EFFECTS OF EXOTIC INVASIVE VEGETATION ON BREEDING BIRDS ALONG THE NORTH CHICKAMAUGA CREEK

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee at Chattanooga

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August 2008

To the Graduate Council:

I am submitting a thesis written by Shannon Elaine Hatmaker entitled "Effects of Exotic Invasive Vegetation on Breeding Birds Along the North Chickamauga Creek." I have examined the final copy of this thesis and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Science, with a major in Environmental Science.

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Acknowledgements

A number of people and organizations must be formally thanked for their support, guidance, and assistance which enabled me to complete my thesis for the degree of Master of Science. My committee chair, Dr. David Aborn, must be thanked first for the hours of help he gave me both in the field and in the office, and for his never ending encouragement. I thank Drs. Joey Shaw and Thomas Wilson, my remaining committee members, for their honest opinions and advice over this two year period. I owe many thanks to several individuals who assisted with the field research including Dr. Aborn, Meagan Binkley, Brandon Dicorato, Jason Hill, Brad Lackey, and my parents, Eddie and Donna Hatmaker. I thank Andy Carroll for assisting me with the map creation for this project.

Funding for this project was granted by the Provost Student Research Award. I also would like to thank the Chattanooga Rotary Club for their scholarship assistance which allowed me to complete my Master of Science degree. Finally, I owe thanks to Nathan Moore for his enduring patience and reassurance throughout this process.

Abstract

The invasion of exotic plants into riparian areas of southeastern United States is a conservation concern not only for native plant communities, but also for wildlife. Breeding bird community structure could be particularly affected by such invasions and subsequent habitat changes as birds respond quickly to changes in habitat resources. During the 2007 breeding season, bird communities were surveyed using the line transect census method at four sites along the North Chickamauga Creek in Hamilton County, Tennessee. Two of the sites were regarded as being highly invaded by exotic understory plant species, while the other two sites remain relatively free of such invasion.

The primary attributes of avian community structure analyzed were diversity and density, both of which were relatively similar among all four sites, showing an overall neutral effect from understory plant invasions. However, a slightly higher diversity index and density of individuals was found at one of the invaded sites. This particular site is also the most highly managed of the four and is also in the early stages of invasion, suggesting that research should be conducted to better understand how avian communities respond to various levels of invasion. Species composition among the sites also varied and the most natural of the four sites supported a greater number of habitat specialists and migratory species, showing that measures of diversity and density should not be used alone when examining avian-habitat relationships. Control of these invasive plants in natural areas is encouraged as some species may actually benefit from their absence. Long-term research on both community structure and demographic measures is needed to observe avian responses over a spatial and temporal scale of habitat change due to plant invasions.

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Chapter 1: Introduction

1.1: Impacts of Exotic Invasive Plants

An introduced, non-native, or exotic plant is one that has been transported by human means across a major geographical barrier, and an invasive plant is one that produces offspring in areas distant from the introduction sites (Richardson et al. 2000). It is estimated that 5,000 exotic plant species exist in the United States, and some of these non-native plants have been able to colonize and invade approximately 700,000 hectares of wildlife habitat a year (Pimental et al. 2000).

Tennessee is home to almost 1,400 vertebrate species, which are supported by an equally diverse landscape (TWRA 2006). However, this biodiversity is at risk of being reduced due to the alteration and destruction of natural habitats (Ehrlich and Wilson 1991). Habitat loss is widely accepted as the greatest threat to biodiversity, with invasive species also being a leading direct cause (Wilcove et al. 1998). The fragmented landscapes now common in urban areas allow for the invasion of exotic vegetation and the replacement of native species, disrupting the entire ecosystem (Didham et al. 2005; McKinney 2002; With 2001). This disruption is a concern to the state of Tennessee as the human population is expected to grow by 1.5 million over the next 20 years which could result in an estimated loss of 12 million acres of forest (TWRA 2006).

The economic cost of invasive plants is difficult to estimate, but a study done on 15 harmful exotic plants estimated costs exceeding $600 million over a 90 year period in the U.S. alone (U.S. Congress 1993). These losses impact agriculture, forestry, and many other segments of the U.S. economy. The harm rendered by exotic invasive plants is not limited to economic damage, but extends to direct negative ecological impacts. Invaders can alter fire regimes, nutrient cycling, hydrology, and energy budgets in a native system (Mack et al. 1999). Plant invasions pose a threat particularly to biodiversity as they cause homogenization of biota (McKinney 2002). In a review of over 150 studies by Levine et al. (2003), a strong competitive effect of exotic species was reported to be one of the major mechanisms by which the exotic species act as successful invaders. Collier et al. (2002) found that native plant species richness and abundance were lower below crowns of Amur honeysuckle (*Lonicera maackii*) in secondary forests in southeastern Ohio. Chinese privet (*Ligustrum sinense*) was reported to reduce herbaceous species and suppress tree regeneration in a western North Carolina mixed hardwood forest (Merriam and Feil 2001). In tropical wetlands of Australia, where para grass (*Urochloa mutica*) was present, the median number of plant species was 75% lower than where the invasive grass was not present (Ferdinands et al. 2005). This decrease in diversity could result in a loss of productivity in ecosystems, as there is a positive relationship between species richness of vascular plants and productivity (Mittelbach et al. 2000).

1.2: Avian Community Structure

In addition to affecting native plant communities, invasive plants create problems for animal communities. The homogenization of plant communities by invasive plants can have a cascading effect on ecosystems by simplifying animal communities (Bock et al. 1986, as in Flanders et al. 2006). Biodiversity loss results in a decrease in genetic resources and productivity, and also alters an ecosystem's performance (Naeem et al. 1994). The carrying capacity of the landscape could also be reduced due to degraded habitat, having a negative impact on wildlife (Scheiman et al. 2003). As birds serve as indicators of the state of the environment (Bibby et al. 2000) and habitat determines population size of birds more than any other factor (Gill 2007) I chose to focus my research on the influence of exotic invasive vegetation on avian community characters. The variables investigated include species diversity and density, and demographic characters found from nest searches, all of which will provide insight into avian-habitat relationships as they are a good reflection of large-scale habitat alteration (Ralph et al. 1993).

Included in Tennessee's rich faunal diversity are 170 species of breeding birds (Nicholson 1997). These species play important ecological roles as seed dispersers, pollinators, and controllers of insect populations. Important attributes of these communities' structure include species diversity and density. Species diversity is a combined measure of species richness, or the number of species, and species evenness, or the relative abundance of species (Molles 2005). Density estimates may serve as early indicators of habitat quality and provide important insight into population changes by providing information on the relation between community structure and environmental factors (Bibby et al. 2000).

Species protection is a critical issue for anthropogenic reasons as well, with important aesthetic and economic benefits at stake (Ehrlich and Wilson 1990). Birding has proven to be valuable in Tennessee, with over 1 million state residents involved in birding activities and 340,000 non-resident visitors watching birds in the state in 2001 (Pullis La Rouche 2005). During that same year, birders spent an estimated $32 billion on wildlife-watching in the U.S., proving the economic significance and overall importance of this activity (Pullis La Rouche 2005).

Reflecting the growing significance of healthy bird communities, many studies have examined effects of vegetation on birds. Several of these studies have shown that exotic invasive vegetation can alter bird communities and negatively affect species diversity and density. Rottenborn (1999) found that as the native vegetation volume decreased, so did bird species richness and density in riparian woodlands of Santa Clara Valley, California. Flanders et al. (2006) found that bird abundance on native-grass sites was 32% greater than on exotic-grass sites in the south Texas rangeland. In Australian tropical wetlands, birds were associated with areas containing little or no invasive para grass (Ferdinands et al. 2005). The invasion of exotic saltcedar (*Tamarix chinensis*) on the Colorado River has corresponded to declines in densities of several migratory insectivores (Hunter et al. 1988).

Many studies, however, have had less conclusive results and present mixed findings. For example, in the grasslands of North Dakota, four abundant species were analyzed. Densities of two of the grassland bird species were lower at points with high cover of leafy spurge (*Euphorbia esula*), an invasive herb, while the other two species showed no significant difference in densities (Scheiman et al. 2003). In the mixed-grass prairie of Manitoba, four of the grassland bird species analyzed correlated positively with native plant species and negatively with exotic plant species, while the other four species correlated negatively with native species and positively with exotic species (Wilson and Belcher 1989). In wetlands of Lake Huron, purple loosestrife (*Lythrum salicaria*) dominated areas had lower avian diversities but higher densities than areas dominated by other vegetation types (Whitt et al. 1999).

However, published research on the effects of exotic invasive vegetation on avian communities in the southeastern United States is conspicuously lacking. A recent study on the effects of Chinese privet in a north Georgia nature preserve found that while the invasive shrub reduced the abundance and richness of native plants, it had no impact on bird abundance and richness (Wilcox and Beck 2007). By further investigating the impacts of exotic invasive vegetation on southeastern forests and avian communities, the importance of future management strategies and control efforts can be determined. This will be of particular concern for riparian areas, such as the North Chickamauga Creek, as riparian forests often act as ecological corridors and can also support a higher species richness and abundance of birds (Peak and Thompson 2006).

Therefore, the main objective of my study was to examine the effects of exotic invasive vegetation on breeding bird diversity and density. Sampling was conducted at four sites along the North Chickamauga Creek during the 2007 breeding season, with two of the sites being highly invaded by dense, understory exotic plants and the remaining two sites being nearly free of invasive vegetation. The North Chickamauga Creek serves as an appropriate study system because of its proximity to Chattanooga, the extensive intact riparian habitat, and the several large tracts of protected public land which are easily accessible. There are also several areas along the Creek which have been invaded by exotic vegetation, allowing changes in habitat to be studied.

