ABSTRACT

KOHUT, SALINA MARVELLE. Avian Use of Suburban Greenways as Stopover Habitat. (Under the direction of George R. Hess and Christopher E. Moorman).

The decline of Neotropical migrant songbirds has called attention to the need for habitat conservation along the entire migratory route, and scientists now recognize the need to conserve stopover habitat in addition to habitat on the breeding and wintering grounds. Greenways are a popular means for accomplishing conservation goals in suburban areas and might provide stopover habitat in urbanizing areas where habitat loss and alteration are accelerating.

My study examined the effects of greenway forested corridor width, greenway vegetative characteristics, and adjacent land cover on the species richness and abundance of migrant songbirds during spring and fall migration. I conducted the study to provide city planners with management recommendations for the construction and maintenance of greenways that will benefit migrating songbirds. During spring and fall migration, 2004, and spring migration, 2005, I surveyed birds in 47 segments of public greenway in Raleigh and Cary, North Carolina, USA representing a range of forested corridor widths and adjacent land covers. I also surveyed three reference sites along trails in William B. Umstead State Park, the largest contiguous forested area (2,201-hectares) nearest the study greenways.

Migrant species richness was higher in wider greenways in both spring and fall. During spring migration, migrant bird richness and abundance generally increased with tree height and percent hardwood tree composition, and abundance was greater in greenways with more shrub cover. During fall migration, migrants occurred most commonly in greenways with lower canopy cover and higher shrub cover. Although forest-interior migrant richness

was not correlated with greenway forest corridor width in either season, they were more abundant in the reference sites than in the greenways during spring and fall. During spring, forest interior migrants were less common in greenways surrounded by more bare earth and pavement cover, both signs of intense development.

Though migrants used greenways of all widths, forested corridors wider than 150 m had the greatest overall diversity and abundance of migrants. Therefore, planners should conserve the widest greenway corridors possible. Shrub and ground cover should be retained within the greenway to provide the complex vegetative structure that migrants use. In urbanizing areas, planners can provide stopover habitat for forest-interior migrants by constructing greenways in areas of lower development intensity and by conserving larger parks or reserves in addition to greenways.

AVIAN USE OF SUBURBAN GREENWAYS AS STOPOVER HABITAT

by

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BIOGRAPHY

Salina Kohut (née Kovach) was born in Uniontown, PA in 1977, but grew up in Garner, NC. As a child, she was keenly interested in the avian world, and spent countless hours observing the feathered fauna of her backyard. She would even perform counts of the birds seen in her yard each morning before school. Salina attended Garner Senior High School where her exceptional science teachers fueled her interest in the natural world. Upon graduating in 1995, she attended the University of North Carolina at Chapel Hill as one of the recipients of the James M. Johnston Scholarship. An avian biology class rekindled Salina's interest in birds. Her involvement with the UNC Newman Catholic Student Center led to her meeting her future husband Matt Kohut. Salina earned a B.S. in Biology in 1999, graduating with distinction.

Following graduation, she pursued her interest in birds first by working as a summer field assistant studying grassland birds in Iowa and then as a waterfowl bander in Colorado. Salina completed an internship at the Florida Keys Wild Bird Rehabilitation Center, and then came to North Carolina State University to work with Woodlot Forestry Research and Development to help complete a natural resources survey of Camp Butner National Guard Training Site. She continued to work at Woodlot Forestry R&D and worked with the Forest Nutrition Cooperative while beginning coursework towards her Master's degree.

Salina married Matthew Kohut in 2004. They have two cockatiels, Annabelle and Mr. Katie. Salina enjoys bird watching, hiking, backpacking, reading, and scrapbooking. She is involved in Young Adult Ministry at her church and volunteers at the Piedmont Wildlife Center rehabilitation hospital.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1: LITERATURE REVIEW

NEOTROPICAL MIGRANTS

Declines and Conservation

Nearctic-Neotropical migrant birds (hereafter "Neotropical migrants") breed in temperate North America but spend the winter in tropical latitudes (Petit 2000). Numerous studies have documented declines of Neotropical migrant songbirds on continental, regional, and local scales, especially in eastern North America (e.g. Graber and Graber 1963, Holmes and Sherry 1988, Robbins et al. 1989, Terborgh 1989, Askins et al. 1990, Sauer and Droege 1992, Hagan et al. 1992, Peterjohn et al. 1995, Ballard et al. 2003, Lloyd –Evans and Atwood 2004). The concern over these declines has prompted extensive investigation of the contributing factors and has spurred the development of conservation measures (e.g. Finch 1991, Hagan and Johnston 1992, Moore et al. 1993, Degraaf and Rappole 1995, Martin and Finch 1995, Moore 2000, Faaborg 2002). Habitat loss, degradation, and fragmentation on the breeding and wintering grounds are seen as complicit in the declines (Sherry and Holmes 1996, Petit 2000, Rappole et al. 2003, also see Robbins 1979, Whitcomb et al. 1981). Fragmentation of forests on the breeding grounds can result in increased levels of brood parasitism (e.g. Robinson et al. 1995, Arcese et al. 1996, but see Gustafson et al. 2001) and nest depredation (e.g. Wilcove 1985, Andrén 1992, Danielson et al. 1997, Heske et al. 1999, Chalfoun et al. 2002, Schmidt 2003 but see Lahti 2001). The spread of invasive, exotic vegetation reduces the cover of native plants to which the birds are adapted (Borgmann and

Rodewald 2004). The use of pesticides also contributes to population declines (Gard et al. 1993, Gard et al. 1995).

More recently, however, researchers have focused on the conditions and events during migration that may contribute to songbird declines (Newton 2006) and have implicated the loss and fragmentation of stopover habitat (Petit 2000, Hutto 2000, Pearson and Simons 2002, Mehlman et al. 2005). Stopover habitats are those areas birds use during migration to rest and refuel between legs of their journey. The suitability of stopover habitat, especially in regards to food availability, can determine whether migration is successful, and ultimately determine breeding success (Newton 2006).

The Importance of Stopover Habitat

Migratory birds are extremely vulnerable during migration (Sillett and Holmes 2002), and migration is especially difficult for juveniles making their first migratory flight in the fall (Woodrey and Moore 1997, Yong et al. 1998, Jones et al. 2002). During this energetically demanding journey (Blem 1980), migrants face challenges such as finding food, water, and cover in unfamiliar areas (Moore et al. 1995). They must contend with inter- and intra-specific competition with other migrants and resident birds (see Kale 1967, Rappole and Warner 1976, Kodric-Brown and Brown 1978, Bibby and Green 1980, Moore and Yong 1991, Yong et al. 1998). Migrants encounter hazards such as variable or adverse weather (e.g. Wiedenfeld and Wiedenfeld 1995, Stokke et al. 2005, Marra et al. 2005) and predators (Aborn 1994, Lindström 1989, Cimprich et al. 2005). In addition, migrants may need to correct for orientation errors (Moore et al. 1995). All of this must be accomplished in a

changing landscape (Heglund and Kagen 2005) with fluctuating resources (Schneider and Harrington 1981).

Consistently finding suitable stopover habitat is an important determinant of migratory success (Moore et al. 1995). Birds that arrive on the breeding grounds with remaining fat stores experience greater reproductive success than those that arrive spent (Smith and Moore 2003). Stopover may range from a few hours to several days (Moore et al. 1995) depending on the bird's energetic condition and on the suitability of the habitat it encounters (Morris 1996, Moore and Kerlinger 1987, Mehlman 2005). The quality of habitat adjacent to natural ecological barriers, such as large bodies of water and mountain ranges, is of particular concern because fueling before or after traversing such barriers is critical (e.g. Moore and Kerlinger 1987, Moore et al. 1990, Kuenzi et al.1991, Barrow et al. 2000). Moore et al. (1993) also recognized agricultural and urbanized areas as ecological barriers. As urbanized areas expand, they can create new barriers to migration. Mitigating habitat loss in areas of high population growth might prevent an urban area from becoming inhospitable to migrating songbirds.

Mehlman et al. (2005) described three functional types of stopover habitat: "fire escapes," "convenience stores," and "full-service hotels." The "fire escapes" are infrequently used, but can provide an emergency stopping place that can be the difference between death and continued migration. "Full-service hotel" locations are large areas of habitat that provide ample food, water, and shelter for many migrants (Mehlman et al. 2005). "Convenience store" stopover sites are small areas in an otherwise inhospitable matrix, such as an urbanized area, that allow migrants to rest briefly and replenish some fat stores in order to reach higher

quality sites (Mehlman et al. 2005). Greenways, linear conservation corridors, are probably best described as "convenience store" sites. Greenways might also be an avenue for birds to navigate through urbanized areas during migration.

Habitat Selection En Route

The precise mechanisms by which birds choose habitats during migration are poorly understood (see Moore and Aborn 2000, Chernetsov 2006 for reviews); the selection of stopover habitat is complex and involves a bird's assessment of geographic, landscape, and habitat factors (Moore et al. 1993). In general, migrant birds select habitat during the early morning hours after nocturnal flight and then refine their habitat selection before settling in (Chernetsov 2006). They also may engage in "morning flight." The purposes of these short, low-altitude flights include continued migration (Bingman 1980), compensation for orientation errors due to wind, and habitat selection (Wiedner et al. 1992). Initial habitat choice is influenced by factors extrinsic to the habitat such as innate habitat preferences, functional morphology, and foraging strategies, after which habitat selection is guided by factors intrinsic to the habitat such as vegetation structure (see Chernestov 2006). Generally, more migrants are supported in areas with taller, more structurally diverse vegetation (e.g. Moore et al. 1990), though some research suggests the opposite (Petit 2000). Food availability, competition, and risk of predation also might factor into habitat selection (Moore et al. 1993, Petit 2000, Chernestov 2006).

In general, birds use a wider range of habitat types during migration than during the breeding season (Chernetsov 2006). The habitat that is used may differ between spring and

fall migration (e.g. Weisbrod et al. 1993, Swanson et al. 2003). However, habitat most similar to the breeding or wintering habitat may be sought (Petit 2000). For example, Parnell (1969) determined that warblers select habitat that resembles their breeding habitat, and Somershoe and Chandler (2004) discovered that some forest-interior specialists that require large blocks of habitat during the breeding season used large hammocks more often during migration in coastal South Carolina. During spring migration along the Gulf coast, birds selected habitat disproportionate to its amount of occurrence (Moore et al. 1990). Distribution across habitat types differs among species (e.g. Parnell 1969), and juveniles and adults of a species can differ in their use of habitat during migration (e.g. Dunn and Nol 1980, Woodrey and Moore 1997, Yong et al. 1998).

The size and distribution of habitat blocks, or "patchiness," can affect habitat suitability (Moore et al. 1993). The theory of island biogeography (MacArthur and Wilson 1967) prompted extensive research examining breeding bird use of isolated habitat patches. Yet, the relative value of small and large habitat patches for migrants is largely unknown (Petit 2000). Many migrant birds use large patches in the breeding season but can be found in smaller habitat patches during migration (e.g. Blake 1986). Several studies have observed migrant bird use of small, often isolated habitat patches, but the increased value of larger areas also has been demonstrated. Martin (1980) found that migrant species richness and abundance increased with increasing area of shelterbelts on the Great Plains. Blake (1986) noted that although large woodlots might have a greater richness of migrant species, small woodlots can be used by a variety of species. Graber and Graber (1983) intimated that small woodlots might not be sufficient in the absence of large forest blocks; migrants foraging in

small, isolated woodlots in Illinois were unable to accumulate fat stores, but migrants foraging in areas with extensive forest cover were able to store fat. In South Carolina, although larger hammocks supported higher species richness and more individuals, the highest migrant densities were found in smaller hammocks (Somershoe and Chandler 2004). Petit (2000) suggested that corridors might allow migrants to move among isolated habitat blocks and find alternative stopover sites. However, there has been no study of the value of the connecting corridors as stopover habitat.

URBANIZATION

National and local trends

In the United States, the conversion of land, especially forest, to urban uses has accelerated in recent decades (Alig et al. 2003) resulting in habitat loss (e.g. Robinson et al. 2005) and species decline (Czech et al. 2000). Between 1980 and 2000, the United States population increased by 24% (US Census Bureau 2006) while the area of developed land grew by 34.1% during approximately the same time period (1982-1997) (US Department of Agriculture 2000). One area of increasing urban expansion and rapid population growth is the six-county Triangle Region of North Carolina. From 1950-1990, urban population in the Triangle tripled and urbanized land area increased ninefold (Triangle Land Conservancy 2003). Wake County, located in the Triangle Region, is the second most populated county in North Carolina (US Census Bureau 2006) and one of the fastest growing counties in the nation (Wake County 2007a). In just twenty years (1980-2000), Wake County more than

doubled its population (Wake County 2007b), and from 1990-2000, population density increased by nearly 50% (US Census Bureau 2006). By 2013, the county's population is expected to surpass one million residents (Wake County 2007b). The infrastructure needed to support this population growth will undoubtedly arise where fields and forests now fill the landscape.

The urban avian community

Changes in the breeding bird community following land development are well known (e.g. Graber and Graber 1963, Batten 1972, Walcott 1974, Aldrich and Coffin 1980, Clergeau et al. 1998; see Chase and Walsh 2006 for review). While urban environs can support larger numbers of breeding birds than the surrounding natural areas (Walcott 1974, Gavareski 1976, Bessinger and Osborne 1982), species richness is lower and most individuals are non-migratory generalists and exotics (Graber and Graber 1963, Batten 1972, Emlen 1974, Walcott 1974, Aldrich and Coffin 1980, Melles et al. 2003).

Urban areas harbor fewer canopy-feeding forest insectivores and more ground foraging seed-eaters and omnivores, including rock pigeons (*Columba livia*), European starlings (*Sturnus vulgaris*), and house sparrows (*Passer domesticus*) (Emlen 1974, Walcott 1974, Bessinger and Osborne 1982, Chase and Walsh 2006), that adapt well to nesting on human structures (Lancaster and Rees 1979). Resident species also are favored over migratory species (Allen and O'Connor 2000). Native cavity nesters (Degraff and Wentworth 1986, Rottenborn 1999, Blewett and Marzluff 2005) and ground nesters (Melles et al. 2003, Mason et al. 2007) are lacking in urban areas. Urban development alters natural plant

communities by replacing pre-urban vegetation with specimen plantings of exotic ornamentals, which are of little value to native bird species (Bessinger and Osborne 1982, Degraaf and Wentworth 1986, Mills et al. 1989) and in some cases have negative consequences for reproductive success (Borgmann and Rodewald 2004).

