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# Habitat Relationships of Breeding Birds in Bottomland Hardwood Forests of the Altamaha River, Georgia

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# HABITAT RELATIONSHIPS OF BREEDING BIRDS IN BOTTOMLAND HARDWOOD FORESTS OF THE ALTAMAHA RIVER, GEORGIA

by

JARED ZIMMERMAN

(Under the Direction of C. Ray Chandler)

## ABSTRACT

Bottomland hardwood forests (bottomlands) dominate most of the river floodplains and lowlands of the southeastern United States. These vanishing and often degraded forests provide habitat for at least seventy species of breeding birds. However, little is known about habitat associations of breeding birds, specifically within mature, closed-canopy bottomlands. It is often assumed that once bottomlands become mature, closed-canopy forests, that they are essentially identical from the perspective of breeding birds. To test this assumption, I examined habitat associations of the overall breeding bird community as well as ten priority species within the little-studied mature bottomlands of the Altamaha River, Georgia. In 2007 and 2008, I conducted point-counts for breeding birds and quantified habitat characteristics at 54 stations. I detected 33 species of birds breeding at stations, 19 of which were Neotropical Migratory bird species. I found that the overall density of breeding birds, the density of breeding Neotropical species, as well as the Avian Conservation Score of stations did not closely track habitat variation within mature bottomlands. However, I found that some individual breeding species were sensitive to habitat variation within mature bottomlands. Yellow-throated vireo (*Vireo flavifrons*) and Hooded Warbler (*Wilsonia citrina*) preferred slightly less canopy cover within mature bottomlands, whereas White-eyed vireo (*Vireo griseus*) preferred more. Kentucky Warbler (*Oporonus formosus*) preferred stations with less variability in tree diameter and more shrubs.  My study illustrates the significance of the Altamaha River bottomlands for the conservation of a diverse assemblage of breeding birds, including numerous Neotropical migratory species of regional conservation concern.  My study also suggests that beyond allowing flooding and tree fall to occur naturally, management of mature Altamaha River bottomlands for diversity in the breeding bird community may be achieved with little active management. However, single-tree or group-selection harvests may be beneficial to a few important breeding Neotropical migratory bird species.

INDEX WORDS:  breeding birds, Neotropical migratory birds, conservation, bottomland hardwood forests, habitat associations, Altamaha River, point counts, forest management

# HABITAT RELATIONSHIPS OF BREEDING BIRDS IN BOTTOMLAND HARDWOOD FORESTS OF THE ALTAMAHA RIVER, GEORGIA

by

JARED ANDREW ZIMMERMAN

B.S. Millersville University, 2004

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for the Degree

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# DEDICATION

This work is dedicated to my Pap, whose tales (sometimes tall ones) about wildlife and nature helped inspire me to become a biologist. This work is also dedicated to my wife Shea. I am immensely grateful for her unlimited and enthusiastic love and support, without which I would not have had the motivation to finish grad school. Lastly, this is dedicated to my parents Jim and Jan, who have always given me love and support in all my efforts, academic and otherwise.

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# CHAPTER I

# INTRODUCTION

Bottomland hardwood forests (hereafter, bottomlands) are predominantly deciduous forests that dominate most of the river floodplains and lowlands of the southeastern United States (Sharitz and Mitsch 1993). These forests are essential habitat for populations of many bird species. For example, bottomlands provide breeding habitat for seventy species of birds, a majority of which are Neotropical migratory bird species of high conservation concern (Pashley and Barrow 1993), and they have a greater diversity of breeding bird species than adjacent upland habitats (Harris and Gosselink 1990). Bottomlands also provide wintering grounds for migrant and resident birds (Dickson 1978) and important stopover sites and corridors for many transient bird species (Pashley and Barrow 1993, Gauthreaux and Belser 2005). Partners in Flight, an international multi-agency partnership for landbird conservation, lists several high-priority species for conservation in bottomlands of the Southeast (Hunter et al. 1993, Hunter et. al. 2001) and, therefore, also list bottomlands as a habitat of concern (Hunter et. al 1993). Furthermore, three extinct North American bird species, Ivory-billed Woodpecker (*Campephilus principalis*), Carolina Parakeet (*Conuropsis carolinensis*), and Bachman's Warbler (*Vermivora bachmanii*) were specialists of bottomlands (Askins 2000). The health of the current bird community in Southeastern bottomlands may be in jeopardy given this habitat's historic and ongoing levels of loss and degradation. The purported rediscovery of the Ivory-billed woodpecker in bottomlands of Arkansas and Florida (Fitzpatrick et al. 2005), whether confirmed or not, has brought much needed attention to this habitat, its avian community, and its conservation challenges.

A long history of human impacts on bottomlands began well before European colonization. Native Americans in the region maintained extensive agricultural fields in floodplains where stands of cane (*Arundinaria gigantea*) likely would have predominated (Hamel and Buckner 1998). When Native American populations declined sharply after 1500, agricultural fields transitioned eventually to forests. Thus, just before heavy European settlement, Southern forests (bottomlands included) were probably at their maximum extent (Hamel and Buckner 1998). In fact, it has been estimated that as much as 74 million ha (57%) of the 130 million ha of forested wetlands in the lower 48 states prior to European settlement were found in the Southeast (Harris and Gosselink 1990). Since European settlement, the amount of loss of bottomlands of the southeastern United States has been substantial, the majority of which came in a heavy period of logging and draining in the late nineteenth and early twentieth centuries (Abernethy and Turner 1987, Sharitz and Mitsch 1993). Even more remarkably, in the latter half of the twentieth century, the loss of forested wetlands (bottomlands included) may have occurred five times faster than loss of other non-wetland forest types in the United States (Abernethy and Turner 1987). For the South Atlantic states (FL, GA, SC, NC, and VA), this rate of loss amounted to just over 11,000 ha/yr from 1940 to 1980 (Abernethy and Turner 1987). Loss of bottomlands is especially pronounced in the Mississippi Alluvial Valley where only around 20% of the historic bottomlands remain (Harris and Gosselink 1990), despite a slowing of forest loss and recent push toward reforestation (Twedt and Loesch 1999).

Many factors have contributed to the loss and degradation of bottomlands. Direct habitat loss occurred primarily from clearcutting and conversion to agriculture and agroforestry (Pashley and Barrow 1993). Remaining forested habitat was fragmented and degraded by alterations in the frequency and intensity of disturbances, primarily flooding. The removal of snags from waterways to increase navigability, the near eradication of beaver, and the creation of man-made levees, dams, and channels have all altered patterns of flooding (Pashley and Barrow 1993). The decrease in the frequency of flooding has added to habitat loss by making bottomlands even more favorable for agriculture and intensive forestry operations. Recently, efforts to reclaim former agriculture or pine silviculture lands have increased, and some have succeeded (Stanturf et al. 2001). Nevertheless, the degree of fragmentation in many areas is so high that despite an overall increase in the acreage of bottomlands, the quality of these forests may be decreasing simultaneously (Pashley and Barrow 1993).

