with a population of 207,951, is the largest. Likewise, the character of these cities varies a great deal, reflecting the differences found in much of the urban mid-southeastern area. I will now introduce and discuss the greenway systems studied for this research. These are treated alphabetically by city. The brief introduction for each city is followed by a discussion of the general characteristics and qualities of the greenway system in that city.

Athens, Georgia

Athens, Georgia is a small city of 45,734 located on the piedmont of north-central Georgia. Athens is the home of the University of Georgia, which has 28,395 students. Because of the city's relatively small size and the large University located within it (students account for more than half of the city's population), Athens is truly an archetypal college town. There is, however, some industry in the city besides the University.

The city center of Athens is located atop a hill overlooking the Oconee River. It is the oldest area of town, and reflects its age in its tightly woven form and the many antebellum buildings that define its architectural style. For such a small city, though, Athens is rather diffused beyond this small downtown. There are several major roads with extensive strip development that partially surround the city. Many residential and commercial areas in Athens are comparatively new. This new, automobile-oriented development has stretched quickly outward from the center city, leaving numerous areas fairly close to the downtown undeveloped. One does not have to travel far from the city center to find patches of woods and scenic river corridors, often interspersed between busy roads and newer housing developments.

At the time of study, the greenway system in Athens consisted of several tracts of land without trails along different forks of the Oconee River, and one newly opened trail along Sandy Creek, called Cook's Trail. For all greenway systems investigated for this study, only greenway sections that include a trail were surveyed. Thus, Cook's Trail was considered to be the greenway in Athens for the

purposes of this study. Cook's Trail runs for a distance of 4.1 miles north and east of the city proper, linking Sandy Creek Nature Center and Sandy Creek Park (Figure 8). The trail is an unpaved footpath winding through forest and swamp. It is described by Walt Cook, the man that the trail is named after, as pseudo wilderness (pers. comm., 1991). Development along the trail is light. Several large tracts of forest and farmland are adjacent to the trail property, with groups of newer homes clustered in a few locations, which are easily visible from the trail in winter.

Cary, North Carolina

Cary, North Carolina, population 43,858, is an affluent suburb adjacent to Raleigh. Once a sleepy farming town in the rolling hills of the North Carolina piedmont, the town has grown recently as upwardly mobile Triangle area professionals have relocated there to escape the increasing frenzy found in the urban centers of Raleigh and Durham. Being a very new suburb, the town is extremely spread out and automobile oriented. Its downtown consists of only two blocks of specialty retail shops. The principal arteries running through and around the town have many new shopping centers and business parks. The majority of new residential development in Cary is in large planned unit developments, which often form suburban pockets surrounded by remnants of the mixed hardwood and softwood forests that are characteristic of the North Carolina piedmont. This diffused urban character has left many areas throughout the town in forest and field.

Cary has taken advantage of its position as a desirable place to live, and early on introduced zoning laws that required large developments to donate so many acres of land

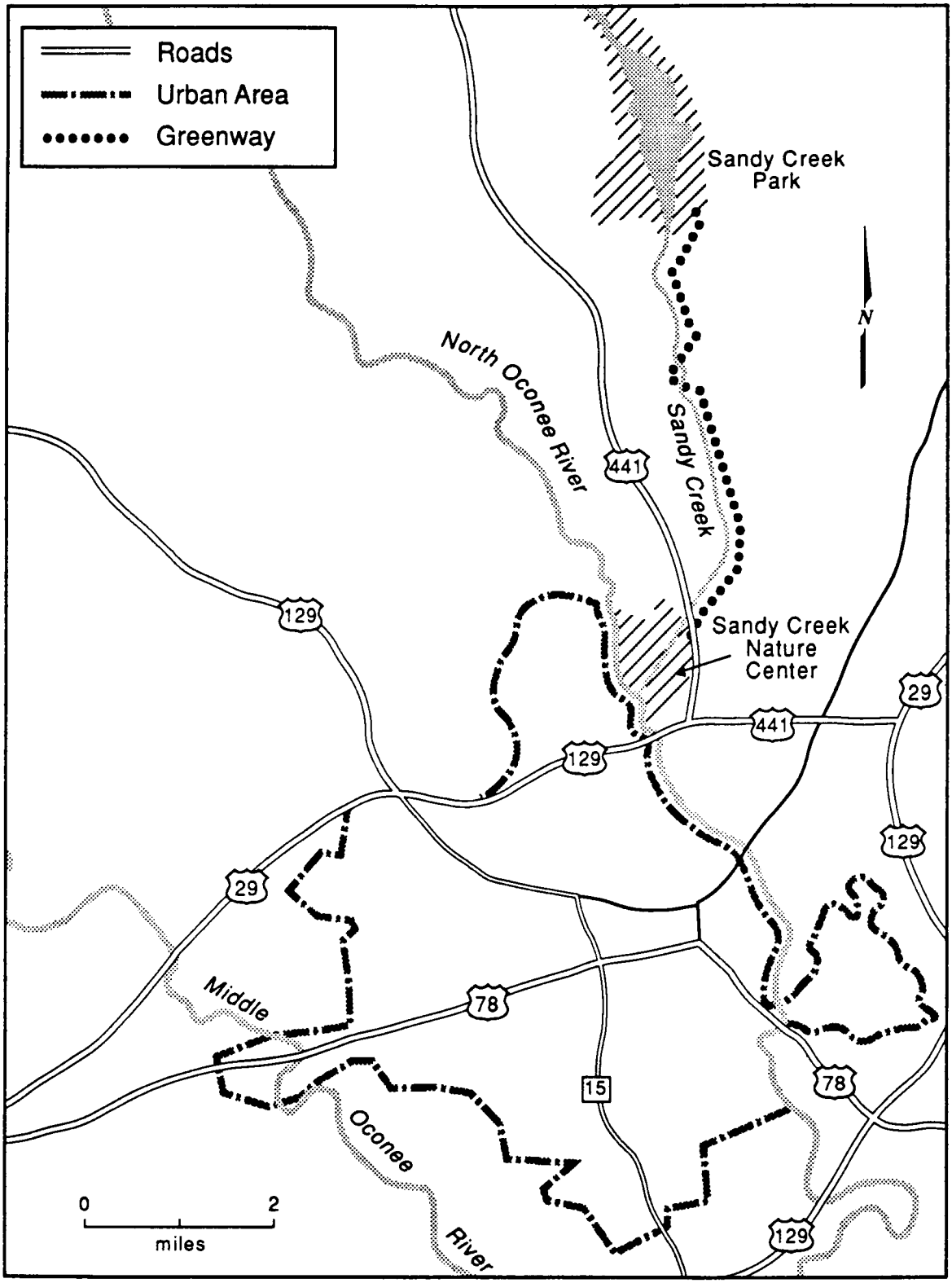


Figure 8 The Athens/Clarke County Greenway, Athens, GA.

to the city per acre of land developed. The developers most frequently would give land that was in the floodplain of the many streams that run through the town, for this land could not be built upon anyway. In turn, the town built trails along these streams for public recreation, and community image improvement. This recreational trail system later became a popular amenity and selling point for the adjacent developments.

At the time of study, Cary had 7.1 miles of public greenway trail in place, spread throughout six principal greenway sections (Figure 9). A seventh section, called the Swift Creek Trail, was being planned (Brown, pers. comm., 1991). The character of the various sections, and their adjacent land uses, varies from trail to trail in the system. Many of the trails closer to the original center of town are on thinner wooded riparian corridors that thread through more densely developed residential neighborhoods. These trails also tend to be relatively short in length. The two largest trails in the system are on the town's periphery to the north and west (Cary Planning Department, 1991). These larger trails are built on wider natural corridors and some areas of these trails were put in place prior to nearby development (Brown, pers. comm., 1991; Clark, pers. comm., 1991). The Cary greenway trails are surfaced in either crushed stone or asphalt. All of the trails run along streams. The longest trail is two and a half miles, the shortest is 4/10 of a mile (Cary Planning and Development Department, 1991). Widths of the publicly owned corridors vary greatly from trail to trail, and from one part of a trail to another. Thus far there is very little maintained trail connectivity between the individual sections of the greenway.

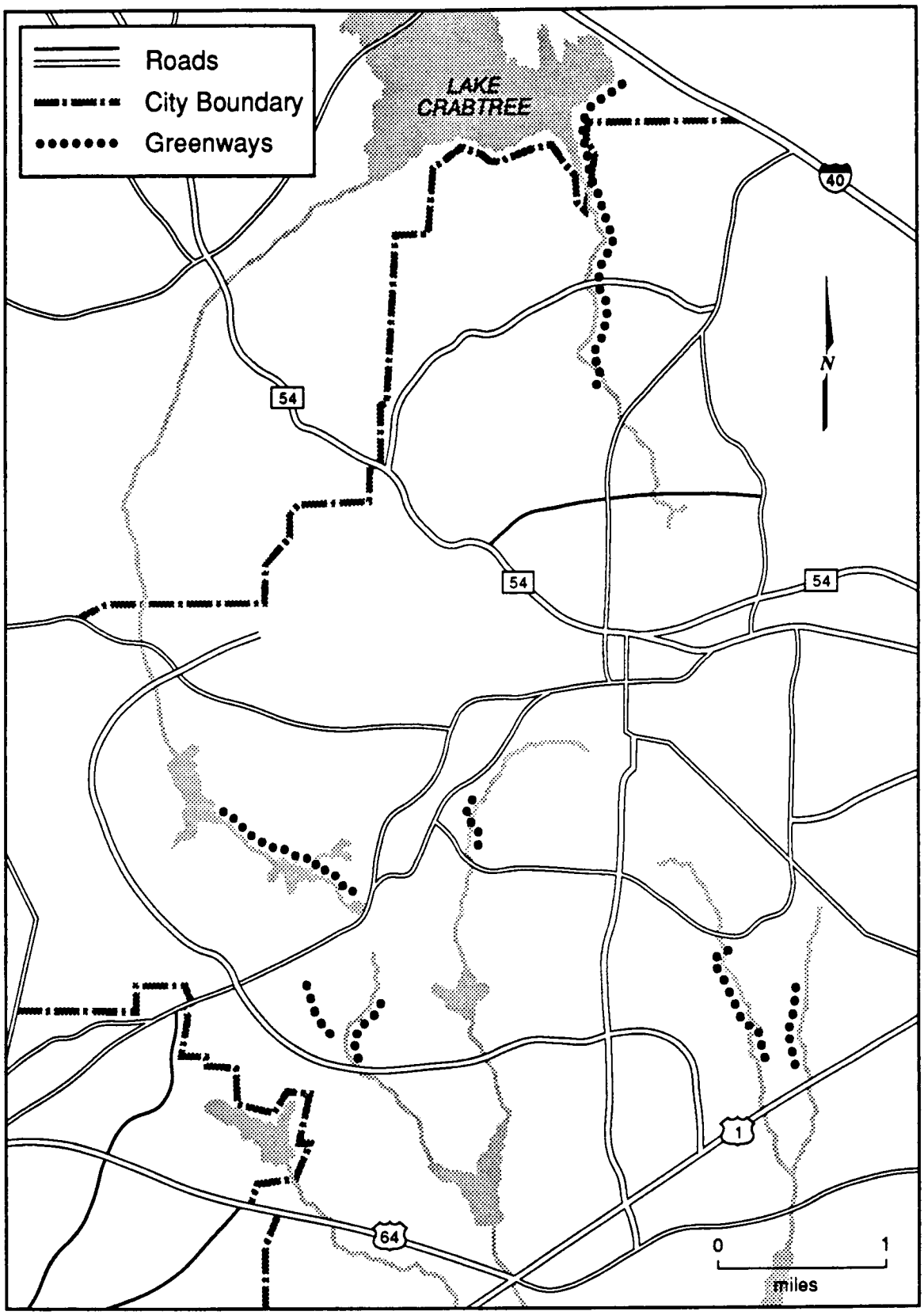


Figure 9 The Cary Greenway System, Cary, NC.

Chattanooga, Tennessee

The city of Chattanooga is on the Tennessee river, at the confluence of a myriad of ridges and valleys in southeastern Tennessee, at the Georgia border. This intersection of transportation routes gave the city the early nick-name of "the funnel of the universe" (Davidson, 1946). The city has always been an important trading and transportation center, and after the Civil War, it became a major manufacturing center as well. The development of the Tennessee Valley Authority in 1933 added greatly to the intensity of industrial development and production here.

Today Chattanooga has a population of 152,466. There are more than 600 major industries in the area, producing at least 1,500 different products. Chattanooga also has a sizable wealthy elite. Many fortunes have been made in manufacturing, transportation and real estate since the Civil War.

The city has a fairly large downtown area with densely packed adjacent residential sections. The three principal ridges that meet at Chattanooga bring forests mixed with up-scale residences within easy view of the downtown. Much development since World War II has been beyond the central city, especially to the east and north of the city proper and, to a lesser extent, in the valleys between the major ridges west of the Tennessee.

The North Chickamauga Creek Greenway is the one trail in the Chattanooga area studied for this research project. There is a pedestrian walkway nearer to downtown, along the Tennessee river, known as "Riverwalk", but the trail corridor here is so thin and the vegetation so managed that wildlife

conservation value was judged to be too insignificant to warrant investigation.

The North Chickamauga Creek Greenway is located to the north of the city, and across the Tennessee River from the bulk of urban Chattanooga (Figure 10). This trail is along North Chickamauga Creek, just upstream from the confluence of the Creek and the Tennessee river, which meet at the North Chickamauga Dam. The trail is in an area characterized by several busy arteries, a few housing developments and a good deal of farm land interspersed with forests and low density, exurban housing. The greenway borders North Chickamauga Creek to the west, and the publicly owned 180 acre Spangler farm to the north. The trail is to be expanded along the Creek into the Spangler farm property in the near future.

Kingsport, Tennessee

Kingsport, Tennessee, originally settled in 1761, was a small village on the Holston River until World War I. The town then metamorphosed into a planned industrial city. Today, the city is a major industrial center with a population of 36,365. It is part of the Johnson City-Kingsport-Bristol, Tennessee-Virginia metropolitan area. The largest employer in state, The Tennessee Eastman Chemical Company, is located here, as is The Kingsport Press, one of the largest book producers in the world.

Kingsport is a small, working-class city which is oriented east-west along its long axis between parallel ridges (Figure 11). The downtown area, designed like half a spoked wheel, is large relative to the size of the city. Much of the city's commercial development, however, lies along 11W to the east of downtown, and other principal

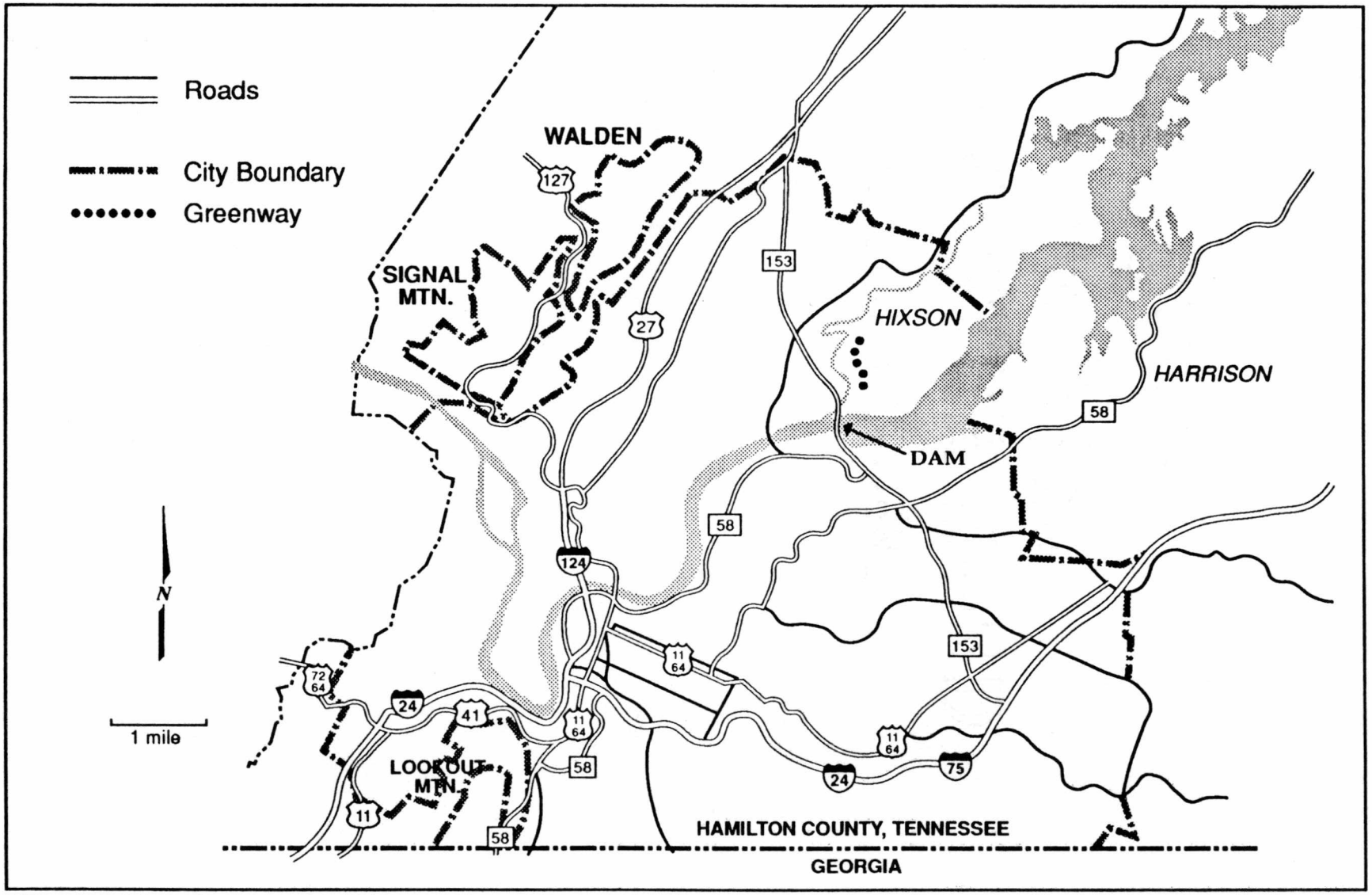


Figure 10 The North Chickamauga Creek Greenway, Chattanooga, TN.