Urbanization's resulting habitat fragmentation, alteration, and loss affects migrating songbirds. If migrating individuals do not encounter suitable habitat, they might have to stop more often, slowing them down and preventing a timely arrival on the breeding ground. Reduction of habitat surrounding a geographic barrier may leave a migrant unable to acquire resources needed for survival. Some of the most critical areas for migrating songbirds, such as coastlines, also are areas of rapid population growth and development (Mehlman et al. 2005).

Identifying and conserving habitats that provide habitat suitable for migrating songbirds within developed landscapes can help mitigate some of the effects of urbanization. Few researchers have examined migrant bird habitat in urban areas. Rodewald and Matthews (2005) determined that migrants in an urbanizing Midwestern landscape were more abundant in mature uplands than in riparian habitat. However, the absence of Neotropical transients was not related to the amount of urban cover within a 1km radius. Though Hostetler et al. (2005) found no significant change in the richness and abundance of migrating birds in a remnant natural area and in an adjacent city park during the two years following the construction of an apartment complex, detections of some individual migrant bird species, such as ovenbirds, declined during fall migration following construction.

Not only does the elimination of habitat brought on by urbanization affect migrating birds, but the addition of structures such as buildings (Klem 1990), communication towers (Crawford and Engstrom 2001), windmills (Johnson et al. 2002), and power lines (Bevanger 1998) can confuse and kill migrating birds. In a 29-year study of a television tower in Florida, more than 44,000 dead birds representing 186 species were collected (Crawford and Engstrom 2001). Erickson et al. (2001 cited by Johnson 2002) estimated that 33,000 birds are killed annually by wind turbines in the US. Klem (1990) estimated between 97.6 and 975.6 million migrating birds die annually from window collisions.

Urban and suburban areas are not entirely unsuitable as habitat for native birds. Vegetation in urban areas, especially shrub and canopy layers, influences the diversity of birds found breeding there (Hooper et al. 1973, Mills et al. 1989) as does the spatial arrangement of the vegetation (Goldstein et al. 1986) both at local and landscape scales (Bolger et al. 1997, Melles et al. 2003). When urbanization is examined along a gradient of rural to urban, the greatest breeding bird diversity may be found in areas of moderate development (Aldrich and Coffin 1980, Blair 1999). For example, suburban development in desert climes can increase species diversity because plantings associated with neighborhoods increase the vegetative complexity (Vale and Vale 1976, Rosenberg et al. 1987, Mills et al. 1989, Germaine et al. 1998). However, this can be at the expense of the most development-sensitive native bird species which disappear as the landscape becomes more urban (Aldrich and Coffin 1980, Blair 1999, Mason et al. 2007).

GREENWAYS

Greenways as a conservation strategy

Greenways are multipurpose, linear, protected open spaces that link natural areas while providing recreation and transportation opportunities (Little 1990, Hay 1991, Searns 1995). The President's commission on Americans Outdoors (1987, referenced by Smith 1993) describes greenways as "fingers of green that reach out from and around and through communities all across America" to "connect parks and forests and scenic country sides, public and private, in recreation corridors for hiking, jogging, wildlife movement, horse, and bicycle riding." Greenways have become a popular means to mitigate the effect of habitat loss and fragmentation associated with urbanization (Hay 1991), especially because it usually is easier to acquire ribbons of land than large forest blocks in rapidly developing areas where land is expensive (Smith 1993). Often, greenways are built where development cannot take place such as in flood prone areas along streams (Little 1990).

Greenways can be constructed along natural or manmade features such as streams, sewer line right-of-ways, and old railroad beds (Little 1990, Hay 1991). The benefits of greenways range from aesthetic and cultural to educational and ecological. Increased connectivity of natural areas facilitates movement of plants and animals to maintain biodiversity (Searns 1995, Hay 1991), and vegetation improves air and water quality and mitigates flooding (Smith 1993). Many residents take pride in their neighborhood greenways and perceive them as an asset to their community and quality of life because they contribute to health and fitness through recreation, provide natural areas, and contribute to favorable

land use patterns (Schafer et al. 2000). The benefits of greenways can go beyond those resulting from the setting aside of land. For example, the Swift Creek greenway trail in Cary, NC was constructed entirely from recycled materials (Town of Cary 2006).

Though greenways present an attractive integration of man and nature, they are not a panacea for conservation in urban areas. The value of conservation corridors such as greenways has been debated (see Simberloff and Cox 1987, Noss 1987, Simberloff et al. 1992, Hess 1994, Beier and Noss 1998). Some of the features of greenways that make them attractive can actually be detractors. The linear nature of greenways increases the amount of edge and exposes birds to negative "edge effects," such as increased nest depredation, and there is minimal interior habitat for area-sensitive species (Mason et al. 2007). The abundance of edge combined with the connectivity of corridors can allow exotic plants and animals to easily spread through the landscape (Simberloff et al. 1992, but see Damschen et al. 2006).The compatibility of recreation and conservation is questioned by some because the presence of human activity can affect the behavior of birds and predators in the landscape (Miller and Hobbs 2000). The presence of people on trails can affect the feeding behavior of birds (Burger and Gochfeld 1998), and this could be especially detrimental during migration when refueling is of utmost importance.

City of Raleigh and Town of Cary Greenways

The City of Raleigh's Capital Area Greenway began as a master's thesis (Flournoy 1972) and became a model for greenway systems in North Carolina and throughout the country (Little 1990). Raleigh's 54-mile, 3000-acre greenway system consists of

"interconnected linear parks that form a City-wide open space network that allows for passive recreation while forwarding the City's environmental protection goals" (City of Raleigh 2006). The goals for Raleigh's greenways include preserving the natural character of the land while providing buffers for other land uses, preserving wildlife corridors, protecting water quality by conserving riparian buffers and managing storm water runoff, and providing multiple use trails for recreation and alternative transportation (City of Raleigh 2006). There are plans to develop additional greenways at a rate of at least 1 mile per year (City of Raleigh 2006). Many of the trails follow streams and sewer line right-of-ways. Town of Cary greenways total 11.08 miles, many of which are located in floodplains unsuitable for development (Town of Cary 2006). The Town of Cary identifies many of the same benefits of their greenways as Raleigh, including recreation opportunity and water quality enhancement, and stresses increased quality of life and property value (Town of Cary 2006).

Conclusion and Further Research

While the effects of urbanization on breeding birds have been explored extensively, there has been little research on how the conversion and alteration of habitat resulting from urbanization affects migrating songbirds (but see Hostetler 2005). The expansion of urbanized land, coupled with the expansion of greenway systems in some communities, positions greenways as a possible medium for accomplishing migrant conservation goals in urban areas. Previous research in Raleigh and Cary greenways revealed that breeding development-sensitive birds were most abundant in wide greenways that contained narrow recreational trails (Mason et al. 2007).

Because migrants often choose stopover habitat that is similar to their breeding habitat, it is possible that the recommendations for Neotropical migrant species on their breeding grounds also may benefit them during migration. There is little research on migrant use of stopover habitat in suburbanizing areas (but see Rodewald and Matthews 2005, Sodhi et al. 1999), and no research specifically examines the value of greenways as stopover habitat. Determining the characteristics of greenways that translate into suitable stopover habitat will provide planners with information needed to design greenways that are favorable to songbirds during migration.

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CHAPTER 2

AVIAN USE OF SUBURBAN GREENWAYS AS STOPOVER HABITAT

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ABSTRACT.--- Greenways are a popular means for accomplishing conservation goals in suburban areas, and if properly designed, they may provide avian stopover habitat in an otherwise inhospitable landscape. We examined the effect of greenway forested corridor width, vegetation composition and structure, and adjacent land cover on the species richness and abundance of migrating songbirds. During spring and fall migration, 2004, and spring migration, 2005, we surveyed birds in 47 segments of public greenway in Raleigh and Cary, North Carolina, USA representing a range of forested corridor widths and adjacent land covers. We also surveyed three reference sites along trails in William B. Umstead State Park, the largest contiguous forested area (2,201-hectares) nearest the study greenways.

Migrant species richness was higher in wider greenways in both spring and fall. During spring migration, migrant bird richness and abundance generally increased with tree height and percent hardwood composition, and abundance increased in greenways with more shrub cover. During fall migration, migrants occurred most commonly in greenways with lower canopy cover and higher shrub cover. Forest-interior migrant richness was not correlated with greenway forest corridor width in either season, but these species were more common in greenways surrounded by less bare earth and pavement cover in the spring. During both seasons, forest-interior species were more abundant in the reference sites than in the greenways.

Though migrants used greenways of all widths, in order to serve the greatest diversity of migrants, planners should conserve the widest greenway corridors possible. Forested corridors wider than 150 m had the greatest diversity and abundance of migrants, especially forest-edge species. Removing shrub and ground cover within the greenway should be

avoided to maintain vegetative complexity. In urbanizing areas, planners can provide habitat for the greatest diversity of migrants by constructing greenways in areas of lower development intensity and by designing greenways in conjunction with larger parks or reserves.

In the United States, the conversion of forest land to urban uses has accelerated in recent decades (Alig et al. 2004), and the resulting fragmentation, degradation, and alteration of habitat are major concerns for biological conservation. Of particular concern are migratory bird species, especially those that migrate to the Neotropics (hereafter "Neotropical migrants"). The widely documented declines in migratory songbird populations (e.g. Graber and Graber 1963, Robbins et al. 1989, Askins et al. 1990, Hagan et al. 1992) prompted extensive investigation of the contributing factors. Initially, the availability and condition of breeding and wintering habitat attracted the most attention. Researchers recently have focused on the conditions and events during migration that might contribute to migrant songbird declines (Newton 2006). Effective conservation measures must include all life history phases including migration (Hagan and Johnston 1992, Moore et al. 1993, Moore 2000, Faaborg 2002).

Neotropical migrants are vulnerable during migration, perhaps more so than during any other time of the year (Sillett and Holmes 2002). During this energetically demanding time (Blem 1980), migrants must find suitable stopover habitat in which to replenish fat stores and rest while avoiding predation (Moore et al. 1995). The condition and availability of stopover habitat can have profound consequences for avian survival. However, the precise mechanisms by which birds choose habitats during migration and the specific habitat requirements for species are poorly understood (see Moore and Aborn 2000, Chernetsov 2006 for reviews).

Although it might be critical to migrating birds, the value of natural areas as stopover habitat in rapidly urbanizing landscapes is virtually unknown (Hostetler et al. 2005).

Breeding birds have been the primary focus of urban bird studies (e.g. Emlen 1974, Bessinger and Osborne 1982, Friesen et al. 1995, Mason et al. 2007). Only recently have researchers begun examining stopover habitat in urban areas (Hostetler 2005, Rodewald and Matthews 2005.)

As multipurpose, linear, protected open spaces, greenways link natural areas while providing recreation opportunities and alternative transportation (Little 1990, Hay 1991, Searns 1995). Greenways have become a popular means to mitigate the effects of habitat loss and fragmentation associated with urbanization (Hay 1991). If properly designed greenways can serve as stopover habitat, they might be a cost effective means of providing this habitat in rapidly developing areas where land is expensive. However, there have been no studies of the value of greenways as stopover habitat.

We studied migrating songbirds in greenways to: 1) determine the influence of greenway forested corridor width and adjacent land cover on migrating bird abundance and species richness, and 2) provide recommendations to urban planners for the design of greenways as migratory bird stopover habitat.

METHODS

Study area.--- We studied migrating bird use of greenways in Raleigh and Cary, Wake County, North Carolina, USA, located in the Central Appalachian Piedmont. In recent decades, the region, known as the Triangle, has experienced rapid population growth and suburban development (Wake County 2002). From 1950-1990, urban population in the Triangle tripled and urbanized land area increased ninefold (Triangle Land Conservancy

2003). When Parnell (1969) conducted his research on migrating warblers near Raleigh, NC, most study sites in his research area, a 20-mile radius circle with Raleigh at the center, were described as "beyond the influence of urbanization." Today that landscape is highly suburbanized. Cary's public greenways total 17.83 km (Town of Cary 2006), and Raleigh has 86.9 km of greenways (City of Raleigh 2006). The canopies of the greenways are dominated by hardwood trees, including red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), tulip-poplar (*Liriodendron tulipifera*), and various oaks (*Quercus* spp.). Pines such as loblolly (*Pinus taeda*), shortleaf (*Pinus echinata*), and Virginia pine (*Pinus virginiana*) are also common. Native understory vegetation includes redbud (*Cercis canadensis*), blackberry (*Rubus* spp.), sumac (*Rhus* spp.), wax myrtle (*Myrica cerifera*), greenbrier (*Smilax* spp.), and wild grape (*Vitis* spp.). Exotic understory vegetation includes privet (*Ligustrum* spp.), autumn olive (*Elaeagnus umbellata*), Japanese honeysuckle (*Lonicera japonica*), and Japanese stiltgrass (*Microstegium vimineum*). We also surveyed three reference sites along trails in William B. Umstead State Park. The park is largely composed of second and third growth woodlands, and is situated in an urban matrix just west of Raleigh. It is the largest contiguous forested area (2,201-hectares) nearest the study greenways. Umstead State Park has 32 km of hiking trails and is connected to the Raleigh greenway system. Dominant hardwood species include oaks, hickory (*Carya* spp.), tulip-poplar, and red maple.

Study site selection.---We sampled migrating birds in 47 forested segments of public greenway during spring 2004, fall 2004, and spring 2005 (Fig. 1). The 200-m long greenway segments followed streams and were chosen to represent a range of greenway forested corridor widths and adjacent land uses. Segments were separated by at least 200 m with one

exception, in which segments were separated by 192 m. The majority of segments (39) were separated by more than 250 m. Many of the segments overlap those used by Sinclair et al. (2005) and Mason et al. (2007). In Umstead State Park, we chose three 200-m long reference segments of trail that paralleled a stream (Fig. 1). Each of these segments was separated by at least 200 meters.