Silviculture, an anthropogenic disturbance, often plays a key role in determining the quality of bottomlands. Physical factors, the plant community, and forest structure within bottomlands can all be impacted by the particular strategy used to harvest trees. Landowners employ two broad silvicultural strategies to grow and harvest timber, even-aged and uneven-aged management (Thompson et al. 1993, Meadows and Stanturf 1997, Brawn et al. 2001). Even-aged strategies result in a stand of forest homogenous in age and structure. A common example of this strategy is clearcutting, where all the trees in a tract of forest are removed simultaneously. Other examples of even-aged silvicultural techniques are the seed tree and shelterwood methods, in which single or a few mature trees are left in order to serve as progenitor, shelter, and shade for regenerating saplings (Thompson et al. 1993). Uneven-aged strategies such as single-tree selection and group selection result in a heterogeneous stand with trees or groups of trees of varying ages (Meadows and Stanturf 1997). Over time in bottomlands, this method creates a varied forest stand similar to what Tanner (1986) found in old-growth bottomlands of northern Louisiana. However, clearcutting is favored commercially because it the easiest to implement and results in the regeneration of shade-tolerant, economically valuable tree species (Meadows and Stanturf 1997). Group selection and single-tree selection, despite creating a more natural forest age structure (Tanner 1986), are not favored by land managers because these methods are harder to use and do not yield as much saleable product as does clearcutting (Meadows and Stanturf 1997).

Like silviculture, natural disturbance can also significantly affect the physical environment, plant community, and forest structure in bottomlands (Tanner 1986, Sharitz and Mitsch 1993, Brawn et al. 2001). The primary mode of natural disturbance in bottomlands is flooding. These forests are frequently inundated when rivers and streams rise beyond their banks, usually in winter or early spring. Nutrient-rich sediment is suspended in floodwaters and eventually deposited on the forest floor (Harris and Gosselink 1990). For this reason, as well as a long growing season, primary productivity of bottomlands tends to be higher than that of adjacent habitats (Brawn et al. 2001). Flooding creates topographic features such as sloughs, backwater channels, natural levees, and oxbow lakes (Tanner 1986). Two adjacent stands of forest may differ only slightly in elevation, perhaps by only a few centimeters, but differ greatly in the duration of flooding events. The diverse species of woody plants in bottomlands differ in their ability to tolerate flooded, anaerobic soils and, therefore, are distributed along hydrologic and topographic gradients (Tanner 1986, Sharitz and Mitsch 1993).

Tree falls are another important disturbance factor in mature bottomlands of the southeastern U.S. A combination of high winds from tornadoes, hurricanes, and storms and already wet soils results in the falling of one or more trees and the creation of a gap the forest canopy (Tanner 1986). A different flora and fauna than that of the adjacent forest are often found in these gaps, increasing the patchiness and overall biodiversity of the forest. Many shade-intolerant tree species require these sunny gaps to become established and grow to maturity (Pashley and Barrow 1993). Tree fall (and to a lesser extent flooding) can bring about species, age, and structural diversity of the forest community (Tanner 1986).

These three primary modes of disturbance in bottomlands – flooding, tree fall gaps, and forestry – all create variation in the structure and composition of mature bottomland forests. Depending on its management history and frequency of disturbance, mature bottomlands forests will vary in stand size and age, species composition, tree and shrub density, basal area, ground cover, canopy cover, and patchiness. These are all components of vertical or horizontal habitat diversity to which birds are sensitive (MacArthur and MacArthur 1961, Wiens and Rotenberry 1981; James and Wamer 1982; Wakely et al. 2007; see Wiens 1989 for a complete review). Thus, flooding, tree falls and forestry are relevant to birds. The first two of these are natural processes with which birds have a long evolutionary experience. Furthermore, they occur on limited temporal and spatial scales. Forestry, however, occurs on a spatial and temporal scale that dominates landscape management decisions. It is safe to say that people have the greatest amount of control over silvicultural practices as compared to other more natural disturbances. Presently, the management of forests, on both private and public land, is often carried out in a multiple-use forestry context (Bean and Rowland 1997, Hamel et al. 2001) – that is, for natural resources and their economic benefits and recreation, in addition to preservation of critical habitat and biodiversity. Therefore, the potential impacts of specific silvicultural practices on bird communities are great.

Many studies specific to bottomlands, especially those within the heavily degraded Mississippi Alluvial Valley, have explored various impacts of silviculture (Baker and Lacki 1997, Conner and Dickson 1997, Twedt et al. 1999, Moorman and Gyunn 2001, Harrison and Kilgo 2004, Loehl et al. 2005, Twedt and Somershoe 2009, Norris et al. 2009). Many studies have also examined the effects on the bottomland forest bird community of particular aspects of habitat fragmentation such as patch size (Kilgo et al. 1998; Sallabanks et. al 2000), edge (Saracco and Collazo 1999; Sallabanks et. al 2000, Kilgo 2005), and stand or corridor width (Hodges and Kremmentz 1996) created by silvicultural practices. While these types of studies are certainly important, they may overlook an important management issue by implying that extensive, closed-canopy bottomlands are all the same from the perspective of the breeding birds. In other words, we tend to think of unfragmented, mature forest as a single management goal. However, silviculture and other disturbances can drive substantial variation in forest structure and composition even within extensive, closed canopy forests, and other studies suggest that breeding birds track this variation.

My research addresses this issue in the important and little-studied bottomlands of the Altamaha River, Georgia. Hodges and Krementz (1996) showed that Neotropical migratory birds were sensitive to the width of riparian forests fragments along the Altamaha River. Also, two bird species of conservation concern, Swainson's Warbler (*Limnothylpis swainsonii*) and the Swallow-tailed Kite (*Elanoides forficatus*), have been studied in this region. Somershoe et al. (2003) and Zimmerman (2003) showed that habitat associations of Swainson’s Warblers and Swallow-tailed Kites, respectively, were highly specific in these forests. Although the Altamaha River has had an extensive history of logging, regeneration over time has created structurally diverse but mostly contiguous tracts of closed-canopy riparian forests. Additionally, the Altamaha River has had no large-scale flood control projects. The Altamaha River, therefore, stands in contrast to areas such as the Mississippi Alluvial Valley. However, with the explosive population growth of the Atlanta area and Georgia in general, increased strain on the natural resources and wildlife of the Altamaha River are perhaps unavoidable. For these reasons, mature bottomlands of the Altamaha River offer a unique opportunity for research on land-management practices and bird communities.

The overall goal of my study was to provide data that, from a multiple-use perspective, guide management and preservation of the breeding bird community in bottomlands of the Altamaha River. My study has two objectives. First, I will quantify habitat relationships of the breeding bird community within mature bottomland forests along the Altamaha River. In particular, I will use the Altamaha’s structurally diverse forests to assess whether there is a single bird community in closed-canopy bottomlands or whether, in fact, bird community composition tracks slight habitat variation within these forests. Second, I will obtain baseline data on the density and diversity of the breeding bird community in mature bottomlands of the Altamaha River prior to potential large-scale changes in land-use.

# CHAPTER II

# STUDY AREA

The Altamaha River forms at the confluence of the Oconee and Ocmulgee rivers near Lumber City, Georgia (31.96$^o$N, 82.96$^o$W). The Altamaha River then flows southeast for 219 kilometers and empties into the Atlantic Ocean near Darien, Georgia (31.31728$^o$N, 81.30844$^o$W). The Altamaha River is not channelized or dammed along its entire length, and its nearly 37,000 km$^2$ drainage represents approximately one fourth of Georgia's land area. This makes it the third largest river by volume in the United States to empty into the Atlantic Ocean. The lower Altamaha River watershed presently has a relatively low human population density. However, in the upper reaches of its tributaries near suburban Atlanta, Georgia, population density is much greater.