My first prediction was that avian diversity would be lower at the invaded sites due to a decrease in structural diversity of vegetation caused primarily by the invasion of exotic plants. The relationship between species diversity and environmental heterogeneity has been well studied, with particular reference to MacArthur's linkage of bird species to foliage height profiles (Molles 2005). MacArthur found that if the vertical structure of vegetation was more diverse, a more diverse bird community was supported (MacArthur 1964, MacArthur and MacArthur 1961, MacArthur 1958). It has been noted that invasive plants have the potential to change vegetation structure, or physiognomy (Remeš 2003), and the primary plant invaders found along the North Chickamauga Creek are no exception. Chinese privet has been found to cause large-scale habitat modification by dominating the shrub layer, displacing native vegetation by shading out both herbaceous and woody plants, and hindering regeneration of native hardwoods (Munger 2003, Urbatsch 2003). Japanese honeysuckle (*Lonicera japonica*) is also a threat to structural diversity because of its ability to compete with native vegetation and also kill shrubs and small trees (PCA 2005).

My second prediction was that avian density would be higher at the invaded sites due to increased shrub density from the invasion of understory exotic species. Higher breeding bird densities are correlated with higher total vegetation volume as plants provide resources in proportion to their vegetation volume (Mille et al. 1991). Important resources for breeding birds include an abundance of food and nest sites. These particular resources could be more available on the invaded sites in this study as both Chinese privet and Japanese honeysuckle produce fruits that are consumed by birds (Munger 2003, PCA 2005). In addition, Chinese privet provides moderately valued cover for birds (Wilcox and Beck 2007) and therefore may attract a more birds due to an increase in available nesting sites.

1.3: Avian Nest Measures

Whereas diversity and density can provide information about avian habitat use, nest searches provide information on avian habitat selection, reflecting behavioral responses that influence survival and fitness (Jones 2001). Some of the nest variables that can be monitored to provide direct measures of reproductive success include clutch size, predation, and parasitism (Ralph et al. 1993). Exotic invasive plants can influence nest placement both within a habitat patch and within the nesting substrate (Leston and Rodewald 2006). This influence can have a negative impact on avian communities by causing decreased fecundity (reproductive success). Borgmann and Rodewald (2004) found that exotic shrubs in Ohio forests could reduce the nesting success of forest birds. In an Illinois forest preserve, American Robins (*Turdus migratorius*) experienced increased nest predation when nests were placed in exotic shrubs (Schmidt and Whelan 1999).

However, Heckscher (2004) found that some forest-interior birds such as the Veery (*Catharus fuscescens*) actually might benefit from the structural changes caused by the invasion of exotic shrubs. There, a high nest success rate was found and attributed to the increased density of shrub-layer vegetation. In the Czech Republic, a comparison of Blackcaps (*Sylvia atricapilla*) using an invasive tree plantation and a native habitat found that although the plantation site supported higher densities, the nesting success was lower, creating an ecological trap (Remeš 2003). These results suggest that the variables of community structure and nest measures should be considered together when investigating the effects of exotic invasive vegetation on breeding birds. Furthermore, because of these mixed results, there is a need for more region-specific studies to determine the effect of invasive vegetation on breeding birds. I therefore chose to search and monitor nests at two of the four study sites along the North Chickamauga Creek, one being a highly invaded and the other a substantially non-invaded site, in addition to the community structure census. This research could provide additional information to the diversity and density studies that may help guide management decisions.

Chapter 2: Methods

2.1: Study Area

The North Chickamauga Creek, located in Hamilton County, Tennessee (Figures 1 and 2) serves as one of the major tributaries of the Tennessee River near Chattanooga. From the Creek's headwaters on Walden Ridge, it flows approximately 50 kilometers south and empties immediately below the Chickamauga Dam. Along the Creek are approximately 2,000 hectares of protected riparian habitat, some of which are accessible either by car or foot trails (NCCC 2002). A majority of the Creek lies in the ridge and valley ecotone, being characterized primarily by deciduous oak-hickory forest, but the more northern portion of the Creek lies on the Cumberland Plateau, an area characterized by mixed mesophytic forest (Braun 1950). A concern, however, is that much of this land is centered in some of the fastest growing communities of Hamilton County, making habitat loss a critical concern. As stated earlier, this rapid urbanization creates new opportunities to disturb remaining habitat.

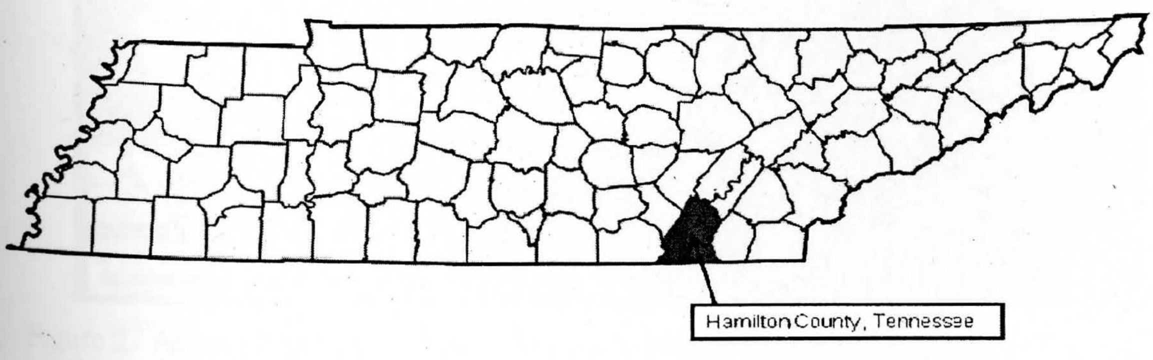

Figure 1. Location of Hamilton County in the state of Tennessee.

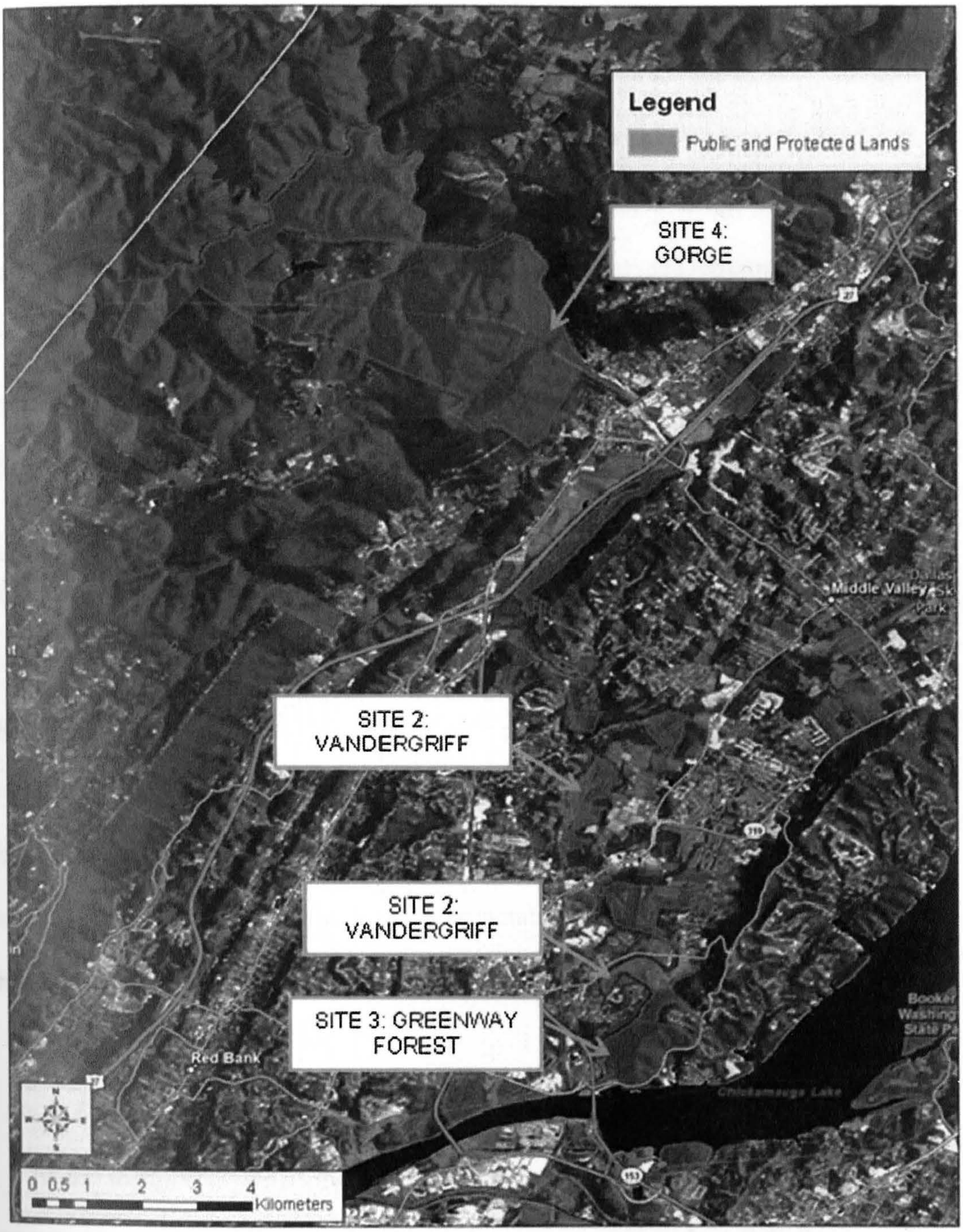

Figure 2. Aerial photograph of study area with study sites labeled. Imagery is from the NBII Community Resource Mapping Project, taken February 2002, with 5m resolution, and 1.73m accuracy.