We examined leaf-off USGS 2003 high-resolution, digital orthoimages and digital land use and zoning maps in a geographic information system (ArcView 3.3) and chose segments in the following land use categories: low density residential (≤7.5 lots/hectare), high density residential (>7.5 lots/hectare), and office/institutional (businesses, schools, etc.). A segment's assigned category was based on the zoned land use within 200 m of the forested corridor on both sides of the segment (Fig. 2). We attempted to choose locations that had similar land use on both sides, but the use with the highest degree of development was chosen to represent the site if the sides differed. Narrow (0-75 m), medium (76-150 m), and wide (>150 m) greenways were represented within each of the land use categories, and we chose segments with relatively constant forested widths. Greenway width was considered to be the average width of the forested corridor containing the greenway path and was not limited to the legal boundary of the greenway. While a right-of-way, easement, or linear parkland can define a greenway's legal bounds, the forested area often extends into properties adjacent to the greenway path.

Land cover variables.---We quantified cover in the land bordering each segment by analyzing leaf-off aerial photography. For each study site, two 200-m x 200-m squares were drawn on each side of and parallel to the forested corridor (Fig. 2). Each square was

populated with a systematic grid of 100 points. At each point, we assigned the land cover to the following categories: canopy, pavement, building, lawn, water, agriculture, and bare earth. In the leaf off photos, points that fell within a deciduous tree canopy were considered canopy. If land cover below a tree's canopy could be determined, both categories were recorded for the point. For each segment, we calculated the percentage of each land cover category by averaging the values calculated from the two adjacent squares.

Avian surveys.---We surveyed birds during spring migration (15 April-14 May), 2004, fall migration (3 September- 27 October), 2004, and spring migration (1 April-15 May), 2005. We performed our surveys along transects, a technique considered more effective in estimating abundance and diversity of migrating songbirds (Wilson et al. 2000, Rodewald and Brittingham 2004). We used 200-m long one-sided belt-transects with the greenway path or mowed edge, if present, as the line of travel. To keep the area surveyed as consistent as possible from greenway to greenway, we surveyed habitat on only one side of the greenway path. Locating a transect in the center of each greenway's forested corridor, though ideal, was not possible. Obstacles such as meandering streams, fences, or downed trees would have prevented an observer from completing the surveys. Observers were unable to walk down the center of the path and survey habitat on either side consistently among greenways because path and mowed edge width varied and paths were not always centrally located. We surveyed the side of the path with the widest forested area. If the two sides had roughly equal forested area, we surveyed the side with the stream.

We traversed each 200-meter-long transect slowly, pausing when flocks were encountered to ensure that all birds were counted. Surveys lasted at least 10 minutes and

averaged 16 minutes. Rodewald and Brittingham (2004) found that detectability declined sharply in shrub and sapling habitats at 20-25 meters from their transects. We counted all birds seen and heard in the survey side within 25 m of the line of travel to minimize bias between greenways that have more shrubs and those that may be more open. Flyovers were not counted. We did not correct for distance and assumed a detectability of one. To minimize bias associated with weather, we did not survey during rainy or windy (>21 km per hour) conditions. During spring 2004, there were two observers. We rotated observers among greenways in different width and land use classes. In fall 2004 and spring 2005 there was one observer. During spring and fall 2004, we conducted surveys between 0700 and 1900 Eastern Standard Time (EST). To limit bias associated with the time of day, each transect was surveyed multiple times during each of the following time periods: 0700-1000; 1000-1300; 1300-1600; 1600-1900 EST. We visited ach of the 47 greenway segments and three reference sites on independent rotations within each time period to cover the range of corridor width and land use combinations. Preliminary analysis of spring 2004 data revealed that the majority of migrant bird detections occurred in the earlier part of the day, so during spring 2005, we conducted surveys between 0700 and 1300 EST. For consistency, we included only the surveys conducted before 1300 EST in our spring analyses. Because sample sizes were low during fall counts, we included surveys during all time periods in our fall analyses.

Guilds.---We classified all birds into migratory guilds and further divided Neotropical and short-distance migrants into breeding habitat guilds based on area sensitivity. Neotropical migrants were defined following Degraaf and Rappole (1995) with the following exceptions: 1) migrant birds with winter ranges that include a significant portion of the

southeastern United States, but are not winter residents in Wake County, were classified as short distance migrants; 2) migrant birds with winter ranges that include Wake County and more northerly breeding ranges were classified as winter residents. Species present in Wake County throughout the year were classified as year-round residents. Determining the migratory status of an individual bird was not possible, so Neotropical migrants included both transients and species that breed locally. Many of the locally breeding Neotropical migrant species recorded during surveys, however, do not breed in the greenways, do not breed in the greenways in great numbers, or are breeders only in the widest (>300 m) greenways (Mason et al. 2007). Only three of our greenway segments exceeded 300 m. We combined Neotropical and short distance migrants into a single migrant bird guild to focus on migrating songbirds. We divided species in the migrant bird guild into three guilds based on area sensitivity during the breeding season (Poole 2005): 1) forest-interior species are the most area-sensitive birds that prefer large contiguous habitats with interior woodland away from forest edges; 2) forest-edge species are less sensitive to patch size and use forest habitats near edges; and 3) field-edge species are birds that prefer scrub-shrub habitat often adjacent to fields. Because the number of surveys completed per season per transect were unequal, we averaged across surveys to calculate guild-level dependent variables for our analyses instead of pooling data. For each transect, we calculated migrant bird species richness as the average number of Neotropical and short distance migrant species detected per visit for each season. We calculated species richness and abundance for the forest-interior, forest-edge, and field-edge guilds in the same manner.

Vegetation surveys.--- We chose points along each transect at 25, 75, 125, and 175 m to survey greenway vegetation during summer 2004. Each point was located 20 m from the transect survey line within the area surveyed for birds. We estimated shrub density, canopy cover, and percentage of pine and hardwood trees at each point, and we averaged the values for each of these variables across the four survey points for each transect.

We estimated shrub density using a density board that was 2.5 m tall and 30.48 cm wide and divided equally into five boxes alternating black and white (Nudds 1977). We made four shrub density readings at each point in four directions: two parallel to and two perpendicular to the greenway path. For each reading, the board was placed 15 m from the point. The observer stood on the survey point, estimated the percentage of each box obscured by vegetation, and assigned each box a score between zero and five corresponding to a range of percent cover in quintiles. For example, a box that was covered by greater than 0 % but less than 20% was assigned a score of one, and a box that was obscured over 80% was assigned a score of five. Boxes that were completely uncovered were assigned a score of zero. We averaged scores for each of the five boxes yielding a mean shrub density score for each direction and then averaged the four directions for a mean shrub density score for each point.

We estimated canopy cover using a concave spherical densiometer. The observer stood on the survey point and estimated canopy cover while facing each of the cardinal directions and then averaged the four readings. Using a hypsometer, we estimated canopy height by measuring three of the tallest canopy trees in the vicinity of the point and then

averaging their heights. We visually estimated the percentage of pine and hardwood trees within a 15 m radius circle centered on the survey point.

Though not within the area surveyed for birds, we measured the width of the path and mowed edge (together, the managed area) at 25, 75, 125, and 175 m along the survey line to evaluate whether the opening created by the managed portion of the greenway influenced the birds found in the forested portion of the greenway. The four measurements were averaged for each transect.

Data Analysis.--- Our dependent variables were the spring and fall square-root transformed species richness and abundance values for the migrant bird, forest-interior, forest-edge, and field-edge guilds. Because of small sample sizes we did not analyze individual species responses. Our independent variables were greenway forested corridor width, vegetation measurements, and measurements of land cover in the landscape immediately adjacent to the greenway segments.

To avoid violation of the assumption of non-colinearity, we tested for correlation among all independent variables (PROC CORR, SAS Institute Inc. 2001). Two variables were considered to be highly correlated if the Pearson correlation coefficient (r) was ≥ 0.6. We eliminated one variable from each correlated pair, and made an effort to retain the variable which was most useful for greenway planning and management. The reduced set of variables consisted of forested corridor width, five greenway vegetation measures, and five measures of adjacent land cover (Table 1). We averaged the species richness and abundance values for the two spring seasons for final analyses because preliminary analysis of each of the spring seasons yielded similar results.

For each season, each of the eight dependent variables was regressed against the reduced set of independent variables in stepwise multiple linear regression analysis using SAS (PROC REG, SAS Institute, Inc. 2001). Only variables significant at $P \leq 0.05$ were used in the final regression models.

For each season, we calculated average guild richness and abundance values for each greenway width category and compared them to the average guild richness and abundance values for the three reference segments using a one-way ANOVA and Tukey's test (FIG. 3).

RESULTS

We recorded 37 Neotropical migrants and six short distance migrants in the greenways and reference sites during the spring and fall migration surveys; 20 were forest-interior species, 16 were forest-edge species, and seven were field-edge species (Table 2).

Sample sizes were low in all seasons, especially during fall migration. During both spring migration periods, 82% of surveys detected migrants, however, during fall, only 31% of surveys recorded migrants. During spring, surveys in which migrants were detected averaged three migrant species and four individuals. The highest migrant richness recorded on a survey was 13 species and the largest abundance recorded was 27 migrants. Blue-gray gnatcatcher, Red-eyed vireo, and Gray Catbird were the most common migrants in the spring. In the fall, surveys which detected migrants averaged 1.6 species and 2.1 individuals. The highest recorded migrant richness on a fall survey was seven and the highest recorded abundance was nine. The most detected species during the fall were Gray Catbird and Ruby-throated Hummingbird, and few forest interior species were recorded.

Spring and fall migrant species richness, fall migrant abundance, spring forest-edge species richness and abundance, and fall field-edge richness and abundance increased with increasing forested corridor width (Tables 3, 4).

The greenway vegetation characteristics most commonly retained in models were canopy height and percentage of hardwood trees. During spring migration, species richness of migrants and species richness and abundance of forest-edge and forest-interior species were highest in greenways with taller trees and a greater percentage of hardwoods (Table 3). During fall migration, forest-interior richness and abundance increased with increasing canopy height while migrant richness and abundance were higher in greenways with less canopy cover (Table 4). Spring migrant abundance, fall migrant richness, and spring field-edge richness and abundance increased with increasing shrub cover (Tables 3, 4).

Only three adjacent land cover variables were retained in the models. Spring migrant richness and field-edge species richness and abundance increased with increasing building cover (Table 3), while fall forest-edge richness and abundance increased with decreasing building cover (Table 4). Spring forest-interior richness and abundance were lowest in greenways surrounded by more pavement and bare earth (Table 3).

Average species richness and abundance of migrants during spring and fall migration was higher in the reference sites than in greenways ≤ 150 m wide (Fig. 3). Few field-edge species were detected in greenways and reference sites, however there were significantly more field-edge species detected in the greenways than in the reference sites. During spring, forest-edge species richness and abundance were similar in greenways >150 m and in the

reference sites (Fig. 3). During both spring and fall migration, significantly more forest-interior species were detected in the reference sites than in greenways of all widths (Fig. 3).

DISCUSSION

Forested Corridor Width.---Species richness of migrating birds during spring, and richness and abundance during fall, were highest in the widest greenway forested corridors, suggesting that wider greenways are more attractive to migrants. However, because migrant birds, especially forest-interior migrants, were detected more frequently in the reference sites than in the greenways, larger parks or reserves should be conserved in urbanizing areas.

The increase in migrant species richness and abundance in wider greenways is consistent with the finding of several studies of the effect of patch size on migrating songbirds (Martin 1980, Blake 1986, Somershoe and Chandler 2004). Martin (1980) demonstrated that migrant species richness and abundance increased with increasing area in shelterbelts on the Great Plains. Blake (1986) recorded greater species richness in larger woodlots during migration in Illinois, and Somershoe and Chandler (2004) observed a greater diversity and abundance of migrants in large hammocks than small hammocks in coastal South Carolina. Similarly, breeding migrants are more abundant in wider corridors. Species richness of breeding Neotropical migrants increased in riparian corridors wider than 100 m (Hodges and Krementz 1996), and Mason et al. (2007) discovered that some area-sensitive migrants breed only in greenway corridors wider than 300 m.

Though species that are area-sensitive during the breeding season also may prefer larger patches during migration, some area-sensitive migrants choose smaller habitat patches

as stopover even when larger patches are available (Petit 2000). We routinely documented forest-interior migrants in greenways narrower than those in which they were found breeding suggesting that they were not as restricted by forested corridor width during migration. Black-throated Blue Warbler, Louisiana Waterthrush, Ovenbird, Prothonotary Warbler, Scarlet Tanager, and Yellow-throated Warbler (see Table 2 for scientific names) did not breed in greenways in our study area less than 300 m wide (Mason et al. 2007), but we recorded all of these species in greenways less than 300 m wide during migration. We also detected White-eyed Vireo and Indigo Bunting in greenways narrower than those in which they were recorded breeding in our study area (Mason et al. 2007). We detected migrants in the two narrowest greenways, both less than 40 m wide and surrounded by commercial development.

Migrating birds often are recorded in small, isolated habitat patches, and these patches may have high densities of migrants (Somershoe and Chandler 2004); however, it is unclear whether these areas offer sufficient resources to meet migrant birds' energetic needs (Graber and Graber 1983, Blake 1986). Narrow greenway segments in our study typically harbored the lowest abundances of migrants regardless of the surroundings. Unlike a small habitat patch that is completely surrounded by development, a greenway offers connectivity to other habitat patches and can provide migrants with a conduit for seeking additional habitat. Thus, migrants are not forced to remain in narrow habitats that may have fewer resources and can more easily travel to alternate locations. Petit (2000) found more fall migrants in habitat fragments that were connected by corridors than in isolated fragments of similar size.

To accommodate the greatest diversity of migrating birds, greenway planners should work with landowners, developers, and land trusts to find creative ways to acquire the widest greenway corridors possible. Mason et al. (2007) concluded that greenway forested corridors should be at least 50 m wide for breeding bird habitat, and Hodges and Krementz (1996) recommend corridors greater than 100 m. While greenways in all width categories were used by migrating songbirds, greenway segments wider than 150 m had the greatest abundance of migrants, especially forest-edge species, and should be conserved where possible. There are various strategies for acquiring greenway land including right-of-ways, conservation easements, and land purchase (Flink and Searns 1993). Though the most expensive option, purchasing linear parkland for greenway construction may be the best way to obtain and protect the widest corridors. In our study area, the portion of a greenway's forested corridor protected by an easement is commonly 15 meters on either side of the stream. While the removal of vegetation within that portion may be regulated, trees and shrubs adjacent to the easement or right of way may not be. Residents and business whose properties contain greenway easements or that border greenway parkland should be encouraged to retain trees and shrubs on their properties thereby increasing the forested corridor width. Designating wider stream buffers can also increase the width of a greenway corridor.