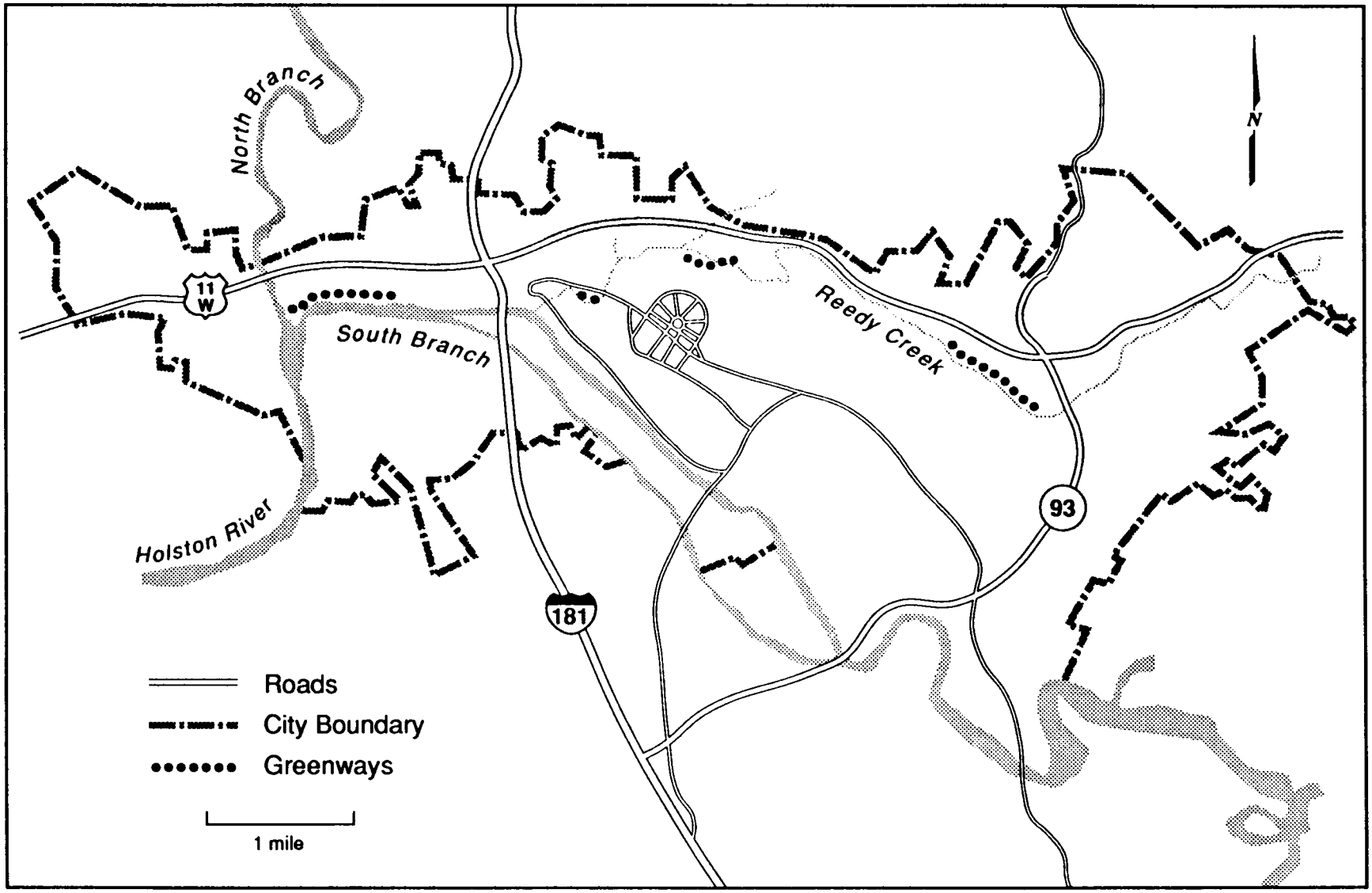


Figure 11 The Kingsport Greenbelt, Kingsport, TN.

arteries running between Kingsport and its neighboring cities of Bristol and Johnson City. There are several large, fairly compact residential areas near the center city, and a great deal of low density suburban development to the east and west.

The Kingsport greenway system, called the Kingsport Greenbelt, consists of four segments with a total of 3.7 miles of trail. These trail sections are on the South Branch of the Holston River, and along Reedy Creek as it runs through the city from east to west (Figure 11). All trails are surfaced in asphalt. The longest trail section runs along Reedy Creek parallel to 11W, in eastern Kingsport. This section is 1.5 miles in length. The shortest section of the greenway system is 0.25 miles of trail that forms a crescent on the inner bend of Reedy Creek as it flows by Cloud Park near downtown.

The width and character of the various corridor sections, and the adjacent land uses, vary greatly from one greenway section to another. Some sections are maintained like city parks, with mown lawns and a few scattered trees, while others thread through wetlands and bottomland hardwood forests. Corridor widths vary from around 30 feet to more than 1,000 feet. Adjacent land uses range from busy thoroughfares and industrial development, to residential neighborhoods of varying density, to large commercial strips. There is a great deal of developed land along the streams between the existing greenway trails. Thus, there is very little continuity in the natural landscape alongside these water courses, and little trail connectivity between these existing greenway sections.

Raleigh, North Carolina

Raleigh is the capital city of North Carolina and the home of North Carolina State University. Besides being a seat of government and an educational center, Raleigh is now a center for electronic equipment manufacturing and food processing. The central city's planned layout is that of a square. There are many fine older homes in this area, interspersed with government offices, businesses, and industrial buildings. The central business district itself is very small compared to the size of the city. A beltway encircles much of Raleigh, excepting the newer northern and western portions (Figure 12).

Raleigh has grown rapidly in recent years, particularly to the north and west. Most of this development typifies modern suburbia: large commercial strips and malls are found along major arteries, with dispersed residential districts between these principle thoroughfares. Patches of forest and thin stream corridors wind between and among these urban elements but are interrupted by the many highways and wide boulevards that serve to connect these suburban developments with each other and to the city center.

The Raleigh greenway system, officially called the Capital Area Greenway System, is extensive. It has 27.95 miles of trail, divided among 19 different greenway sections. These trails run through much of the city (Figure 12). This system was begun in 1974 and was based on Bill Flournoy's 1972 master's work in the Landscape Architecture Department at North Carolina State University (see discussion on page 6). As mentioned in Chapter 1, the Raleigh greenway system was the nation's first comprehensive, city-wide trail network. These trails take advantage of the impressive

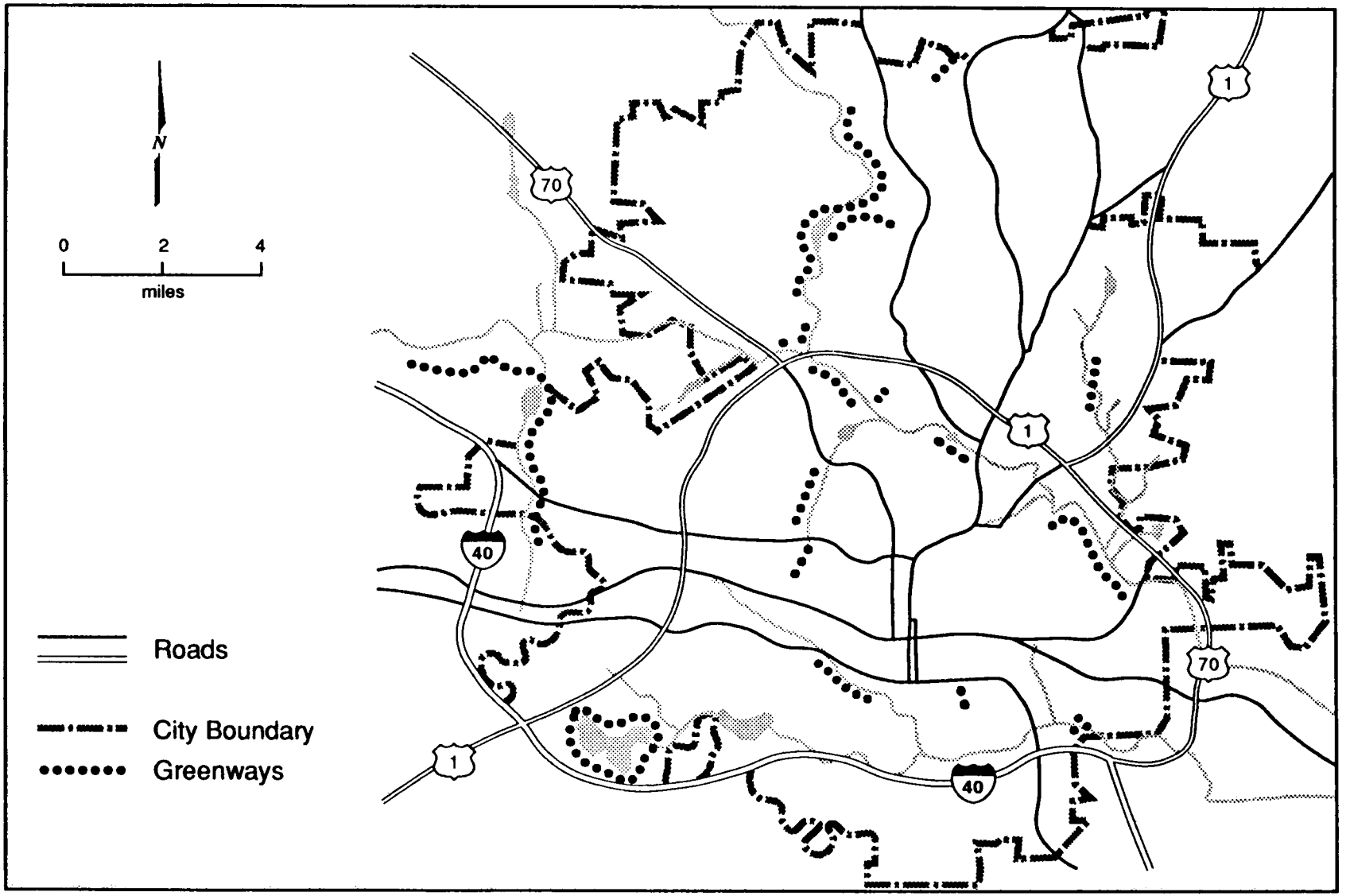


Figure 12 The Capital Area Greenway System, Raleigh, N.C.

network of streams that runs through the city. All but two of the trails are along at least one of these urban streams. The excepted two trails encircle large man-made lakes to the north and west of the city: Shelley Lake and Lake Johnson, respectively.

The character of the trails, their length, and the types of adjacent land uses vary considerably from place to place within the greenway system. Most of the trails are asphalt surfaced, but some sections of these trails are unpaved. One trail, the Loblolly Trail, more closely resembles a back-country hiking trail, with steep inclines and a thin, dirt path. This trail, at six miles, is also the longest in Raleigh. The shortest section of the greenway system is Lassiter Mill Trail, which is 0.2 miles long. The character and qualities of the individual trails also vary a great deal. The West Millbrook Trail, in extreme north Raleigh, is essentially a series of sidewalks. Other sections of the greenway system include Beaver Dam Trail, which occupies a median between parallel residential streets, Fallon Creek Trail, which links a city park with ball fields to the more natural setting of a stream corridor, and Brentwood Trail, which links several residential areas, a school and a park. Additional trails exhibit other characteristics. Land uses adjacent to the trails range from the 5,000 acre Umstead State Park at one end of Loblolly Trail, to dense urban development and busy streets, which are found next to Rocky Branch and Little Rock Trails, for example. In all, the Raleigh greenway system exhibits a tremendous variation in character from one section to another.

Winston-Salem, North Carolina

Winston-Salem, with a population of 143,485, used to be two separate cities located amidst the rolling hills of the central piedmont of North Carolina. The city of Salem was originally settled by members of the Moravian Church in 1766, and the younger city of Winston was established as an industrial center in 1849. The city of Winston-Salem was created by the merging of these two communities in 1913.

Winston-Salem is first in industry in the Carolinas and one of the chief cities of the South. R.J. Reynolds founded his tobacco company in Winston in 1875. Other area manufacturers are The Hanes Group, makers of nylon hosiery, Strohs Brewing Company, and Westinghouse Electric Corporation. There are nearly 300 smaller industries, and several major regional banks also located in the city. Winston-Salem shares the regional spotlight with it's neighboring cities of Greensboro and High Point. Together, these three cities form the piedmont Triad metropolitan community of Greensboro - Winston-Salem - High Point.

Winston-Salem's downtown is proportionally larger than Raleigh's. There are many tobacco warehouses, banks and offices in this locale, as well as a relatively extensive retail area. Old Salem, the original center of the Moravian community, lies about a mile south of downtown and is a tourist attraction. Besides these two areas, much of Winston-Salem resembles Raleigh. Much of the community's growth, like Raleigh's, is very recent and reflects the influence of the automobile. Interstate 40 threads through the city from east to west, just south of the downtown (Figure 13). There are many commercial developments along this thoroughfare, especially at the eastern and western

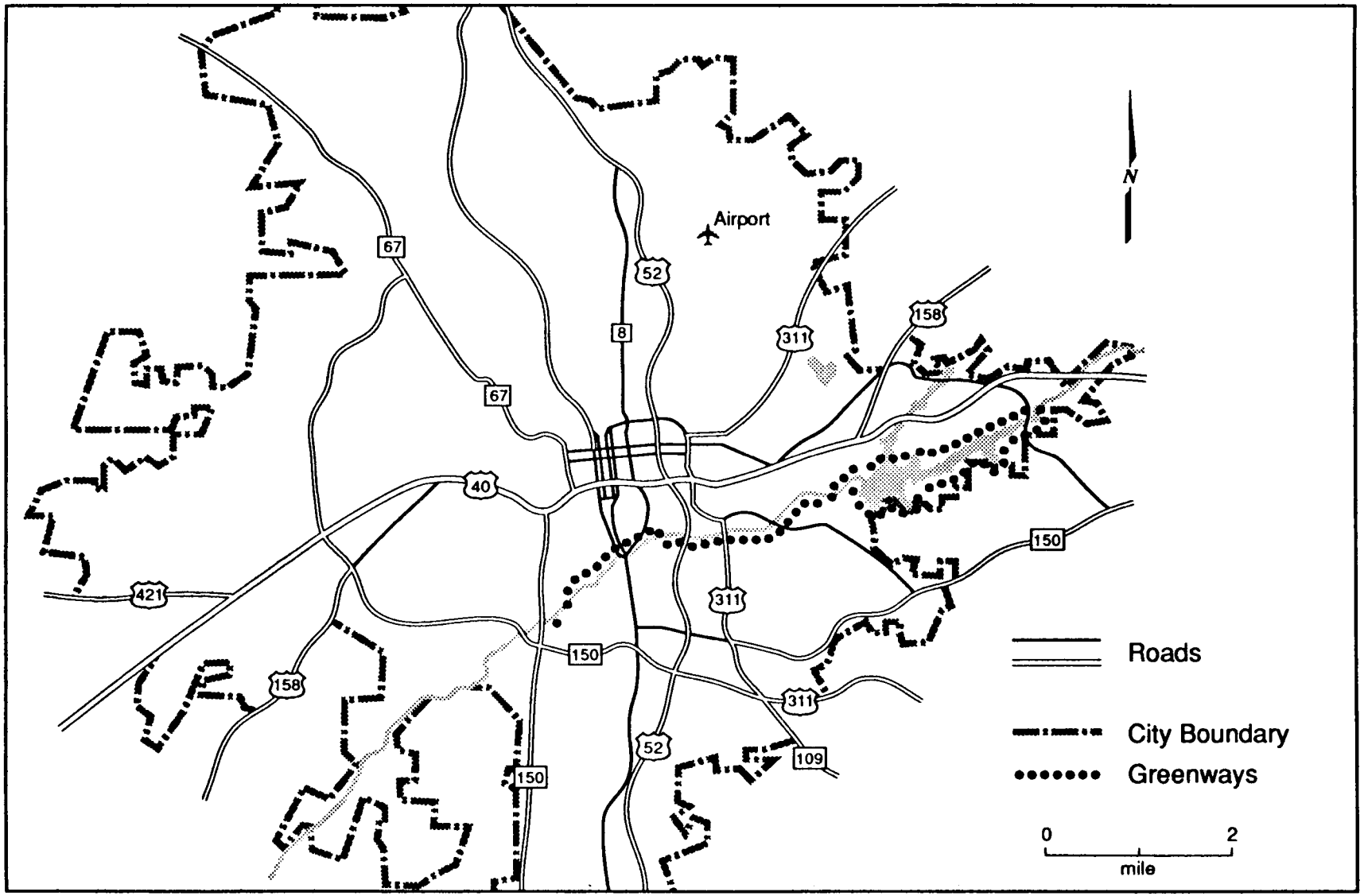


Figure 13 The Winston-Salem/Forsyth County Greenway System, Winston-Salem, N.C.

gateways to the city. Other major arteries radiate from the city center to the north and south. Much of the most recent residential development in Winston-Salem is found to the north, east and west of the city.

Winston-Salem's greenway system currently consists of two segments that are linked by both trail and natural landscape connectivity: Salem Creek Trail and Salem Lake Trail. There is a combined total of 11 miles of trail in these two segments. These trails run southwest to northeast through south-central Winston-Salem, and around the periphery of Salem Lake, respectively (Figure 13).

Paved throughout, the Salem Creek Trail runs along Salem Creek for 4.5 miles, where it connects to the Salem Lake Trail. There are many municipal parks and a public golf course along the Salem Creek trail. These public spaces serve to buffer the trail from the urban environment, which consists of several stream-side industries, medium density lower to middle income residential areas, and some retail development. The trail passes below several major arteries on its way from the Marketplace Mall in the west, to the dam at Salem Lake in the east (Figure 13).

Salem Lake, at the extreme eastern edge of Winston-Salem, is a man-made impoundment created in 1919 that is used as a municipal water supply and for recreation (City-County Planning Board of Forsyth County and Winston-Salem, 1990b). The southern arm of the lake is encircled by the Salem Lake Trail (Figure 13). This trail is 6.5 miles in length, and is wide and predominantly unpaved, save for a small segment of the trail on the backside of the dam nearest to the Salem Creek Trail. A large portion of Salem Lake's watershed is in forest, and the trail passes through much of this forest on

its route around the southern portion of the lake. Outside of the managed area of the watershed are several major roads, some suburban to exurban residential development, commercial strips, and large tracts of forest and farmland.

The six cities in which I analyzed greenway systems -- Athens, Cary, Chattanooga, Kingsport, Raleigh and Winston-Salem -- are representative of much of the variation found in the urban mid-southeast. Their urban greenway systems likewise cover much of the variability found in urban greenway systems of this region.

Though there is great variation in these urban greenway systems, they all share some meaningful similarities. For the concerns of this study, one of the most important similarities shared by these greenways is that of their incremental stages of implementation, and in turn, their fragmented character. It should be clear from this introduction to the study sites that the majority of urban greenway systems in the mid-southeastern United States are not a single whole, but a collection of often disjointed pieces. Even within a single greenway system, these individual segments often have different priorities and characteristics.

Chapter 4

Research Methods

It is now appropriate to discuss how the selected urban greenway systems were investigated to assess their wildlife conservation value. This assessment was done by:

- looking at greenway corridor widths and connectivity in the natural environment along these corridors.

- investigating vegetation management and the types of habitats found within the greenway system.

- determining the character of adjacent land uses and the connectivity of the greenway to source areas for species.

- estimating apparent wildlife conservation priorities for the greenway.

- looking for the actual presence of at least one of the chosen umbrella species in each trail segment of the greenway system.

There are many interconnected and complicated aspects of a conservation system that combine to make it more or less successful for wildlife conservation. These include influences outside of the greenway itself. Thus, it is useful to look for actual evidence of umbrella wildlife species in the greenway, in addition to using logical extrapolation and reasoning of what should be present given the merits of the particular reserve's design. The final item in this list is thus given emphasis for this study, and

was regarded as conclusive evidence of true wildlife conservation value in the surveyed greenway systems and their constituent segments. Several methods of data collection were used to examine the criteria listed above.

Reviews of the greenway master plans, associated maps and other written materials were used to assess apparent priorities for wildlife conservation in each greenway system, and corridor widths, individual greenway segment lengths, and overall greenway system extent. These materials were provided by greenway officials in each city.