The Altamaha River is flanked by extensive bottomlands (Figure 1), also called Southern floodplain forests (Kuchler 1964, Type 113). I use the general term "bottomlands" to refer to difficult-to-distinguish mix of three forested wetland communities – bottomland hardwood forests, floodplain forests, and floodplain swamps (Florida Natural Areas Inventory, 1990). The existence and makeup of these specific community types is largely contingent upon hydrology. Floodplain swamps may be inundated with deep water nearly year-round, whereas floodplain forests are flooded for weeks or months annually. Bottomland hardwood forests are at slightly higher elevations and flood infrequently (not annually). The hydrological regime of the Altamaha River dictates local topography, soil composition, and availability of nutrients. This in turn influences plant community composition and diversity in bottomland hardwood forests (Sharitz and Mitsch, 1993). Oak (*Quercus* spp.), sweet gum (*Liquidambar styraciflua*), ash

(*Fraxinus* spp.), baldcypress (*Taxodium distichum*), and gums (*Nyssa* spp.) are trees typical of the canopy throughout the study area. Where mid- and understory layers are present, typical species include hawthorn (*Crataegus* spp.), American hornbeam (*Carpinus caroliniana*), red maple (*Acer rubrum*), palmetto (*Serenoa repens*), river birch (*Betula nigra*), green briar (*Smilax* spp.), blackberry (*Rubus* spp.), and cane (*Arundinaria gigantea*) (Somershoe et al. 2003).

A 65-kilometer-long corridor of bottomland hardwood forest along the Altamaha River served as my study area. I conducted fieldwork within approximately 3 kilometers of the Altamaha River in Georgia's Appling, Tattnall, and Jeff Davis Counties (Fig. 2). Big Hammock Wildlife Management Area, Bullard Creek Wildlife Management Area, and Moody Forest Natural Area were my three specific study sites. Big Hammock and Bullard Creek are both managed by the Georgia Department of Natural Resources' Division of Wildlife, and Moody Forest is owned and managed by The Nature Conservancy.

Big Hammock is a 2810-ha preserve along the north bank of the Altamaha River near Glennville, Tatnall County, Georgia (31.85°N, 82.06°W). It is composed almost entirely of bottomland hardwood forest and is relatively uniform in topography. The floodplain on this section of the river is relatively wide. Flooding in Big Hammock is semi-permanent to permanent, creating many sloughs, oxbow lakes, and cypress/gum swamps. Much of Big Hammock has little mid- or understory plant species.

Bullard Creek is a 5625-ha preserve in Jeff Davis and Appling Counties located approximately 8 km north of Hazelhurst, Georgia (31.95°N, 82.48°W). Bullard Creek is located on a bluff on the south side of the Alatmaha River. Bottomlands are less dominant at this site and much of the upland habitat at Bullard Creek is planted slash pine (*Pinus elliotti*), with infrequent natural sandhill habitat. The bottomland forest that is found there is more varied in topography and terraced than at Big Hammock. Flooding events are shorter in duration and the forest is composed of various bottomland hardwood species with scattered gum and cypress. Palmetto and cane are common understory species at Bullard Creek.

Moody Forest, located on the south bank of the Altamaha, is an 1820-ha preserve in Appling County approximately 8 km north of Baxley, Georgia (31.93°N, 82.27°W). This preserve retains intact an entire suite of common southeastern Georgia habitats, including mature longleaf pine/wiregrass uplands, mesic flatwoods, bottomlands, as well as gum/cypress swamps. Additionally, The Nature Conservancy is actively restoring all of the pine uplands at the preserve. Flooding and forest composition at Moody Forest are intermediate between Big Hammock and Bullard Creek. However, bottomlands at Moody are more mature overall than at Big Hammock or Bullard Creek.

From January through April (2007), I visited each of these sites to establish point-count stations (hereafter, stations) based on several criteria. I qualitatively chose stations along a continuum of mature forest characteristics such as forest age, stand density, canopy coverage, and ground and shrub coverage. Stations were chosen in relatively uniform forest stands at least 100 m from any abrupt changes in landscape such as roads, water, or other forest types. Stations were at least 200 m from any other station. I established a total of 61 stations. Most stations were located at Big Hammock and Bullard Creek (35 and 20, respectively); six stations were located at Moody Forest. I did not establish more stations at Moody Forest because access to some otherwise suitable areas was too difficult or was time prohibitive.

# METHODS

*Point Counts*. – In 2007, I performed point-counts for breeding birds from May 2 to June 18. In 2008, I performed point counts from May 2 to June 14. Three point counts were performed at each station in each of the two years of the study. Each round of point counts took approximately 15-20 days. I used 10-minute point-counts with distance sampling to measure bird abundance (Reynolds et al. 1980, Ralph et al. 1993, Bibby et al. 2000, Buckland et al. 2001). I performed point counts from just after sunrise around 0600 EDT until no later than 1000 EDT or until the point at which bird vocalizations noticeably diminished. I rotated the time at which point counts were performed at each station to reduce among-station bias due to time of day. I did not perform point counts in rain or in wind greater than approximately 12 km/hr in order to minimize weather-related bias. Prior to point counts in 2007 and 2008, I performed several practice point counts to ensure my accuracy in bird identification and distance estimation. All birds seen and heard within 150 meters of the station were recorded. The radial distance between me and each bird detected (by sight or sound) was recorded in four distance categories, 0–25 m, 25–50 m, 50–100 m, and 100–150m.

Because the focus of this study was on breeding birds only, I excluded three groups of species from analysis: non-breeding migrants, flyovers, and wide-ranging species. Several species of birds were recorded only in the first few days of each season and had no prior record of breeding in the region (Schnieder et al. 2010). These species were considered to be "non-breeding migrants," passing through the station to breeding ranges farther north (Scarlet Tanager, Blackpoll Warbler, etc.; Appendix A). Detections of birds merely flying over the station above the canopy, and unlikely to be occupying the habitat in the survey area were recorded as "flyovers" (such as Chimney Swift [*Chaetura pelagica*], Great Egret [*Ardea alba*], etc.;

Appendix A). Several species of birds were considered to be “wide-ranging species” (such as Red-shouldered Hawk [*Buteo lineatus*], American Crow [*Corvis brachyrhynchos*], Wood Stork [*Mycteria Americana*], etc.; Appendix A). These species either were not territorial or had territories that extended far beyond the station. Although flyovers and wide-ranging species may breed within the study area, these detections could not be correlated with use of the habitat at a given station.

*Vegetation sampling.* – I quantified the habitat once at each station in 2007. I measured basal area, tree frequency and species composition, shrub density, percent canopy coverage, and percent herbaceous ground cover. With the exception of basal area, I sampled these variables within 0.04-ha (11.3-m diameter) circle-plots (James and Shugart 1970). I measured basal area with 2 or 4-factor metric timber-cruising prisms. Trees that were counted with the cruising prisms were identified to species and measured (diameter at breast height, dbh) in order to determine species contributions to the total basal area of the station. I estimated percent canopy cover with a spherical densitometer, a convex mirrored surface that is divided into 96 squares. The percent canopy cover is equal to the total number of squares with canopy present divided by 96. Percent canopy cover was measured at four locations at cardinal directions and 11.3 m from the center of the station (Figure 3). Percent ground cover was measured by sighting through an ocular tube at 20 points along two transects oriented in the cardinal directions (Figure 2). Herbaceous ground cover was recorded as either present or absent at each of the 20 points. I defined shrubs as stems less than 3 cm in diameter (James and Shugart 1970). Shrub density was determined by counting the number of stems encountered with outstretched arms while walking the two transects and then dividing the number of shrubs by the area occupied by the transects (Figure 3).