Though many forest-interior species were recorded using greenways, there were more forest-interior migrants detected in the reference sites suggesting that area-sensitive migrants may prefer larger forest patches during stopover over habitat strips like greenways. Therefore, though greenways are a popular means for conserving open space, planners

should avoid focusing solely on greenways and incorporate large reserves into their open space master plans.

Greenway Vegetation.--- Vegetation characteristics within the greenways were better predictors of migrant species richness and abundance than the characteristics describing land cover immediately adjacent to the surveyed greenway segments. Though habitat use during migration can vary with bird species, geographic location, and season, habitats with heterogeneous vegetative structure often are those that support the most diverse and abundant migrant community (see Petit 2000 for review). In the spring, migrants occurred more commonly in hardwood-dominated greenways with taller canopies and more shrub cover. Rodewald and Brittingham (2005) found a similar relationship during spring migration in which Neotropical migrants were more abundant in urban woodlots with taller trees. During the fall, migrant richness was greater in greenways with more open canopies and more shrub cover. During spring, Rodewald and Brittingham (2005) documented higher temperate migrant abundances in urban woodlots with open canopies and heterogeneous horizontal structure.

Vegetation structure was important to migrants using the greenways in both seasons, but the significant relationship between more open canopies and the richness and abundance of migrants in the fall suggests a seasonal shift to habitats with more shrub cover. Other researchers have documented heavier use of shrub and scrub habitats during fall migration (Suthers et al. 2000, Swanson et al. 2003, Rodewald and Brittingham 2004). Greenways with canopy gaps or low canopy coverage allow sunlight to reach the forest floor thereby stimulating understory growth. Migrants may be attracted to these gaps and open areas

because they are higher quality habitat with greater arthropod abundances and more fruiting shrubs in the fall. Gaps with dense shrub or midstory growth may also offer birds protection from predators during migration, a period when they are especially vulnerable (Bowen et al. 2007). Because we did not measure subcanopy height, we are unable to determine to whether birds more abundant in greenways with more open canopies may have been attracted to this vegetation layer in addition to the shrubs.

While development-sensitive breeding birds were least abundant in greenways in our study area with more extensive managed area along the recreational trails (Mason et al. 2007), we failed to document a similar relationship between managed area and migrating birds, indicating that migrating birds may not be as sensitive to the division of habitat created by the greenway path and associated maintained areas. In fact, trail management activities may indirectly benefit migrants because the greenway path and mowed edges create a canopy opening within the forested corridor that allows sunlight in and promotes the growth of shrubs and saplings along the path that may attract migrants. Rodewald and Brittingham (2002) documented the highest species richness and abundance of fall migrants along forest edges with high densities of shrubs and saplings.

Maintaining shrubs and other understory vegetation within a greenway is a balance between conserving habitat, maintaining aesthetics, and providing safe public spaces (Luymes and Tamminga 1995). Dense shrubs can create the perception for some people that an area is unsafe; however, removing bushes and shrubs, especially those which produce fruit in the fall, could reduce the quality of greenways as stopover habitat by reducing the amount of food and cover available. Residents near a proposed greenway trail in our study area who

were surveyed regarding their concerns about the trail often commented that shrubs should be removed to improve trail visibility and to eliminate potential hiding places for those with nefarious intentions (Ivy 2001). Avoiding indiscriminate understory clearing and restricting shrub pruning and removal to areas of reduced visibility can increase safety and maximize habitat potential. The necessary removal of shrubs can be offset by planting native fruiting shrubs elsewhere in the greenway. During the construction of a new greenway path, clearing should be reduced to the minimum necessary for activities such as grading, paving, and bridge construction.

Adjacent Land Use.---The adjacent land cover variables generally were poor predictors of migrant species richness and abundance. Adjacent building coverage was the most frequently retained variable in final models, but the relationships were inconsistent. During spring migration, we recorded more migrant species and higher field-edge species richness and abundance in greenways with higher adjacent building cover, but forest-edge species richness and abundance increased with decreasing building cover adjacent to the greenways in the fall. Mason et al. (2007) recorded fewer Neotropical migrants breeding in greenways with more adjacent building cover. Similarly, Friesen et al. (1995) recorded fewer breeding Neotropical migrants in woodlots surrounded by more houses. During migration, Rodewald and Matthews (2005) found no statistical relationship between migrants and the percentage of urban land within one kilometer of their study sites; however, though not significant, they did document a weak relationship between urbanization and temperate migrants.

It seems counterintuitive that greater migrant richness in the greenways would be associated with more building cover in the adjacent landscape. This relationship may explained by an indirect attraction to residential neighborhoods. Migrating songbirds often congregate in mixed species flocks with other migrants and resident birds, especially chickadees and titmice, to increase foraging efficiency or to gain protection from predators (Morse 1970, Berner and Grubb 1985, Rodewald and Brittingham 2002, Hobson and Van Wilgenberg 2006). Chickadees and titmice are common in residential areas and are attracted to bird feeders or other resources there. Migrating songbirds associating with them also may appear attracted to residences. Chickadees and titmice were recorded in surveys with the greatest richness of migrants; however, we did not collect information on individual flocks, so we are unable to determine whether migrants detected in our surveys were being led by resident birds.

An association with high building cover adjacent to the greenway may also be explained by a lack of suitable habitat in built-up areas. Some office complexes and high density residential neighborhoods may have few trees and shrubs thereby relegating migrants to the greenway, while low density residential neighborhoods often have more trees and shrubs allowing migrants to forage beyond the greenway corridor. Field-edge richness and abundance in the fall was higher in greenways with fewer adjacent buildings. The influence of vegetation composition and structure in residential neighborhoods on the abundance and richness of migrants, as well as resident birds, in greenways is an area of future study.

Some migrants may avoid stopping over in greenways located in built-up areas. During spring migration, we recorded fewer forest-interior species and individuals in

greenways with high adjacent pavement and bare ground cover which are indicators of intense development to which forest-interior species are sensitive. Similarly, Mason et al. (2007) recorded fewer Neotropical migrants breeding in greenways with high adjacent pavement cover and bare earth, and observed a decline in forest-interior species as bare earth adjacent to the greenways increased.

Spring vs. fall migration.---Though sample sizes were low during spring, even fewer migrants were encountered during fall surveys, especially forest-interior migrants. As a result, the fall forest-edge and forest-interior models had low R^2 values and should be interpreted with caution. Detection can be more difficult in fall when migrants are cryptically colored and less vocal. In an attempt to increase detections, following the transect surveys we performed point counts using playbacks of owl vocalizations and chickadee and titmouse mobbing calls. The use of mobbing calls prior to a count can increase the richness and abundance of birds surveyed during the non-breeding season (Turcotte and Desrochers 2002). The counts rarely detected additional migrants, and we did not use them in the analysis. Seasonal divergences in migration route may affect the abundances of some species (Weisbrod et al 1993), so it is possible that fewer migrants passed through the area during fall migration.

Design and Management Recommendations.---One of the greatest challenges to conserving and managing habitat for migratory birds is the need for a diversity of habitats that can accommodate migrants during multiple phases of their annual cycle. Management recommendations employed for breeding migrants may not be sufficient to accommodate those species during spring and fall migration. Many of the associations between birds and

greenway characteristics are the same during migration as during the breeding season. Greenways might be able to accommodate migrants during both the breeding and non-breeding season if designed using the following recommendations:

1. Avoid removing shrub and ground cover within the greenway to maintain vegetative complexity and provide habitat for a wider variety of migrants during both spring and fall migration.
2. Conserve greenways with forested corridors that are greater than 150 m wide wherever possible. Even the widest greenways, on average, harbored fewer migrants than the reference sites in Umstead State Park.
3. Construct new greenways in areas where there is lower development intensity. Areas with fewer buildings, less pavement, and less bare earth are more likely to have more canopy and shrub cover that can compliment the habitat in the greenway and together create a wider corridor or larger habitat area.
4. Do not limit open space planning to greenways. Establish larger patches of habitat such as city, county, or state parks in conjunction with greenways.

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TABLE 1. Description of independent variables used in stepwise multiple regression analysis on guild species richness and abundance measures from Raleigh and Cary, NC greenways (2004-2005).

Independent Variable	Description
Corridor width	Average width (m) of the forested corridor of each 200-m long surveyed segment
Land Cover Measures	
Adjacent bare earth	Percent bare earth cover in land adjacent to the segment[d]
Adjacent building	Percent building cover in land adjacent to the segment[d]
Adjacent canopy	Percent canopy cover in land adjacent to the segment[d]
Adjacent lawn	Percent lawn cover in land adjacent to the segment[d]
Adjacent pavement	Percent pavement cover in land adjacent to the segment[d]
Greenway Vegetation Measures	
Canopy cover	Percent canopy cover within the segment's forested corridor[a,e]
Canopy height	Canopy height within the segment's forested corridor[b, e]
Managed area	Width of the path and mowed border adjacent to the area surveyed for birds
Percent hardwoods	Percentage of hardwoods within the segment[e]
Shrub cover	Index of percent shrub cover in the segment[c,e]

[a] Measurements made using a concave spherical densitometer.

[b] Measurements made using a digital hypsometer.

[c] Measurements made using a density board (Nudds, 1977).

[d] Average percent cover within two 200 X 200 m areas adjacent to either side of the greenway segment measured on aerial photographs in a GIS.

[e] Averaged across four points within the portion of the transect surveyed for birds.

TABLE 2. Migrant bird species occurrences in greenways and reference sites presented by adjacent land use and width categories. Each cell contains the number of segments in the corresponding category in which the species was recorded during spring migration (S) (2004-2005) or fall migration (F) (2004). Adjacent land use categories are: LDR, low-density residential (≤ 7.5 lots/hectare); HDR, high-density residential (> 7.5 lots/hectare); OFC, Office/Institutional. Reference segments are indicated by REF.

	Adjacent Land Use						Forested Corridor Width (m)							
	LDR		HDR		OFC		0-75		76-150		>150		REF	
Number of Sites	(19)		(12)		(16)		(10)		(23)		(14)		(3)	
Guild/Species	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Field-edge Species														
Blue Grosbeak (*Guiraca caerulea*)[n]					1				1					
Blue-winged Warbler (*Vermivora pinus*)				1								1		
Common Yellowthroat (*Geothlypis trichas*)[s]	11	2	8	2	12	5	6	1	15	4	10	4	1	
House Wren (*Troglodytes aedon*)[s]	4		4		2		2		7		1			
Indigo Bunting (*Passerina cyanea*)[n]	3		1		2		1		2		3			
Prairie Warbler (*Dendroica discolor*)[n]	2						1		1					
Yellow-breasted Chat (*Icteria viren*)[n]					1						1			
Forest-edge Species														
Baltimore Oriole (*Icterus galbula*)[n]	1		1						2					

TABLE 2. Continued.

Blue-gray Gnatcatcher (*Polioptila caerulea*)[n]	17	1	12		16	1	8		23		14	2	3	
Blackpoll Warbler (*Dendroica striata*)[n]	12		5	1	6		4		14	1	5			
Eastern Kingbird (*Tyrannus tyrannus*)[n]			1		3				1		3			
Eastern Wood-Pewee (*Contopus virens*)[n]	2				2	2			3		1	2	2	1
Great Crested Flycatcher (*Myiarchus crinitus*)[n]	15	1	6		12		5		16	1	12		3	
Gray Catbird (*Dumetella carolinensis*)[s]	17	6	11	8	13	8	8	6	20	6	13	10		
Magnolia Warbler (*Dendroica magnolia*)[n]	1	1		1				1	1			1		1
Orchard Oriole (*Icterus spurius*)[n]			1		2				2		1			
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)[n]	1		1		1				2		1			
Red-eyed Vireo (*Vireo olivaceus*)[n]	15		8		12	2	6		16		13	2	3	1
Ruby-throated Hummingbird (*Archilochus colubris*)[n]	9	5	12	3	12	8	7	1	12	7	14	8	3	
Summer Tanager *(Piranga rubra*)[n]	2				7				5		4		2	
White-eyed Vireo (*Vireo griseus*)[s]	3		5		9	1	1		8	1	8			
Palm Warbler (*Dendroica palmarum*)[n]			1						1					
Yellow Warbler (*Dendroica petechia*)[n]	2		2		3		1		4		2			
Forest-interior Species														
Acadian Flycatcher (*Epidomax virscens*)[n]	7	1	5		3		1		7	1	7		3	
American Redstart (Setophaga ruticilla)[n]	11	3	6	1	6	1	5	1	12	3	6	1	1	3
Black-and-white Warbler (*Mniotilta varia*)[n]	10		6		5	1	1		12		8	1	3	2
Blue-headed Vireo (*Vireo solitarius*)[s]	3	1	1	1	2	1		1	3	1	3	1	1	

TABLE 2. Continued.

Black-throated Blue Warbler (*Dendroica caerulescens*)[n]	13		5		6	1	5		10		9	1	1	2
Black-throated Green Warbler (*Dendroica virens*)[n]	1	1			1				1	1	1		1	1
Canada Warbler (*Wilsonia mericana*)[n]			1						1					
Hooded Warbler (*Wilsonia merica*)[n]	7	1	2		3		2		6	1	4		1	
Kentucky Warbler (*Oporornis formosus*)[n]					1						1			
Louisiana Waterthrush (*Seiurus motacilla*)[n]	3		3		2				4		4		1	
Northern Parula (*Parula mericana*)[n]	15		10		11		7		17		12		3	
Northern Waterthrush (*Seiurus noveboracensis*)[n]	3						1				2			
Ovenbird (*Seiurus aurocapillus*)[n]	7		3		7		1		7		9		2	
Prothonotary Warbler (*Protonotaria citrea*)[n]					1		1							
Scarlet Tanager (*Piranga olivacea*)[n]	7		1		3		2		6		3			
Swainson's Thrush (*Catharus ustulatus*)[n]	1		1		1		2		1					
Veery (*Catharus fuscescens*)[n]	2								1		1			
Worm-eating Warbler (*Helmitheros vermivorus*)[n]			2		1						3		1	1
Wood Thrush (*Hylocichla mustelina*)[n]	10	2	8	3	4	1	2		12	4	8	2	1	
Yellow-throated Warbler (*Dendroica dominica*)[n]					1						1		3	

[n] Neotropical migrant

[s] Short distance migrant

TABLE 3. Final regression models, reported with coefficients and partial F-statistic significance levels for included variables for greenways in Raleigh and Cary, NC during spring migration (2004-2005). Significance levels set at $\alpha = 0.05$ for variable inclusion in models.