Interviews with greenway managers, planners, city naturalists and other knowledgeable parties were also used. These interviews complemented and qualified the above mentioned written materials, and also provided information on adjacent land uses and vegetation management strategies. Individuals with special knowledge of local wildlife were also interviewed. These interviews assisted in determining which greenway segments contained the selected wildlife umbrella species. Their testimony was considered appropriate evidence of the presence or absence of the chosen umbrella species in each greenway segment for which they were knowledgeable.

First hand investigation of the greenways was conducted. This investigation gave conclusive evidence regarding vegetation management, habitat availability, connectivity in the natural environment and the character of adjacent land uses. First hand greenway investigation also was used to assess the presence or absence of the chosen umbrella wildlife species. This was done by looking for visual evidence of the species, and through the use of scent stations. The choice of umbrella species and the methods

used to determine their presence are described in detail below.

Umbrella Species

It is difficult if not impossible to inventory every species of wildlife in a reserve. Some researchers suggest that such a taxonomic (species by species) approach isn't even the best technique for ecosystem level management or evaluation (Main, 1987). Main also suggests that ecosystem monitoring should be inexpensive, not overly time consuming and ultimately must be useful to the manager of the reserve.

As stressed in Chapter 2, the goal of conservation biology is to preserve the characteristic diversity of an ecosystem -- or as close an approximation as possible -- and not simply to maximize species diversity *per se*. If this is our goal, it would seem wise to choose some of the more disturbance- and/or spatially-sensitive species that characterize an ecosystem, and look for their presence as an indicator that the integrity of the system is close to intact. This presence/absence data should be analyzed in addition to using an evaluation of the physical design elements of the greenway system as the sole measure of wildlife conservation value within the greenway.

It should be pointed out that the presence or absence of a particular species in no way measures if a minimum viable population of that species exists in the area. However, minimum viable population numbers for an individual wildlife species are difficult to assess, as are accurate population sizes. Thus, presence/absence research should be conducted in a way that the inventory will not miss evidence of resident species, but also not over emphasize the importance

of one or a few individual animals that are not reflective of a true resident population. This strategy of looking for more sensitive species has been advocated by many (for example, Sullivan and Shaffer, 1975; Bennett, 1987; Ehrlich and Murphy, 1987; Friend, 1987; Main, 1987; Shaffer, 1990).

Though the presence of more sensitive species will not always indicate that all is well with every other species in the system, it is a good indicator of ecosystem health and a general guideline that ecological parameters are sufficient for other less sensitive species (For example, Sullivan and Shaffer, 1975; Ehrlich and Murphy, 1987). This evaluative strategy is consistent with Main's above suggestions of being inexpensive and relatively easy to use. According to Ehrlich and Murphy:

> . . .[Focusing on] large animal umbrella species . . . make efforts at habitat conservation so much more likely to succeed (1987:208).

Compared to using indicator species for assessment, an individual species by species (autecological) approach to ecosystem evaluation is far less inferential. Many have argued that an autecological evaluation is the only approach to take if one is working to conserve an individual species (say an endangered animal) or a few rarer ones (Main, 1987). But, as stated above, most agree that a species by species approach is impractical for comprehensive ecosystem management.

For this research, I chose to assess wildlife conservation success at the community level. The use of indicator species was therefore believed to be of most value. Such an evaluation should prove to be especially worthwhile when used in conjunction with evaluating ecologically

sensitive vegetation management, corridor widths, connectivity in the natural landscape and adjacent land uses.

I used terrestrial mammals for the chosen umbrella species to help in assessing wildlife conservation value of urban greenways in the mid-south. Terrestrial, because animals that move along the ground are generally more sensitive to fragmentation in the natural landscape, and mammals, because a great deal of information exists with respect to these animals. The availability of background information on the chosen species was extremely helpful in this research.

In an urban environment, there is a very limited number of larger-bodied and/or wider ranging mammal species in residence. This is due to many of the factors discussed in Chapter 2 concerning fragmentation and alteration of needed habitat, and to the generally inhospitable nature of the urban matrix. To a large degree, the species that remain in the urban environment are ecological generalists that are smaller-bodied and are less disturbed by the presence of humans and by human activities. (Adams and Dove, 1989). Examples of such urban-adapted species in the southeastern United States are various types of rats and mice (family Cricetidae; which includes the muskrat), raccoons (*Procyon lotor*), grey squirrels (*Sciurus carolinensis*), eastern cottontail rabbits (*Sylvilagus floridanus*), and Virginia opossums (*Didelphis virginiana*). Larger terrestrial mammals such as the black bear (*Ursus americanus*), bobcat (*Felis rufus*), and mountain lion (*Felis concolor*) are almost always absent in or near urban environments, excepting an occasional animal moving through the area, or in rare cases where large

amounts of suitable habitat exists in close proximity to an urban area.

The task then, was to choose species that are more sensitive to human disturbance and spatial restrictions than most common urban-dwelling terrestrial mammals, yet have a better chance of surviving in and near urban environs in the mid-southeastern United States than species such as the black bear, bobcat and mountain lion. This gave a very limited number of species to select from for use in this study. Considering these constraints, I selected grey fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), and white-tailed deer (*Odocoileus virginianus*) as the umbrella species to use as part of the assessment of the wildlife conservation value of urban greenway systems in the mid-south. For these animals to be present in a section of the greenway, ecological parameters have to be sufficient. These parameters include having a large enough area, appropriate habitat, good connectivity to other areas of the greenway, or larger natural areas beyond the greenway, and no excessive disturbance from the urban matrix. Thus, If any of these umbrella species are present on a particular greenway segment, that section is deemed successful for wildlife conservation -- for ecological parameters at the site are probably adequate for a host of other, less sensitive species as well. I will now briefly discuss each of these chosen umbrella species.

The Grey Fox

The grey fox (*Urocyon cinereoargenteus*) is smaller than the red fox, and more common in wooded environments (Burrows, 1968; Chapman and Feldhamer, 1982; Greenberg, 1988; Whitaker, 1989). It weighs between 7 1/4 and 13 pounds at maturity.

Like the red fox, it is predominantly nocturnal in habit. The grey fox's range is from the eastern U.S. west to the Dakotas, down through Nebraska, Kansas and Oklahoma, west through the southwestern U.S. to California, and up the coast to Oregon (Whitaker, 1989). It is absent in most of the Rocky Mountains, and some of the western and northwestern plains. The grey fox is more abundant in the deep southeastern U.S. than the red fox.

The grey fox enjoys an extremely catholic diet. It eats many diverse plant foods, with heaviest use concentrated on persimmon, cherry, blackberry, corn, apples, nuts and squaw-root (Martin, Zim and Nelson, 1951; Burrows, 1968; Greenberg, 1988; Whitaker, 1989). The fox also eats numerous invertebrates, including insects; and abundant small mammals, particularly rabbits and a variety of other rodents. Greenberg (1988), studying grey fox ecology in east Tennessee, found that the fox alters its use of various woodland and field habitats depending on the season. This timing of use is related to the seasonal availability of food resources. Plant foods, particularly fruits and berries, are exploited most heavily in the summer and autumn. In the winter, when these plant foods are scarce, the grey fox makes increased use of small mammals for food. In the spring, insects are utilized most frequently. In essence, it appears that the grey fox switches trophic level with the seasons (Greenberg, 1988). This allows the grey fox to maintain a fairly consistent foraging and home range size, while seasonally exploiting a diverse range of food stuffs. Diurnal activity patterns also fluctuate according to season, and appear to be correlated with the availability of cover.

In the eastern U.S., the grey fox's habitat is chiefly deciduous forest and forest edge environments (Burrows, 1968;

Greenberg, 1988). It frequently lives along forested riparian corridors in landscapes composed of a mosaic of agricultural fields and forests. It is the only American canid with the ability to climb, and will periodically forage or hide in trees (Burrows, 1968; Whitaker, 1989). It dens frequently in hollow trees and logs, rock piles and small caves.

The Red Fox

The red fox (*Vulpes vulpes*) was originally brought from Europe and released in New York, New Jersey, Maryland, Delaware and Virginia for fox hunting, as the grey fox was not a good substitute, being slower and having less stamina (Burrows, 1968; Whitaker, 1989). The red fox has since expanded its range throughout most of North America, excepting the desert southwest, much of the Rockies, and low-laying coastal areas in the southeast, such as parts of the eastern Carolinas and the Florida peninsula (Whitaker, 1989). Part of this range expansion was accomplished by interbreeding with native foxes, especially to the north.

The red fox usually weighs between 7 7/8 and 15 pounds as an adult, slightly heavier than the grey fox. Its chosen habitat is a mix of agricultural fields and forest, though generally with more open land, edges and brushy environs than grey fox habitat (Burrows, 1968). Both species of fox select areas of greatest diversity and use edges heavily (Chapman and Feldhamer, 1982). The adult red fox dens less frequently than the grey fox. Often a red fox will simply curl up in a field with its tail over its face (Burrows, 1968; Whitaker, 1989). When it does den, it frequently will make use of an abandoned woodchuck (*Marmota* sp.) or badger (*Taxidea taxus*) burrow (Burrows, 1968; Chapman and Feldhamer, 1982). The red

fox, though chiefly nocturnal and very secretive, is occasionally sighted in exurban or suburban areas with nearby forests and fields. Regionally, the red fox is less abundant than the grey in the southeastern U.S., but is noted as being more adaptable to living near human settlements throughout its range than the grey (Chapman and Feldhamer, 1982).

The red fox's diet is very similar to that of the grey fox, with plant foods, small mammals, birds and insects all being exploited in proportions that depend on availability. The red fox's larger body size enables it to periodically eat larger animals than the grey fox. Some examples are livestock such as calves, sheep, pigs and goats, and wild animals such as turkeys or an occasional fawn. (Chapman and Feldhamer, 1982). Grey fox have also been seen taking these animals for food, but very infrequently.

Home range sizes are variable between individual foxes, but do not appear to vary much between red foxes and grey foxes (Chapman and Feldhamer, 1982). There is some seasonal adjustment in home range size, especially for females due to the birth of pups, but the changes are not drastic enough to have influenced presence/absence data collected for this study (Pelton, pers. comm., 1990). Red and grey fox home range shapes are normally twice as long as they are wide, and generally cover 57 to 162 hectares (Ables, 1969). Size and shape of fox home ranges are influenced by the availability of food, inter-specific and intra-specific competition, the character of habitat and the qualities of the local landscape, including natural and man-made physical barriers (Chapman and Feldhamer, 1982). This normal home range size, the types of foods that the fox exploits, the secretive nature of these animals, and the kinds of required habitat for cover, denning, and for the acquisition of food, should

all make it obvious that these two species of fox will be at their spatial, habitat and disturbance limits in the types of landscapes that normally compose urban greenways in the mid-south. Where these greenways do not offer appropriate habitat, are small and unconnected to larger undeveloped areas, and/or are too close to principal centers of disturbance, grey and red foxes will be absent.

The White-tailed deer

The White-tailed deer (*Odocoileus virginianus*) is the most common game animal in North America (Nahlik, 1974; Chapman and Feldhamer, 1982). It is believed that the ancestors of the white-tailed deer crossed the Bearing land-bridge several million years ago. Today, there are no counterparts to *Odocoileus* spp. beyond the Western hemisphere (Chapman and Feldhamer, 1982). The historical range of the white-tailed deer was concentrated in the mid-latitudes of North America, with some population extending into northern Mexico. Anthropogenic habitat alteration since European settlement has reduced the amount of forest cover and increased forest edges and agricultural fields over large areas of North, Central and South America, and in response, the white-tailed deer has expanded its range greatly (Nahlik, 1974; Chapman and Feldhamer, 1982). Even though this habitat alteration was beneficial to the white-tailed deer, its population notably declined in many areas due to intense hunting pressure. It has since rebounded because of hunting restrictions, stocking and other management techniques, and declines in the populations of their predators (Whitaker, 1989). The white-tailed deer's range now extends from central Canada to northern South America, excepting some of the arid regions of the western U.S. (Nahlik, 1974; Chapman and Feldhamer, 1982; Whitaker, 1989).

The white-tailed deer is a fairly large animal, though there is considerable variation in its size from region to region. Generally, the white-tail is largest in northern forested areas, and smallest in the Florida Keys (Nahlik, 1974; Chapman and Feldhamer, 1982; Whitaker, 1989). In the mid-southeastern U.S., the male white-tail generally weighs from 150-250 pounds, and females usually weigh between 100-200 pounds (Walthen and New, 1989). Heaviest weights are typically achieved at three to five years of age.

The white-tailed deer is one of the most adaptable animals in the world. This adaptability is reflected in its tremendously variable diet. The white-tail is both a browser and a grazer, and has been called the red fox of the herbivores because of its dietary diversity (Chapman and Feldhamer, 1982:883). In the southeastern U.S., the white-tail most frequently eats green succulent leaves, acorns and stems of both woody and herbaceous plants in the spring. In the summer, the diet continues to be dominated by green succulent plants, with mushrooms and acorns also important. In the fall, acorns become the dominant food item in the diet. Mushrooms, grapes, persimmon, Japanese honeysuckle, apples, sumac, blueberries, and the leaves of woody plants are also important. In winter, acorns continue to be prominent in the diet, with some grasses, Japanese honeysuckle, mushrooms and grapes also represented. In late winter, the white-tail makes increased use of rhododendron leaves, particularly in the southern Appalachians. Succulent woody twigs are also exploited in winter (Chapman and Feldhamer, 1982; Walthen and New, 1989; Whitaker, 1989). Contrary to popular opinion, the white-tail does not seem to eat hardened woody twigs in any season in the southeastern U.S.(Chapman and Feldhamer, 1982).

As mentioned above, the white-tailed deer is a creature of edge habitats, and makes heavy use of forest, field and farmland edge environments. The white-tailed deer is considered to be relatively insensitive to human disturbance compared to many other mammals of its size, though it is also known to be shy and secretive. Wherever the white-tail is to successfully live and reproduce, it will need a diverse mix of habitats (particularly the edges of dissimilar habitat types), good cover for birthing, bedding down and safety from predators, and a reliable source of water (Chapman and Feldhamer, 1982). Additionally, the white-tail will need sufficient area to forage for food, find cover, bed down, mate, reproduce, and to provide for minimum territory (the latter especially for bucks). In the southeastern U.S., the white-tailed deer's areal requirements are estimated to be a minimum of 80 hectares of appropriate habitat for does, and to be more than 250 hectares for bucks (Walthen, pers. comm., 1991). These are very general areal guidelines that will vary depending on specific habitat characteristics, landscape structure, and time of year. These land-area figures, however, should be sufficiently large to encompass most seasonal variation in range size required for foraging, rutting and other activities of survival and reproductive importance for white-tailed deer of the southeast.

Though the white-tailed deer is popularly recognized as cohabiting suburban and farmland areas with humans, the large body size of the deer, and its overall spatial requirements for habitat, make it even less likely than the red or grey fox to be resident in the narrow areas of open space surrounded by urban land uses that characterize most urban greenways of the mid-south. When any particular greenway segment does not meet the above discussed needs of the white-

tailed deer, the species is likely to be absent from that section of greenway.

The observed presence of either the white-tailed deer or the red or grey fox is inferential evidence that ecological parameters are sufficient for most other less sensitive species in that particular greenway section. And thus, presence of at least one of these umbrella species is considered to be a good assessment of the overall wildlife conservation value of the individual greenway sections surveyed for this study, especially as compared to the majority of typical urban lands.

Using more than one umbrella species for evaluating urban greenway wildlife conservation value is helpful in circumventing problems associated with local or subregional ecological peculiarities that can limit the population of an individual species. Some examples of these possible limiting factors are over-hunting, disease, inter-species competition, and the inherent lack of appropriate habitat. It is very unlikely, however, that any of these limiting factors will severely reduce the subregional population of all three of the chosen umbrella species. Therefore, the presence of at least one of these umbrella species should be an accurate measure of the wildlife conservation value of a particular urban greenway segment.

Presence/Absence Data

There are certain limitations to presence/absence data for assessing which wildlife species are in residence on a particular urban greenway segment, and in turn, for judging the wildlife conservation value of the greenway. The most obvious of these is that presence proves that the species is

resident, but absence does not necessarily prove that the species is not (Pelton, pers. comm., 1990). Another fundamental limitation with this kind of assessment is that it in no way demonstrates if there is a viable population of any of the species that are described as present. Furthermore, the way that presence/absence assessment is usually conducted, it is merely a momentary snap-shot of a truly dynamic ecological system. Species that are absent at the time of inventory may not be several years from now, and species that were present may become locally extinct in the future. Lastly, a problem with any type of species inventory for assessing the wildlife conservation value of a particular land area, is that it is difficult to tell if that land area itself is the critical link in providing appropriate habitat and space for the species of interest that are shown to be present, and not some combination of that land area and locally adjacent parcels.

Still, presence/absence data can be of considerable use. This data, together with information on corridor widths, vegetation management, connectivity in the natural environment and adjacent land uses, can shed light on the true state of wildlife conservation in urban greenways of the mid-southeastern United States.

There were several ways that presence or absence of the chosen umbrella species was determined for this study. These methods were: expert knowledge of resident wildlife species in individual segments of each greenway system, visual evidence observed while walking the greenway (vegetation impact, scat and tracks), and through the use of scent stations that attract omnivorous and carnivorous species to a particular location to improve the chances of track and scat observation. These methods were applied starting with expert

opinion, then visual inspection and scent stations were used, most often concurrently.

A scent station is a simple device that has been used for estimating wildlife species populations, and for assessing the presence or absence of one or several species. Scent stations are more accurate for presence/absence inventories than for true population estimations, however (Minser, pers. comm., 1990; Pelton, pers. comm., 1990). Instructions for using scent stations were provided by personal communications with several wildlife experts who had used such stations for wildlife research and game management. These people were Dr. William Minser and Dr. Michael Pelton, both in the Forestry, Wildlife and Fisheries Department at the University of Tennessee, and Doug Scott, a biologist with the eastern division of the Tennessee Wildlife Resources Agency (1990).

A scent station consists of an olfactory animal attractor and a medium to collect the tracks of any animals that are lured by the scent. The scent stations used for this study were one meter circular areas of ground cleared of debris with a hoe, and covered with an amply thick layer of sifted, powdered lime as a medium to collect the animal tracks. A scent post was placed in the center of this one meter circle of lime. The scent post was a wooden popsicle stick with a cotton ball soaked in cod liver oil or red fox urine skewered on the top. This type of scent station is only useful for attracting omnivorous or carnivorous animals. White-tailed deer are not attracted to these stations. Thus, the scent stations were used in this study to increase the likelihood of recording the presence of red and grey foxes only. This is exactly the help that was needed, as it is fairly easy to ascertain visual evidence of the presence of

the larger white-tailed deer, and very difficult to find evidence of the smaller and more elusive fox without a tool such as a scent station to increase the probability of observation.

The placement of the individual scent stations is very important because of the way animals move through the landscape. I made extra efforts to situate the stations in locations that were at the convergence of several different habitats, were near convenient stream crossings, or showed evidence of previous use by wildlife as a pathway. The possibility still existed, however, that the particular location of the scent station could limit its effectiveness for inventorying resident red and grey fox. Because of this inherent uncertainty, I placed multiple scent stations in each greenway segment. The number of scent stations per greenway segment depended on the size of the segment and the availability of potentially productive sites for locating the stations.