The North Chickamauga Creek Conservancy has played a critical role in acquiring and protecting land along the creek, which is primarily owned and managed by three groups. At the northern portion of the Creek, there are 2,800 hectares of natural area which have been designated the North Chickamauga Creek Gorge Class II Natural-Scientific State Natural Area and are managed by the Tennessee Department of Environmental and Conservation (TDEC). This area is characterized by mixed mesophytic forest, undisturbed for approximately 80 years, on the slopes of the Cumberland Plateau. Along the middle and southern portions of the Creek are several tracts of land managed by the Tennessee Wildlife Resources Agency (TWRA) as Wildlife Management Areas (WMA). One of the largest is the 76 hectare Vandergriff tract, which is actively managed for small game hunting such as dove and waterfowl. The southern-most portion of the Creek is the 88 hectare North Chickamauga Creek Greenway, managed by the city of Chattanooga for recreational use (NCCC 2002). A majority of the Greenway is oak-hickory forest, undisturbed for approximately 50 years. However, a portion of the Greenway was to be a native prairie and the vegetation in this area has been growing undisturbed for approximately 10 years.

2.2: *Avian Community Structure*

As the main objective of this study is to examine habitat relationships between bird communities and areas highly invaded by exotic vegetation, I used the line transect method. This is a common avian community census technique used to record bird species, and the data can then be used to calculate diversity and density. This method is particularly valuable in large areas, and the species detections are less biased than point counts, which can be influenced from bird movement (Bibby 2000).

By considering accessibility, size, proximity to the Creek, level of plant invasion, and time constraints, four transects were located in four separate sites along the North Chickamauga Creek. Site 1 is located in the Greenway and will be referred to as the Greenway Field (Figure 3). The transect was 2000 meters of a grassy recreational trail, which runs parallel to the Creek, and has been highly invaded by understory species such as Chinese privet, Japanese honeysuckle, and Multiflora rose (*Rosa multiflora*). All of these plant species have been given a Rank 1 by the Tennessee Exotic Pest Plant Council for their severe threat to native plant communities (TNEPPC 2004). Greenway Field was once managed by the Fish and Wildlife Service as a native prairie restoration site, however this project has not been active for at least 10 years.

Site 2 is located on the Vandergriff WMA tract and will be referred to as Vandergriff (Figure 4). The transect is 2000 meters long, but does not parallel the Creek entirely due to the limited walkable trails at this site. This is the second of the highly invaded sites, with the primary invader being Chinese privet As the site is managed primarily for dove hunting, there are two feed plots located near the transect.

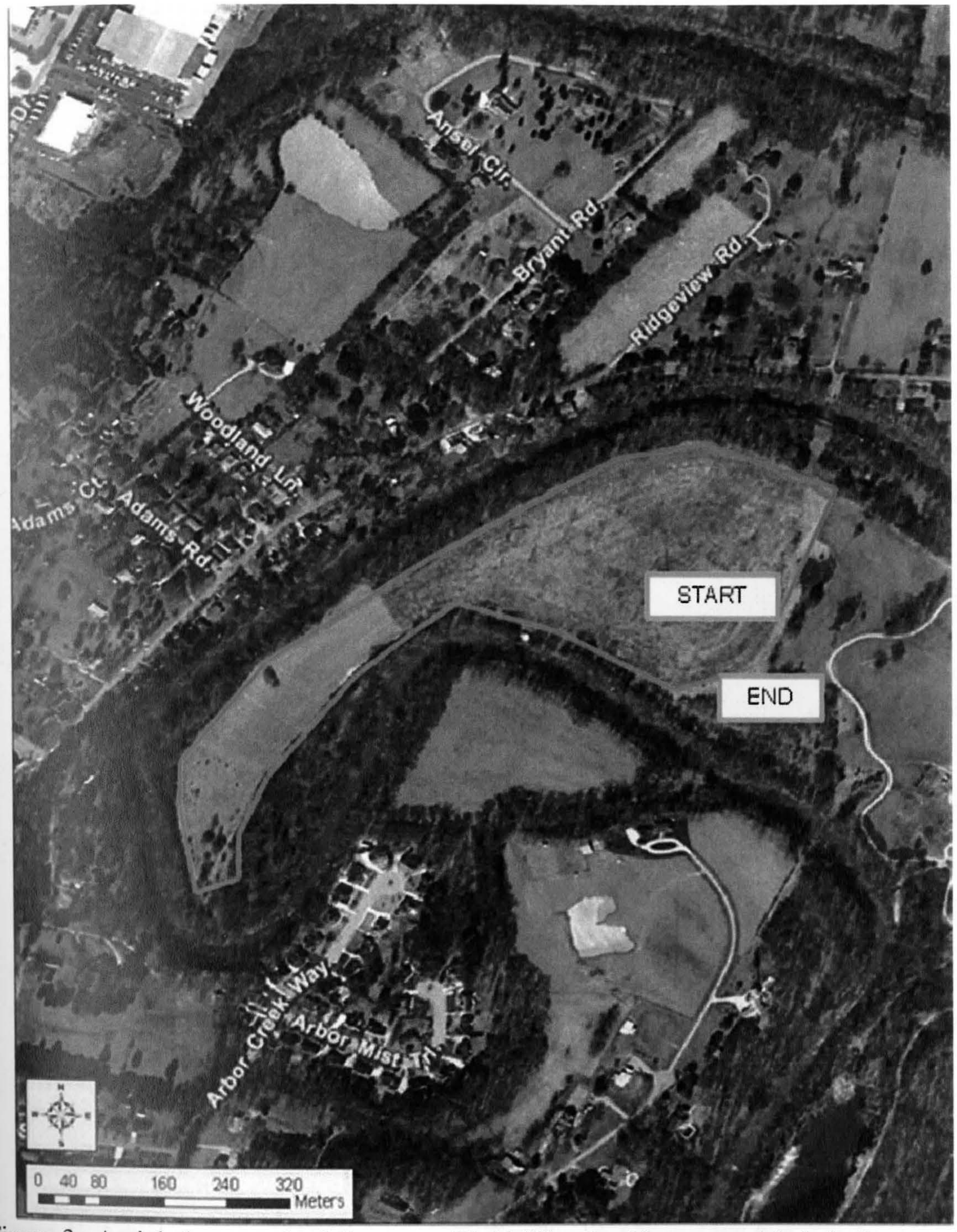

Figure 3. Aerial photograph of Greenway Field (Site 1) with transect labeled. Imagery is from ArcGIS Online, taken February 2002, with 0.5m resolution, and 1.73m accuracy.

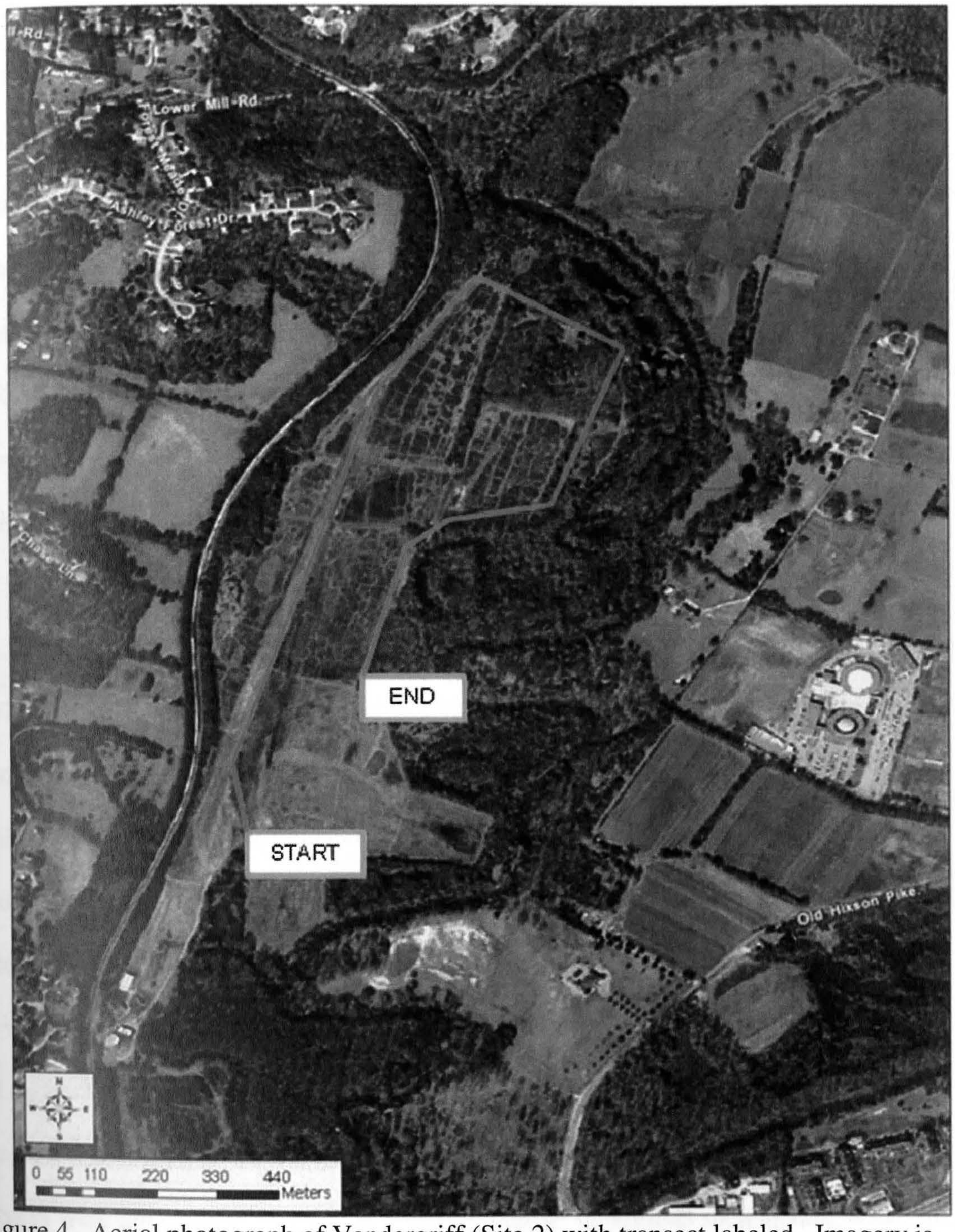

Figure 4. Aerial photograph of Vandergriff (Site 2) with transect labeled. Imagery is from ArcGIS Online, taken February 2002, with 0.5m resolution, and 1.73m accuracy.