*Statistical Analysis.* – Shapiro-Wilk W-tests, which are sensitive to even the smallest departures from normality, showed that basal area and DBH CV did not fit normal distributions. However, these variables did have unimodal distributions that approached normality and were therefore not transformed. Inspection of the residuals, normal quantile plots and Shapiro-Wilk W-tests results of tree density, percent ground cover, and shrub density revealed that these variables had distributions that may violate test assumptions. Therefore, tree density was log-transformed and shrub density and percent canopy cover were transformed into categorical variables. For shrub density, raw shrub count data were placed into three categories, zero (0 shrubs), low (1 to 15 shrubs), and high (≥16 shrubs). Percent ground cover was also assigned to three categories, zero (0%), low (5 – 25%) and high (≥30%).

I used Program DISTANCE 5.0 (Release 2) to estimate detectibility and density of breeding birds (Thomas et al. 2010). This program fits several detection models (uniform, half-normal, and hazard rate,) to point count data to calculate a detection probability function and density (Buckland et al. 2001). I used the Conventional Distance Sampling analysis engine to compare the uniform and half-normal detection models. The hazard rate model is only available in the Multiple Covariate Distance Sampling analysis engine. A minimum 60 detections is required to calculate detectibility and density for point-counts (Buckland et al. 2001). Therefore, I did not have enough detections to fit a separate detection probability function for each species at each station. Instead, I calculated an overall detection probability function for each species that had at least 60 detections pooled across both study years and all stations. I then used these species-specific detection probability functions to calculate density of each species at each station (post-stratification, Buckland et al. 2001). Where <5% of the detections of a species occurred in the outer annuli, I truncated those detections to obtain better model fit (Buckland et al. 2001). The most parsimonious model for the detection function was chosen by selecting the model with the lowest Akaike's Information Criterion (AIC; Burnham and Anderson 2004).

I calculated Breeding Bird Density (BBD) by adding together all species-specific densities at each station. I calculated Neotropical Migratory Bird (NT) density similarly, except I used densities of NT species only (Hamel 1992). Neotropical Migratory Bird species are species that breed in the United States and migrate to wintering grounds south of the United States (Hamel 1992). I also used species-specific densities to calculate Avian Conservation Scores (ACS) for each station (Twedt 2005). ACS are an open-ended measure of the overall conservation value of a site based upon Partners In Flight (PIF) regional conservation concern scores (Bird Conservation Region 027, Panjabi et al. 2005) and densities of the species that breed there.

I used linear regressions to examine time-of-day and within-years (date) relationships with basic breeding bird data such as number of detections and number of species. I used paired-t-tests to compare among years the number of detected species, total detections at each station, and number of detections for each species. I used linear regressions to examine the relationships between mean time-of-day and mean date and BBD, NT density, and ACS. Analysis of variance (ANOVA) and *a-posteriori* Tukey-Kramer tests were used to test for differences in BBD, NT densities, and ACS among my three study sites, Bullard Creek, Big Hammock, and MF. I used linear regressions to examine bivariate relationships between BBD, NT densities, and ACS and each of four continuous habitat variables. I used ANOVA and *a-posteriori* Tukey-Kramer HSD tests to look for added variation in BBD, NT density, and ACS due to categorical habitat variables. I used multiple regressions to model multivariate relationships of BBD, NT density, and ACS and six habitat variables. Continuous habitat variables included basal area, log tree density, percent canopy cover, and DBH CV and categorical variables included shrub density and percent ground cover. I also included mean time of day of point counts and mean date of point counts in the models in order to account for as much variation as possible.

I used logistic regression analyses to examine species-specific relationships with habitat variables. I chose 10 Neotropical species because of specific conservation concern in this group (Hamel 1992, Hunter et al. 2001): Ruby-throated Hummingbird (*Archilochus colubris*), Wood Thrush (*Hylocichla mustelina*), , White-eyed Vireo (*Vireo griseus*), Yellow-throated Vireo (*Vireo flavifrons*), Yellow-throated Warbler (*Dendroica dominica*), Prothonotary Warbler (*Protonitoria citrea*), Swainson's Warbler (*Limnothlypis swainsonii*), Kentucky Warbler (*Oporonis formosus*), Hooded Warbler (*Wilsonia citrina*), and Summer Tanager (*Piranga rubra*). Each logistic regression model included the same six untransformed habitat variables as well as mean time of day of point counts and mean date of point counts. Log-likelihood tests were used to determine which variables were effective in modeling the presence or absence of a given species. The odds ratios were then used to assess and compare the importance of individual variables in each species model. All analyses were performed using SAS JMP 8.0 statistical software (SAS Institute, Inc 2008) using a statistical significance level (alpha error rate) of $P = 0.05$ (Sokal and Rohlf 1995). All means are reported ±1 standard error (±1SE) and all regression coefficients (b) are partial standardized coefficients.

# CHAPTER III

# RESULTS

## Point Counts

In the spring of 2007 and 2008, I conducted 346 point counts at 61 stations where I detected 6639 birds of 61 species (common and scientific names of each detected species can be found in Appendix A). Flyovers, migrants, and wide-ranging species accounted for 442 detections (of 28 species, Appendix A) and were not used in the analyses. Seventeen point counts from six stations were excluded from analysis because they were clearcut between 2007 and 2008. One station (six point counts) was surveyed in poor weather conditions and was also considerably different in habitat conditions than were other stations. This station was identified as an outlier and was not included in analyses. Therefore, I detected 5842 individuals of 33 breeding bird species on 323 point counts (54 stations; Table 1). The six most commonly detected species were Red-eyed Vireo, Acadian Flycatcher, Carolina Wren, Northern Parula, Northern Cardinal, and Tufted Titmouse. These six species accounted for over half (55.6%) of all detections. Blue-gray Gnatcatcher, Northern Cardinal, and Tufted Titmouse were detected at all 54 stations and six other species were detected at greater than 90 % of stations. I detected 19 species of breeding Neotropical migratory birds (NT; Table 1). Detection of these species made up 62% of the total detections. I detected 14 - 24 bird species at each station over the two years of the study, with an average of 19.00 ± 0.28 (N=54) bird species per point count. I detected from 8 - 27 individual birds and averaged of 18.09 ± 0.19 individual birds per point count.

## Breeding Bird Density, NT density, and Avian Conservation Scores

Detections were sufficient to allow calculation of density and Avian Conservation Scores (ACS) for 20 species of breeding birds, 10 of which were Neotropical migratory birds (Table 1). The average density of these 20 species among all stations was 0.70 ± 0.22 birds ha$^{-1}$ and ranged from 0.07 - 4.15 birds ha$^{-1}$. Blue-gray Gnatcatcher (4.15 birds ha$^{-1}$), Acadian Flycatcher (1.28 birds ha$^{-1}$), and Red-eyed Vireo (1.29 birds ha$^{-1}$) had the greatest average densities among these species. Species-specific densities, effective detection radius estimates, and detectibility estimates can be found in Appendices B, C, and D, respectively.

The density and ACS values above were based on the 20 species (10 NT) for which I was able to calculate detection probability and density empirically. However, I was also able to quantify community-level habitat relationships of all 33 breeding species by estimating detection probabilities for the remaining 13 species. I used the highest reported detectibility estimates for any of the 13 species found in Twedt and Somershoe (2009). For detectibility estimates of species not found in Twedt and Somershoe (2009), I set the detectibility value conservatively at 0.5. I used estimated values based on all 33 to further examine community-level habitat relationships. I did not use these estimated values to examine site variation, temporal variation, or species-specific relationships.