Scent stations were used for up to three nights in each greenway segment. Because I was only looking for evidence of presence or absence, as soon as one of the umbrella species was confirmed to be present in a greenway segment, scent station inventorying and visual observations in that segment were suspended. Three days was the amount of time recommended by Dr. Michael Pelton (pers. comm., 1990) as sufficient to observe evidence of resident red and grey fox populations, while also missing one or a very few animals in the greenway segment that are not representative of a true resident population. After three days without evidence of one of the chosen umbrella species, it was deemed that none of the species were present as a resident population.

Attempts were made to make the scent station inventories during three consecutive nights, but this was not always possible, mostly due to rain. Repeated inclement weather restricted the use of scent stations to only one night in the Cary, North Carolina greenway system. The results for this system, therefore, are preliminary. The need for repeated monitoring of the scent stations provided me with ample opportunity to look for field evidence of white-tailed deer and to become familiar with other attributes of the greenways.

Chapter 5

Results

What is the wildlife conservation value of the chosen urban greenways? The results of this study are now presented alphabetically by the name of the city that contains each greenway system.

Athens, Georgia

Cook's Trail, along Sandy Creek from Sandy Creek Park to Sandy Creek Nature Center, is located north and east of the city of Athens proper. The trail is 4.1 miles long (Figure 14). It was opened in early 1991 and is the first and only trail in the Athens greenway system. The trail snakes through an environment of riparian forest and swamp that has been left in its natural state. Sandy Creek Park, connected to the trail to the northeast, is a highly managed area with mown lawns, a few remnant wooded patches, active recreational facilities, and a man-made lake. The Sandy Creek Nature Center, on the southeastern end of the trail, is principally in a mixed forest cover of pine and hardwoods, and is a wildlife preserve. Both the Park and the Nature Center are of considerable size.

The trail itself is a maintained dirt path, which is restricted to foot traffic only -- no horses or bicycles are allowed. As previously mentioned, the character of the trail has been described as "pseudo wilderness" by Walt Cook (pers. comm., 1991), the man who the trail is named after. There are several extensive wooden boardwalks to allow the trail to remain usable in periods of higher water, and to be sensitive to the natural runoff patterns of water movement in the area.

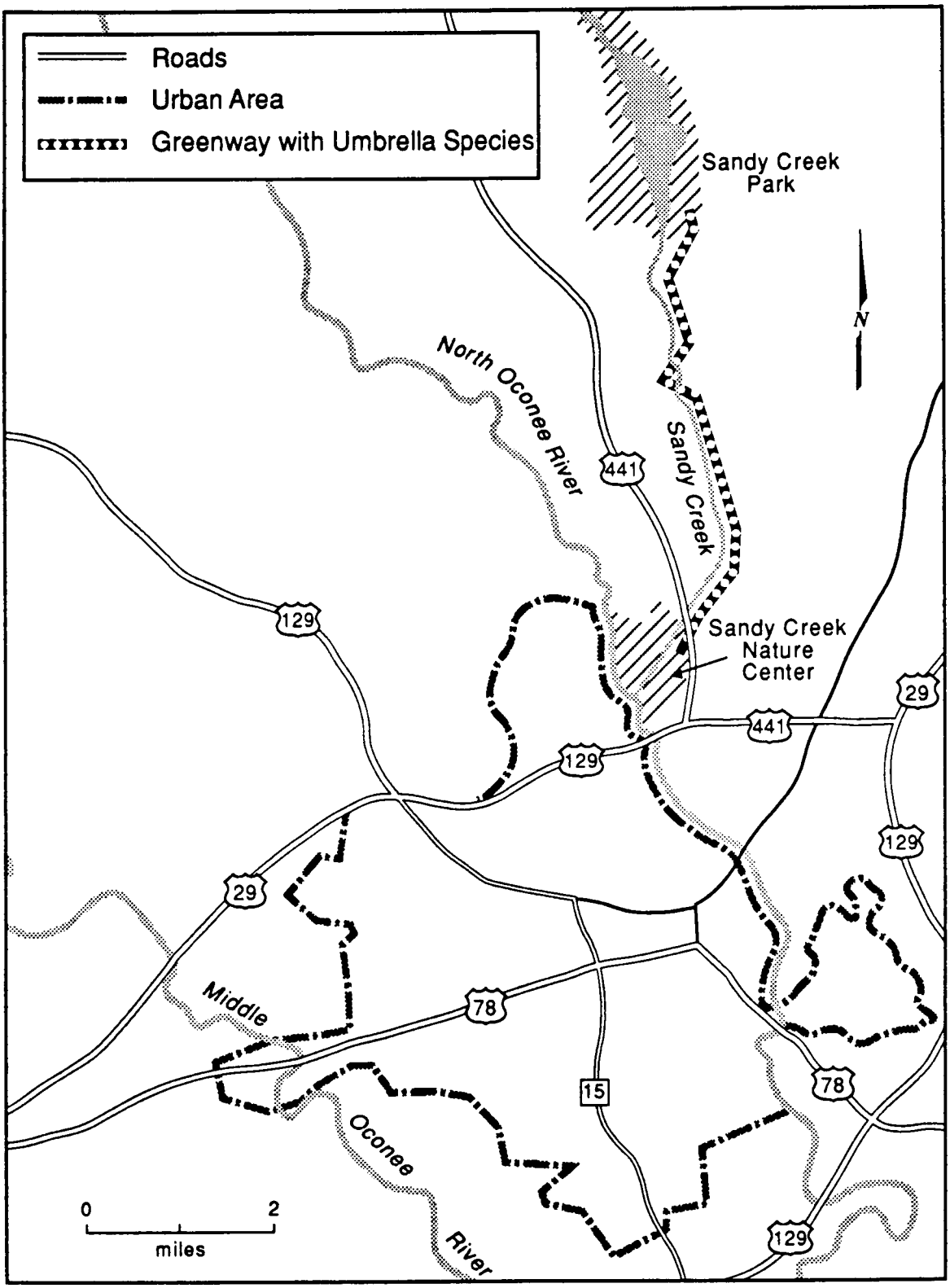


Figure 14 Wildlife conservation in the Athens/Clarke County Greenway, Athens, GA.

On its southeastern end, Cook's Trail passes under a four-lane principal road before entering the nature center. The underpass is very wide, and vegetation grows right to the edge of the underpass on both sides of the road.

The publicly controlled corridor width along the trail is a minimum of 100 feet, and a maximum of almost 1/4 mile. At one location, the trail itself is built only 10 feet from the border of the publicly controlled corridor. Land uses adjacent to the preserved riparian corridor are primarily exurban in nature. There are extensive tracts of forest intermixed with farmland and fields, older rural residences, and several large new housing developments clustered in a few locations (Clarke County Department of Parks, 1991; Walt Cook, pers. comm., 1991). Thus, connectivity in the natural landscape is quite good within the greenway corridor, between the greenway corridor and the Park on one end and the Nature Center on the other, and between this system and undeveloped adjacent lands.

Priorities of the system are primarily recreational (Walt Cook, pers. comm., 1991). However, the emphasis is on recreation in a natural setting. Other priorities include floodplain protection, the improvement and conservation of water quality, and the preservation of habitat and corridors for wildlife (Aguar, 1989; Raltson, 1990; Clarke County Department of Parks, 1991).

The presence/absence investigation for umbrella species on Cook's Trail used a combination of expert knowledge and visual observation. While walking the trail, evidence of white-tailed deer was abundant, as was evidence of beaver, rabbit, raccoon, opossum and many other less sensitive animals. Expert knowledge (Walt Cook, pers. comm., 1991)

provided evidence for the presence of grey fox, and to a lesser extent red fox, within the greenway. Several river otter, also a fairly sensitive species to disturbance, habitat alteration and spatial restrictions, were found to be present along the trail as well.

In sum, Cook's Trail of the Athens Greenway system is successful for conserving wildlife. Even though the trail is completely within the city limits of Athens, it is not truly urban in nature. This is due to the greenway's location on the outskirts of the small city of Athens, and the dominant adjacent land uses, which are primarily exurban. This situation surely contributes to the wildlife conservation value found along the greenway.

Cary, North Carolina

The Cary Greenway System has 7.1 miles of trail spread between six principal segments. As mentioned earlier, only one night of scent station inventorying was accomplished for this system due to repeated inclement weather. Therefore, the wildlife inventory data for the Cary greenway system is incomplete, and will be presented here only as preliminary findings. All other information on this greenway system has been collected.

Recreation is the priority for the Cary Greenway System (Brown, pers. comm., 1991). Other priorities include floodplain and water quality protection, town and neighborhood image improvement, alternative transportation routes, and "nature conservation" (Brown, pers. comm., 1991; Cary Planning and Development Department, 1991). Each of the individual greenway segments of the Cary Greenway System will

now be discussed in turn, beginning with the Black Creek Trail.

The Black Creek Trail of the Cary Greenway System (labeled as #1 in Figure 15) is 2.5 miles long (Cary Planning and Development Department, 1991). It is located on the north side of the town of Cary, and runs north and south along Black Creek between West Dynasty Drive and Lake Crabtree. It is a paved trail that is on a broad, wooded floodplain surrounded by low density upper-middle class housing, several newer suburban office parks, and large tracts of forest. The Cary Parkway and Weston Parkway both cross the trail from east to west. This floodplain is predominantly in hardwood forest, with only small disturbed areas in fields where several driveways or the mentioned Parkways cross the floodplain. The width of the publicly controlled corridor itself varies between 100 and 500 feet. There is much open space (fields and several small forested patches) surrounding Lake Crabtree in the Lake Crabtree County Park. Skirting the Lake to the north is Interstate 40. To the north across the Interstate, and farther to the west of Black Creek Trail, are an abundance of fields and forests. Black Creek Trail is the longest, widest and least urban section of the Cary Greenway system.

The wildlife inventory here consisted of two days of visual observations, and one night of scent station inventory. Six scent stations were set, all south of where the Cary Parkway crosses the trail (Figure 15). Evidence of grey fox and white-tailed deer was abundant, even south of the Cary parkway (Figure 15). Squirrels, and tracks of muskrat, raccoon and opossum, were also observed.

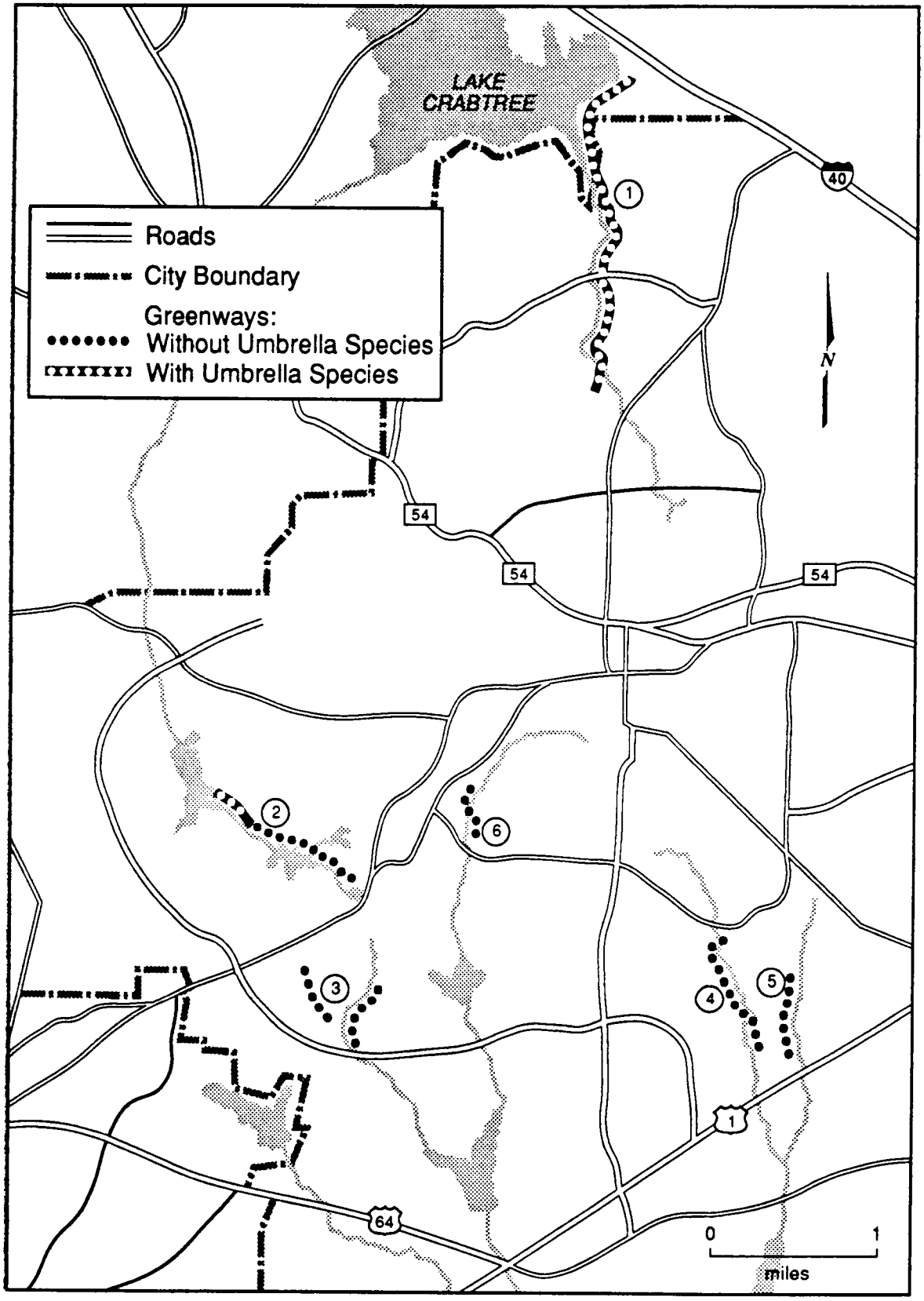


Figure 15 Wildlife conservation in the Cary, NC Greenway System.

The Oxford Hunt Trail (labeled as #2 in Figure 15) is 1.5 miles long and located on the western side of the town of Cary (Cary Planning and Development Department, 1991). It starts in the east on West Chatham Street near Old Apex Road, and winds its way west to the 310 acre Fred G. Bond Metro Park (Figure 15). En route, Oxford Hunt Trail circles a small man-made lake in a heavily manicured commons area surrounded by condominiums, goes through a culvert under West Chatham Street, runs behind a high density development of single family homes, and enters a wide, forested maintenance vehicle trail before entering Bond Park. Oxford Hunt Trail is paved to the east, and is dirt surfaced from the maintenance vehicle trail to Bond Park. The trail's corridor width ranges from close to 300 feet near Bond Park to less than ten feet through the culvert under West Chatham Street. There is a large man-made lake in Bond Park, with considerable swampy environs along its eastern shore. Bond Park itself is chiefly forested. Cary Parkway runs north-south to the west of Bond Park (Figure 15). Beyond the Parkway is considerable open space, with several large housing developments currently under construction (Clark, pers. comm., 1991).

The wildlife inventory in Oxford Hunt Trail consisted of two days of visual inspection, one night of scent station use, and expert opinion (pers. comm., 1991). Four scent stations were used. I found evidence of raccoon, muskrat and cottontail rabbit in the far eastern section of the trail, just east of the manicured area surrounded by condominiums. I found only evidence of raccoon between the trail's culvert underpass below West Chatham Street and the maintenance vehicle trail near Bond Park to the west. Clark (pers. comm., 1991) reported the presence of grey fox and white-tailed deer in the extreme western portion of Oxford Hunt

Trail near Bond Park, in the forested areas along the maintenance vehicle trail.

Tarbert-Gatehouse Trail, Coatbridge Trail and McCloud Court Trail are interconnected short trails that are considered together for this study (labeled #3 in Figure 15). Combined, the trails are 1.26 miles in length. Located in southwestern Cary, these trails form a "Y", with the base located near the intersection of Lake Pine Road and the Cary Parkway (Cary Planning and Development Department, 1991; Figure 15). This greenway segment is located in a medium density older residential area on two thin hardwood forested riparian corridors that run between the developed areas and join in the south, just north of Cary Parkway. South of Tarbert Drive, the trails are crushed stone. To the north of Tarbert Drive, the two forks of this segment are paved and thread for a short distance through two small neighborhood parks with active recreational facilities. The corridor widths in this greenway segment are nowhere over 150 feet, and frequently they are far less.

The wildlife inventory in this segment consisted of one day of visual observation and one night of scent station investigation. Five scent stations were used. Evidence of muskrat, raccoon and squirrel was found. None of the umbrella species were recorded as present. Expert opinion considers there to be only a slight chance of the presence of red or grey fox in this section, and no chance of white-tailed deer being present (Clark, pers. comm., 1991).

The Hinshaw Trail, in southwestern Cary, is a paved trail that is 0.79 miles in length (labeled #4 in Figure 15; Cary Planning and Development Department, 1991). It is on a hardwood forested floodplain between extensive areas of

established, medium density residential development. The greenway corridor is fairly wide, probably greater than 200 feet in some places. Towards the southern end, the corridor narrows to approximately 50 feet. The trail runs north-south from Greenwood Circle to Seabrook Avenue. East Maynard Road and Seabrook Avenue, both busy thoroughfares, frame the corridor to the north and south respectively (Figure 15). Across Seabrook Avenue is MacDonald Woods Park, a small park with a playground.

The wildlife survey on Hinshaw Trail included one day of visual observation, one night of scent station inventory, and expert comments. I set five scent stations along the trail. There was abundant evidence of raccoon, opossum, muskrat, squirrel and domestic dogs and cats. None of the umbrella species were represented. Tony Clark, Cary Parks and Recreation Supervisor (Clark, pers. comm., 1991), believes that if there are grey fox on this trail, their numbers are very low. He added that there is no chance of white-tailed deer in this greenway section.

The Pirates Cove Trail (Labeled #5 in Figure 15), is located near the Hinshaw Trail in southeastern Cary. It is surrounded by large areas of established, medium density residential development, similar to that found around the Hinshaw Trail. The trail runs north-south for 0.65 miles between Greenwood Circle and Glengary Drive, on a forested floodplain of mixed hardwood and softwood. This floodplain is thinner than that of the Hinshaw Trail, and Straight Branch Creek, which flows through it, is small and meandering. Approximate corridor widths range from 180 feet to less than 40 feet. The southern end of the trail is adjacent to U.S. Route 1, which here is a divided, controlled

access highway. The trail itself is surfaced in crushed stone.

The wildlife inventory on Pirates Cove consisted of one day of visual observation, one night of scent station investigation, and expert comments. Four scent stations were set along this trail. No evidence for the presence of the umbrella species was found (or expected, based on Clark, pers. comm., 1991). Raccoon, muskrat, opossum, and domestic dog and cat tracks were recorded.

The final trail segment to be discussed for the Cary Greenway System is Higgins Trail (labeled #6 in Figure 15; Cary Planning and Development Department, 1991). Higgins Trail is located in central Cary, just south and west of downtown. The trail runs alongside of Swift Creek on a thin forested floodplain of mixed hardwood and softwood. The corridor is nowhere more than 150 feet wide, and is mostly less than 80 feet wide. Higgins Trail is 0.4 miles long, and surfaced in crushed stone. There are several workout stations along the trail. Adjacent land use is older, medium to high density residential development. This residential development extends for some distance in all directions away from the trail.