Site 3 is located in the Greenway and will be referred to as the Greenway Forest (Figure 5). This transect is 2250 meters of a paved recreational trail that runs parallel to the Creek. There are no major plant invasions in this area, so it is considered a more natural site. Site 4 is located in the North Chickamauga Creek Gorge Class II Natural-Scientific State Natural Area and will be referred to as the Gorge (Figure 6). This transect is 1750 meters due to steep terrain on the Upper Hogsback Trail. The trail selected is on the south-facing slope of the Gorge and runs parallel to the Creek, however, it was much further from the Creek so that the noise from this portion of the Creek would not bias the bird detections. The Gorge also has no major plant invasions and was therefore selected to represent the second natural site.

Bird surveys began within one hour of sunrise from May 14, 2007 to July 27, 2007 and ended no later than three hours after sunrise, with a total of ten surveys conducted at each site. However, an additional site was surveyed during the first week until it was realized that the site was unsafe due to crime reports and Vandergriff was used instead, resulting in a total of only nine visits to Vandergriff. Every site was visited once a week and the order of transects was randomized each week by rotating the day of the week in which each site was sampled. The transects were walked at a steady pace and each individual bird either seen or heard was put into one of three distance-based categories: less than 50 meters from the transect, greater than 50 meters, or fly over. Surveys were not conducted on days in which weather conditions such as rain, wind, or morning fog could influence detection ability.

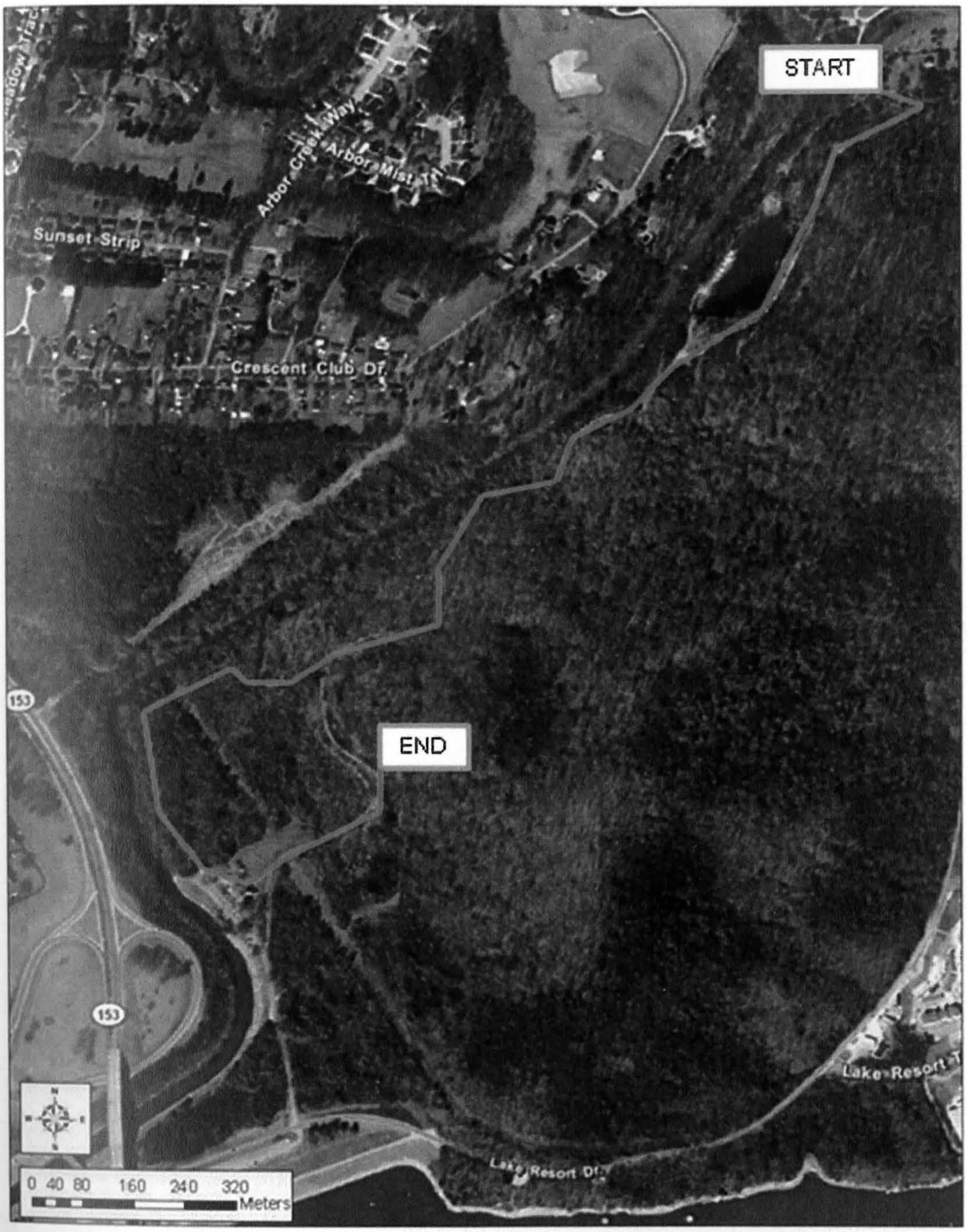

Figure 5. Aerial photograph of Greenway Forest (Site 3) with transect labeled. Imagery is from ArcGIS Online, taken February 2002, with 0.5m resolution, and 1.73m accuracy.

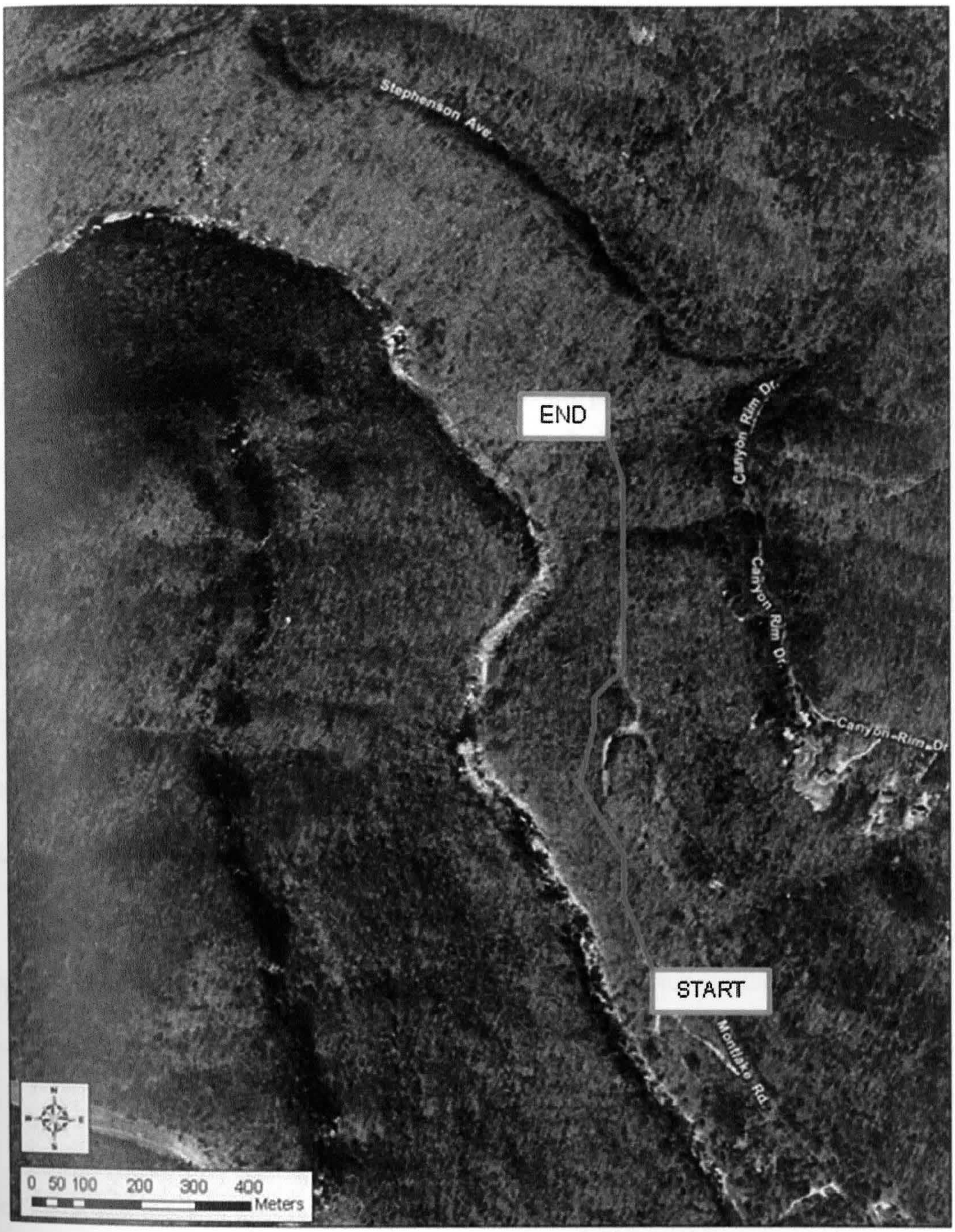

Figure 6. Aerial photograph of the Gorge (Site 1) with transect labeled. Imagery is from ArcGIS Online, taken February 2002, with 0.5m resolution, and 1.73m accuracy.