					Greenway Composition and Structure				Adjacent Land Use		
Dependent Variable*	Model R^2	Model P	Intercept	Forested Width	Canopy Cover	Canopy Height	Hard-woods	Shrub Cover	Building Cover	Pavement Cover	Bare Earth
Migrant Richness	0.583	P<0.001	-0.5165	0.0019		0.0064	0.0105		0.0152		
				P<0.001		P=0.008	P<0.001		P=0.029		
Migrant Abundance	0.362	P<0.001	-0.1234				0.0151	0.1639			
							P<0.001	P=0.010			
Field-edge Richness	0.221	P=0.004	0.0890					0.1019	0.0128		
								P=0.005	P=0.020		
Field-edge Abundance	0.323	P<0.001	0.4298		-0.0067			0.1839	0.0185		
					P=0.029			P<0.001	P=0.013		
Forest-edge Richness	0.641	P<0.001	-0.4613	0.0013		0.0040	0.0108				
				P<0.001		P=0.033	P <0.001				
Forest-edge Abundance	0.596	P<0.001	-0.7895	0.0017		0.0058	0.0143				
				P<0.001		P=0.035	P<0.001				
Forest-interior Richness	0.512	P<0.001	-0.5153			0.0097	0.0074			-0.0129	-0.0267
						P<0.001	P=0.006			P=0.008	0.015
Forest-interior Abundance	0.464	P<0.001	-0.7104			0.0120	0.0089			-0.0147	-0.0334
						P=0.001	P=0.013			P=0.022	P=0.022

* All dependent variables were square-root transformed in regression analyses.

TABLE 4. Final regression models, reported with coefficients and partial F-statistic significance levels for included variables for greenways in Raleigh and Cary, NC during fall migration (2004). Significance levels set at $\alpha = 0.05$ for variable inclusion in models.

					Greenway Composition and Structure			Adjacent Land Use
Dependent Variable*	Model R^2	Model P	Intercept	Forested Width	Canopy Cover	Canopy Height	Shrub Cover	Building Cover
Migrant Richness	0.363	P<0.001	0.7667	0.0018	-0.0095		0.1038	
				P=0.001	P=0.003		P=0.046	
Migrant Abundance	0.305	P<0.001	1.2735	0.0024	-0.0111			
				P<0.001	P=0.004			
Field-edge Richness	0.324	P<0.001	0.8274	0.0018	-0.0088			
				P<0.001	P=0.002			
Field-edge Abundance	0.354	P<0.001	1.1245	0.0022	-0.0122			
				P<0.001	P<0.001			
Forest-edge Richness	0.134	P=0.011	0.4326					-0.0168
								P=0.011
Forest-edge Abundance	0.129	P=0.013	0.4539					-0.0174
								P=0.013
Forest-interior Richness	0.211	P=0.006	-0.5106			0.0041	0.0690	
						P=0.048	P=0.039	
Forest-interior Abundance	0.125	P=0.015	-0.4246			0.0059		
						P=0.015		

* All dependent variables were square-root transformed in regression analyses.

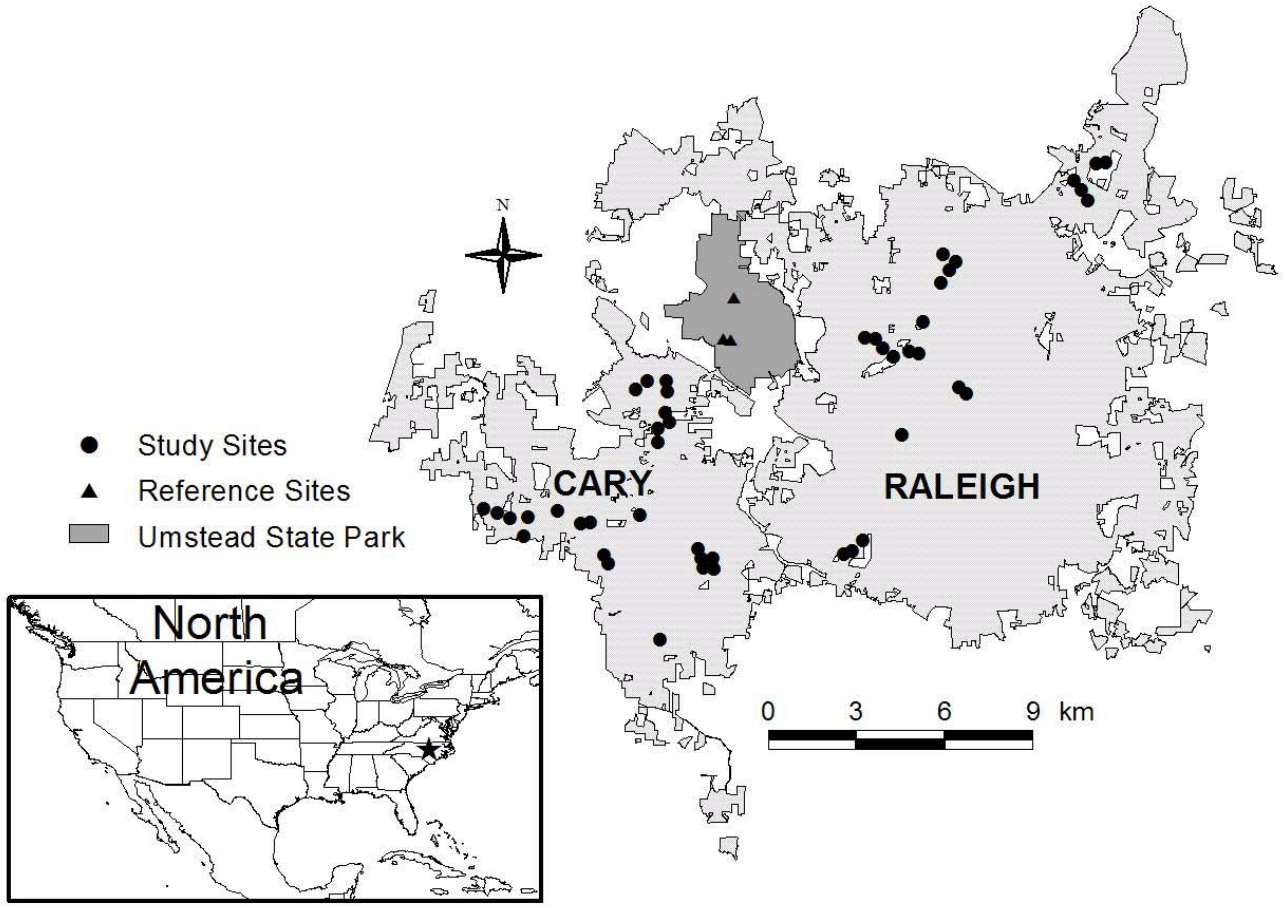

FIG. 1. Greenway segment and reference site locations in Raleigh and Cary, North Carolina, USA.

FIG. 2. Forested corridor width and adjacent land use were determined for each 200-m greenway segment in ArcGIS. Land cover variables were measured in two 200-m x 200-m areas on either side of the forested corridor.

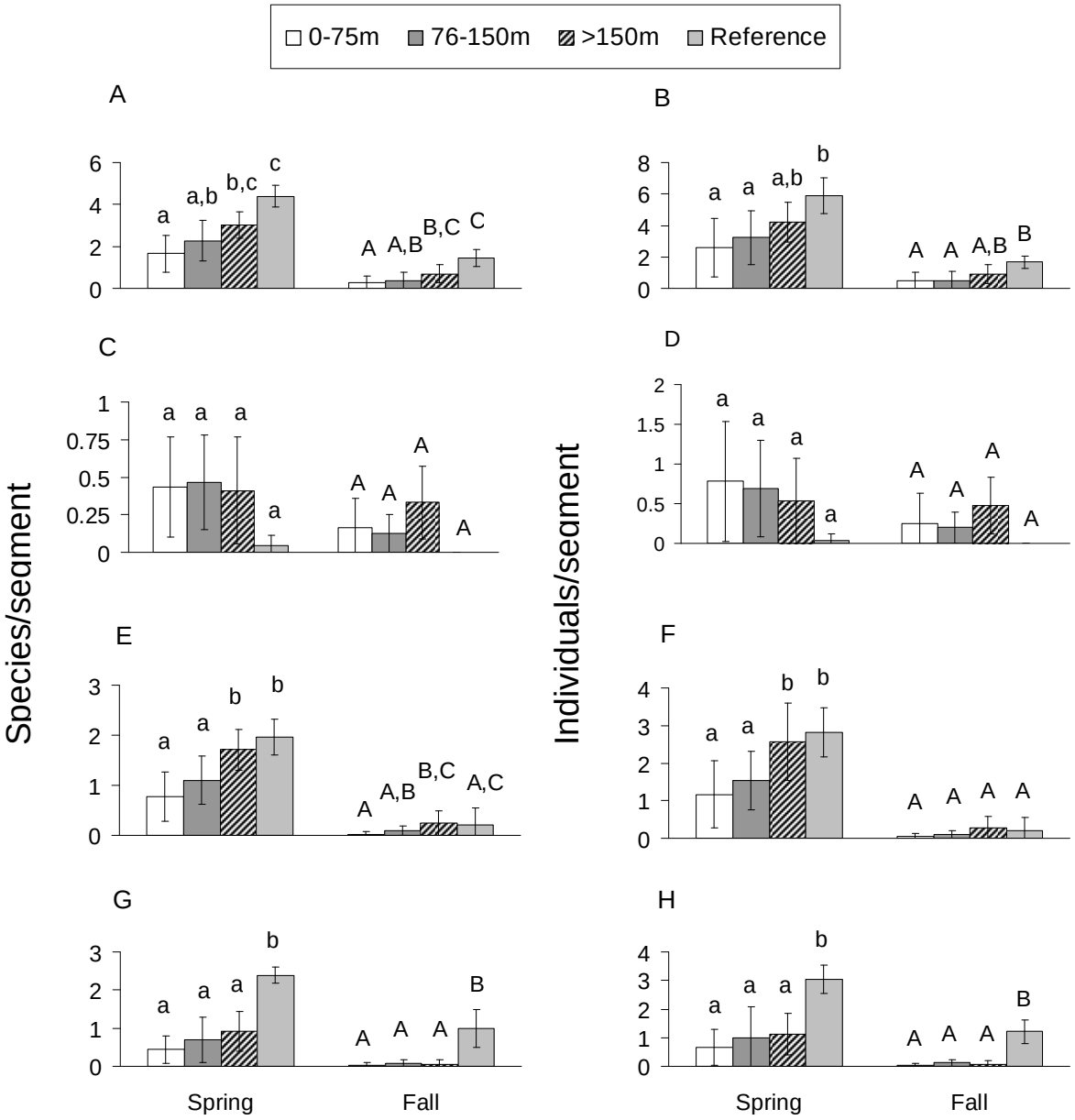

FIG. 3. Mean richness and abundance of migrating birds using reference sites in Umstead State Park and Raleigh and Cary, NC greenways of differing forested corridor width categories during spring (2004-2005) and fall (2004) shown with standard deviation bars. (A) migrant species richness, (B) migrant abundance, (C) field-edge species richness, (D) field-edge abundance, (E) forest-edge species richness, (F) forest-edge abundance, (G) forest-interior species richness, (H) forest-interior abundance. Richness and abundance calculated as average number of migrant bird species and individuals detected per survey per segment per category. Bars with the same letter are not significantly different ($P < 0.05$, Tukey).

CHAPTER 3: APPENDICES

APPENDIX 1. Winter resident and year-round resident species occurrences in greenways and reference sites presented by adjacent land use and width categories. Each cell contains the number of segments in the corresponding category in which the species was recorded during spring migration (S) (2004-2005) or fall migration (F) (2004). Adjacent land use categories are: LDR, low-density residential (≤7.5 lots/hectare); HDR, high-density residential (>7.5 lots/hectare); OFC, Office/Institutional. Reference segments are indicated by REF.

	Adjacent Land Use						Forested Corridor Width (m)							
	LDR		HDR		OI		0-75		76-150		>150		REF	
Number of sites	(19)		(12)		(16)		(10)		(23)		(14)		(3)	
Species/Guild	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Winter Residents														
Brown Creeper (*Certhia americana*)	1								1					
Cedar Waxwing (*Bombycilla cedrorum*)	13		8		14		8		17		10			
Dark-eyed Junco (*Junco hyemalis*)	1								1					
Golden-crowned Kinglet (*Regulus satrapa*)		1		3						3		1		1
Hermit Thrush (*Catharus guttatus*)	4	3	1		2	1	1		6	3		1		
Ruby-crowned Kinglet (*Regulus calendula*)	18	10	12	6	15	8	10	4	22	13	13	7	2	2
White-throated Sparrow (*Zonotrichia albicollis*)	19	12	12	5	15	12	10	8	23	14	13	7	2	1
Yellow-bellied Sapsucker (*Sphyrapicus varius*)		4		1		3		4		3		1		1
Yellow-rumped Warbler (*Dendroica coronata*)	19	19	12	12	16	16	10	8	23	6	14	3	3	3
Year-round Residents														

APPENDIX 1. Continued.

American Crow (*Corvus brachyrhynchos*)	10	7	3	3	3	6	4	3	10	9	2	4		
American Goldfinch (*Carduelis tristis*)	19	18	12	9	16	13	10	7	23	21	14	12	3	1
American Robin (*Turdus migratorius*)	19	16	12	11	16	10	10	9	23	16	14	12		
Barred Owl (*Strix varia*)	1						1							
Belted Kingfisher (*Ceryle alcyon*)	5	1	5	1	4		2		6	1	6	1	2	
Black Vulture (*Coragyps atratus*)					1				1					
Blue Jay (*Cyanocitta cristata*)	18	14	9	8	12	14	9	8	21	18	9	10	1	
Brown Thrasher (*Toxostoma rufum*)	13	7	8	7	12	6	9	5	15	7	9	8		
Brown-headed Cowbird (*Molothrus ater*)	18		11		13		8		21		13		3	
Brown-headed Nuthatch (*Sitta pusilla*)	6	7	9	6	11	7	6	4	13	10	7	6		
Canada Goose (*Branta canadensis*)			1		3		2		1		1			
Carolina Chickadee (*Poecile carolinensis*)	19	19	12	12	16	16	10	10	23	23	14	14	3	3
Carolina Wren (*hryothorus ludovicianus*)	19	19	12	12	16	16	10	10	23	23	14	14	3	3
Chipping Sparrow (*Spizella passerina*)	6		4		7	1	5		10	1	2			
Common Grackle (*Quiscalus quiscula*)	13	4	10		8	2	8		15	4	8	2	2	
Downy Woodpecker (*Picoides pubescens*)	17	15	12	11	9	9	6	4	20	19	12	12	2	2
Eastern Bluebird (*Sialia sialis*)	5	6		3	2	4	2	3	5	9		1		1
Eastern Phoebe (*Sayornis phoebe*)	4	2	3	2	5	2	3	1	6	1	3	4		
Eastern Screech-Owl (*Otus asio*)	1								1					
Eastern Towhee (*Pipilo erythrophthalmus*)	19	14	12	7	16	10	10	6	23	17	14	8		
European Starling (*Sturnus vulgaris*)	2	1	2	1	4	2	3	1	4	3	1			
Fish Crow (*Corvus ossifragus*)	2	1	2		5	2	3		5	3	1			

APPENDIX 1. Continued.