The Wildlife survey of Higgins Trail consisted of two days of visual observation, and one night of scent station inventory. Three scent stations were set to inventory wildlife along this trail. No evidence for the presence of the umbrella species was found. Tracks for raccoon, muskrat, squirrel, and domestic dogs and cats were observed.

The Cary Greenway System, as should be clear from the above discussion, varies in its wildlife conservation value

from section to section. It appears from this preliminary wildlife survey that only Black Creek Trail (#1) and the western end of Oxford Hunt Trail (#2) contain any of the umbrella species (Figure 12). The majority of the greenway segments are in natural wooded vegetation. Parts of eastern Oxford Hunt Trail (#2) and northern sections of the Tarbert-Gatehouse - Coatbridge - McCloud Court trail complex (#3) are maintained as mown lawn. Corridor widths vary considerably between and within segments. Generally, the widest corridors are found in the greenway segments on the edge of town, the thinnest corridors are closer to the center of Cary. According to this preliminary wildlife survey, presence of the umbrella species is restricted to the edges of town. None of the umbrella species were recorded along greenway segments closer into the urbanized area of Cary.

Chattanooga, Tennessee.

The North Chickamauga Creek Greenway, dedicated in summer, 1990 (Rogers, pers. comm., 1991) is the first principal trail of the Chattanooga Greenway System. The greenway is a 1.5 mile long trail located on a publicly owned 70 acre parcel of land. This trail is north of downtown Chattanooga, and across the Tennessee river from the majority of the city (Figure 16). The trail is on the eastern side of North Chickamauga Creek, just upstream from where the creek flows into the Tennessee river, at the North Chickamauga Dam.

The trail is paved and the land that it runs through is chiefly forested. There are substantial areas of hardwoods, some patches of pine, and a few sections covered in a mixture of the two. This upland forested area slopes steeply down to the creek shore, where there is a thin riparian forest. A wide cleared power line right of way runs perpendicular to

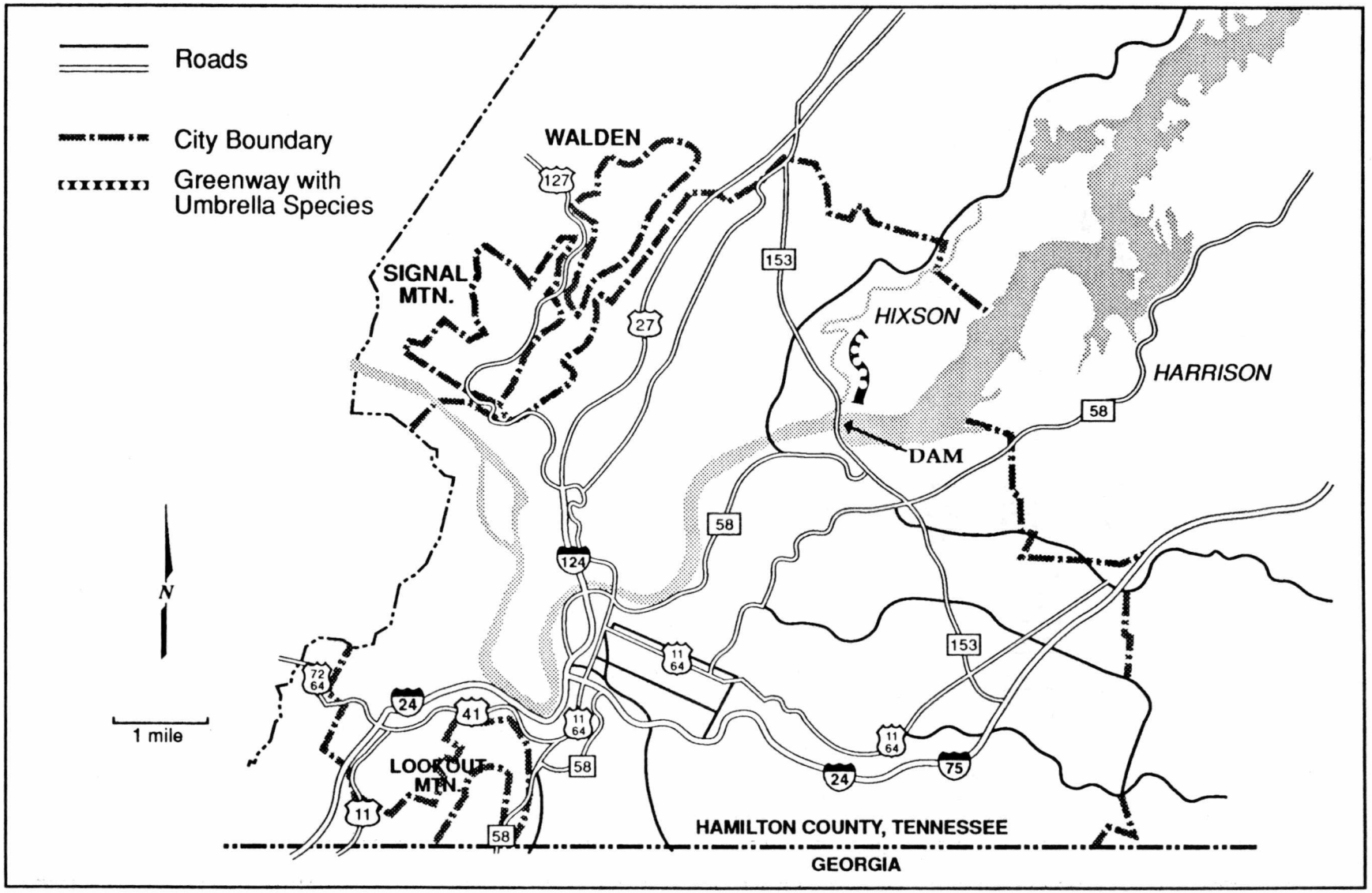


Figure 16 Wildlife conservation in the North Chickamauga Creek Greenway, Chattanooga, TN.

the creek, and crosses both the trail and creek. The greenway land is between 200 and 300 yards wide.

TVA owns a 200 acre tract of forested land that borders this greenway parcel to the east and southeast. The Spangler Farm, a 180 piece of property recently purchased by the city for expansion of the greenway, borders the greenway land to the north. North Chickamauga Creek runs along the greenway to the west. Other adjacent land uses include two busy thoroughfares, the North Chickamauga Dam complex, several newer residential developments, and large areas of low density, exurban housing and farms interspersed with remnant forests. This area is principally removed from the majority of urban Chattanooga.

The wildlife investigation of this greenway consisted of two days of visual observation and one night of scent station inventory. There were seven scent stations set up to assess the presence or absence of red and grey fox. After only one night of scent station use, red fox tracks were recorded at two of the seven stations. Thus, further nights of scent station inventory were not required. Even after extensive visual investigation, no evidence for the presence of white-tailed deer was found. Other wildlife species noted on the greenway were raccoon, opossum, squirrel, cottontail rabbit and muskrat.

According to the criteria set forth in this study, the North Chickamauga Creek Greenway is successful for preserving wildlife, though the more sensitive white-tailed deer was absent. As discussed above, the greenway land itself is very wide and forested, is on the edge of urban Chattanooga, and is surrounded by several kinds of land uses, including forested areas, farms, low density housing and several busy

arteries. The locational situation of this greenway appears to have positively influenced its wildlife conservation value.

Kingsport, Tennessee

The Kingsport Greenbelt System consists of four segments with a total of 3.7 miles of trail (Figure 17; Frasier, pers. comm., 1990; Miller, pers. comm., 1991). The character of the four trails differs considerably from one to another, as do adjacent land uses. All trails are paved. The Greenbelt System's priorities are chiefly recreation, floodplain protection and neighborhood and city image improvement (Spoden, et al., 1989; Frasier, pers. comm., 1991). Wildlife and nature conservation are secondary priorities.

The Cloud Park Trail (labeled #1 in Figure 17) is the smallest segment of the Kingsport Greenbelt System, at 0.25 miles in length. It is near downtown, and runs along an inner bend of Reedy Creek, as the creek winds around Cloud Park. Cloud Park consists of a softball field, basketball court, lawns and a parking lot. The Park is fronted by a busy thoroughfare. There are few trees in the park except right on the Reedy Creek stream bank, on the outside edge of the trail. Across the small creek is a steep bank with a thin strip of riparian forest. Behind this screen of trees is a large wood-products factory. The trail is cut off at either end by urban structures that are built nearly to the water's edge.

The wildlife inventory on the Cloud Park Trail consisted of three days of visual observations and a full three nights of scent station investigation. Three scent stations were used. None of the umbrella species were found to be present.

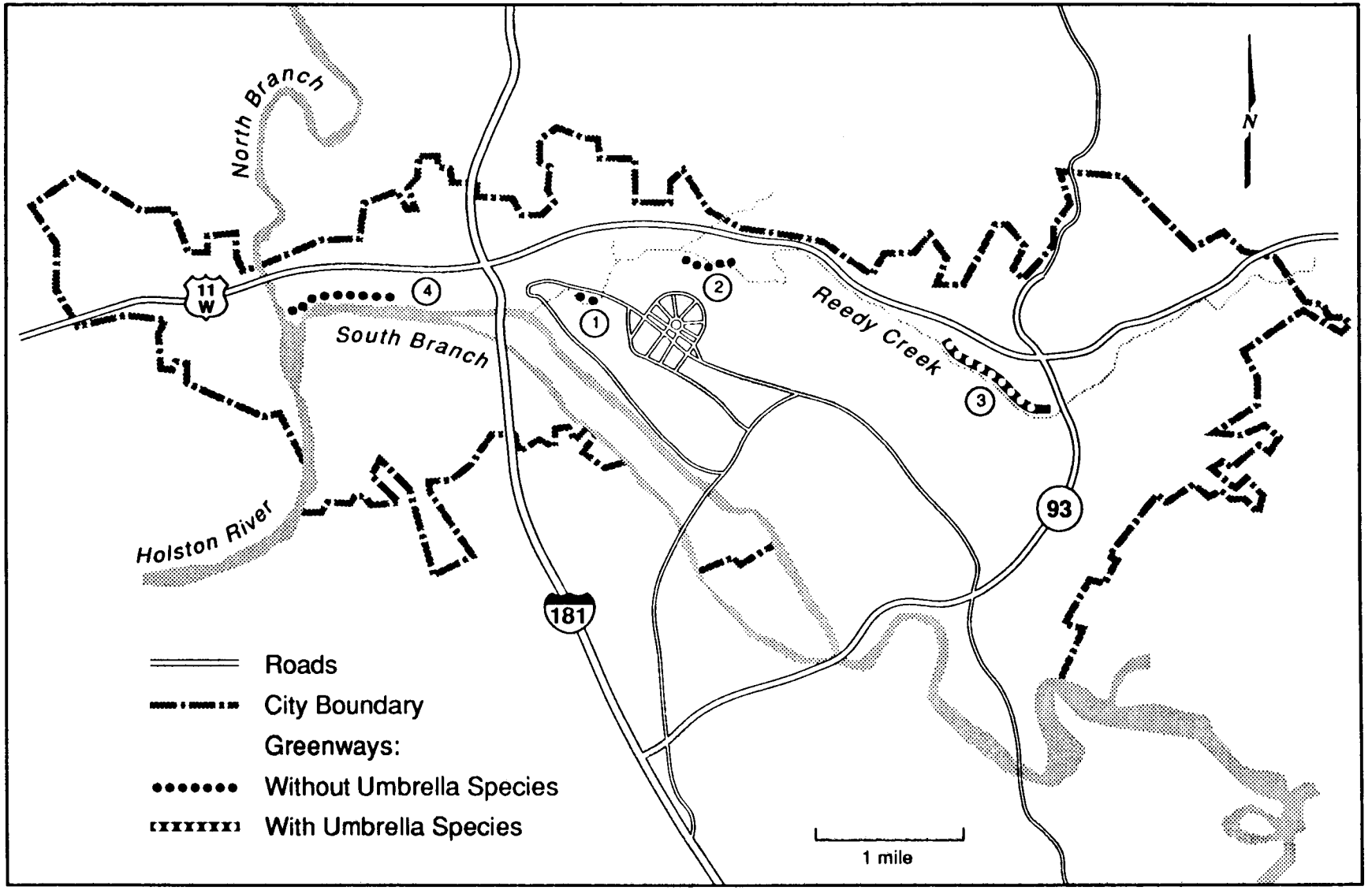


Figure 17 Wildlife conservation in the Kingsport Greenbelt, Kingsport, TN.

Sightings of squirrel, domestic cats and a groundhog (*Marmota monax*) were made. Tracks of domestic dogs, raccoon and muskrat were also recorded.

The Holston Valley Hospital Trail (labeled #2 in Figure 17) runs for nearly 0.75 miles along Reedy Creek behind the Holston Valley Hospital, near downtown Kingsport. Adjacent land uses include hospital buildings, parking lots and a parking garage, a busy street, some high density residential development, and several large open fields with hedgerows. This is the most heavily used of the four trails in Kingsport (Frasier, pers. comm., 1991). Only the very banks of the creek are forested along this stretch, with the remainder of the publicly controlled corridor mown fairly level. The natural vegetation connectivity is slight, as parking lots near one end of the trail and a road on the other end limit this connectivity. Corridor width varies from less than 30 feet to over 1,000 feet, where some of the fields mentioned are owned by the city and are included in width measurements.

The wildlife investigation for this greenway segment was done using three days of visual observation and a full three nights of scent station inventory. Five scent stations were used along the trail's length. None of the umbrella species were present. Tracks of muskrat, raccoon, domestic cats and many domestic dogs were seen at or near the scent stations.

The Kingsport Mall Trail (labeled #3 in Figure 17) is the longest and least urban of the Kingsport greenway segments. This trail is on the edge of town and runs for 1.5 miles west to east through a large riparian hardwood forest and wetland along Reedy Creek, parallel to 11W and behind the businesses on that highway (Figure 17). In this area, 11W is a busy highway with substantial commercial development. The

primary entrance to the trail is via the rear of the Kingsport Mall parking lot. The riparian forest widens and narrows as the trail passes from the back of one business to another. There is a 6.5 acre wetland along the trail which is owned by the city and considered part of the greenway. Thus, corridor width varies substantially, but ranges between 30 feet in some sections to more than 1,000 feet in the area of the wetland. Across Reedy Creek is a long, steep hardwood forested bank that rises to an area of low density, up-scale housing. The eastern end of the Kingsport Mall Trail terminates where highway 93 crosses perpendicular to the trail and Reedy Creek.

The wildlife investigation in this trail, like the others in this system, consisted of three days of visual observation and three nights of scent station use. Six scent stations were employed along the trail. Mink were spotted twice, and tracks of many raccoon, squirrel and muskrat were recorded in stream-side mud and in the scent stations themselves. On the third night, red fox tracks were collected at two of the scent stations. No evidence of white-tailed deer was found.

The final segment in the Kingsport Greenbelt System is called Riverfront Park Trail (labeled #4 in Figure 17). This trail is the oldest in the system and was built on an existing city park along the South Branch of the Holston River, approximately two miles east of the city center. Running parallel to the park is a very busy road. The park itself sits below this artery, on a broad floodplain. In places, this park is greater than 300 feet wide. Its thinnest portions are approximately 75 feet from roadway to river. The trail is 1.2 miles long, and threads through the park parallel to both the river and the highway.

Typical of a city park, this greenway segment is mown to the river's edge, and is punctuated by a number of mature trees. There is no brushy undergrowth, and no true forest. There is substantial erosion along the river, and some of the remaining trees near the river are toppling into the water due to this erosion.

Chiefly because of this vegetation management, and to a lesser degree because of the isolation forced upon the Riverfront Park Trail by the principal road above, this greenway segment was deemed the least likely of the four Kingsport Greenbelt segments to support any of the umbrella species. Doug Scott, a biologist with the eastern division of the Tennessee Wildlife Resources Agency, concurred (pers. comm., 1991). If all of the other greenway segments in this system had shown the presence of at least one of the umbrella species, then this trail would have been surveyed. But only one of the other trails showed the presence of an umbrella species, so this greenway segment was not inventoried. It was assumed that none of the umbrella species were present along the trail.

In sum, only one trail of four in the Kingsport Greenbelt System, the Kingsport Mall Trail, showed evidence of any of the umbrella species. In several trail segments, vegetation management was not conducive to wildlife conservation. Chosen minimum corridor widths in several segments appeared overly thin to facilitate wildlife movement. Additionally, urban form often precluded connectivity in the natural environment and restricted corridor widths. As a system, the Kingsport Greenbelt is not successful for wildlife conservation, though one segment on the edge of town is.

Raleigh, North Carolina

Priorities for Raleigh's Capital Area Greenway System include recreation in a natural setting, floodplain protection, the provision of alternative transportation routes, improvement of "the quality of life", the conservation of habitats for wildlife, and "taking the edge" off of the urban environment (Schindler, 1989). The character of the greenway segments differ considerably throughout the system. I will now cover each of these trail segments in turn, focusing on their wildlife conservation value.

The West Millbrook Trail (labeled #1 in Figure 18) is 0.3 miles in length and is principally a series of sidewalks connecting West Millbrook Junior High School to Weathergreen Drive in extreme northern Raleigh (Figure 18; Raleigh Parks and Recreation Department, 1990a). There is only 0.34 acres in public control here, including the sidewalk itself (Raleigh Parks and Recreation Department, 1990b). Expert knowledge of this greenway section specified that none of the umbrella species would be present, and that the segment was not worth inventorying (Connors, pers. comm., 1991).

Sawmill Trail (labeled #2 in Figure 18) is located in northwestern Raleigh along a tributary to Leadmine Creek. The trail is a 0.9 mile long dirt path that runs between Bent Creek Trail in the south and Sawmill Road in the north (Figure 18; Raleigh Parks and Recreation Department, 1990a, 1990b). The 32.7 acre publicly controlled corridor for the trail (Raleigh Parks and Recreation Department, 1990b) is in forest. This forest is mostly pine to the north, and mixed hardwoods to the south. In 1988, a tornado destroyed a large part of the forest in the northern portion of this trail, (Connors, pers. comm., 1991), and many trees remain down.