Breeding bird density (BBD) calculated for 20 species ranged from 10.28 - 18.46 birds ha$^{-1}$ with a mean density of 13.99 ± 0.24 birds ha$^{-1}$ (Table 2). ACS values ranged from 353.92 - 490.40 with a mean ACS of 415.8 ± 4.82 (Table 2). Mean density of NT species was 10.49 ± 0.24 birds ha$^{-1}$ with values ranging from 6.98 - 14.88 birds ha$^{-1}$ (Table 2).

Community-wide values using all 33 species were similar to values using 20 species (Table 2). Mean BBD was 14.19 birds ha$^{-1}$ and ranged from 10.39 - 18.46 birds ha$^{-1}$ (Table 2). Mean NT density was 10.66 birds ha$^{-1}$ and ranged from 7.09 - 15.46 birds ha$^{-1}$ (Table 2). Mean ACS was 448.10 and ranged from 370.56 - 566.35 (Table 2).

## Site Variation

ACS values differed among the three study sites (ANOVA; $F_{2,53}$=7.10, P<0.01) but BBD and NT density did not (Fig. 4, BBD: ANOVA, $F_{2,53}$=1.98, P=0.15; NT density: ANOVA, $F_{2,53}$=2.29, P=0.11). Mean ACS values were greater at Moody Forest (454.5) than at Big Hammock (Fig. 4, 402.5; Tukey-Kramer HSD, P<0.01) but did not differ between Moody Forest and Bullard Creek (Fig. 4; Tukey-Kramer HSD, P=0.09). ACS values were similar between Bullard Creek and Big Hammock (Fig. 4; Tukey-Kramer HSD, P=0.08).

## Temporal Variation

*Time of Day*. – The number of individual birds detected (b= -0.31, $R^2$=0.10, $F_{1,322}$=1.46, P=0.01) and the number of species detected (b= -0.18, $R^2$=0.03., $F_{1,322}$= 10.20, P<0.01) were fewer in point counts later in the morning (Fig. 5). This relationship was also found when I correlated the mean time of day of point counts at each station with BBD (Fig. 6; b= -0.33, $R^2$=0.11, $F_{1,53}$=6.22, P=0.02). NT density and ACS of stations, however, were unrelated to mean time of day (NT: b= -0.24, $R^2$=0.06, $F_{1,53}$=3.11, P=0.08; ACS: b= -0.23, $R^2$=0.053, $F_{1,53}$=2.96, P=0.09).

*Within Years.* – The number of species detected (b=0.01, $R^2$=0.01, $F_{1,322}$=3.25, P=0.07) and the number of birds detected (b=0.01, $R^2$<0.01, $F_{1,322}$=0.44, P=0.51) were both unrelated to point count date. BBD (b=0.20, $R^2$=0.04, $F_{1,53}$=2.14, P=0.15), NT density (b=0.16, $R^2$=0.03, $F_{1,53}$=1.38, P=0.25) and ACS (b=1.07, $R^2$<0.01, $F_{1,53}$=0.15, P=0.70) were unrelated to the mean point count date for each station.

*Among Years.* – The number of bird species and the number of individual birds per station did not differ significantly between years (number of individual birds: paired t-test, t = 2.00, P = 0.47, df=53; number of bird species: paired t-test, t=2.00, P=0.71, df=53). Similarly, the number of detections of each species (Table 1) did not differ between years (paired t-test; t=2.04, P=0.82, df=32).

## Habitat Assessment

A total of 442 individual trees of 27 species and 13 genera was recorded in this study (Table 3). Oaks (*Quercus* species) of eight species made up 33.7% of the total recorded trees. Laurel oak (*Q. laurifolia*), willow oak (*Q. phellos*) and water oak (*Q. nigra*) were three commonly recorded oak species. Sweetgum (*Liquidambar styraciflua*), was the most frequently recorded tree (19.5%) by species and the second most common by genus. Other commonly recorded trees were gum species (*Nyssa* spp., 15.0%) and baldcypress (*Taxodium distichum*, 7.0%). Data were collected for two individual trees that were not identified (Unknown 1 and 2; Table 4).

The average basal area at each station was 29.22 ± 1.36 $\text{meters}^2\ \text{ha}^{-1}$ and ranged from 10 - 64 $\text{meters}^2\ \text{hectare}^{-1}$ (Table 4,). The coefficient of variation of DBH (DBH CV) was used as a measure of variability in tree size and thus the evenness of stand age. DBH

CV values ranged from 23.84 - 116.26 with a mean of 59.90 ± 2.84 (Table 4, N=54). As expected in mature, closed canopy forests, percent canopy cover ranged from 88.02% - 96.1% with a mean of 92.83 ± 0.27 % (Table 4). Mean tree density was 337.6 ± 32.56 trees $ha^{-1}$ and ranged from 48.4 - 1013.5 trees $ha^{-1}$ (Table 4, N=54). Shrub density ranged from 0 - 8238 shrubs $ha^{-1}$ and had a mean of 1127.21 ± 212.41 shrubs $ha^{-1}$ (Table 4, N=54). Percent ground cover ranged from 0% - 95% with a mean of 25.56 ± 3.34 % (Table 4, N=54). For categories of zero, low, and high percent ground cover there were 13, 18, and 23 of 54 stations, respectively. Shrub density categories zero, low, and high had 12, 32, and 10 of the 54 stations, respectively.

## Habitat Effects

*Community-wide patterns.* –The breeding bird community responded weakly to habitat variation. BBD and NT density were unaffected by basal area, log tree density, percent canopy cover, and DBH CV (Table 5). BBD, NT density, and ACS were also unaffected by shrub density and ground cover (Table 5). However, ACS values were higher at stations with more variable tree diameters (DBH CV, Table 5, b=0.29, $R^2$=0.08, $F_{1,53}$=4.69, P=0.04).

In the multiple regression models of habitat, BBD increased as tree density (Table 6, b= -0.33, P=0.01) and canopy cover decreased (Table 6, b= -0.25, P=0.051). NT density decreased as log tree density increased as well (Table 7, b= -0.35, P=0.02). NT density also increased as variability in tree diameter decreased (Table 7, b= -0.30, P=0.03). However, variation in ACS could not be modeled effectively with the eight variables (Table 8, $R^2$=0.22, $F_{10, 53}$=1.23, P=0.29).

Community-level habitat relationships for all 33 breeding species, with few exceptions, mirrored relationships from those calculated from 20 species. BBD and NT density remained unrelated to all six individual habitat variables (Table 5). However, ACS values for 33 species decreased with more canopy cover (Table 5, b= -0.39, $R^2$=0.15, $F_{1,53}$=9.48, p<0.01) and were lower where shrub cover was absent (417.8) compared to where it was present (Table 5, low = 454.0; high = 465.6; Tukey Kramer HSD: absent vs. low, P=0.03; absent vs. high: P=0.04).

Multivariate habitat relationships calculated for 33 species were similar to habitat relationships calculated from 20 species as well. BBD increased as tree density (Table 6, b= -0.37, P=0.01) and canopy cover decreased (Table 6, b= -0.29, P=0.03). NT density for 19 species increased with decreasing log tree density just as did for 10 species (Table 7, b= -0.37, P=0.01). NT density for 19 species was also lower where variability in tree diameter was high (Table 7, b= -0.31, P=0.03). ACS values calculated from all 33 species decreased with increasing canopy cover (Table 8, b= -0.33, P=0.02) but were unrelated to all other habitat variables (Table 8).