Great Blue Heron (*Ardea herodias*)			1	1		2				1	1	2	2	
Green Heron (*Butorides virescens*)	1	1							1	1				
Hairy Woodpecker (*Picoides villosus*)	6	1	3	2	3	1	1		8	1	3	3	2	2
House Finch (*Carpodacus mexicanus*)	14	4	8	3	12	6	10	4	18	6	6	3		
House Sparrow (*Passer domesticus*)	2	1			3	1	3	2	1		1			
Mallard (*Anas platyrhynchos*)	2		2		4		3		1		4		2	
Mourning Dove (*Zenaida macroura*)	16	4	9	2	13	5	9	4	18	3	11	4	3	
Northern Cardinal (*Cardinalis cardinalis*)	19	19	12	12	16	15	10	10	23	22	14	14	3	3
Northern Mockingbird (*Mimus polyglottos*)	5	4	2	2	8	10	5	3	9	8	1	5		
Pileated Woodpecker (*Dryocopus pileatus*)														1
Pine Warbler (*Dendroica pinus*)	9	2	3	1	2		3	1	8	2	3		3	1
Red-bellied Woodpecker (*Melanerpes carolinus*)	19	19	12	12	13	14	8	10	23	21	13	14	3	3
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	4	1	2		2	1	1		6	1	1	1	1	
Red-shouldered Hawk (*Buteo lineatus*)	8	1	4	1	1	4	1		10	5	2	1		
Red-tailed Hawk (*Buteo jamaicensis*)	1										1			
Song Sparrow (*Melospiza melodia*)					2	1	1	1	1					
Tufted Titmouse (*Baeolophus bicolor*)	19	19	12	12	16	15	10	10	23	22	14	14	3	2
Turkey Vulture (*Cathartes aura*)	1					1				1	1			
White-breasted Nuthatch (*Sitta carolinensis*)	17	15	7	11	9	12	7	7	17	20	9	11	1	2
Yellow-shafted Flicker (*Colaptes auratus*)	10	12	7	7	5	9	5	4	11	15	6	9		1

APPENDIX 2. Species recorded in each greenway segment and reference site during migration surveys; [s] = recorded during spring only; [f] = species recorded during fall only.

Alleghany 1 Average width: 233.4 m Adjacent land use: OI
American Crow[s], American Goldfinch, American Redstart[s], American Robin, Black-and-white Warbler[s], Black-throated Blue Warbler[s], Blue-gray Gnatcatcher[s], Blue Jay[f], Brown-headed Cowbird[s], Brown-headed Nuthatch, Brown Thrasher[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[f], Downy Woodpecker[f], Eastern Phoebe, Eastern Towhee[s], Tufted Titmouse, Eastern Wood-Pewee[f], Gray Catbird, Great Crested Flycatcher[s], Hairy Woodpecker[s], Hooded Warbler[s], House Finch, Kentucky Warbler[s], Mourning Dove, Northern Cardinal, Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird, White-breasted Nuthatch[f], White-eyed Vireo[s], Wood Thrush, White-throated Sparrow, Yellow-rumped Warbler, Northern Flicker

Alleghany 2 Average width: 366.7 m Adjacent land use: LDR
Acadian Flycatcher[s], American Goldfinch, American Robin, Belted Kingfisher, Blue-gray Gnatcatcher[s], Black-and-white Warbler[s], Blue Jay, Brown-headed Cowbird[s], Black-throated Blue Warbler[s], Brown-headed Nuthatch, Brown Thrasher[f], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat, Downy Woodpecker, Eastern Phoebe[f], Eastern Towhee, Tufted Titmouse, European Starling[s], Gray Catbird[f], Great Crested Flycatcher[s], Hairy Woodpecker[s], Hermit Thrush[f], Hooded Warbler[s] House Finch, Indigo Bunting[s], Mourning Dove[s], Northern Cardinal, Northern Mockingbird[f], Northern Parula[s], Northern Waterthrush[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-tailed Hawk[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird, Turkey Vulture[s], Unknown Warbler[f], White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow, Wood Thrush[s] Yellow-rumped Warbler[s], Yellow Warbler[s]

Beaverdam Average width: 43.3 m Adjacent land use: HDR
American Goldfinch[s], American Redstart[s], American Robin, Blue-gray, Gnatcatcher[s], Blue Jay, Brown-headed Cowbird[s], Brown-headed Nuthatch, Brown Thrasher, Carolina Chickadee, Carolina Wren , Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Downy Woodpecker[s], Eastern Towhee[s], Tufted Titmouse, Gray Catbird[s], House Finch[s], House Wren[s], Magnolia Warbler[f], Mourning Dove, Northern Cardinal, Northern Mockingbird[s], Northern Parula[s], Red-bellied Woodpecker, Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Unknown Warbler[f], White-breasted Nuthatch, White-throated Sparrow, Wood Thrush[s], Yellow-bellied Sapsucker[f], Yellow-rumped Warbler, Northern Flicker[f]

Black Creek 1 Average width: 125.3 m Adjacent land use: OI
Acadian Flycatcher[s], American Goldfinch, American Robin[s], Belted Kingfisher[s], Blackpoll Warbler[s], Blue-gray Gnatcatcher[s], Blue Jay, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker[s], Eastern Phoebe[s], Eastern Towhee[s], Tufted Titmouse, Gray Catbird[s], Hermit Thrush [s], Mallard [s], Mourning Dove[s], Northern Cardinal[s], Northern Parula[s], Red-bellied

Woodpecker[s], Red-eyed Vireo[s], Red-shouldered Hawk, Ruby-crowned Kinglet, Scarlet Tanager[s], Summer Tanager[s], White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow[s], Wood Thrush[s], Yellow-rumped Warbler[s]

Black Creek 2 Average width: 230.1m Adjacent land use: OI
Acadian Flycatcher[s], American Goldfinch[s], American Redstart[s], American Robin[s], Black-and-white Warbler[s], Black-throated Blue Warbler[s], Blue-gray Gnatcatcher[s], Blue-headed Vireo[s], Blue Jay, Belted Kingfisher[s], Brown-headed Nuthatch, Brown Thrasher[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Downy Woodpecker[f], Eastern Phoebe[s], Eastern Towhee, Tufted Titmouse, Gray Catbird[s], Louisiana Waterthrush[s], Northern Cardinal, Northern Parula[s], Ovenbird[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird, Summer Tanager[s], White-breasted Nuthatch, Worm-eating Warbler[s], Yellow-rumped Warbler[s], Northern Flicker[f], Yellow-throated Warbler[s]

Black Creek 3 Average width: 174.3 m Adjacent land use: LDR
Acadian Flycatcher[s], American Goldfinch, American Redstart[s], American Robin[s], Black-and-white Warbler[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue-gray Gnatcatcher, Blue Jay, Brown-headed Cowbird, Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[f], Common Yellowthroat[s], Downy Woodpecker[s], Eastern Towhee[s], Tufted Titmouse, Gray Catbird[s], Great-crested Flycatcher[s], Indigo Bunting[s], Louisiana Waterthrush[s], Mallard[s], Mourning Dove, Northern Cardinal, Northern Parula[s], Northern Waterthrush[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Rose-breasted Grosbeak[s], Ruby-crowned Kinglet, Red-shouldered Hawk[s], Ruby-crowned Kinglet[f], Ruby-throated Hummingbird, Scarlet Tanager[s], White-breasted Nuthatch[s], White-eyed Vireo[s], White-throated Sparrow[s], Northern Flicker[f], Yellow-rumped Warbler[s],

Black Creek 4 Average width: 89.3 m Adjacent land use: HDR
Acadian Flycatcher[s], American Goldfinch, American Redstart[s], American Robin, Black-and-white Warbler[s], Black-throated Blue Warbler[s], Blue-gray Gnatcatcher[s], Blue Jay[s], Brown-headed Cowbird[s], Brown-headed Nuthatch, Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Bluebird[f], Eastern Phoebe[s], Eastern Towhee, Tufted Titmouse, Golden-crowned Kinglet[f], Hooded Warbler[s], Indigo Bunting[s], Louisiana Waterthrush[s], Northern Cardinal, Northern Parula[s], Orchard Oriole[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[s], Rose-breasted Grosbeak[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird, White-eyed Vireo[s], White-breasted Nuthatch[f], White-throated Sparrow[s], Wood Thrush[s], Yellow-rumped Warbler[s], Northern Flicker[f], Yellow Warbler[s]

Black Creek 5 Average width: 440.1 m Adjacent land use: HDR
Acadian Flycatcher[s], American Goldfinch, American Redstart[s], American Robin, Black-and-white Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Common Grackle[s], Common Yellowthroat, Downy Woodpecker, Eastern Phoebe[f], Eastern Towhee[s], Tufted Titmouse,

Gray Catbird, Great-crested Flycatcher[s], Mourning Dove[s], Northern Cardinal, Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Scarlet Tanager[s], White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow[s], Wood Thrush[s], Yellow-rumped Warbler[s], Northern Flicker

Black Creek 6 Average width: 104.9 m Adjacent land use: HDR
Acadian Flycatcher[s], American Goldfinch, American Redstart[s], American Robin[s], Black-and-white Warbler[s], Blue-gray Gnatcatcher[s], Brown-headed Nuthatch[s], Blue Jay[s], Blackpoll Warbler[s], Brown-headed Cowbird[s], Brown Thrasher, Carolina Chickadee, Carolina Wren, Canada Warbler[s], Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker[s], Eastern Towhee, Tufted Titmouse, Fish Crow[s], Great Crested Flycatcher[s], Gray Catbird, Hairy Woodpecker, House Finch, House Wren[s], Mourning Dove[s], Northern Cardinal, Pine Warbler, Red-bellied Woodpecker, Ruby-crowned Kinglet[s], Red-eyed Vireo[s], Red-headed Woodpecker[s], Red-shouldered Hawk[s], Ruby-throated Hummingbird[s], White-breasted Nuthatch, White-eyed Vireo[s], Wood Thrush, White-throated Sparrow[s], Palm Warbler[s], Yellow-rumped Warbler[s], Northern Flicker

Crabtree 1 Average width: 38.0 m Adjacent land use: OI
American Goldfinch, American Robin, Blackpoll Warbler[s], Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Nuthatch, Canada Goose[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[s], Eastern Towhee, European Starling[s], Fish Crow[s], Gray Catbird, House Finch, House Sparrow, Mallard[s], Mourning Dove, Northern Cardinal, Northern Mockingbird, Prothonotary Warbler[s], Red-bellied Woodpecker[f], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Song Sparrow[f], Tufted Titmouse, White-throated Sparrow, Yellow Warbler[s], Yellow-rumped Warbler

Crabtree 2 Average width: 32.4 m Adjacent land use: OI
American Goldfinch[s], American Robin[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch, Canada Goose[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Eastern Phoebe[s], Eastern Towhee[s], European Starling[s], Fish Crow[s], Gray Catbird[f], House Finch, House Sparrow[s], Mourning Dove, Northern Cardinal, Northern Mockingbird, Red-bellied Woodpecker[f], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Song Sparrow[s], Tufted Titmouse, White-eyed Vireo[s], White-throated Sparrow, Yellow-rumped Warbler

Durant 1 Average width: 47.4 m Adjacent land use: LDR
American Crow, American Goldfinch, American Redstart[s], American Robin, Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Brown-headed Nuthatch[f], Brown Thrasher, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker[s], Eastern Bluebird, Eastern Towhee, European Starling, Fish Crow[s], Gray Catbird, Great Crested Flycatcher[s], Hermit Thrush[s], House Finch, House Sparrow, House Wren[s], Mourning Dove, Northern Cardinal, Northern Flicker, Northern Mockingbird, Northern Parula[s], Pine

Warbler, Red-bellied Woodpecker, Red-eyed Vireo[s], Red-headed Woodpecker[s], Ruby-crowned Kinglet[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow, Yellow-bellied Sapsucker[f], Yellow-rumped Warbler

Durant 2 Average width: 86.2 m Adjacent land use: OI
American Crow[f], American Goldfinch, American Redstart[s], American Robin, Blackpoll Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher, Brown-headed Cowbird[s], Brown-headed Nuthatch, Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat, Downy Woodpecker[s], Eastern Bluebird[f], Eastern Towhee, Eastern Wood-Pewee[s], European Starling, Fish Crow, Gray Catbird, Great Crested Flycatcher[s], House Finch[s], House Wren[s], Mourning Dove[s], Northern Cardinal, Northern Mockingbird, Orchard Oriole[s], Red-bellied Woodpecker[s], Red-headed Woodpecker[s], Red-shouldered Hawk[f], Ruby-crowned Kinglet, Ruby-throated Hummingbird[f], Song Sparrow[s], Tufted Titmouse, White-eyed Vireo[s], White-breasted Nuthatch[f], White-throated Sparrow, Yellow-rumped Warbler[s]

Durant 3 Average width: 83.4 m Adjacent land use: HDR
American Goldfinch, American Redstart, American Robin, Baltimore Oriole[s], Black-and-white Warbler[s], Blackpoll Warbler, Blue-gray Gnatcatcher[s], Blue-headed Vireo[f], Blue Jay[f], Brown Thrasher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch, Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Bluebird[f], Eastern Towhee, European Starling, Fish Crow[s], Gray Catbird, House Finch, House Wren[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[s], Northern Mockingbird, Northern Parula[s], Red-bellied Woodpecker, Red-headed Woodpecker[s], Red-shouldered Hawk, Ruby-crowned Kinglet, Ruby-throated Hummingbird, Tufted Titmouse White-breasted Nuthatch[f], White-eyed Vireo[s], White-throated Sparrow, Wood Thrush, Yellow Warbler[s], Yellow-rumped Warbler[s]