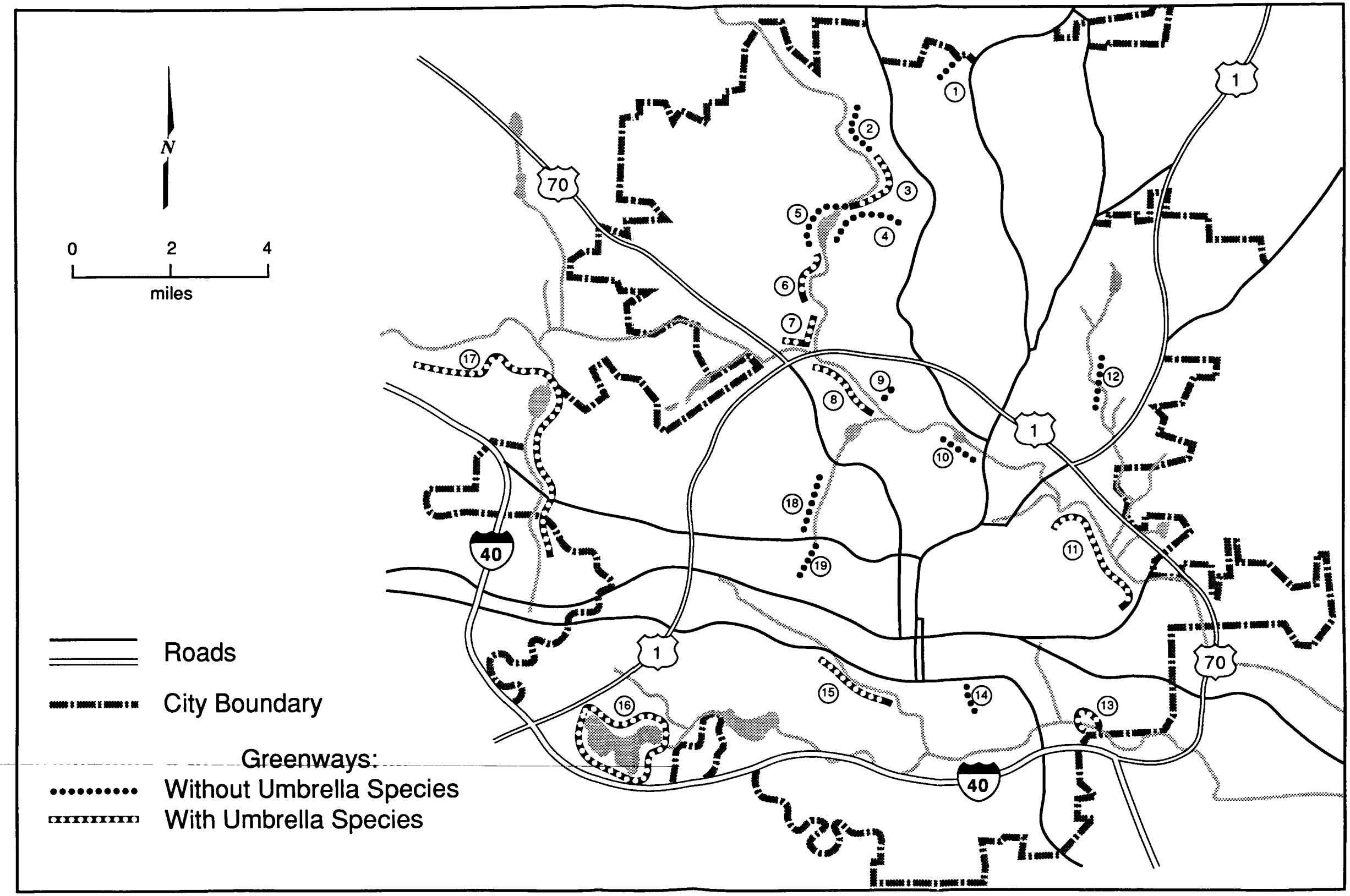


Figure 18 Wildlife conservation in the Capital Area Greenway System, Raleigh, N.C.

The trail is surrounded with medium to high density housing to the east and west, a major road to the north, and another greenway segment to the south. Connectivity in the natural landscape is limited to the north by Sawmill Road, and to the east and west by dense housing up to the corridor edge. Greater connectivity exists to the south, due to the Bent Creek Trail-Shelley Lake Trail area.

The wildlife survey in Sawmill Trail consisted of three days of visual observation and three nights of scent station inventory. Three scent stations were used along the trail. None of the umbrella species were present. Raccoon, opossum and domestic cat tracks were found.

Bent Creek Trail (labeled #3 in Figure 18) is located on 12 acres along Leadmine Creek in northwestern Raleigh, and connects to Sawmill Trail in the north and Shelley Lake Trail in the south. It is bisected by two busy roads: North Hills Drive and Lynn Road. The trail is paved and is 1.08 miles long (Raleigh Parks and Recreation Department, 1990a, 1990b). A small dirt trail diverges and reconnects to the main path between Lynn Road and North Hills Drive. The corridor is wide and forested. Adjacent land uses are medium density residential developments, several busy roads and some open space, particularly in Shelley Lake Park. Connectivity in the natural environment is fairly good, especially to the south and east, where there is much land in Shelley Lake Park and sizable remnant forested patches amidst low to medium density housing across Leadmine Creek from the trail.

The wildlife inventory in Bent Creek Trail consisted of two days of visual observation and one night of scent station use. Three scent stations were used. Evidence of red fox was found at one of the scent stations located between Lynn

Road and North Hills Drive, close to Shelley Lake Park. No other evidence of fox was found, nor was there any evidence of white-tailed deer. Tracks of domestic dogs and cats, raccoon, opossum, squirrel and muskrat were observed.

Snelling Branch Trail is a paved trail that is located in north Raleigh. The trail is 0.5 miles in length, and runs along Snelling Branch Creek between North Hills Drive near Shelley Lake Trail in the west, and Optimist Park in the east (labeled #4 in Figure 18; Raleigh Parks and Recreation Department, 1990a, 1990b). The corridor width is less than 80 feet, except in Optimist Park, where it is wider. Besides portions of Optimist park, this trail corridor is forested. Some areas with upland pine forest are found close to Optimist Park, away from the creek, but the majority of forest is bottomland hardwood. Sizable areas of medium to high density housing are adjacent to the trail in the north and south. This trail is heavily used, especially by school children. Natural landscape connectivity is limited on all sides, due to busy roads, fairly dense residential development, and the vegetation management in Optimist Park.

Three days of visual observation and three nights of scent station inventory were used to assess this trail's wildlife component. Three scent stations were set along the trail. None of the umbrella species were found to be present. Raccoon and squirrel tracks were observed. One scent station was destroyed by a vandal.

The Shelley Lake Trail surrounds Shelley Lake in northwestern Raleigh, and is the focal point of the Capital Area Greenway System (labeled #5 in Figure 18; Connors, pers. comm., 1991). The trail is paved, and runs for 2.5 miles on 70 acres of publicly controlled land within Shelley Lake

Park. Much of this land is mown, with a few scattered mature trees. To the east of the lake is a large bottomland hardwood forest, and some marshy areas where Snelling Branch empties into the lake. The park is nearly surrounded by busy roads and several large areas of medium density residential development, which limits natural landscape connectivity. Three greenway trails meet at the park, though two of these connections are only constructed pedestrian trail junctions that do not represent connectivity of natural environments.

The wildlife inventory here consisted of three days of visual observations and three nights of scent station investigation. Four scent stations were set, all in the bottomland hardwood forest and its surrounding environs to the east of Shelley Lake. None of the umbrella species were found. Abundant raccoon, domestic cat and muskrat tracks were observed.

The Ironwood Trail connects to Shelley Lake Trail in the east, near the Shelley Lake Dam and Millbrook Road. The trail then follows Leadmine Creek south for 0.8 miles to North Hills Drive (labeled #6 in Figure 18; Raleigh Parks and Recreation Department, 1990a, 1990b). The trail is paved and is on a 22.4 acre corridor (Raleigh Parks and Recreation Department, 1990b). This corridor is wide (up to 400 feet in places) and covered in a mixture of bottomland hardwood and pine forests. Adjacent land use is principally low to medium density newer residential developments. Natural landscape connectivity is fairly good, chiefly because of the remnant forest patches in adjacent residential areas, and the continuation of the riparian corridor to the south, even after the trail terminates at North Hills Drive.

The wildlife inventory here consisted of one day of visual observation and one night of scent station investigation, using two stations. Red fox tracks were observed the first day, along with tracks of muskrat, raccoon and opossum. There was no evidence for the presence of white-tailed deer.

The North Hills Trail connects to North Hills Drive in two places, and follows the outer bend of Generation Drive between these connections, where Leadmine Creek flows into Crabtree Creek. This trail is just south of the southern end of Ironwood Trail (labeled #7 in Figure 18; Raleigh Parks and Recreation Department, 1990a, 1990b). North Hills Trail is 1 mile long, paved, and is on a 10 acre piece of property (Raleigh Parks and Recreation Department, 1990b). This greenway segment is principally covered in bottomland hardwood forest, with small pockets of pine forest towards North Hills Park. Adjacent land uses include high density multi-family housing, low density single-family housing, and the extensively forested North Hills Park. Connectivity in the natural landscape is good between the trail and North Hills Park, and continuing southeastward along Crabtree Creek. Natural connectivity is poor to the north and west.

The wildlife inventory on this trail was accomplished through three days of visual observations and three nights of scent station investigation, using three stations. Both red and grey fox were present on this trail. White-tailed deer was absent. Raccoon, domestic cat and muskrat tracks were also observed.

The Alleghany Trail (labeled #8 in Figure 18) is a 0.9 mile long paved path on a 19.5 acre publicly controlled corridor (Raleigh Parks and Recreation Department, 1990a, 1990b). This trail is just south of North Hills Trail and

North Hills Park, along Crabtree Creek between Alamance Road and Hertford Street (Figure 15). This is a fairly wide mixed hardwood and softwood forested corridor with low to medium density, older residential development on the same side of the creek as the trail, and a mixed commercial district back a distance from the creek bank on the opposite side. This trail is just inside of the city's principal beltline. The beltline limits natural landscape connectivity to some extent, as does denser urban development further south and east along Crabtree Creek. Natural connectivity is good between this trail and North Hills Park.

The wildlife inventory here was accomplished by three days of visual observation and three nights of scent station investigation, using two stations. Red fox was present. Grey fox and white-tailed deer were not present. Numerous raccoon, muskrat and domestic dog prints were also observed.

Lassiter Mill Trail runs from the busy Lassiter Mill Road to the end of the smaller Old Lassiter Mill Road in north-central Raleigh, and is completely internal to Lassiter Mill Greenway Park (Labeled #9 in Figure 18; Raleigh Parks and Recreation Department, 1990a, 1990b). The trail is paved, and runs for 0.2 miles. It is to be connected to the nearby Alleghany Trail in the near future (Raleigh Parks and Recreation Department, 1990b). This small (2.6 acre), thin corridor is a combination of riparian forest on the steep stream bank, and mown lawn on the more level areas of the park. Adjacent land uses include several busy roads, medium to high density older residential neighborhoods and the old Lassiter Mill ruins and spillway. Natural landscape connectivity is low in this area, due to busy roads and especially the low bridge over the stream which somewhat isolates Lassiter Mill Trail from the Alleghany Trail.

Three days of visual observation and three nights of scent station investigation employing one station were used to search for umbrella species on this trail. None were present. Domestic dog, raccoon and squirrel tracks were observed.

The Fallon Creek Trail is a 0.5 mile long paved path located in north-central Raleigh (labeled #10 in Figure 18; Raleigh Parks and Recreation Department, 1990a, 1990b). The trail starts at the end of Noble Road, and winds its way past soccer fields and into a riparian forest dominated by hardwoods along Crabtree Creek, en route to Oxford Road where the trail ends. The corridor encompasses 29.5 acres, and is nearly 800 feet wide near Oxford Road. Kiwanis Park borders the greenway to the south and west. There are several principal roads in the area, major commercial developments, and some medium to high density residential areas. Natural landscape connectivity is low to the south and east, but better, though not extensive, to the northwest.

This trail section was surveyed for the presence of umbrella species through three days of visual observation and three nights of scent station use. Two stations were set up for this inventory. None of the umbrella species were present. Raccoon, muskrat, domestic dogs and squirrel were abundant.

Buckeye Trail is located in eastern Raleigh, just inside the beltway (labeled #11 in Figure 18), and runs along Crabtree Creek for 2.5 miles (Raleigh Parks and Recreation Department, 1990b). It is a paved trail, and is on 160.7 acres of broad, hardwood-forested floodplain (Raleigh Parks and Recreation Department, 1990a). The trail begins at the intersection of Raleigh and Crabtree Boulevards, and meanders

east to Milburnie Road. There are few adjoining houses, and the trail is essentially near the eastern edge of urban Raleigh (Connors, pers. comm., 1991). There is a good deal of natural landscape connectivity in this trail, especially to the south and east. The beltway may limit connectivity in the natural landscape further to the east, however.

There is expert knowledge of the presence of grey fox on this trail (Connors, pers. comm., 1991). Additionally, I found visual evidence for the presence of white-tailed deer.

Brentwood Trail (labeled #12 in Figure 18) is 0.75 miles long, and located in northeastern Raleigh along Marsh Creek (Raleigh Parks and Recreation Department, 1990b). The trail is paved and threads through a managed park environment with ball fields and playground equipment, and into a small bottomland forest as it runs from Ingram Drive in the north to Arrowood Drive in the south. Brentwood Trail is completely internal to Brentwood Park. The trail is in a densely developed residential neighborhood near two busy boulevards and borders Brentwood Elementary School on its east side. Natural landscape connectivity is low.

Three scent stations were used for three nights, along with three days of visual observation, to assess the presence or absence of the chosen umbrella species in the trail. None of the umbrella species were present. Plentiful raccoon tracks were observed, as were tracks of muskrat and squirrel. One of the scent stations was destroyed by a small human-set fire.

Dacian Valley Trail is a small circular greenway segment along Walnut Creek in southeastern Raleigh (labeled #13 in Figure 18; Raleigh Parks and Recreation Department, 1990b).

The trail is a 0.3 mile long dirt path on 2.8 acres of publicly controlled land that begins at the end of Dacian Road (Raleigh Parks and Recreation Department, 1990a). There is a picnic area and basketball court near the trail entrance, and some bottomland forest along the trail closer to Walnut Creek. This trail is located on the southeastern edge of urban Raleigh, in an area experiencing some new residential development (Connors, pers. comm., 1991). Dacian Valley Trail is just inside the the Raleigh beltway, near where Interstate 40 diverges from the beltway and heads southeast. There are substantial forested areas beyond the beltway, along Walnut Creek. Connectivity in the natural landscape is good here, excepting fragmentation due to the beltway and Interstate 40.

There are both red and grey fox in the greenway segment, and white-tailed deer are known to be present east of the trail along Walnut Creek, beyond the beltway (Connors, pers. comm., 1991). Detailed visual inspection indicated that White-tailed deer are not present in the greenway segment itself.

Little Rock Trail (labeled #14 in Figure 18) is located in south-central Raleigh along Garner Branch Creek between Lenoir Street and McMakin Street (Raleigh Parks and Recreation Department, 1990a, 1990b). It is a 0.9 mile long paved trail on 22.4 publicly controlled acres. More than half of this acreage is in Chavis Park, which has a pool, picnic areas and expansive mown lawns. Further south along the creek, the trail dips into a small remnant forest shortly before ending at McMakin Street. The trail is surrounded by high density older housing and several busy streets, and is near Carnage Junior High School (Raleigh Parks and Recreation

Department, 1990b). Natural landscape connectivity is very low.

Two scent stations were used for three nights, along with three days of visual observations to inventory wildlife in the trail. None of the umbrella species were present. Abundant domestic dog and cat tracks, and some evidence of muskrat, squirrel, opossum and raccoon were observed.

Rocky Branch Trail (labeled #15 in Figure 18) is 0.5 miles long and runs along Rocky Branch Creek between Western Boulevard near Pullen Park and South Saunders Street (Raleigh Parks and Recreation Department, 1990b). The trail is paved, uses several sidewalks en route, and runs adjacent to busy Western Boulevard for much of its length. There is a nearly continuous riparian forest along the creek near the trail, and expansive lawns sloping to the trail from the adjacent Dorothea Dix Hospital. On the backside of the hospital are several large open areas covered in old fields and remnant forest patches. The north and east sides of the trail are near busy streets and dense urban development, the south and west sides of the trail face the hospital and the open lands. For the most part, the creek and riparian forests buffer the trail from busy roads and development. Natural landscape connectivity is marginal, and exists only to the south and west.

There is expert knowledge of the presence of red fox along the trail (Connors, pers. comm., 1991), but no grey fox. No evidence for the presence of white-tailed deer was observed.

Lake Johnson Trail is actually a system of trails encircling Lake Johnson in southwestern Raleigh (labeled #16

in Figure 18). These trails are surfaced in either pavement, dirt, or pine bark. This trail system totals 5.5 miles in length, and is internal to the 310 acre Lake Johnson Park (Raleigh Parks and Recreation Department, 1990a, 1990b). The majority of the park is forested, but it is more managed on the eastern side of the lake between Lake Dam Drive and Avent Ferry Road. West of Avent Ferry Road, the trail becomes rougher and threads through more extensive mixed hardwood and softwood forests. The entire Lake Johnson area is inside of the Raleigh beltway, with Interstate 40 forming the southern border of the park (Figure 15). Medium to high density residential areas and several large commercial developments are located outside of the park. Natural connectivity in the landscape is highest on the south and west sides, though it is not extensive because of existing development and highways.

The wildlife investigation here consisted of a combination of expert opinion and visual observation. There is expert knowledge for the presence of both red and grey fox within this trail system, but none for white-tailed deer (Connors, pers. comm., 1991). No evidence of white-tailed deer was found through visual observation, even west of Avent Ferry Road in the more remote areas of the trail system.

Loblolly Trail (labeled #17 in Figure 18) is the longest and most remote trail in the Capital Area Greenway System. It is a dirt hiking trail that runs for 6 miles along Richland Creek and the Wake County Flood Control Lake, between the 5,000 acre Umstead State Park and Old Trinity Road in west Raleigh (Raleigh Parks and Recreation Department, 1990b). Only part of the trail is within the Raleigh city limits, and nearly three miles of the trail are in Umstead State Park itself. Except for the area nearest to

Old Trinity Road and the agricultural research fields of North Carolina State University , Loblolly Trail runs through forest. Bottomland hardwoods, upland pine forests, and areas of mixed forest are all represented along the trail. Natural landscape connectivity is well developed here, especially to the west and north.

There is absolute certainty of the presence of all of the umbrella species along this trail (Connors, pers. comm., 1991). Additionally, there is recent evidence of bobcat in the area, and an occasional black bear as well (Connors, pers. comm., 1991).

Beaver Dam Trail (labeled #18 in Figure 18) is located in west-central Raleigh along Beaver Dam Creek (Raleigh Parks and Recreation Department, 1990b). The greenway occupies a thin corridor of lawn and riparian forest between the parallel streets of Nottingham Drive and Banbury Road. The trail itself runs parallel to both of these streets and the creek, and connects Beaver Dam Park to Hymettus Woods Park at either end of the trail. Hymettus Woods Park is forested, while Beaver Dam Park is maintained as mown lawn. Older, medium to high density residential areas surround the trail and busy Wade Avenue borders Hymettus Woods Park. The trail is paved and is 1.4 miles long. The trail corridor is 19.2 acres (Raleigh Parks and Recreation Department, 1990a). Connectivity in the natural landscape is very low.

The wildlife inventory here consisted of three days of visual observation and three nights of scent station investigation, using four stations. None of the umbrella species were found. I found abundant evidence of domestic dogs and cats, and a few tracks of raccoon, muskrat and squirrel.

The Gardner Street Trail (labeled #19 in Figure 18) is the final greenway segment of the Raleigh system to be discussed. This trail is located in west-central Raleigh along Beaver Dam Creek, south of Beaver Dam Trail (Raleigh Parks and Recreation Department, 1990b). The trail is 0.7 miles long, and is a combination of public sidewalk and dirt trail between Jaycee Park and the Raleigh Little Theatre and Rose Garden. Most of this corridor (2.7 acres) is maintained as lawn, or is simply a sidewalk. There are small areas of riparian forest along the northern portion of the trail, and plentiful urban forest within Jaycee Park itself. Adjacent land use is primarily medium to high density established residential areas, and a few major arteries. This trail is similar to Beaver Dam Trail (#18), but is only half as long, and a good portion of its length is sidewalk. Natural landscape connectivity is low in this trail, but the connection to Jaycee Park in the north is favorable.