2.2.1: Data Analysis

The line transect data were used to calculate species diversity and density of birds, and also determine the species richness at each site. I used the Shannon-Wiener index to measure species diversity:

$$H = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where H is the Shannon-Wiener diversity index, p_i is the proportion of the ith species, and s is the number of species in the community (Molles 2005). Data were pooled by individuals detected within sites so that all census dates were combined. Because the Shannon-Wiener indices are relative numbers, they could not be tested statistically. Density (birds/ha) was calculated by using the number of individuals recorded within 50 meters of the transect. Species abundance was ranked to determine the most common species detected at each site. Both species richness and density of birds were analyzed statistically to determine differences using the chi-square (X^2) test (Howell 2004).

As a further measure of community structure, the similarity of bird species composition for each site was calculated using the Sorenson-Dice similarity index (Brown and Lomolino 1998). The index is expressed as:

$$\frac{2C}{N_1 + N_2}$$

where C is the number of species present in both units, N_1 is the total number of species present in the first site, and N_2 is the total number of species present in the second site. This number is then multiplied by 100 to express as percent similarity. These indices were then compared between similar sites (e.g. invaded to invaded, natural to natural) and between dissimilar sites (e.g. invaded to natural) for a total of six comparisons.

2.3: *Habitat Analysis*

Vegetation physiognomy variables were recorded in sample plots along the same transect routes used for the bird census (Bibby 2000). Plots began at the start of each transect and were located 50 meters apart. Therefore, Sites 1 and 2 had 41 vegetation plots, Site 3 had 46, and Site 4 had 36 plots. Each plot was 20 meters in diameter to account for the width of many of the trails used for transects. Broad structural components were recorded in August 2007. These were canopy height, canopy cover, subcanopy height, subcanopy cover, understory height, understory cover, and ground cover. However, canopy and subcanopy heights were measured again in May 2008 using a laser rangefinder to more accurately record tree heights. Percent cover was estimated using a densitometer and recorded in increments of ten percent.

Statistical analysis was done on both vegetation height characteristics and percent cover. After being checked for normality, the mean height data were tested for differences using a one-way ANOVA in SigmaStat Version 3.2., as an ANOVA allows multiple means to be tested for differences (Howell 2004). If a significant difference was found between the height means of all sites, then a Tukey's post hoc test was performed to determine pairwise comparisons between sites. A Tukey's test is more conservative than a Fisher's post hoc test but less conservative than the Bonferroni procedure (Howell 2004). The Bonferroni procedure was not used because there is no consensus among ecologists or statisticians for when to use it (Nakagawa 2004). Vegetation percent cover data were analyzed using a chi-square test in SigmaStat Version 3.2 as this test is often used on categorical data (Howell 2004).

2.4: Avian Nest Measures

Nest searches were conducted during the 2007 and 2008 breeding seasons at both the Greenway Field site and Greenway Forest site. These sites were selected as one represented a highly invaded habitat while the other a relatively non-invaded site. They are within walking distance to one another, which was important as nest searching is an incredibly time-consuming and labor-intensive process. During the 2007 season, only Northern Cardinal and Indigo Bunting nests were searched for, with the belief that focusing on only two species would allow me to develop a highly productive search image. However, during the 2008 season, after finding very few nests of the desired species during the previous year's surveys, nest searches were done to find any species which had a nest that could be easily monitored (i.e. no nests were monitored that were placed above ten feet because the mirror could not extend that high).

All nests found were monitored following the USDA Forest Service guidelines (Ralph et al. 1993). Nests with eggs only were checked every three to four days to count eggs and note brood parasitism if present. Once hatched, the nests were checked every other day to monitor the status. This data was then used to calculate nest success using the Mayfield method (Mayfield 1975). Time (in days) to incubation and fledging used in calculating nest success were obtained for each species from Ehrlich et al. (1988). There were not enough nests located at either site to justify taking habitat measures at the nest site for analysis.

It is important to note that monitoring was done with extreme care and distance was always kept from the nest by checking them with an extendable mirror. Because the birds were not handled or disturbed in doing this research, the Institutional Animal Care and Use Committee (IACUC) at the University of Tennessee at Chattanooga did not deem it necessary for me to submit a protocol for review. Therefore, there was no IACUC approval needed for inclusion in this thesis.

Chapter 3: Results

3.1: Avian Community Structure

A total of 80 species were detected either by visual or auditory means at the four study sites (Appendix A). There was a significant difference in the number of bird species between sites ($X^2 = 555.67, p < 0.001$). The highest number of species was found at Vandergriff, followed by Greenway Forest, then Greenway Field, and the Gorge had the fewest number of species (Table 1). The fifteen most abundant species at each site are listed in Table 2 and a complete list of species abundance is in Appendix A. There was no significant difference in bird density between sites ($X^2 = 2.65, p = 0.66$). Diversity indices were similar between all sites, with Vandergriff having the highest species bird species diversity, followed closely Greenway Field, Greenway Forest, and then the Gorge (Table 1).

Greenway Field and Greenway Forest had the highest similarity of species between the two sites, with Greenway Field and Vandergriff also having a similar Sorenson-Dice index. Vandergriff and Greenway Forest had the next most similar species composition between sites, followed by Greenway Forest and the Gorge. The lowest similarity indices were Vandergriff and the Gorge, and lastly Greenway Field and the Gorge (Table 3).

Table 1. Number of species, density (birds/ha), and diversity at each study site.

Site	Greenway Field	Vandergriff	Greenway Forest	Gorge
# of Species	49	56	50	36
Density (birds/ha)	5.51	6.27	3.39	2.01
Diversity Index (H)	1.33	1.40	1.30	1.26

Table 2. Most abundant species at each study site.

	Greenway Field	Vandergriff	Greenway Forest	Gorge
1.	Northern Cardinal	Indigo Bunting	Northern Cardinal	Red-eyed Vireo
2.	American Robin	Field Sparrow	Carolina Chickadee	Carolina Wren
3.	Field Sparrow	Northern Cardinal	Carolina Wren	Black-throated-green Warbler
4.	Eastern Towhee	Eastern Towhee	Eastern Tufted Titmouse	Worm-eating Warbler
5.	Carolina Wren	Carolina Wren	Eastern Towhee	Carolina Chickadee
6.	Indigo Bunting	American Crow	Blue Jay	American Crow
7.	Carolina Chickadee	American Goldfinch	Red-eyed Vireo	Black-and-white Warbler
8.	European Starling	Eastern Tufted Titmouse	American Robin	Northern Cardinal
9.	Blue-gray Gnatcatcher	Common Grackle	Blue-gray Gnatcatcher	Pileated Woodpecker
10.	Eastern Tufted Titmouse	Yellow-breasted Chat	Downy Woodpecker	Blue-gray Gnatcatcher
11.	Brown-headed Cowbird	Eastern Bluebird	Mourning Dove	Blue Jay
12.	Common Grackle	Blue-gray Gnatcatcher	Eastern Pheobe	Eastern Tufted Titmouse
13.	Blue Jay	Carolina Chickadee	Red-bellied Woodpecker	American Goldfinch
14.	White-eyed Vireo	American Robin	Hairy Woodpecker	Downy Woodpecker
15.	Northern Rough-winged Swallow	White-eyed Vireo	Cedar Waxwing	Scarlet Tanager

Table 3. Sorenson-Dice similarity indices between study sites (in percentages).

	Greenway Field	Vandergriff	Greenway Forest
Vandergriff	74		
Greenway Forest	75	70	
Gorge	49	52	63

3.2: Habitat Analysis

The mean heights and mean percent cover of canopy and subcanopy vegetation were generally higher at Greenway Forest and the Gorge, which were the two natural sites (Table 4). There was no observable trend in understory height, while understory cover was higher at Greenway Field and Greenway Forest. As displayed in Table 5, canopy, subcanopy, understory and ground cover were all found to be significantly different between sites ($p < 0.001$). Habitat characteristics are displayed graphically in Figures 7 and 8.

Canopy, subcanopy, and understory heights were all found to be significantly different between sites ($p < 0.001$) and pairwise comparisons are recorded in Table 6. All site comparisons for canopy height were statistically different; however, Greenway Forest and the Gorge were the most similar. Subcanopy height comparisons were different for all except between Greenway Forest and the Gorge. All sites had similar mean understory heights except when Greenway Forest and the Gorge were compared and when Greenway Field and the Gorge were compared.

Table 4. Mean(SD) habitat structure characteristics at each study site.