*Species-specific patterns.* – Although breeding bird community patterns were not strongly related to habitat, I was able to detect habitat patterns at the species level for five of the ten species for which analyses were performed (Table 9): White-eyed Vireo, Yellow-throated Vireo, Prothonotary Warbler, Kentucky Warbler, and Hooded Warbler. Models for Ruby-throated Hummingbird, Wood Thrush, Yellow-throated Warbler, Swainson’s Warbler, and Summer Tanager failed to explain a significant amount of variation in presence/absence of those species (Table 10).

Basal area and percent canopy cover were important habitat variables for modeling Yellow-throated Vireo presence/absence (Table 9). For each 1% increase in canopy cover, Yellow-throated Vireos were approximately half as likely to be present (0.49 odds ratio). The likelihood of Yellow-throated Vireo presence decreased slightly (0.89 odds ratio) for each $1m^2ha^{-1}$ increase in basal area. Canopy cover was the only important habitat variable in the presence/absence models for both Hooded Warbler and White-eyed Vireo (Table 9). Hooded Warblers were less than half (0.45 odds ratio) as likely to be present for each 1% increase in canopy cover. White eyed Vireos, however, were more than eight times (8.6 odds ratio) more likely to be present with each 1% increase in canopy cover. Shrub density and DBH CV were important factors in modeling presence/absence of Kentucky Warbler (Table 9). For every 1% increase in DBH CV, Kentucky Warblers were around 20% less likely to be present (0.81 odds ratio). The effect of shrub density on Kentucky Warbler presence was minimal (1.001 odds ratio). DBH CV was an important habitat factor in modeling presence/absence of Prothonotary Warbler (Table 9), although the actual effect of this variable was slight (1.08 odds ratio).

# CHAPTER IV

# DISCUSSION

Mature bottomland hardwood forests of the Altamaha River support a diverse assemblage of breeding birds. At least 33 bird species were confirmed breeders in these forests, and an additional 30 species used bottomlands as migration stopovers, foraging habitat, or nesting and roosting sites. That 22 of the 33 breeding species were Neotropical migratory bird species underscores the significance of Altamaha River bottomlands for avian conservation. Whether based on the sample of 20 or 33 breeding species, approximately 80% of the breeding bird density is made up of Neotropical species.

If one of the goals of regional forest management in the southeast is to maintain bird diversity, my results clearly demonstrate that the closed-canopy bottomlands of the Altamaha can make an important contribution to this goal. However, the forest itself is far from uniform. Mature bottomland sites varied in their silvicultural histories and in the degree of natural disturbances such as flooding and tree fall. These forces resulted in bottomlands that varied substantially in species composition and several structural variables: basal area (10 - 64 $m^2$ $ha^{-1}$), tree density (48-1013 trees $ha^{-1}$), variability in tree diameter (DBH CV, 24 – 116 %), shrub density (0 -8328 shrubs $ha^{-1}$), ground cover (0 – 95%), and to a lesser extent canopy cover (88 – 96 %). However, despite this range of habitats within mature bottomlands, diversity of breeding birds at the community level was not strongly related to habitat variation.

## Community-Level Habitat Relationships

The breeding bird community that I quantified in bottomlands of the Altamaha River was consistent with other studies along the Altamaha (Hodges and Kremmentz 1996) and, more generally, in the southeastern U.S (Buffington et al. 1997, Heltzel and Leberg 2006, Wakely et al. 2007, Norris et al. 2009, Twedt and Somershoe 2009). Hodges and Kremmentz (1996) detected 48 total breeding as well as migratory species in bottomlands along the Altamaha River, 19 (39%) of which were NT species. Of the 33 species that I confirmed to be breeding in Altamaha bottomlands, 19 (58 %) were NT species. If I were to include in that value several probable but un-confirmed breeding species, the percentage of NT species would probably remain within the typical range for Southeastern bottomlands of 48 to 65% (Pashley and Barrow 1993). The diversity of NT species is important because many of these species are of regional conservation concern (Hunter et al. 2001, Panjabi et al. 2005). I regularly detected three NT species that Partners in Flight lists as priority species for the South Atlantic Coastal Plain (Physiographic Region 3, Hunter et al. 2001): Swainson's Warbler, Yellow-throated Warbler, and Prothonotary Warbler. Additionally, 19 of the 33 (58%) breeding species that I detected have PIF regional conservation concern scores ≥14. PIF recommends that these species should receive additional planning and management attention in order to increase or stabilize their regional populations (Punjabi et al. 2005). The diversity of the breeding avifauna in Altamaha River bottomlands is perhaps even more notable when compared to other habitats regionally. Mature bottomlands have higher diversity and density of breeding birds than do pine uplands (Dickson 1978) and have greater conservation value than early-successional bottomlands (Norris et al. 2009).

The Altamaha River is clearly important for conservation of breeding birds. However, a long history of human use, predominately forestry, along with natural forces such as flooding and tree fall, has created substantial variation in the structure of mature bottomlands. Thus, we expect bird communities to vary because countless studies have shown that birds track variation in habitat (e.g. Cody 1985, Wiens 1989). Specifically, classic studies have shown that bird communities can vary in relation to vertical habitat heterogeneity factors such as foliage height, foliage volume, and leaf surface area (MacArthur and MacArthur 1961, MacArthur 1964). Bird communities can also be arranged according to horizontal habitat heterogeneity or patchiness (MacArthur and MacArthur 1964, Rotenberry and Wiens 1981). Species composition of vegetation, both vertically and horizontally, can also be important in bird community composition (Rotenberry and Wiens 1981, Rotenberry 1985). Some recent bird community studies have occurred within Southern bottomlands in particular and have examined habitat associations as they relate to forestry practices. Specifically, these studies have shown that breeding bird communities are usually sensitive to habitat conditions that result from different levels of intensity of silvicultural activities (e.g. Heltzel and Leberg 2006, Norris et al. 2009, Twedt and Somershoe 2009). My results, however, suggest that within mature Altamaha River bottomlands, habitat effects on the overall breeding bird community were small.

BBD and NT density increased with decreases in tree density and perhaps canopy cover, although the canopy was essentially closed among sites (Tables 6 and 7).

Relatively dense stands may be slightly younger and more uniform in age. Therefore, there could be less room for developed shrub or ground-cover layers, making those stands less structurally diverse. Completely closed canopies limit light penetration and therefore reduce the likelihood that other forest layers will be present or well developed. Complete closure of the canopy could also limit access or movement for species that forage or nest within the upper canopy. For these reasons, high tree density and closure of the canopy could prohibit many priority shrub or ground cover-dependent species. This could explain why ACS values were highest at low percent canopy cover values and where shrubs were present (Tables 4 and 5). DBH CV was also an important variable in both BBD and ACS values. However, these were weak relationships (e.g. ACS was only ~5% smaller in high canopy-closure sites) and, ultimately, there was little overall variation in ACS, BBD, and NT density within mature Altamaha River bottomlands.

There are at least four factors that could contribute to a lack of strong bird-habitat relationships at the community level in mature Altamaha River bottomlands. First, equal turnover of species along habitat gradients could explain a lack of strong habitat effects. Moving along a given habitat gradient could increase the habitat suitability for one breeding species, while simultaneously decreasing the habitat suitability for another. In this scenario, there is little or no net gain in diversity or density. However, conservation value of a site may vary depending upon the species present. This may explain why shrub density, for instance, had no effect on breeding bird density or NT density, yet clearly affected the conservation value of the site.