According to expert knowledge, none of the umbrella species are present on this greenway trail (Connors, pers. comm., 1991). After my inventory of the similar but more extensive neighboring Beaver Dam Trail showed no presence of these species, I decided to accept Mr. Connors' assessment. No wildlife inventory was performed.

In summary, the Capital Area Greenway System is partially successful in conserving the larger, more disturbance- and space-sensitive animals used as umbrella species for this study. Trail numbers 3, 6, 7, 8, 11, 13, 15, 16, and 17 contained at least one of the three umbrella species (Figure 15). This is about half of the trails in the Capital Area Greenway System. Only two trails, the Loblolly Trail and the Buckeye Trail, had evidence of white-tailed deer in addition to fox.

Winston-Salem, North Carolina

The Winston-Salem/Forsyth County Greenway System was begun in 1984, and consists of two urban greenway trails (City-County Planning Board of Forsyth County and Winston-Salem, 1990a, 1990c). These trails are interconnected, and together run from south-central Winston-Salem to the eastern edge of the city, around Salem Lake (Figure 16). The principal goals for this greenway system are, in descending order, to provide passive recreational areas, alternative transportation routes, and flood and erosion control; to maintain and to improve water quality; to preserve wildlife habitat; and to provide buffers between adjacent and often incompatible land uses (City-County Planning Board of Forsyth County and Winston-Salem, 1990c). Due to inclement weather, scent station use was restricted to two nights in the Winston-Salem/Forsyth County Greenway System, rather than the three nights that were recommended by Dr. Michael Pelton (pers. comm., 1991) as a good length of time for assessing the presence or absence of the umbrella species. These wildlife results should therefore be considered somewhat preliminary. The Salem Creek Trail was the pilot trail for the Winston-Salem/Forsyth County Greenway System. Though planning for the system began in 1984, as mentioned above, this trail was not opened in its entirety until 1989 (City-County Planning Board of Forsyth County and Winston-Salem, 1990c). The trail is 4.5 miles long, and runs along Salem Creek from the Marketplace Mall in the west to the dam at Salem Lake in the east (Figure 16). This pedestrian trail is paved, and strings together four public parks and a public golf course. The minimum width for the trail corridor is 40 feet, but because of adjacent public lands, it is typically much wider.

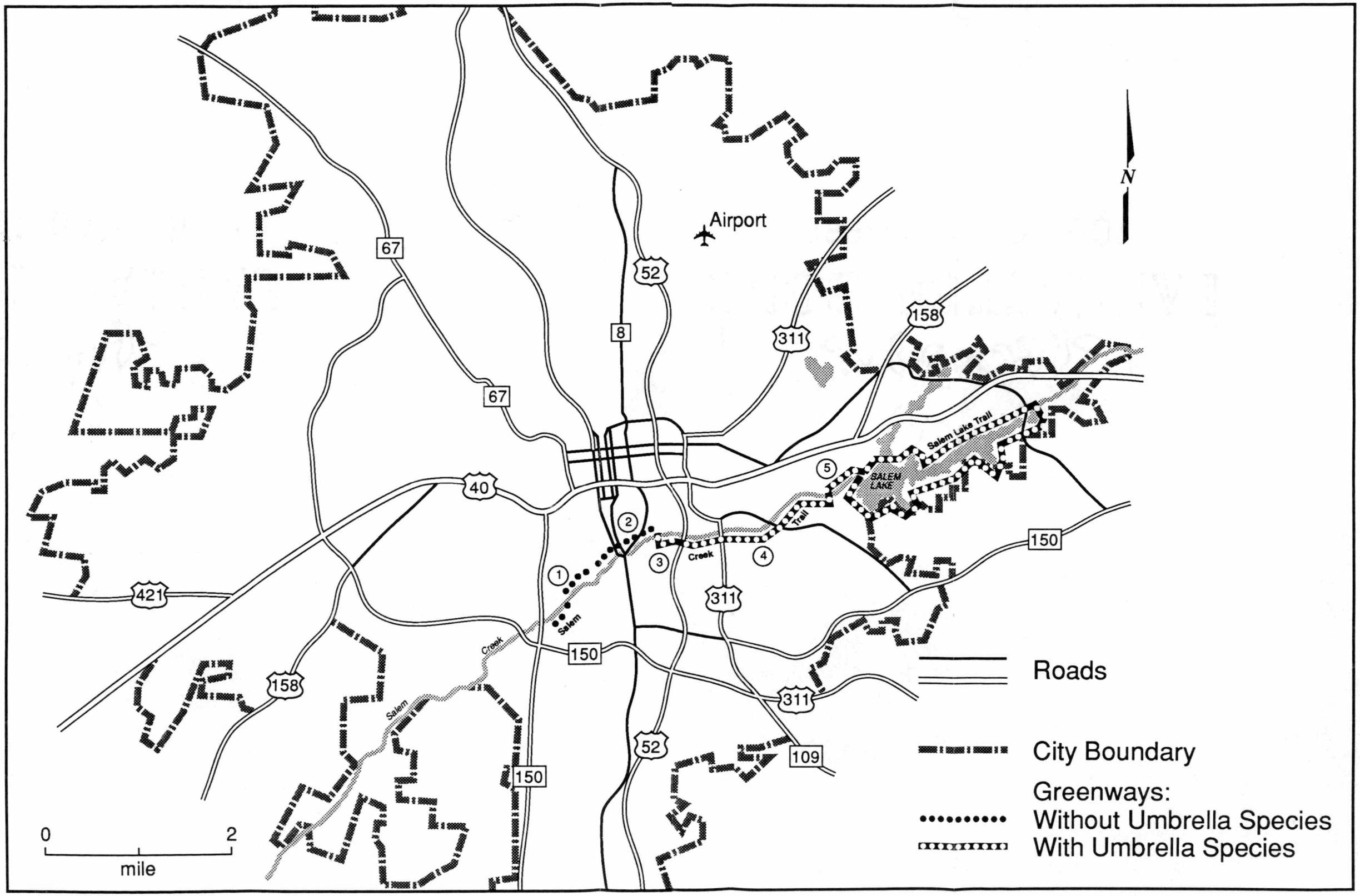


Figure 19 Wildlife conservation in the Winston-Salem/Forsyth County Greenway System, Winston-Salem, N.C.

The character of this trail differs greatly from one end to the other. As the greenway threads to the east, it passes from park to park and under several major arteries. These variations cause several natural changes in the trail's character, and produce breaks in the connectivity of the natural environment. Because of these variations, and their expected effect on wildlife along the trail, I have divided up the trail into five principal sections. For the wildlife inventory, each of these segments was treated separately, and here will be discussed as sections one through five of the Salem Creek Trail.

Section one of the Salem Creek Trail runs east from behind Marketplace Mall to Washington Park, about 0.5 miles west. It is a fairly thin corridor, maintained as mown lawn except on the steeper creek margins, and follows both a sewer easement and a power line right of way. Washington Park contains three ball fields and a picnic area, and is almost all lawn. West of Washington Park is a busy road and stream-side facilities for Duke Power and Lighting Company. The combination of the power company and the road obstruct natural landscape connectivity along the creek. Other adjacent land uses are medium to high density residential development, industrial areas, and several small commercial districts. Peters Creek Parkway borders Marketplace Mall to the west, and blocks natural landscape connectivity along the creek in that direction.

The wildlife inventory here consisted of three scent stations used for two nights, and two days of visual observation. None of the umbrella species were found. Tracks of raccoon, and domestic dogs and cats, were observed.

Section two of the Salem Creek Trail runs from just west of Washington Park to Central Park (Figure 16). Between these two parks the greenway simply follows the sidewalk along Salem Avenue. Thus, only Central Park itself was surveyed for wildlife in this section of the greenway trail. Central Park is small, has two ball fields, and is maintained as mown lawn, save for the thin, steep margins along the creek bank which are in brush and forest. Happy Hills Park, which is similar to Central Park in size and character, is across Salem Creek from Central Park. Both parks have erosional problems at the stream margins. Other adjacent land uses are several busy roads, some small industrial development, and large areas of medium to high density housing.

Two scent stations were used for two nights in conjunction with two days of visual observation to survey wildlife presence within this section of the trail. None of the umbrella species were found. Tracks of domestic dog, raccoon and squirrel were observed.

Section three of the Salem Creek Trail extends from Happy Hills Park (the trail crosses the creek into Happy Hills Park from Central Park) east to the U.S. 52 highway overpass (Figure 16). This section is slightly longer than 0.7 miles. Between the park and the highway, the trail threads through a linear corridor of lawn alongside a riparian forest that follows Salem Creek. This riparian forest is much wider than the forested stream banks in the previous two sections. Adjacent land uses include dense, older residential areas, some stream-side industry opposite the trail, and several major roads.

The wildlife investigation here consisted of using four scent stations for two nights, in conjunction with two days of visual observation. Evidence of red and grey fox was found. Tracks of squirrel, raccoon, muskrat and domestic cats and dogs were also observed.

Section four of the Salem Creek Trail is from the U.S. 52 bridge west to where the trail crosses back to the north side of Salem Creek (Figure 16). This trail section is over 1.5 miles long and includes Civitan Park and Reynolds Park Golf Course. Like section three, the trail threads through a corridor composed of lawn, and is adjacent to a riparian forest that follows the Creek. The forest is even wider here than in section three, however, with significant brushy undergrowth along its margins. Adjacent land uses include medium density residential areas, several major roads, and a continuation of stream-side industry with some added office development along the north side of the creek, interspersed with fragments of riparian forest and brush. Civitan Park includes three ball fields and is maintained in lawn throughout. Reynolds Park Golf Course is likewise maintained in close-cropped lawn.

The wildlife investigation in section four consisted of two days of visual observation and two nights of scent station survey using four stations. Grey fox tracks were evident both nights. Raccoon, opossum, and domestic cat and dog tracks were also recorded.

Section five of the Salem Creek Trail extends from where the trail crossed to the north side of the creek, westward to the Salem Lake Trail near the Salem Lake Dam (Figure 16). This trail section is approximately 1 mile long. It has more forest within and adjacent to the corridor than any of the

previously described sections. There is low to medium density housing back a distance from Salem Creek on the opposite side of the creek from the trail (south side). A railroad line runs adjacent to the creek and trail, sitting above them both on the north side of the trail, away from the creek. The trail is buffered from these tracks by nearly 70 feet and a thin line of forest and brush.

I set two scent stations and used them for two nights to collect wildlife data here, in addition to two days of visual observation. There was abundant evidence of grey fox and raccoon.

The Salem Lake Trail is connected to the Salem Creek Trail, and encircles the southern arm of Salem lake (Figure 19; City-County Planning Board of Forsyth County and Winston-Salem, 1990b, 1990c). The Salem Lake Trail is a wide dirt trail that is 6.5 miles long. One small section of the trail, located behind the dam near Salem Creek, is paved. The trail was built in the 1930's, and has since been improved and incorporated into the Winston-Salem/Forsyth County Greenway System (City-County Planning Board of Forsyth County and Winston-Salem, 1990b). A large portion of the lake's watershed is protected from development, and is forested in hardwoods, pine, or a mixture of the two. This protected area covers hundreds of acres.

Adjacent land uses are chiefly suburban to exurban in nature. The lake itself is on the eastern edge of Winston-Salem. Interstate 40 crosses the northern arm of the lake, and several other major roads thread through the area. There are numerous large housing developments mixed with several commercial strips. These urban land uses are interspersed with large patches of forest, fields and a few farms. Land

use in this area generally changes from more to less developed from west to east.

Expert knowledge of wildlife around Salem Lake and visual observation were used together to assess the presence or absence of umbrella species. Diane Peck, who manages the recreational facilities at Salem Lake, has observed grey fox and white-tailed deer along the trail (Peck, pers. comm., 1991). Ms. Peck emphasized that she had seen white-tailed deer only around the eastern areas of the trail. I found plentiful evidence for both red and grey fox throughout the protected watershed, but likewise, found evidence for the presence of white-tailed deer only in the eastern portion of the Salem Lake Trail.

The majority of the Winston-Salem/Forsyth County Greenway System is successful at preserving the more sensitive wildlife species that are here used as indicators of wildlife conservation value. The westernmost sections of Salem Creek Trail (discussed as sections one and two) did not have any of the umbrella species. These sections, however, are the most isolated and managed in the greenway system, and are further into the city proper. Adjacent lands near these sections are more developed, corridors are thinner, and there is more lawn and less forest than in other sections of the greenway system. From Happy Hills Park east, both red and grey fox were found along Salem Creek Trail. In addition to red and grey fox, white-tailed deer were present in the eastern portion of the Salem Lake Trail, which is eastward of most of urban Winston-Salem.

Chapter 6

Discussion and Conclusions

Demonstrated Trends in Wildlife Conservation at the Study Sites

The results of the wildlife surveys revealed that urban greenways in the mid-southeastern United States vary in their wildlife conservation value. Some systems, or segments within systems, are good at conserving wildlife, while others are very poor at conserving wildlife -- particularly the larger and more disturbance-sensitive species that are frequently absent from the urban environment. But why do certain greenways have umbrella species, while others do not? When the individual greenway segments are analyzed in terms of their specific greenway characteristics and adjacent land uses, some of the reasons for these observed patterns in wildlife conservation become clear (Table 2).

First, adjacent land use seems to have strongly influenced the presence of umbrella species in the surveyed urban greenways. The one greenway segment surrounded by extensive forest had both umbrella species. All five (100%) of the greenways in an exurban environment had red or grey fox, and four of the five (80%) had deer. Six of fourteen greenway segments in suburban residential areas (43%) had red or grey fox; only one (7%) had white-tailed deer. Of the five surveyed greenway segments in areas of mixed suburban use (suburban residential, plus commercial and/or industrial land uses), three (60%) had red or grey fox, and none had white-tailed deer. In only one of seven (14%) greenway segments in urban residential areas were red or grey fox present; deer were absent in all cases. Two of five greenway

Table 2. Characteristics, Adjacent Land Uses, Connectivity and Umbrella Species Presence/Absence of all Surveyed Greenway Segments.

GREENWAY SEGMENTS ↓	PRINCIPAL ADJACENT LAND USES						VEGETATION MANAGEMENT OF THE GREENWAY SEGMENTS				WIDTH OF GREENWAY			LOCALIZED ADJACENT LAND USES			CONNECTIVITY		PRESENCE OF UNBRELLA SPECIES	
	LARGE FOREST	EXURBAN	SUBURBAN RESIDENTIAL	SUBURBAN MIXED USE	URBAN RESIDENTIAL	URBAN MIXED USE	CITY PARK	LAWN W/ SMALL FOREST	1/2 TO 3/4 FOREST	CHIEFLY FOREST	THIN	MEDIUM	WIDE	LARGE FORESTED PARK OR AREA	LARGE OPEN LAWN AREA	BUSY MAJOR ROAD(S)	LARGE SCALE	SMALL SCALE	RED AND/OR GREY FOX	WHITE-TAILED DEER
ATHENS		X								X			X	X	X		X		X	X
CARY-1		X								X			X		X	X	X		X	X
CARY-2A		X								X		X		X			X		X	X
CARY-2B			X					X			X									
CARY-3			X							X		X			X	X				
CARY-4			X							X		X			X	X				
CARY-5			X							X		X				X				
CARY-6					X					X	X									
CHICKA-MAUGA		X								X			X	X		X		X	X	
KINGSPORT-1						X	X					X				X				
KINGSPORT-2						X		X				X				X				
KINGSPORT-3				X						X		X					X		X	
KINGSPORT-4				X			X						X			X				
RALEIGH-1			X				X				X									
RALEIGH-2			X							X		X		X		X				
RALEIGH-3			X							X			X	X		X			X	
RALEIGH-4			X							X	X			X	X	X				
RALEIGH-5			X				X						X	X		X				
RALEIGH-6			X							X			X		X				X	
RALEIGH-7			X							X		X		X		X		X	X	
RALEIGH-8				X						X		X		X		X		X	X	
RALEIGH-9					X			X			X					X				
RALEIGH-10				X					X				X		X	X				
RALEIGH-11			X							X			X	X		X	X		X	X
RALEIGH-12					X			X				X			X	X				
RALEIGH-13			X						X			X		X		X		X	X	
RALEIGH-14					X			X				X				X				
RALEIGH-15						X		X				X			X	X			X	
RALEIGH-16			X							X			X	X		X			X	
RALEIGH-17	X									X			X	X			X		X	X
RALEIGH-18					X			X			X			X		X				
RALEIGH-19					X			X			X			X		X				
W/S-CREEK-1						X		X			X				X	X				
W/S-CREEK-2						X	X					X			X	X				
W/S-CREEK-3					X			X				X				X		X	X	
W/S-CREEK-4						X		X				X		X	X	X		X	X	
W/S-CREEK-5				X					X			X		X				X	X	
W/S-LAKE		X								X			X	X		X	X		X	X

Key to Greenway/Wildlife table.
Vegetation management of the greenway segments: **CITY PARK** = mostly lawn, with a few mature trees. **LAWN W/SMALL FOREST** = mostly lawn with small amount of area in forest. **1/2 to 3/4 Forest** = between 1/2 and 3/4 forest, the rest in lawn. **CHIEFLY FOREST** = nearly all of the greenway segment is in forest.
Width of greenway: **THIN** = almost all of greenway is less than 100' wide, often considerably less. **MEDIUM** = greenway width varies a lot, several areas less than 50' wide, others greater than 150' wide. **WIDE** = less than 100' wide only for a short distance, if at all. Vast majority of greenway is *much* more than 100' wide.
Localized adjacent land uses: **LARGE FORESTED PARK OR AREA** = large forested park, or other large forested area adjacent to the greenway. **LARGE OPEN LAWN AREA** = large mowed park or other large lawn-type area adjacent to the greenway. **BUSY MAJOR ROAD(S)** = major road or roads with heavy use *directly* adjacent to the greenway.
Connectivity: **SMALL-SCALE** = connectivity to nearby small natural areas. **LARGE-SCALE** = connectivity to extensive natural areas beyond the greenway system.

segments (40%) in areas of urban mixed use (urban residential, plus commercial and/or industrial land uses) had red or grey fox; deer were absent. The greenway segments that are chiefly successful for wildlife conservation tend to be surrounded by the least urban land uses. In short, the urban greenways most successful in conserving wildlife are, in fact, the least urban.

More localized adjacent land uses may also influence the presence of umbrella species. For instance, a large forested area or forested park may abut a greenway that is otherwise in an exurban, suburban or urban area. Eleven of eighteen greenway segments (61%) with a local forested area had red or grey fox present. Five of these (28%) also had white-tailed deer. Large open lawn areas also frequently abut urban greenways, in many of the adjacent land use categories. Four of ten greenway segments (40%) with a large lawn area nearby had red or grey fox. One of these (10%) also had white-tailed deer. A third type of localized adjacent land use -- a busy major road -- is also included in Table 2. However, there are so many greenways with an adjacent busy road, and so much qualitative variation within this category, that little useful information was found by analyzing the effect of this variable on wildlife conservation. A localized forest abutting the greenway is somewhat positively correlated with umbrella species presence, but not strongly so. A localized large open lawn area does not appear to positively affect the presence of either of the umbrella species, but in an urban or suburban area, I doubt if the presence of a large lawn area near the greenway is detrimental (compared to the alternative of adjacent developed lands without open lawn).