	Greenway Field (n=41)	Vandergriff (n=41)	Greenway Forest (n=46)	Gorge (n=36)
Canopy Height (m)	11(5.5)	6.4(5.3)	15(4.0)	17(2.9)
Canopy Cover (%)	27(17)	29(25)	52(22)	58(21)
Subcanopy Height (m)	2.9(2.0)	1.8(2.3)	5.7(2.2)	6.2(1.1)
Subcanopy Cover (%)	17(17)	10(14)	47(24)	54(15)
Understory Height (m)	1.9(0.4)	1.7(0.5)	1.9(0.5)	1.5(0.3)
Understory Cover (%)	60(20)	31(20)	49(23)	28(12)
Ground Cover (%)	96(7.4)	92(13)	73(12)	78(16)

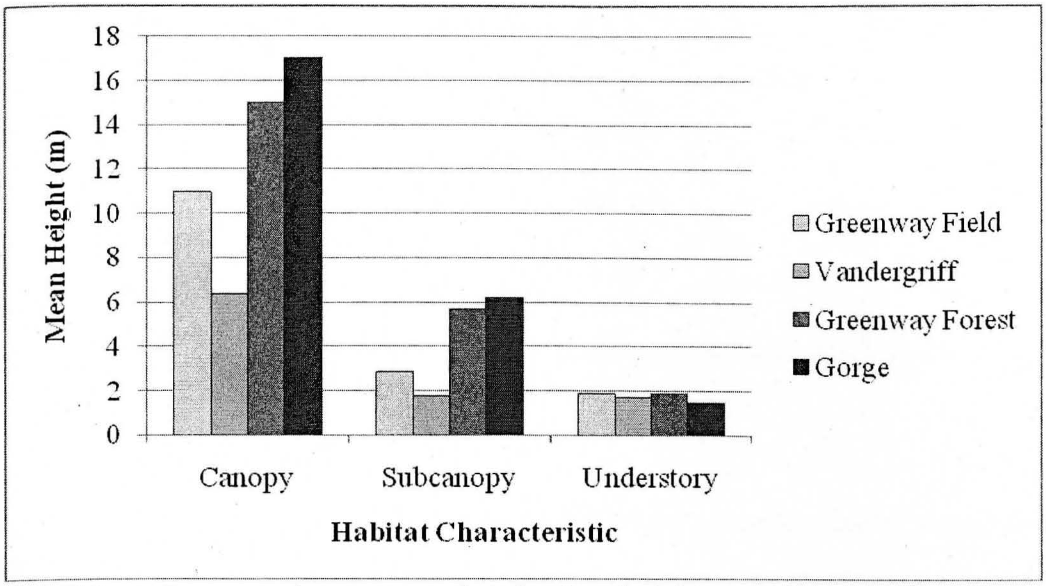

Figure 7. Mean canopy, subcanopy, and understory heights at each study site.

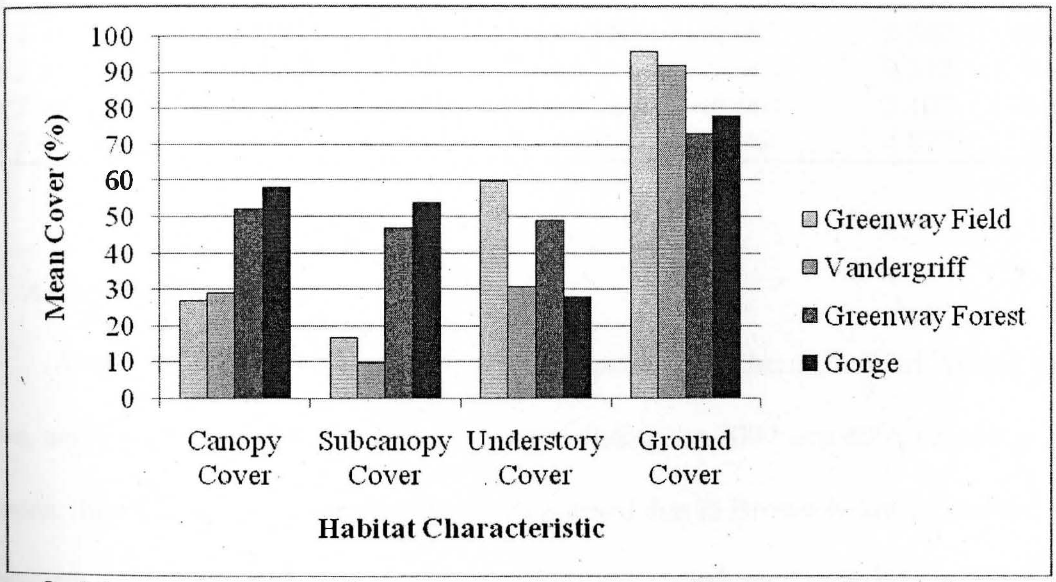

Figure 8. Mean percent cover for canopy, subcanopy, understory, and ground vegetation at each study site.

Table 5. Test statistics and significance values for ANOVA and chi-square analysis of habitat structure characteristics.

	F	p-value	X^2	p-value
Canopy Height (m)	41.79	<0.001*	N/A	N/A
Canopy Cover (%)	N/A	N/A	1632	<0.001
Subcanopy Height (m)	46.22	<0.001*	N/A	N/A
Subcanopy Cover (%)	N/A	N/A	1602	<0.001
Understory Height (m)	6.29	<0.001*	N/A	N/A
Understory Cover (%)	N/A	N/A	1029	<0.001
Ground Cover (%)	N/A	N/A	234	<0.001

* = significance value justifies a post hoc test

Table 6. Test statistics and significance values for Tukey's post hoc test of vegetation height means.

	Canopy Height		Subcanopy Height		Understory Height	
	q	p-value	q	p-value	q	p-value
Site 1 vs. Site 2	6.797	<0.001	3.777	0.038	2.577	0.263
Site 1 vs. Site 3	4.875	0.003	9.042	<0.001	0.882	0.924
Site 1 vs. Site 4	8.176	<0.001	10.107	<0.001	5.582	<0.001
Site 2 vs. Site 3	11.865	<0.001	12.926	<0.001	2.312	0.359
Site 2 vs. Site 4	14.749	<0.001	13.759	<0.001	3.107	0.124
Site 3 vs. Site 4	3.687	0.045	1.647	0.649	4.877	0.003

3.3: Avian Nest Measures

A total of eight nesting attempts of three species, Northern Cardinal, Mourning Dove, and Carolina Chickadee, were monitored during the 2007 and 2008 breeding seasons. Nests found once they had been abandoned due to Brown-headed Cowbird parasitism were not included in nest success analysis. Northern Cardinal had an overall nest success of 0.48 (i.e. a 48% chance of surviving to the next day) in Greenway Field and zero success in Greenway Forest. The one Mourning Dove nest located in Greenway Field had zero success. The only successful nesting attempt was a Carolina Chickadee nest at the Greenway Forest site (Table 7).

Table 7. Nest survival rates (in proportions) for the incubation period (NSR_i), the nestling period (NSR_n), and overall nest success of nests monitored at two sites.

	Greenway Field			Greenway Forest		
	NSR_i	NSR_n	Nest Success	NSR_i	NSR_n	Nest Success
Northern Cardinal*	0.78	0.58	0.48	0.02	0.0	0.0
Mourning Dove(n=1)	0.176	0.0	0.0	-	-	-
Carolina Chickadee(n=1)	-	-	-	1.0	1.0	1.0

* = (n=3) for Greenway Field and (n=3) for Greenway Forest.

Chapter 4: Discussion

4.1: Impacts of Exotic Invasive Vegetation on Avian Community Structure

Overall, the invasion of exotic plants onto sites along the North Chickamauga Creek seems to have a neutral or slightly positive effect on avian community structure. Both diversity and density were found to be higher on at least one of the invaded sites. However, several correlations between vegetation structure and bird community structure emerged and each deserves a separate discussion.

Diversity indices were similar among all sites, however diversity of bird species was highest at Vandergriff. These results do not support the original prediction that diversity would be higher at the natural sites. MacArthur (1964) reported the role of heterogeneity in the foliage height profile in determining bird species diversity. While there has been criticism for this vegetation physiognomy and bird diversity relationship from many authors (Fleishman and Mac Nally 2006, Fleishman et al. 2003, Rotenberry 1985, Willson 1974), it remains a widely accepted concept of avian ecology.

A diverse vertical vegetation profile provides more foraging opportunities and can therefore support a variety of species (Gill 2007). I therefore predicted that the natural sites would have higher diversity as the invaded sites would have decreased vertical vegetation structure. The vegetation analysis shows that the natural sites have more vertical diversity, with both higher mean canopy and subcanopy heights, and also higher mean percent canopy and subcanopy cover compared to the invaded sites. However, the diversity indices do not follow these same patterns. The similar diversity indices suggest no effect on species diversity from exotic plant invasion at my study sites. The food resources provided by plants is likely the most important factor birds respond to

(Rotenberry1985) so the similarity in diversity of species between sites could be showing that the invasive plants are providing a comparable amount of foraging opportunities.

It must also be noted that the site supporting the highest diversity, Vandergriff, is also under the highest level of management relative to the other three study sites. If the management techniques at Vandergriff, paired with the invasion of exotic understory species, are to be viewed as a disturbance to the system, then perhaps the high diversity could be explained by the intermediate disturbance hypothesis. Connell (1975) suggested that high diversity is a result of continually changing conditions within an ecosystem (Molles 2005). Vandergriff is in the early stages of invasion relative to Greenway Field, which has not been managed in over 10 years. The Gorge is also the most undisturbed site of the four studied and had the lowest species diversity. Research has also shown that moderate levels of development may also increase species diversity (Blair 1996). While these factors could help explain the higher diversity found Vandergriff, they were not the focus of this project and a closer look at other community structure components such as species richness, abundance, and composition is warranted.

Species richness, or simply the number or species, was highest at Vandergriff, very similar between Greenway Forest and Greenway Field, and lowest at the Gorge. While richness alone is a rather crude meaure, the composition of species reveals interesting information on the types of birds using invaded or non-invaded sites. A recent study on *Tamarix* invasion in riparian communities of the desert Southwest reported that species abundance for many species was highest at intermediate invasion levels (van Riper et al. 2008). While this could hold true for Vandergriff as well, it does not help explain why the similarity indices between Vandergriff and Greenway Field were so high but the number of species was quite different. Similarly, the Sorenson-Dice indices for Greenway Field and Greenway Forest were just as high, however, this could be a related to the closeness of these two sites to one another geographically. Fleishman et al. (2003) found that the best predictor of species richness was total vegetation volume. While this is not something I measured, perhaps the invasive plants did provide more vegetation volume, in turn providing more food resources (e.g. fruits, seeds, insects). However, this is speculative and should be a topic for future research.