Second, it is possible that habitat variation within mature Altamaha River bottomlands could be unrelated to density and diversity yet strongly related to productivity of the bird community instead. A species could occupy in equal abundance all sites along a given habitat gradient. Outwardly, it would appear that the habitat variable has no effect on that species. However, that particular species could differ in its survival or its reproductive output along that habitat gradient (Van Horne 1983). This highlights the importance of confirming results of habitat association studies such as mine with studies that, despite being time intensive and costly, specifically examine survival and reproductive output.

Third, diversity in tree species composition of mature bottomlands could explain a lack of strong relationship between breeding birds and structural habitat variation (Rotenberry 1985). It is possible that much of the information about tree species composition is also contained within habitat structure variables because they are both shaped by the same forces (e.g. flooding, tree fall, and silviculture). However, perhaps as bottomlands mature beyond a certain threshold, tree species composition and habitat structure become increasingly unrelated, and the breeding bird community begins to respond more strongly to the former than to the latter. That many bird species preferentially select certain tree species within bottomlands for foraging could help to explain this (Gabbe et al. 2002).

Finally, it may be the case that, despite considerable variation in some measured habitat variables within mature bottomlands, there could be additional and independent habitat features to which the bird community actually responds. For instance, the breeding bird community may in reality be responding to variables such as leaf arrangement, foliage height diversity or volume, insect abundance, or other habitat features. Such key features could be constant across ranges of variation in measured habitat variables such as tree density, basal area, or species composition. Therefore, the bird community would appear similarly unrelated to variation in measured habitat variables.

## Species-Specific Habitat Relationships

Despite a lack of strong habitat relationships at the community-level, my results indicate that individual species do respond to habitat variation in mature bottomlands. I was unable to detect significant habitat variables for five species within mature bottomlands: Ruby-Throated Hummingbird, Wood Thrush, Yellow-throated Warbler, Swainson's Warbler, and Summer Tanager (Table 10). Studies from Louisiana bottomlands were also unable to show strong habitat relationships for a few of these species across larger ranges in habitat variation (Norris et al. 2009, Twedt and Somershoe 2009). This was not surprising given that some of these species, such as Summer Tanager and Ruby-throated Hummingbird, may breed in a variety of habitats. Contrary to my results, however, Swainson's Warblers have been shown to be highly specific in selecting breeding habitat (Graves 2002, Somershoe et al. 2003). For instance, Somershoe et al. (2003) found that Swainson's Warblers specifically select Altamaha River bottomland sites with high cane densities, small stem densities, substantial herbaceous ground cover, and abundant leaf litter. The inability to model habitat preferences for Swainson's Warbler in my study is significant because this species has one of the highest PIF conservation concern scores in the region. The lack of habitat preferences could have resulted from failure to quantify habitat variables that were relevant for Swainson's Warbler. For instance, I did not quantify leaf litter, and I did not specifically quantify cane density, even though I considered cane to be a shrub. I also noticed that many of the Swainson's Warbler territories that I found were located at edges of roads or the ecotone between bottomland and upland habitats. I avoided these areas when establishing point-count stations because habitat at edges is typically different from the forest interior. Where Swainson's Warblers were detected, they tended not to be near the center of the point-count stations where most habitat variables were measured.

I was able to detect habitat variables within mature bottomlands that were important for White-eyed Vireo, Yellow-throated Vireo, Prothonotary Warbler, Kentucky Warbler, and Hooded Warbler (Table 9). Yellow-throated Vireo favored stations that had a canopy that was not completely closed and had lower basal area (Table 9). This was not surprising given that this species is known for breeding in the subcanopy of relatively open, edge-like forest habitats (Rodewald and Ross 1996).

Unexpectedly, White-eyed Vireo showed a strong preference for higher canopy cover (Table 9). It would appear that my findings were inconsistent with this species' avoidance of large trees and a closed canopy (Hopp et al. 1995). This species is more abundant in earlier successional stages (Heltzel and Leberg 2006, Twedt and Somershoe 2009), but my results and those of Norris et al. (2009) show that it occupies mature bottomlands as well. However, this unexpected canopy cover relationship could have resulted because stands with both mature canopy trees and a developed midstory canopy would be both attractive to this species and have high canopy closure.

Unlike White-eyed Vireo, Hooded Warbler preferred a more open canopy. Gaps in the canopy should in theory result in more developed shrub layer required by this species for nesting. My results are therefore in support of commonly identified habitats for this species: early to mid-successional forests and small canopy gaps within mature forests (Ogden and Stutchbury 1994).

Kentucky Warbler, a ground-nesting species (McDonald 1998), avoided variability in tree diameter and preferred, albeit weakly, stations with higher shrub density (Table 9). The positive association with shrub density is perhaps unsurprising because it’s possible that areas with developed shrub layers could also have sufficient ground cover for this species. This species has been shown to reach greater densities in single-tree and group selection harvested areas (Heltzel and Leberg 2006, Norris et al. 2009, Twedt and Somershoe 2009) and these areas likely have greater diversity in tree age classes. For this reason, the result that Kentucky Warbler was negatively and not positively associated with DBH CV is puzzling.

It is curious that the presence of two shrub-nesting species, White-eyed Vireo and Hooded Warbler was not related to shrub density. Similarly, that the ground-nesting Kentucky Warbler, was not strongly associated with ground cover is unexpected. As in the case of Swainson’s Warbler, these species were less likely to be found in the center of stations, and as a result could have been occupying slightly different habitat than what was available in the center of the station. Lastly, the lack of strong habitat associations by Prothonotary Warbler could have occurred because I did not measure variables relevant for that species such as the presence of snags or water (Petit 1999).

## Management Implications

My study has three clear management implications. First, mature bottomlands of the Altamaha River contribute to the conservation of diverse breeding bird communities in the southeast.  If one goal of forest management is to maintain high bird diversity - and this is an important goal given the ecological and economic importance of birds (Clout and Hay 1989, Kerlinger and Wiedner 1990, Sekercioglu 2006) - then preserving bottomland forest on the Altamaha is highly desirable.  Conversion of Altamaha River bottomlands for other land uses, such as agriculture, urban development, or intensive silviculture would diminish the conservation value of these forests to protect breeding birds and biodiversity in general.  Therefore, land managers should strive to protect tracks of mature Altamaha River bottomlands that are as large, contiguous, and diverse as possible.

Second, my results suggest that the breeding bird community in Altamaha River bottomlands is not sensitive to habitat variation within mature forest stands.  In other words, habitat variation within closed-canopy bottomlands was largely irrelevant to the goal of managing for a diverse bird community.  This may come as good news to land managers because they would have the luxury of managing “loosely” for diversity instead of managing for several different targets.  Bottomlands, like many habitats, are mediated largely by disturbance, flooding and tree fall in this case (Brawn et al.  2001). Therefore, managers of mature bottomlands may need only to ensure that these processes continue to occur naturally in order to maintain a diverse assemblage of breeding birds.

Finally, individual species within mature Altamaha River bottomlands can be sensitive to habitat variation.  If managers want to manage for species instead of communities, they can, but, only by attending to finer-scale details of forest structure.  Moreover, managing in order to balance habitat requirements for individual breeding species, the majority of which are of conservation concern, may be cumbersome.  For example, I found that White-eyed vireos preferred higher canopy coverage while Hooded Warblers avoided it. Despite this, my results suggest that if land managers choose to harvest timber, single-tree selection or small group-selection harvests may be appropriate or even beneficial to some high-priority species. For instance, Somershoe and Twedt (2009) found that in Louisiana bottomlands, selectively harvested sites had greater Avian Conservation Scores than did unharvested control sites. Selective harvests create habitat similar to natural tree fall gaps, which appear from my results to be important to several high priority bird species in mature bottomlands. Low-intensity harvests such as these may still retain priority species – Prothonotary Warbler and Yellow-throated Vireo – that showed preferences for forest-interior habitat features (Moorman and Guynn 2001, Norris et al. 2009). However, for species such as Swainson's Warbler, Kentucky Warbler, and Hooded Warbler, benefits from such harvests will occur but may not be seen for many post-harvest (Twedt and Somershoe 2009). Additionally, single-tree or group-selection harvests in mature bottomlands that were historically clearcut would introduce diversity in forest age, a factor that may also be important to some breeding bird species.