Second, characteristics of the greenway segments themselves also influenced the presence of umbrella species. For the purposes of analysis, Table 2 presents three categories of greenway width -- wide, medium and thin. Definitions for each appear at the bottom of the Table. I found that nine of twelve wide greenway segments (75%) had red or grey fox, and five of ten (50%) had white-tailed deer as well as fox. Nine of eighteen medium width greenway segments (50%) had red or grey fox. One of these (6%) also had white-tailed deer. No thin greenways had either umbrella species. A strong positive relationship exists between increasing greenway width and the presence of umbrella species.

In addition to width, vegetation management within the greenway should influence the observed presence or absence of umbrella species. Of the five surveyed greenway segments that are managed like a city park (chiefly lawn, with a few scattered, mature trees), none had umbrella species present. Three of eleven greenways that are mostly lawn, but contain a small forest component (27%), had red or grey fox. None had white-tailed deer. Two of three greenway segments that are approximately 1/2 to 3/4 forest, with the remainder in lawn (67%), have red or grey fox. None had white-tailed deer. Nineteen surveyed greenway segments are 3/4 to all forest. Of these, thirteen (68%) had red or grey fox, and six (32%) had white-tailed deer in addition to fox. This analysis shows that the more forested a greenway is, the better the chances that it will contain umbrella species.

There is a good deal of correlation between the above discussed greenway characteristics and principal adjacent land uses surrounding each greenway (Figure 20). This makes it more difficult to say with certainty what specific

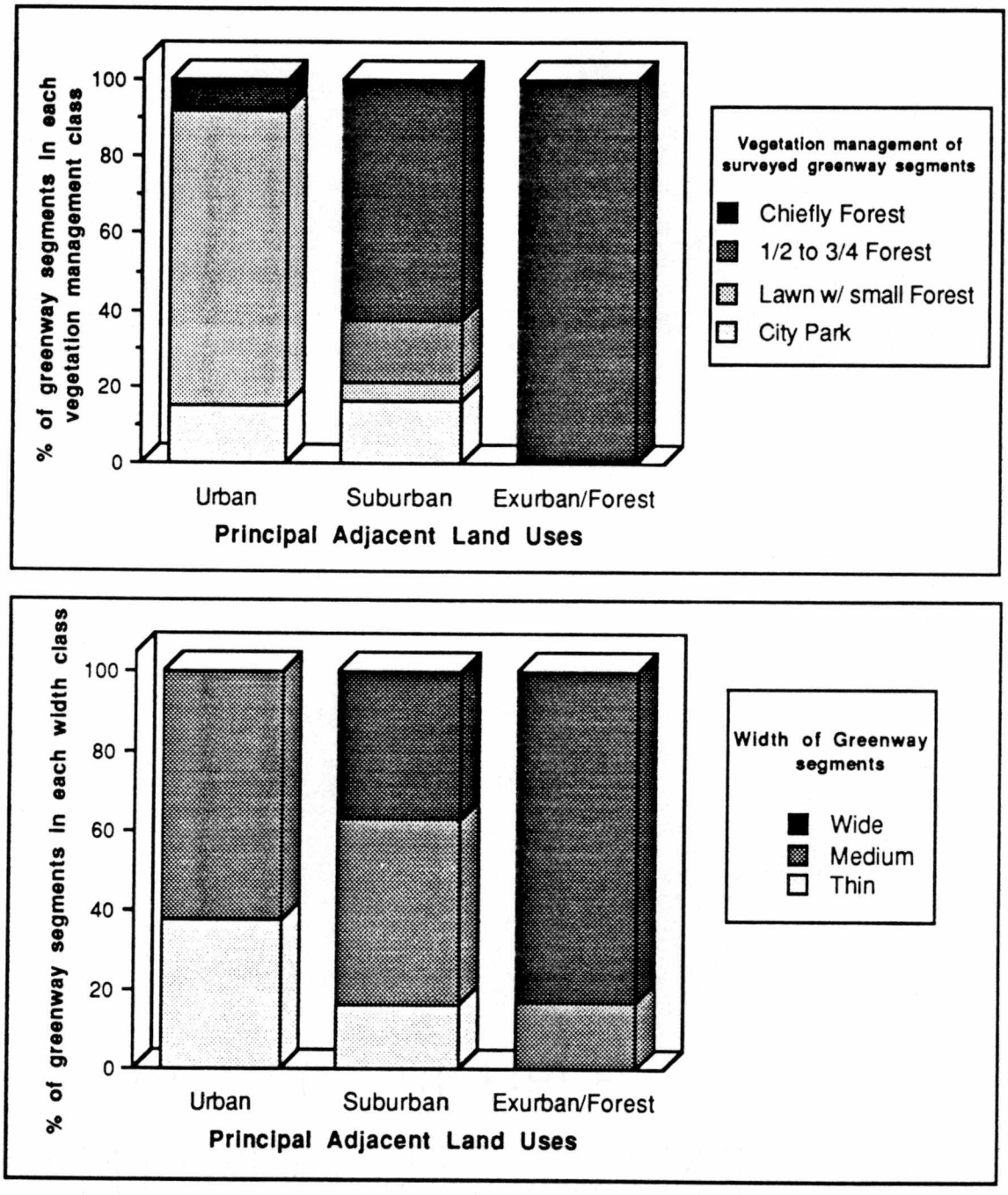


Figure 20 Relationship between greenway characteristics and principal adjacent land use.

landscape characteristic(s) is(are) chiefly responsible for the presence of umbrella species. Of the thirteen surveyed greenway segments in urban areas (residential and mixed use combined), two (15%) are managed like a city park, ten (77%) are mostly lawn with a small forest component, and one (8%) is nearly all forest. Of the nineteen surveyed greenway segments in suburban areas (residential and mixed use combined), three (16%) are managed like a city park, one (5%) is mostly lawn with a small forest component, three (16%) are between 1/2 and 3/4 forest, and twelve (63%) are chiefly forest. Of the six greenways surrounded by exurban land use or a very large forested area, all six are chiefly forested.

Though the interactions that lead to the presence or absence of umbrella species in any particular greenway segment are complex, some general patterns have emerged from this research. Greenway trail segments with more forest cover, wider corridors, greater amounts of adjacent open space and better connectivity in the natural landscape were the greenway segments with umbrella species. Greenway segments without umbrella species commonly shared the attributes of smaller overall size, less forest cover and more lawn, thinner corridors, closeness to particularly disruptive urban elements, and little connectivity in the natural environment. This pattern of characteristics shared by greenways that either do or do not have presence of umbrella species, generally adheres to the premises discussed in Part I of this thesis concerning nature reserve design and urban wildlife conservation.

Combinations of the greenway attributes favorable to wildlife appear most common in greenway segments that are further from the urban core. Thus, there is a demonstrated general positive correlation between increasing distance from

the city center and the presence of umbrella species within greenway segments (Figure 21).

Much of this analysis begs the question: "Which landscape features are most important for wildlife conservation in urban areas: those of the greenway itself, or those of adjacent lands?" To try to answer this question, I grouped greenway characteristics (width and vegetation management) into two categories: wildlife-positive and not necessarily wildlife-positive (the latter includes characteristics that are either neutral or negative). Only greenways that were wide and at least one half forested were considered wildlife-positive. All other combinations were considered not wildlife-positive. Likewise, I grouped adjacent land uses into wildlife-positive and not wildlife-positive categories. Only larger forested environments and exurban areas were considered wildlife positive. The effect of wildlife-positive and not wildlife-positive greenway characteristics and adjacent land use on the presence of fox and deer is presented in Table 3. Though Table 3 is informative on its own, I found that considering information on large-scale and small-scale connectivity (from Table 2), further clarified the relationships between greenway design and landscape character in regards to wildlife conservation in urban greenways.

From this analysis, I found that every site that had a wildlife-positive greenway design and wildlife-positive adjacent land use, with large-scale connectivity to sizable natural areas beyond the greenway, had white-tailed deer present. The one greenway that was wildlife-positive with wildlife-positive adjacent land use that did not have white-tailed deer lacked large-scale connectivity to larger natural areas beyond the greenway. The one site in which white-

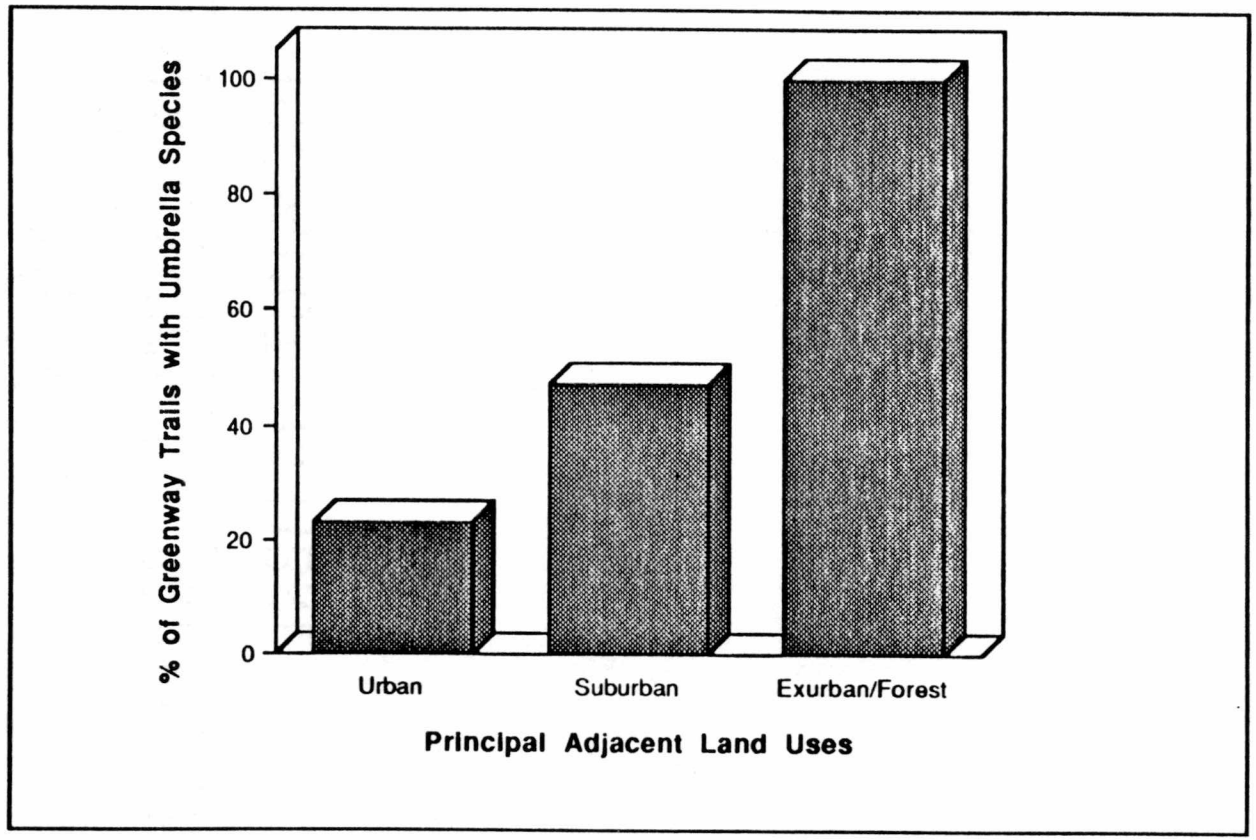


Figure 21 Demonstrated trend in increasing presence of umbrella species with less developed adjacent lands.

Table 3. The Effects of Adjacent Land Use and Characteristics of the Greenway on the Presence of Umbrella Species

Ecological Landscape Features		# of Trails	FOX		DEER	
Greenway Charact-eristics	Adjacent Land Uses		Present	Absent	Present	Absent
Positive	Positive	6	6	0	5	1
Positive	Not Positive	5	4	1	1	4
Not Positive	Positive	0	0	0	0	0
Not Positive	Not Positive	27	8	19	0	27

Notes: This table highlights the effects of adjacent land use and characteristics of the greenway itself on the presence of umbrella species. Greenway characteristics include vegetation management and corridor width. For this analysis, a wildlife-positive greenway is considered to be both wide and from half to completely forested. Any other combination of attributes is deemed not wildlife-positive. The adjacent land uses category includes only principal adjacent land uses (urban, suburban, exurban, or large forest). Exurban and large forest are considered wildlife-positive. Any other adjacent land use is regarded as not wildlife-positive.

tailed deer were found in a wildlife-positive greenway that had adjacent land use that was not wildlife-positive, the greenway segment had large-scale connectivity to extensive undeveloped lands beyond the greenway system. White-tailed deer were everywhere limited to areas from the very edge of the urban environment outward into the country. Throughout this study, no white-tailed deer were found closer into the city than in greenway trails on the edge of the urbanized area. Large-scale connectivity to extensive natural areas beyond the city appears to be of paramount importance for the presence of white-tailed deer in urban greenways.

Every site that had a wildlife-positive greenway design and wildlife-positive adjacent land use had fox present -- regardless of large-scale connectivity. All but one site where the greenway design is wildlife-positive, but adjacent land use was not necessarily wildlife-positive, had fox. Eight of the twenty seven sites that are not wildlife-positive in either the greenway or adjacent lands, had fox present. All of these eight had small-scale connectivity to small natural areas directly adjacent to the greenway.

It is clear that the character of adjacent land use is the best predictor of urban wildlife conservation (Figure 21). However, to say that adjacent land use is the controlling factor for wildlife conservation in urban greenways is to unfairly simplify the situation. The above analysis (and Figure 20) demonstrates that both work bilaterally to enhance or limit such value. Some urban greenway segments may be successful for wildlife conservation without any purposeful wildlife-positive design merit, simply because they abut lands that are wildlife-positive. Likewise, a greenway segment that is itself wildlife-positive may have its wildlife conservation value limited if the

greenway is adjacent to particularly dense and caustic urban areas. But if a greenway is very wide, forested, and well connected to other natural areas, it should contain umbrella species, even if it is in a densely developed urban area.

What factors affect the degree to which urban greenways are designed to be more or less wildlife-positive? The morphological traits of urban greenways that either enhance or limit wildlife conservation value are the outcome of a group of distinct processes. Many factors that can limit wildlife conservation are beyond the control of greenway designers, managers and planners. Some of these factors, however, are at least partially under the control of these greenway administrators, though it must be recognized that these people are public employees, and as such, are instruments of public opinion and government policy without complete personal choice of action. The principal greenway features that planners, designers and managers can potentially guide are the way that vegetation is managed in the greenway, the chosen greenway corridor widths, and the amount of existing natural landscape connectivity that is preserved with greenway development.

There are a complex set of anthropocentric considerations that act to affect the management of vegetation and the amount of natural landscape connectivity within urban greenways. These include real or perceived safety from crime, aesthetics based on perceptions of landscape order and neatness that ignore ecological function, and competing priorities for land use within the greenways (such as active recreational facilities), which may necessitate a more manicured environment (Frasier, pers. comm., 1990; Brown, pers comm., 1991; Connors, pers. comm.,

1991; Cook, pers. comm., 1991; Hunt, pers. comm., 1991; Miller, pers. comm., 1991).

When a greenway is developed, vegetation that offers food and cover for wildlife is frequently removed. This vegetation removal is often far more extensive than simply clearing an area for the greenway trail. The entire character of the land that the greenway is built on may be altered. Riparian and upland forests, for example, are often replaced by open lawns, ball fields and playground equipment. The introduction of people and their pets onto land that was previously inaccessible can also negatively effect the wildlife conservation value of these lands. Thus, the existing wildlife conservation value on remnant lands can be reduced by the development of an urban greenway.

As the first part of this study detailed, their are many wildlife positive vegetation management and landscaping techniques that can be used to enhance the wildlife value of greenways -- including planting certain food and shelter plants when the original vegetation must be cleared, or when the area to become a greenway was previously managed like a city park. Yet, these are rarely used in the urban greenways surveyed for this study. Wildlife-positive landscaping strategies appear to be underused in urban greenways because of other priorities for use of the land, as discussed above; the lack of funding for such projects, and ecological ignorance.

Lessons for Urban Wildlife Conservation

In setting aside areas as greenways, the hope is that we can protect the land from future degradation associated with continued urban expansion and habitat fragmentation. But

sadly, urban lands that are developed for greenways often have their current wildlife value degraded in the process of trying to preserve them from the potentially worse degradation projected for the future.

That many urban greenways in the mid-southeastern United States are not preserving wildlife seems oftentimes to be the result of a lack of wildlife knowledge on the part of greenway advocates, planners, designers and managers, and low priorities for wildlife conservation in general. This lack of wildlife knowledge and low priorities for wildlife can be seen most clearly in the way vegetation in the greenway is managed, and in the selection of corridor widths in relation to the available open land for corridor preservation. Unfortunately, this does not stop urban greenway enthusiasts from repeatedly proclaiming how good urban greenways are for wildlife (for example, Mathews, 1989; City-County Planning Board of Forsyth County and Winston-Salem, N.C., 1990c; Little, 1990; Clarke County Department of Parks, 1991). It is misleading for greenway advocates, developers and planners to promise true wildlife conservation -- even with the best of intentions -- if they cannot deliver. And quite often, they are not delivering. The majority of urban greenway segments that preserve umbrella species seem to owe their success in wildlife conservation to fortuitous circumstances relating to adjacent land uses, and existing vegetation cover and natural connectivity in the greenway, rather than to any design or management strategies purposefully administered to increase wildlife conservation value. This dependence on factors outside of the preserved greenway area makes greenways that have umbrella species present today particularly vulnerable to future changes in surrounding land use, especially the reduction of natural landscape connectivity.

I believe that urban greenways in the mid-southeastern U.S. could be much better for wildlife conservation than they currently are if tenets from island biogeographic theory and landscape ecology, and wildlife-positive landscape strategies, were incorporated into the planning, design and management of urban greenway systems. In a global context, urban greenways will hardly never contribute to the preservation of the most endangered and rare wildlife species. Nor will they serve as corridors for the movement of terrestrial species that must relocate because of potential climate change, as has been suggested as a possible function of larger, non-urban greenway corridors (Forman, 1990). But, urban greenways can still play a role in wildlife conservation. If vegetation were left in its natural state or managed for wildlife, corridors were preserved to be as wide and continuous as possible, wildlife-positive plantings and vegetative buffers were added to the greenway environment, and greenway trails, bridges and other structures were built so as to not hinder connectivity in the natural environment, urban greenways could preserve more of the larger, more disturbance- and space-sensitive animals that are frequently absent from the urban environment. Even greenway trails penetrating deep into the urban fabric may be able to support red or grey fox if these and other suggestions from Part I were incorporated into their design and management. If these suggestions were employed, perhaps even bobcat and black bear, species that normally avoid urban areas, could live comfortably in larger urban greenway trails on the city edge, where white-tailed deer are currently the most disturbance- and space-sensitive animals in residence.

To begin to increase wildlife conservation value in urban greenways, urban residents must express an interest in preserving wildlife in and near the city, and develop a taste

for the different vegetation aesthetics that come with natural areas. Guidance from persons that are knowledgeable about wildlife conservation and ecologically based landscape design and management strategies is also desperately needed in the design and management of urban greenway systems in the mid-southeastern United States, if these systems are to reach their true wildlife conservation potential. Until public opinion and resources are committed to wildlife conservation as a greenway priority, urban greenway advocates, planners, designers and managers should be more conservative in their statements about the wildlife conservation benefits that will accrue as a result of urban greenway establishment.

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