Falls River 1 Average width: 108.0 m Adjacent land use: OI
American Crow[f], American Goldfinch, American Robin, Black Vulture[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Nuthatch, Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Bluebird[f], Eastern Towhee, Gray Catbird[s], Great Crested Flycatcher[s], Hooded Warbler[s], House Finch, Mourning Dove, Northern Cardinal, Northern Flicker, Northern Mockingbird, Red-bellied Woodpecker, Red-eyed Vireo[s], Red-headed Woodpecker[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird[f], Summer Tanager[s], Tufted Titmouse, Turkey Vulture[f], White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow, Yellow-rumped Warbler[s]

Falls River 2 Average width: 121.0 m Adjacent land use: OI
Blackpoll Warbler[s], Blue Jay[s], Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat[f], Downy Woodpecker, Eastern Bluebird[s], Eastern Towhee, Fish Crow[s], Gray Catbird[s], Great Crested Flycatcher[s], Hairy Woodpecker[s], House

Finch[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[f], Northern Mockingbird[s], Northern Parula[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[f], Summer Tanager[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow, Yellow-rumped Warbler[s]

Higgins Average width: 74.4 m Adjacent land use: LDR
American Goldfinch[f], American Redstart, American Robin, Black-and-white Warbler[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Blue-headed Vireo[f], Brown Thrasher, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat, Downy Woodpecker, Eastern Bluebird[f] Eastern Towhee, Gray Catbird, Great Crested Flycatcher[s], House Finch, Indigo Bunting[s], Mallard[s], Northern Cardinal, Northern Flicker, Northern Parula[s], Northern Waterthrush[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird, Scarlet Tanager[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch, White-throated Sparrow, Yellow-bellied Sapsucker[f], Yellow-rumped Warbler

Hinshaw 1 Average width: 110.4 m Adjacent land use: LDR
American Crow, American Goldfinch, American Redstart, American Robin, Black-and-white Warbler[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Black-throated Green Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Blue-headed Vireo[s], Brown Creeper[s], Brown Thrasher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Bluebird[s], Eastern Towhee, Eastern Wood-Pewee[s], Gray Catbird[s], Great Crested Flycatcher[s], Hermit Thrush[f], House Finch[s], House Wren[s], Louisiana Waterthrush[s], Mourning Dove[s], Northern Cardinal, Northern Parula[s], Northern Flicker[f], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[f], Scarlet Tanager[s], Swainson's Thrush[s], Tufted Titmouse, Unknown Warbler[f], Veery[s], White-breasted Nuthatch, White-throated Sparrow, Wood Thrush[s], Yellow-rumped Warbler[s]

Hinshaw 2 Average width: 148.4 m Adjacent land use: LDR
Acadian Flycatcher, American Goldfinch, American Redstart, American Robin, Black-and-white Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Brown Thrasher[f], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Phoebe[s], Eastern Towhee, Gray Catbird[s], Great Crested Flycatcher[s], Hairy Woodpecker[s], Hermit Thrush[s], Hooded Warbler[s], House Finch[s], Mourning Dove[s], Northern Cardinal, Northern Flicker, Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[s], Ruby-crowned Kinglet[s], Scarlet Tanager[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[s], Wood Thrush, Yellow-rumped Warbler[s]

Hinshaw 3 Average width: 145.3 m Adjacent land use: LDR

American Goldfinch, American Redstart[s], American Robin, Black-and-white Warbler[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Common Grackle, Downy Woodpecker, Eastern Towhee, Gray Catbird[s], Great Crested Flycatcher[s], Hairy Woodpecker[s], Hooded Warbler[s], House Wren[s], Mourning Dove[f], Northern Cardinal, Northern Flicker, Northern Mockingbird[f], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch, White-throated Sparrow[s], Wood Thrush, Yellow-rumped Warbler[s]

Ironwood Average width: 252.8 m Adjacent land use: LDR
Acadian Flycatcher[s], American Goldfinch, American Robin, Blackpoll Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher, Brown-headed Cowbird[s], Brown-headed Nuthatch, Carolina Chickadee, Carolina Wren, Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Towhee, Gray Catbird, Great Crested Flycatcher[s], Hairy Woodpecker[f], Hooded Warbler[s], Magnolia Warbler[f], Mourning Dove[s], Northern Cardinal, Ovenbird[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-headed Woodpecker, Red-shouldered Hawk[s] Ruby-crowned Kinglet, Ruby-throated Hummingbird, Summer Tanager[s], Tufted Titmouse, Veery[s], White-breasted Nuthatch, White-throated Sparrow, Wood Thrush[s], Yellow-rumped Warbler[s]

Lynn Average width: 170.3 m Adjacent land use: HDR
American Goldfinch, American Robin, Belted Kingfisher[s], Black-and-white Warbler[s], Blackpoll Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Blue-winged Warbler[f], Brown Thrasher, Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[f], Downy Woodpecker, Eastern Kingbird[s], Eastern Phoebe, Eastern Towhee, Gray Catbird, Great Crested Flycatcher[s], Great Blue Heron[s], Northern Cardinal, Northern Flicker, Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow[s], Wood Thrush[s], Worm-eating Warbler[s], Yellow-rumped Warbler[s]

North Hills 1 Average width: 124.6 m Adjacent land use: OI
American Crow[f], American Goldfinch, American Robin, Belted Kingfisher[s], Black-and-white Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher, Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Canada Goose[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat, Downy Woodpecker, Eastern Kingbird[s], Eastern Phoebe[f], Eastern Towhee, European Starling[s], Gray Catbird[f], Great Blue Heron[f], Great Crested Flycatcher[s], House Finch, Mourning Dove[s], Northern Cardinal, Northern Flicker, Northern Mockingbird, Red-bellied Woodpecker, Red-eyed Vireo[s], Rose-breasted Grosbeak[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird, Tufted Titmouse, White-eyed Vireo[f], White-throated Sparrow, Yellow-rumped Warbler

North Hills 2 Average width: 271.3 m Adjacent land use: HDR
American Crow[f], Acadian Flycatcher[s], American Goldfinch[s], American Robin, Belted Kingfisher[s], Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Brown Thrasher[f], Canada Goose[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Downy Woodpecker, Eastern Towhee, Gray Catbird, Great Crested Flycatcher[s], House Finch[s], Mallard[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Tufted Titmouse, Unknown Warbler[f], White-throated Sparrow[s], Yellow-rumped Warbler[s]

Oxxford Hunt Average width: 66.9 m Adjacent land use: LDR
American Crow[f], American Goldfinch, American Redstart[s], American Robin, Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Downy Woodpecker, Eastern Bluebird[f], Eastern Phoebe[s], Eastern Towhee , Gray Catbird, Great Crested Flycatcher[s], House Finch[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[s], Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow, Yellow-rumped Warbler[s]

Oak Park 1 Average width: 65.9 m Adjacent land use: OI
American Crow[f], American Goldfinch[s], American Redstart[s], American Robin, Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Yellowthroat[s], Eastern Towhee, Gray Catbird[s], Great Crested Flycatcher[s], Hooded Warbler[s], House Finch[s], Mourning Dove[s], Northern Cardinal, Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Swainson's Thrush[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow, Yellow-bellied Sapsucker[f], Yellow-rumped Warbler

Oak Park 2 Average width: 263.3 m Adjacent land use: OI
American Goldfinch, American Robin, Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Yellowthroat, Downy Woodpecker, Eastern Bluebird[f], Eastern Kingbird[s], Eastern Towhee[s], Gray Catbird, Great Crested Flycatcher[s], House Finch[s], House Sparrow[s], House Wren[s], Indigo Bunting[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[f], Northern Mockingbird[f], Northern Parula[s], Red-bellied Woodpecker[f], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Tufted Titmouse, White-eyed Vireo[s], White-throated Sparrow, Yellow-rumped Warbler

Parkway Average width: 76.1 m Adjacent land use: LDR
American Crow, American Goldfinch, American Robin, Blue Jay, Blue-gray Gnatcatcher[s], Brown-headed Nuthatch[f], Brown Thrasher[s], Carolina Chickadee, Carolina Wren, Common Grackle[f], Dark-eyed Junco[s], Eastern Bluebird[f], Eastern Towhee, Gray Catbird[s], House Finch[s],

Mourning Dove[s], Northern Cardinal, Northern Flicker, Pine Warbler[s], Red-bellied Woodpecker, Red-headed Woodpecker[s], Ruby-crowned Kinglet[f], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch[f], White-throated Sparrow, Yellow-rumped Warbler[s]

Pirate's Cove 1 Average width: 152.9 m Adjacent land use: HDR
American Goldfinch, American Redstart[s], American Robin, Black-and-white Warbler[s], Black-throated Blue Warbler[s], Blue-gray Gnatcatcher[s], Blue Jay[f], Brown Thrasher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch, Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Towhee[s], Gray Catbird[s], Great Crested Flycatcher[s], House Finch, Mourning Dove, Northern Cardinal, Northern Flicker, Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[s], Wood Thrush, Yellow-rumped Warbler[s]

Pirate's Cove 2 Average width: 109.0 m Adjacent land use: LDR
American Crow[s], American Goldfinch[s], American Redstart[s], American Robin, Belted Kingfisher[s], Black-and-white Warbler[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Blue-headed Vireo[s], Brown Thrasher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Towhee, Gray Catbird[s], Great Crested Flycatcher[s], Hooded Warbler[f], House Finch[s], Louisiana Waterthrush[s], Northern Cardinal, Northern Flicker, Northern Parula[s], Ovenbird[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[s], Ruby-crowned Kinglet[s], Scarlet Tanager[s], Tufted Titmouse, White-breasted Nuthatch[s], White-throated Sparrow, Wood Thrush[s], Yellow-rumped Warbler[s]

Shelley Average width: 120.8 m Adjacent land use: LDR
American Crow, American Goldfinch, American Robin[s], Blackpoll Warbler[s], Blue Jay[s], Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Downy Woodpecker, Eastern Screech-Owl[s], Eastern Towhee, Gray Catbird, Hermit Thrush[s], Mourning Dove, Northern Cardinal, Northern Parula[s], Ovenbird[s], Pine Warbler[s], Red-bellied Woodpecker, Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow, Yellow-rumped Warbler[s]

Sawmill 1 Average width: 95.7 m Adjacent land use: LDR
Acadian Flycatcher[s], American Crow[s], American Goldfinch, American Redstart[s], American Robin[s], Belted Kingfisher[s], Black-and-white Warbler[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay[s], Blue-gray Gnatcatcher[s], Brown Thrasher, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Downy Woodpecker, Eastern Towhee, Gray Catbird[s], Great Crested Flycatcher[s], Green Heron[f], Hermit Thrush[f], Hooded Warbler[s], Mourning Dove[s], Northern Cardinal, Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[s], Ruby-crowned Kinglet[s],

Ruby-throated Hummingbird[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[s], Yellow-rumped Warbler[s]

Sawmill 2 Average width: 64.3 m Adjacent land use: HDR
Acadian Flycatcher[s], American Crow[s], American Goldfinch, American Robin, Belted Kingfisher[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher, Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Phoebe[s], Eastern Towhee, Gray Catbird, Hairy Woodpecker[s], House Finch[s], Mallard[s], Mourning Dove[s], Northern Cardinal, Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Swainson's Thrush[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[s], Yellow-rumped Warbler[s]

Swift Creek Average width: 366.2 m Adjacent land use: OI
Acadian Flycatcher[s], American Crow, American Goldfinch, American Robin, Belted Kingfisher[s], Blackpoll Warbler[s], Black-throated Blue Warbler, Blue Jay[s], Blue-gray Gnatcatcher[s], Blue-headed Vireo, Brown Thrasher, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Towhee, Empidonax Flycatcher[f], Gray Catbird, Great Blue Heron[f], Great Crested Flycatcher[s], Hairy Woodpecker[f], Louisiana Waterthrush[s], Mallard[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[f], Northern Mockingbird, Northern Parula[s], Orchard Oriole[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo, Ruby-crowned Kinglet, Ruby-throated Hummingbird, Scarlet Tanager[s], Summer Tanager[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow, Wood Thrush[s], Yellow Warbler[s], Yellow-rumped Warbler

Trafalgar Average width: 55.2 m Adjacent land use: LDR
American Crow[s], American Goldfinch, American Robin, Barred Owl[s], Blue Jay, Brown Thrasher, Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Chipping Sparrow[s], Common Grackle[s], Eastern Bluebird[s], Eastern Towhee[s], Hooded Warbler[s], House Finch[s], Mourning Dove[s], Northern Cardinal, Northern Flicker, Northern Mockingbird[s], Prairie Warbler[s], Red-bellied Woodpecker, Ruby-crowned Kinglet, Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[s], Yellow-rumped Warbler

Tarbert 1 Average width: 103.7 m Adjacent land use: LDR

Acadian Flycatcher[s], American Crow, American Goldfinch, American Robin, Baltimore Oriole[s], Black-and-white Warbler[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Black-throated Green Warbler[f], Blue Jay, Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch, Carolina Chickadee, Carolina Wren, Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Bluebird[f], Eastern Towhee, Eastern Wood-Pewee[s], Empidonax Flycatcher[s], Fish Crow[s], Gray Catbird[s], Great Crested Flycatcher[f], House

Finch[s], Mourning Dove[s], Northern Cardinal, Northern Flicker, Northern Parula[s], Pine Warbler, Red-bellied Woodpecker, Red-shouldered Hawk[s], Ruby-crowned Kinglet, Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[s], Wood Thrush[s], Yellow-bellied Sapsucker[f], Yellow-rumped Warbler

Tarbert 2 Average width: 94.3 m Adjacent land use: HDR
American Crow, American Goldfinch[s], American Robin, Blue Jay[s], Blue-gray Gnatcatcher[s], Brown-headed Nuthatch[f], Brown Thrasher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Downy Woodpecker, Eastern Towhee[s], Golden-crowned Kinglet[f], Gray Catbird, Great Crested Flycatcher[s], Hermit Thrush[s], House Finch[s], House Wren[s], Northern Cardinal, Northern Flicker, Northern Parula[s], Pine Warbler[s], Red-bellied Woodpecker, Red-shouldered Hawk[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch, White-throated Sparrow, Wood Thrush[s], Yellow-rumped Warbler[s]