Relative species abundance also varied among sites with the Gorge supporting a unique species composition. In the top 15 most abundant species list for each site, many species were found to be common at all sites. However, there are some important differences as well. Greenway Field had large numbers of European Starling, a non-native bird that competes with native cavity nesters, and Brown-headed Cowbird, the only obligate brood-parasite breeding in Tennessee and a source of concern for nest success of many avian species (Nicholson 1997). Interestingly, the only study site where the Brown-Headed Cowbird was not recorded was the Gorge. Northern Rough-winged Swallow is also of interest as this species has a diet composed entirely of insects, revealing that there could be a large flying insect population at this site. Vandergriff, the second invaded site, had large numbers of Yellow-breasted Chat, a neotropical migratory species that has declined in numbers due to the loss of early successional forests and brushy areas, and Eastern Bluebird which are associated with open areas such as forest clearings and agricultural landscapes (Nicholson 1997).

Greenway Forest supported large numbers of two cavity nesters, the Red-bellied Woodpecker and Hairy Woodpecker, which rely on mature forests, but also had high numbers of Mourning Dove, Eastern Phoebe, and Cedar Waxwing, all of which use areas such as open forests, woodlot edges or residential areas. The abundance of the latter group of species could be related to the presence of a power-line right of way that runs through the southern portion of this forest and bisected the transect, creating an opening in the forest. The Gorge, the second natural site, had large numbers of several neotropical migratory species which all spend the breeding season in mature forests. Many of the unique species abundant at this site have specific habitat requirements. The Worm-eating Warbler is sensitive to habitat fragmentation, the Black-and-white Warbler is an area-sensitive species, Pileated Woodpeckers are forest interior species relying on large trees, and the Scarlet Tanager prefers extensive forests (Nicholson 1997). Migratory species are of special concern as research has shown population declines for particular species (Aborn 2007) and it is important to note that the Gorge contained the highest number and proportion of migratory species recorded. Of the total 35 migratory species recorded at all four study sites, 15 were found at Greenway Field, 18 at Vandergriff, 18 at Greenway Forest, and 20 (or 56% of all species at this site) in the Gorge.

These differences in species composition could be linked to a few habitat variables. Species composition can be associated with floristics, particularly from the presence or absence of invasive plants when these plants may either limit or increase food availability (Fleishman et al. 2003). There is also support from other research for the idea that as development increases, habitat specialists decline (Zipperer 2002). This could help explain the absence of many of the warbler species, for example, from the invaded sites as these sites are also closer to urban areas, housing developments, and agricultural land than the two natural sites. Friesen et al. (1994) found that the diversity and abundance of migrants decreased as the level of near-by development increased, regardless of the size of the forest they were occupying. However, this explanation is speculative as I did not measure these parameters associated with development.

There was no statistical difference in bird densities found between sites. However, the raw data showed a difference that is biologically important. Habitat determinates of bird density include vegetation volume and percent foliage cover (Mills et al. 1991) where higher density generally correlates with higher percent cover. However, the results from this study do not support the latter supposition. While the two highly invaded sites, Greenway Field and Vandergriff, supported the highest density of birds, they also had the lowest canopy and subcanopy percent covers. Interestingly, the understory percent cover at Vandergriff, which had the highest density of birds, was more similar to the understory percent cover at the Gorge, which had the lowest density of birds.

It was predicted that the invasion of dense understory species such as Chinese privet would have given different results. However, it is important to note that Vandergriff is a highly-managed property along the Creek and the location of the transect at this site was highly influenced by accessibility. A portion of the transect was parallel to a feed plot containing planted corn and therefore no understory layer. This habitat modification therefore influenced the vegetation analysis by displaying the mean understory cover at this site to be lower than it is in reality. This management technique could also be influencing the results as the feed plots are designed to attract small game such as dove and waterfowl, but could be attracting other bird species as well to Vandergriff.

If greater levels of invasion are to be believed as the reason for increased density of birds, then the question of what these plants are providing that would attract more individuals must be answered. A similar study found higher densities of birds on high privet-density plots only in the winter and this was attributed to abundance of privet berries (Wilcox and Beck 2007). Certainly food prevalence could influence bird density but this increase is not necessarily beneficial to avian communities as exotic vegetation is often deficient in dietary resources (Rottenborn 1999). An increase in nesting sites could serve as another cause for increased bird density, however this is not always regarded as a good measure of habitat quality. Vickery et al. (1992) found that high density did not correspond with the highest reproductive success of the species studied. Van Horne (1983) noted that territorial birds of low fitness levels may be found at higher densities in poor habitat because the favorable habitat is limited. Therefore, higher densities do not necessarily reflect good habitat.

The results also reveal the fact that other parameters could be influencing bird densities. Many studies have looked at the effects of urbanization on bird communities, and there is a general conclusion that urban environments have a higher density of individual birds (Blair 1996, Mills et al. 1989, Tilghman 1987). Development may increase available critical resources needed by birds. For example, the use of bird feeders in suburban areas and the use of buildings as roost sites could attract more individual birds. While this was not the aim of my study, I believe this should be considered as the two invaded sites could be considered to be in more urban areas than the two natural sites.

Collectively, the community structure measures of diversity and density show there is generally little effect on bird communities due to environmental changes from exotic plant invasion as measured by this project. While diversity and density was slightly higher at the two invaded sites, Vandergriff stood out as being the highest. If this site is considered to have the best habitat based solely on these two variables and without collecting demographic data as well, then it could be concluded that an intermediate level of invasion is preferred by bird communities. However, other diversity components such as species richness, abundance and composition should be taken into consideration when analyzing the effects of invasive vegetation on bird communities as many species are habitat specialists with strict requirements.

4.2: Impacts of Exotic Invasive Vegetation on Avian Nest Success

Unfortunately, there were not enough nests located and fully monitored to draw a valuable conclusion on the effect of invasive vegetation on nest success between Greenway Field and Greenway Forest. It is still interesting to note that the Northern Cardinal nesting attempts did not survive beyond the incubation stage at Greenway Forest, while some at the Greenway Field site were not predated until already hatched. Future research should be conducted to determine the predation patterns in invaded versus native habitats and why differences in predation rates could be occurring. In general, research has found that fecundity is decreased when exotic shrubs are selected for nest sites. Nest failure has been attributed to a reduction in nest substrates resulting in less nest-site partitioning, therefore allowing predators to develop a focused search image (Borgmann and Rodewald 2004) and also a branch architecture in exotic plants that allows predators easier access to the nest with the absence of physical deterrents such as thorns on exotic plants (Schmidt and Whelan 1999).

The collection of demographic data in addition to census monitoring is strongly encouraged. Nest searches can give information on clutch size and predation rates, but mist netting could also be valuable. Mist netting in invaded and non-invaded sites could reveal differences in adult and juvenile survivorship and recruitment of many bird species. Both nest searches and mist netting would measure productivity of the areas studied and provide species specific responses to changes in habitat.

4.3: Conservation Implications and Suggestions for Future Research

As all of the study sites used in this project are protected areas, they are under some form of management. However, it seems that at least two of the sites, Greenway Field and Vandergriff, are not being managed for the whole ecosystem. To adequately address issues surrounding plant invasions, an integrated management system for the entire ecosystem, rather than for the invasive species itself, proves most beneficial (Hobbs and Humphries 1994, Mack et al. 1999). The results presented in this project may not reflect a negative correlation between exotic plants and bird community structure, but the differences between sites still show a need for invasion control due to the presence of species in need of protection at the natural sites and potentially harmful species at the invaded sites. It is well understood that invasive plants can decrease native plant diversity and that their spread into natural habitats should be prevented. This study shows that the invasive plants do not have a strong positive effect on bird communities and therefore control efforts should be continued. Also, removal of certain invasive plants which serve as important food sources for birds could prevent birds from being active dispersers of the seeds, helping to control the spread of those plants (Wilcox and Beck 2007).

Because the transition from exotic plant removal to native plant recovery can result in perturbations to certain ecosystem functions, an adaptive approach to management could be suggested (Westman 1990). The intermediate disturbance hypothesis should also be taken into consideration when considering conservation strategies related to exotic plant management (Hobbs and Huenneke 1991). The results of my project could support this hypothesis, showing that areas with moderate disturbance levels had higher species richness and density of birds. This could be useful knowledge to managers as dense understory invasive plants in the southeast can be very difficult to remove completely. Certainly an avian response threshold to various levels of invasion, not just the extremes, should be studied in the future so that we can fully understand how ecosystem health is impacted.

In the future, additional study sites should be included to hopefully produce less ambiguous results. Due to time constraints, I was only able to assess four sites with one transect at each site, but I would suggest between six and ten sites be studied at various invasion levels to gain more firm effects on avian communities from habitat changes. Long-term studies over several breeding seasons are also needed to observe the corresponding changes in vegetation due to invasion and avian community responses. This information must also be paired with demographic data such as fecundity in order to accurately determine the productivity of the system. Invasive plants are likely to impact avian communities in other ways as well and the use of these plants as food sources and in behavioral activities should also be observed. This could be particularly beneficial by analyzing the effects of food resources on specific foraging groups such as insectivores and frugivores. There is a lack of information on avian response to exotic plant invasion in the southeast and immediate devotion to the issue of plant invasions is strongly encouraged. Extra attention should be given to habitat specialists and studies should also be done at the species level in addition to the community level so that individual responses can be better understood.

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Appendix

Appendix A:

Relative abundance of bird species recorded at sites along the North Chickamauga Creek.

Common Name	Scientific Name	Site 1	Site 2	Site 3	Site 4
Acadian Flycatcher	*Empidonax virescens* Vieillot	0.00	0.00	0.00	0.01
American Crow	*Corvus brachyrhynchos* Brehm	0.01	0.04	0.01	0.04
American Goldfinch	*Carduelis tristis* Linnaeus	0.01	0.04	<0.01	0.03
American Robin	*Turdus migratorius* Linnaeus	0.11	0.03	0.04	<0.01
Barn Swallow	*Hirundo rustica* Linnaeus	<0.01	<0.01	0.00	0.00
Barred Owl	*Strix varia* Barton	0.00	0.00	<0.01	0.00
Belted Kingfisher	*Megaceryle alcyon* Linnaeus	<0.01	0.00	<0.01	0.00
Black Vulture	*Coragyps atratus* Bechstein	0.00	<0.01	0.00	0.00
Black-and-white Warbler	*Mniotilta varia* Linnaeus	<0.01	0.00	<0.01	0.04
Blackpoll Warbler*	*Dendroica striata* Forster	0.00	0.00	<0.01	0.00
Black-throated-green Warbler	*Dendroica virens* Gmelin	0.00	0.00	<0.01	0.12
Blue Grosbeak	*Passerina caerulea* Linnaeus	0.00	0.01	0.00	0.00
Blue Jay	*Cyanocitta cristata* Linnaeus	0.03	0.02	0.05	0.03
Blue-gray Gnatcatcher	*Polioptila caerulea* Linnaeus	0.03	0.03	0.04	0.03
Brown Thrasher	*Toxostoma rufum* Linnaeus	0.02	<0.01	0.01	0.00
Brown-headed Cowbird	*Molothrus ater* Boddaert	0.03	0.01	0.01	0.00
Canada Goose	*Branta Canadensis* Linnaeus	0.00	0.01	0.00	0.00
Carolina Chickadee	*Poecile carolinensis* Audubon	0.05	0.03	0.12	0.05
Carolina Wren	*Thryothorus ludovicianus* Latham	0.05	0.05	0.10	0.14
Cedar Waxwing	*Bombycilla cedrorum* Vieillot	0.02	0.00	0.01	0.00
Chimney Swift	*Chaetura pelagic* Linnaeus	<0.01	0.01	<0.01	<0.01
Chipping Sparrow	*Spizella passerine* Bechstein	0.01	0.01	0.00	0.00
Common Grackle	*Quiscalus quiscula* Linnaeus	0.03	0.03	0.01	0.00
Common Yellowthroat	*Geothlypis trichas* Linnaeus	0.00	0.01	0.00	0.00
Connecticut Warbler*	*Oporornis agilis* Wilson	0.00	0.00	<0.01	0.00
Downy Woodpecker	*Picoides pubescens* Linnaeus	0.01	0.01	0.03	0.02
Eastern Bluebird	*Sialia sialis* Linnaeus	<0.01	0.03	<0.01	0.00
Eastern Kingbird	*Tyrannus tyrannus* Linnaeus	0.00	<0.01	0.00	0.00
Eastern Meadowlark	*Sturnella magna* Linnaeus	<0.01	<0.01	0.00	0.00
Eastern Phoebe	*Sayornis phoebe* Latham	0.00	0.01	0.02	0.01
Eastern Towhee	*Pipilo erythrophthalmus* Linnaeus	0.07	0.08	0.06	0.00
Eastern Tufted Titmouse	*Baeolophus bicolor* Linnaeus	0.03	0.04	0.07	0.03
European Starling	*Sturnus vulgaris* Linnaeus	0.03	0.01	0.00	0.00
Field Sparrow	*Spizella pusilla* Wilson	0.09	0.11	0.01	0.00
Gray Catbird	*Dumetella carolinensis* Linnaeus	<0.01	<0.01	0.00	0.00
Great Blue Heron	*Ardea herodias* Linnaeus	<0.01	<0.01	<0.01	0.00
Great-crested Flycatcher	*Myiarchus crinitus* Linnaeus	<0.01	0.00	0.01	<0.01
Green Heron	*Butorides virescens* Linnaeus	0.00	<0.01	0.00	0.00
Hairy Woodpecker	*Picoides villosus* Linnaeus	<0.01	<0.01	0.01	<0.01
Hooded Warbler	*Wilsonia citrine* Boddaert	0.00	0.00	0.00	0.01
House Finch	*Carpodacus mexicanus* Müller	<0.01	<0.01	0.01	0.00
House Sparrow	*Passer domesticus* Linnaeus	<0.01	0.00	0.00	0.00
Indigo Bunting	*Passerina cyanea* Linnaeus	0.05	0.12	0.01	0.02
Louisiana Waterthrush	*Seiurus motacilla* Vieillot	0.00	0.00	0.00	<0.01
Mallard	*Anas platyrhynchos* Linnaeus	0.00	0.00	<0.01	0.00
Mourning Dove	*Zenaida macroura* Linnaeus	0.02	0.02	0.02	0.02
Northern Bobwhite	*Colinus virginianus* Linnaeus	0.00	<0.01	0.00	0.00
Northern Cardinal	*Cardinalis cardinalis* Linnaeus	0.18	0.11	0.21	0.04
Northern Mockingbird	*Mimus polyglottos* Linnaeus	0.01	0.01	0.01	0.00

Appendix A: Continued.

Common Name	Scientific Name	Site 1	Site 2	Site 3	Site 4
Northern Rough-winged Swallow	*Stelgidopteryx serripennis* Audubon	0.02	0.01	<0.01	0.00
Orchard Oriole	*Icterus spurious* Linnaeus	<0.01	0.00	0.00	0.00
Pileated Woodpecker	*Dryocopus pileatus* Linnaeus	0.01	<0.01	0.01	0.04
Prairie Warbler	*Dendroica discolor* Vieillot	0.00	<0.01	0.00	0.00
Purple Martin	*Progne subis* Linnaeus	<0.01	0.00	0.00	0.00
Red-bellied Woodpecker	*Melanerpes carolinus* Linnaeus	0.01	<0.01	0.02	0.00
Red-eyed Vireo	*Vireo olivaceus* Linnaeus	<0.01	<0.01	0.05	0.17
Red-headed Woodpecker	*Melanerpes erythrocephalus* Linnaeus	<0.0a	0.00	<0.01	0.00
Red-winged Blackbird	*Agelaius phoeniceus* Linnaeus	0.00	<0.01	0.00	0.00
Red-shouldered Hawk	*Buteo lineatus* Gmelin	<0.01	<0.01	0.00	<0.01
Red-tailed Hawk	*Buteo jamaicensis* Gmelin	0.00	<0.01	<0.01	0.00
Rose-breasted Grosbeak	*Pheucticus ludovicianus* Linnaeus	0.00	0.00	0.00	<0.01
Ruby-throated Hummingbird	*Archilochus colubris* Linnaeus	0.00	<0.01	<0.01	<0.01
Scarlet Tanager	*Piranga olivacea* Gmelin	0.00	0.00	0.01	0.02
Song Sparrow	*Melospiza melodia* Wilson	0.01	0.01	<0.01	0.00
Summer Tanager	*Piranga rubra* Linnaeus	0.00	<0.01	0.00	<0.01
Swainson's Thrush*	*Catharus ustulatus* Nuttall	0.00	0.00	0.00	<0.01
Tree Swallow	*Tachycineta bicolor* Vieillot	<0.01	0.01	0.00	0.00
Turkey Vulture	*Cathartes aura* Linnaeus	0.00	0.00	0.00	<0.01
White-breasted Nuthatch	*Sitta carolinensis* Latham	0.00	<0.01	0.01	<0.01
White-crowned Sparrow*	*Zonotrichia leucophrys* Forster	0.00	<0.01	0.00	0.00
White-eyed Vireo	*Vireo griseus* Boddaert	0.03	0.02	0.01	<0.01
Wild Turkey	*Meleagris gallopavo* Linnaeus	0.00	0.01	<0.01	0.00
Wood Duck	*Aix sponsa* Linnaeus	<0.01	0.00	0.00	0.00
Wood Thrush	*Hylocichla mustelina* Gmelin	<0.01	<0.01	0.01	0.01
Worm-eating Warbler	*Helmitheros vermivorus* Gmelin	0.00	0.00	<0.01	0.07
Yellow-billed Cuckoo	*Coccyzus americanus* Linnaeus	<0.01	0.00	<0.01	0.00
Yellow-breasted Chat	*Icteria virens* Linnaeus	0.02	0.03	0.00	0.00
Yellow-shafted Flicker	*Colaptes auratus* Linnaeus	<0.01	<0.01	<0.01	0.00
Yellow-throated Vireo	*Vireo flavifrons* Vieillot	0.00	<0.01	0.01	0.01
Yellow-throated Warbler	*Dendroica dominica* Linnaeus	0.00	0.00	0.00	<0.01

* = non-breeding migratory species.

Vita

Shannon Elaine Hatmaker was born and raised in Chattanooga, Tennessee. She graduated from Hixson High School in 2001. After high school, she attended Clemson University in Clemson, South Carolina, where she received a Bachelor of Science degree in Biological Sciences in 2005. She then worked as a field technician with the Student Conservation Association in Montana, Washington, and California and later as an herbarium assistant at Clemson University's Bob and Betsy Campbell Museum of Natural History.

Shannon began work towards a Master of Science degree in Environmental Science at the University of Tennessee at Chattanooga in 2006. While there, she was awarded an InterExchange Foundation grant to serve as an international volunteer in Tanzania for one semester with Roots & Shoots, the educational branch of the Jane Goodall Institute. She also worked with the Society for Conservation Biology as a conference assistant for the 22nd annual meeting, held in Chattanooga. After completion of her Master of Science degree, Shannon hopes to pursue a career in conservation biology and education with an international non-profit organization.