Umstead 1 Reference Segment
Acadian Flycatcher[s], American Goldfinch, American Redstart[f], Belted Kingfisher[s], Black-and-white Warbler, Black-throated Blue Warbler, Black-throated Green Warbler[f], Blue Jay[s], Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Downy Woodpecker[f], Eastern Bluebird[f], Eastern Wood-Pewee[f], Golden-crowned Kinglet[f], Great Blue Heron[s], Great Crested Flycatcher[s], Hairy Woodpecker[f], Magnolia Warbler[f], Mallard[s], Mourning Dove[s], Northern Cardinal, Northern Parula[s], Ovenbird[s], Pine Warbler, Red-bellied Woodpecker, Red-eyed Vireo, Red-headed Woodpecker[s], Ruby-crowned Kinglet[f], Ruby-throated Hummingbird[s], Summer Tanager[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[f], Wood Thrush[s], Yellow-bellied Sapsucker[f], Yellow-rumped Warbler, Yellow-throated Warbler[s]

Umstead 2 Reference Segment
Acadian Flycatcher[s], American Goldfinch[s], American Redstart[f], Black-and-white Warbler, Black-throated Blue Warbler[f], Black-throated Green Warbler[s], Blue-gray Gnatcatcher[s], Blue-headed Vireo[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Common Grackle[s], Downy Woodpecker, Eastern Wood-Pewee[s], Great Crested Flycatcher[s], Hairy Woodpecker[s], Mourning Dove[s], Northern Flicker[f], Northern Cardinal, Northern Parula[s], Pileated Woodpecker[f], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Summer Tanager[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch[f], White-throated Sparrow[s], Worm-eating Warbler, Yellow-rumped Warbler[s], Yellow-throated Warbler[s]

Umstead 3 Reference Segment
Acadian Flycatcher[s], American Goldfinch[s], American Redstart, Belted Kingfisher[s], Black-and-white Warbler[s], Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker[s], Eastern Wood-Pewee[s], Great Blue Heron[s], Great Crested Flycatcher[s], Hairy Woodpecker, Hooded Warbler[s], Louisiana Waterthrush[s], Mallard[s], Mourning Dove[s], Northern Cardinal, Northern

Parula[s], Ovenbird[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Tufted Titmouse, Unknown Warbler[f], White-throated Sparrow[s], Yellow-rumped Warbler[s], Yellow-throated Warbler[s]

Weston 1 Average width: 128.9 m Adjacent land use: OI
American Crow[s], American Goldfinch, American Redstart[s], American Robin[s], Black-and-white Warbler[s], Blue Grosbeak[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher, Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Common Grackle[f], Common Yellowthroat[s], Downy Woodpecker[f], Eastern Towhee[s], European Starling[f], Great Crested Flycatcher[s], House Finch[s], Northern Cardinal, Northern Flicker, Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-headed Woodpecker[f], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s], Scarlet Tanager[s], Tufted Titmouse , White-breasted Nuthatch, White-throated Sparrow[s], Yellow-rumped Warbler[s]

Weston 2 Average width: 234 m Adjacent land use: OI
American Goldfinch, American Redstart[s], American Robin, Black-and-white Warbler[s], Black-throated Blue Warbler[s], Black-throated Green Warbler[s], Blue-gray Gnatcatcher[s], Blue Jay[f], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Chipping Sparrow[s], Common Yellowthroat[s], Downy Woodpecker[s], Eastern Towhee, Eastern Wood-Pewee[s], Gray Catbird[s], Great Crested Flycatcher[s], House Finch[s], Mourning Dove[s], Northern Cardinal, Northern Mockingbird[f], Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[f], Ruby-throated Hummingbird[s], Summer Tanager[s], Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow[s], Wood Thrush[s] , Yellow-rumped Warbler

Walnut 1 Average width: 112.8 m Adjacent land use: HDR
American Crow[s], American Goldfinch, American Robin, Belted Kingfisher, Blue Jay, Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch, Brown Thrasher[f], Carolina Chickadee, Carolina Wren, Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Towhee, European Starling[s], Gray Catbird[s], House Finch[s], Louisiana Waterthrush[s], Mourning Dove[s], Northern Cardinal, Northern Mockingbird[f], Northern Parula[s], Pine Warbler[s], Red-bellied Woodpecker, Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch[f], White-throated Sparrow, Yellow-rumped Warbler

Walnut 2 Average width: 277.4 m Adjacent land use: HDR
American Crow[f], American Goldfinch, American Robin, Belted Kingfisher[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay[s], Blue-gray Gnatcatcher[s], Blue-headed Vireo[s], Brown Thrasher, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Towhee[s], Golden-crowned Kinglet[f], Gray Catbird, Great Blue Heron[f], Hairy Woodpecker, Hooded Warbler[s], Louisiana Waterthrush[s], Mourning Dove[s], Northern Cardinal, Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird,

Tufted Titmouse, White-breasted Nuthatch[f], White-throated Sparrow, Worm-eating Warbler[s], Yellow-rumped Warbler[s]

Walnut 3 Average width: 243.2 m Adjacent land use: OI

American Crow[f], American Goldfinch, American Redstart[f], American Robin, Black-and-white Warbler[f], Blue-gray Gnatcatcher, Blue Jay[f], Brown-headed Nuthatch[f], Brown Thrasher, Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Kingbird[s], Eastern Towhee, Eastern Wood-Pewee[f], Fish Crow[s], Gray Catbird, Great Crested Flycatcher[s], Mallard[s], Mourning Dove[f], Northern Cardinal, Northern Flicker, Northern Mockingbird[f], Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo, Ruby-crowned Kinglet, Ruby-throated Hummingbird, Tufted Titmouse, White-breasted Nuthatch[f], White-eyed Vireo[s], White-throated Sparrow, Yellow-bellied Sapsucker[f], Yellow-breasted Chat[s], Yellow-rumped Warbler[s]

White Oak 1 Average width: 107.3 m Adjacent land use: LDR
American Goldfinch, American Robin, Belted Kingfisher[s], Blue Jay[s], Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Chipping Sparrow[s], Common Grackle[s], Common Yellowthroat[s], Downy Woodpecker, Eastern Phoebe[f], Eastern Towhee[s], Gray Catbird[s], Great Crested Flycatcher[s], House Finch[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[s], Northern Parula[s], Pine Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[s], Ruby-crowned Kinglet[s], Scarlet Tanager[s], Tufted Titmouse, White-throated Sparrow, Wood Thrush[s], Yellow-rumped Warbler

White Oak 2 Average width: 73.2 Adjacent land use: LDR
American Goldfinch, American Robin, Belted Kingfisher[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown-headed Cowbird[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Downy Woodpecker, Eastern Bluebird[s], Eastern Towhee[s], Gray Catbird[s], Great Crested Flycatcher[s], Hairy Woodpecker[s], Hermit Thrush[s], Hooded Warbler[s], House Finch[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[f], Northern Mockingbird[s], Northern Parula[s], Prairie Warbler[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Ruby-crowned Kinglet, Ruby-throated Hummingbird[s], Tufted Titmouse, White-breasted Nuthatch, White-eyed Vireo[s], White-throated Sparrow, Wood Thrush[s], Yellow Warbler[s], Yellow-rumped Warbler

White Oak 3 Average width: 102.3 m Adjacent land use: LDR

Acadian Flycatcher[s], American Crow[f], American Goldfinch, American Redstart[s], American Robin, Black-and-white Warbler[s], Blackpoll Warbler[s], Blue-gray Gnatcatcher[s], Blue Jay[f], Brown Thrasher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[f], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[s], Downy Woodpecker, Eastern Phoebe[s], Eastern Towhee, Gray Catbird[s], Great Crested Flycatcher[s] ,

Green Heron[s] , Hairy Woodpecker[s], House Finch, House Sparrow[s], Magnolia Warbler[s], Mourning Dove[s], Northern Cardinal, Northern Flicker[f], Northern Mockingbird[s], Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[s], Ruby-crowned Kinglet[s], Scarlet Tanager[s], Summer Tanager[s], Tufted Titmouse, Unknown Warbler[f], White-breasted Nuthatch[s], White-throated Sparrow[s], Wood Thrush[s], Yellow-rumped Warbler[s]

White Oak 4 Average width: 97.9 m Adjacent land use: OI
American Goldfinch, American Robin[s], Blackpoll Warbler[s], Black-throated Blue Warbler[s], Blue Jay, Blue-gray Gnatcatcher[s], Brown Thrasher[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[s], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow, Common Yellowthroat, Eastern Bluebird, Eastern Phoebe[s], Eastern Towhee[s], Gray Catbird[s], Great Crested Flycatcher[s], Hairy Woodpecker[s], Hermit Thrush[s], House Finch, Indigo Bunting[s], Mourning Dove[s], Northern Cardinal, Northern Mockingbird[s], Northern Parula[s], Ovenbird[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-shouldered Hawk[f], Ruby-crowned Kinglet[s], Ruby-throated Hummingbird[s] , Summer Tanager[s], Tufted Titmouse[s], White-breasted Nuthatch, White-throated Sparrow, Yellow Warbler[s], Yellow-bellied Sapsucker[f], Yellow-rumped Warbler

White Oak 5 Average width: 74.4 m Adjacent land use: LDR
American Crow[s], American Goldfinch, American Redstart[s], American Robin, Black-throated Blue Warbler[s], Blue Jay[s], Blue-gray Gnatcatcher[s], Blue-headed Vireo[s], Brown-headed Cowbird[s], Brown-headed Nuthatch[f], Carolina Chickadee, Carolina Wren, Cedar Waxwing[s], Chipping Sparrow[s], Common Grackle[f], Common Yellowthroat[s], Downy Woodpecker, Eastern Bluebird, Eastern Phoebe[s], Eastern Towhee[s], Fish Crow[f], Golden-crowned Kinglet[f], Gray Catbird[s], Great Crested Flycatcher[s], Hairy Woodpecker[s], House Finch[s], House Wren[s], Mourning Dove[s], Northern Cardinal, Northern Mockingbird, Northern Parula[s], Red-bellied Woodpecker, Red-eyed Vireo[s], Red-headed Woodpecker[s], Red-shouldered Hawk[f], Ruby-crowned Kinglet, Tufted Titmouse, White-breasted Nuthatch, White-throated Sparrow, Yellow-bellied Sapsucker[f], Yellow-rumped Warbler

APPENDIX 3. End point coordinates of greenway and reference site transects in UTM meters with NAD83 datum. All points are in UTM zone 17S.

Transect	End Point 1		End Point 2	
	Easting	Northing	Easting	Northing
Alleghany 1	712610.29	3967046.05	712495.06	3967205.91
Alleghany 2	712794.66	3966878.78	712963.40	3966790.11
Beaverdam	710179.36	3964972.07	710196.34	3965165.00
Black Creek 1	700080.07	3967042.32	700050.09	3967227.64
Black Creek 2	700132.76	3966584.91	700191.81	3966772.96
Black Creek 3	700030.56	3965706.88	700134.12	3965865.86
Black Creek 4	700330.46	3965298.37	700227.61	3965467.59
Black Creek 5	699808.50	3964984.49	699792.73	3965182.06
Black Creek 6	699762.94	3964422.03	699773.45	3964618.72
Crabtree 1	709184.12	3968794.81	709335.46	3968663.98
Crabtree 2	709654.20	3968412.44	709809.70	3968332.17
Durant 1	717164.50	3976087.63	717330.92	3975981.79
Durant 2	717507.06	3975682.59	717666.72	3975566.92
Durant 3	717867.07	3975095.04	717781.66	3975262.68
Falls River 1	718101.08	3976765.71	718292.63	3976755.23
Falls River 2	718501.33	3976766.98	718688.43	3976817.17
Higgins	699076.39	3961304.46	699128.81	3961485.03
Hinshaw 1	701606.30	3959938.23	701570.75	3960126.85
Hinshaw 2	701723.41	3959507.68	701695.97	3959694.74
Hinshaw 3	701908.54	3959140.89	701835.11	3959314.81
Ironwood	710975.07	3969758.33	710936.17	3969950.81
Lynn	712090.49	3972002.73	712013.50	3972168.62
North Hills 1	710321.76	3968514.52	710463.89	3968650.92
North Hills 2	710708.08	3968561.07	710899.49	3968529.20
Oxxford Hunt	697108.15	3961024.36	696970.64	3961094.37
Oak Park 1	708433.20	3969170.49	708630.31	3969150.91
Oak Park 2	708874.60	3969118.85	709049.22	3969044.90
Parkway	695523.10	3961443.40	695655.39	3961576.48
Pirates Cove 1	702223.69	3959537.36	702273.58	3959726.64
Pirates Cove 2	702290.90	3959070.95	702278.53	3959267.25
Shelley	711603.32	3971556.74	711762.92	3971466.49
Sawmill 1	711731.79	3972652.97	711775.05	3972840.30
Sawmill 2	712210.51	3972415.87	712360.63	3972537.34
Swift Creek	700140.14	3956076.36	700005.26	3956213.02
Trafalgar	696520.67	3961066.90	696677.22	3960945.39
Tarbert 1	697635.45	3959565.04	697562.73	3959742.53
Tarbert 2	697865.25	3959255.47	697725.88	3959395.20
Umstead 1	702931.42	3970643.05	702939.80	3970831.47
Umstead 2	702437.41	3968888.53	702503.50	3969070.83

APPENDIX 3. Continued.

Transect	End Point 1		End Point 2	
	Easting	Northing	Easting	Northing
Umstead 3	702725.59	3968990.11	702905.02	3968922.96
Weston 1	699331.35	3967013.75	699247.32	3967193.37
Weston 2	698713.59	3966722.87	698891.66	3966770.18
Walnut Creek 1	707693.87	3959940.39	707880.15	3959876.60
Walnut Creek 2	708121.94	3959984.30	708246.24	3960129.32
Walnut Creek 3	708561.33	3960417.35	708588.73	3960594.78
White Oak 1	692378.14	3961591.87	692562.35	3961516.07
White Oak 2	692926.13	3961394.10	693126.01	3961397.07
White Oak 3	693500.37	3961214.12	693665.11	3961114.60
White Oak 4	694236.14	3961252.47	694406.73	3961231.89
White Oak 5	694256.14	3960349.80	694163.78	3960512.45