Beyond single-tree or group-selection harvests, I do not recommend more intensive methods such as clearcuts or seed-tree harvests for conservation of bird communities within mature bottomlands. Clearcuts would certainly create habitat for early-successional species, but many of these species use small forest openings or tree-fall gaps within mature bottomlands as well. Even though high-priority gap-dependent species would eventually return to clearcut areas, habitat for these species may need to be located within a larger landscape of mature forest that clearcuts would remove. Plus, clearcut harvests would also eliminate the preferred breeding habitat of many forest-interior species which may take decades to recover. Nevertheless, clearcuts or any harvest method may be appropriate if it results in little change in the overall regional landscape (Mitchell et al. 2001) and it maintains an appropriate balance between conserving bird community diversity and benefiting one or a few high-priority bird species.

In conclusion, my study illustrates the significance of the Altamaha River bottomlands for the conservation of a diverse assemblage of breeding birds, including numerous Neotropical migratory species of regional conservation concern. My study also suggests that beyond allowing flooding and tree fall to occur naturally, management of mature Altamaha River bottomlands for diversity in the breeding bird community may involve very little active management. However, single-tree or group-selection harvests may be beneficial to a few important breeding NT species.

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Table 1. List of breeding bird species with number of detections from 346 point counts performed in 2007 and 2008 in bottomland forests of the Altamaha River, Georgia. List does not include actively migrating bird species or wide-ranging breeding birds. See Appendix A for a complete list of detected species.

| Common Name (Scientific Name) | 2007 | 2008 | Total | % Freq. |
|---|---|---|---|---|
| Red-eyed Vireo (*Vireo olivaceus*)[1,2] | 397 | 392 | 789 | 100.0 |
| Acadian Flycatcher (*Empidonax virescens*)[1,2] | 319 | 341 | 660 | 100.0 |
| Northern Parula (*Parula americana*)[1,2] | 252 | 225 | 477 | 98.1 |
| Carolina Wren (*Thryothorus ludovicianus*)[2] | 216 | 250 | 466 | 100.0 |
| Northern Cardinal (*Cardinalis cardinalis*)[2] | 221 | 221 | 442 | 100.0 |
| Tufted Titmouse (*Baeolophus bicolor*)[2] | 210 | 205 | 415 | 100.0 |
| Blue-gray Gnatcatcher (*Polioptila caerulea*)[1,2] | 185 | 160 | 345 | 100.0 |
| White-eyed Vireo (*Vireo griseus*)[1,2] | 158 | 164 | 322 | 88.9 |
| Yellow-billed Cuckoo (*Coccyzus americanus*)[1,2] | 162 | 150 | 312 | 100.0 |
| Prothonotary Warbler ( *Protonitoria citrea*)[1,2] | 130 | 135 | 265 | 79.6 |
| Red-bellied Woodpecker (*Melanerpes carolinus*)[2] | 97 | 106 | 203 | 96.3 |
| Blue Jay (*Cyanocitta cristata*)[2] | 85 | 81 | 166 | 90.7 |
| Great Crested Flycatcher (*Myiarchus crinitus*)[1,2] | 87 | 77 | 164 | 88.9 |
| Pileated Woodpecker (*Dryocopus pileatus*)[2] | 81 | 80 | 161 | 94.4 |
| Summer Tanager (*Piranga rubra*)[1,2] | 57 | 48 | 105 | 74.1 |
| Brown-headed Cowbird (*Molothrus ater*)[2] | 52 | 41 | 93 | 81.5 |
| Downy Woodpecker (*Picoides pubescens*)[2] | 33 | 52 | 85 | 81.5 |
| Mourning Dove (*Zendaida macroura*)[2] | 32 | 50 | 82 | 57.4 |
| Carolina Chickadee (*Poecile carolinensis*)[2] | 40 | 41 | 81 | 72.2 |
| Yellow-throated Vireo (*Vireo flavifrons*)[1,2] | 32 | 46 | 78 | 50.0 |
| Yellow-throated Warbler (*Dendroica dominica*)[1,3] | 9 | 19 | 28 | 22.2 |
| Wood Thrush (*Hylocichla mustelina*)[1,3] | 20 | 6 | 26 | 33.3 |
| Swainson’s Warbler (*Limnothlypis swainsonii*)[1,3] | 16 | 7 | 23 | 22.2 |
| Hairy Woodpecker (*Picoides villosus*) | 9 | 3 | 12 | 22.2 |
| Hooded Warbler (*Wilsonia citrina*)[1,3] | 7 | 4 | 11 | 14.8 |
| Ruby-throated Hummingbird (*Archilochus colubris*)[1,3] | 5 | 6 | 11 | 18.5 |
| Kentucky Warbler (*Oporonis formosus*)[1,3] | 4 | 1 | 5 | 9.3 |
| Pine Warbler (*Dendroica pinus*) | 5 | -- | 5 | 7.4 |
| Indigo Bunting (*Passerina cyanea*)[1,3] | 3 | 1 | 4 | 5.6 |
| Common Yellowthroat (*Geothlypis trichas*)[3] | 2 | -- | 2 | 3.7 |
| Gray Catbird (*Dumetella carolinensis*)[1,3] | 2 | -- | 2 | 3.7 |
| Blue Grosbeak (*Guiraca caerulea*)[1,3] | -- | 1 | 1 | 1.9 |
| Eastern Towhee (*Pipilo erythrophthalmus*)[3] | 1 | -- | 1 | 1.9 |
| Total | 2929 | 2913 | 5842 | |

[1] Neotropical Migratory Bird Species (NT)

[2] Species with sufficient detections to calculate detectibility empirically

[3] Species detectibility derived from Twedt and Somershoe (2009) or estimated

Table 2. Summary statistics for breeding bird density (BBD), breeding Neotropical Migratory Bird (NT) density, and Avian Conservation Score (ACS) from stations (N=54) in bottomland hardwood forests of the Altamaha River, Georgia.

| | Mean | Lower 95% CL | Upper 95% CL | Minimum | Maximum |
|---|---|---|---|---|---|
| 20 Species (10 NT) | | | | | |
| BBD (ha$^{-1}$) | 13.99 | 13.52 | 14.47 | 10.28 | 18.46 |
| NT density (ha$^{-1}$) | 10.49 | 10.02 | 10.97 | 6.98 | 14.875 |
| ACS | 415.80 | 406.14 | 425.48 | 353.92 | 490.40 |
| | | | | | |
| 33 Species (19 NT) | | | | | |
| BBD (ha$^{-1}$) | 14.19 | 13.71 | 14.66 | 10.39 | 18.46 |
| NT density (ha$^{-1}$) | 10.66 | 10.19 | 11.14 | 7.09 | 15.46 |
| ACS | 448.10 | 435.63 | 460.57 | 370.56 | 566.35 |

Table 3. List of tree species detected and number of detections from timber cruising 54 stations in bottomland forests of the Altamaha River, Georgia. Species listed as "Unknown" were unable to be identified but were unique from all other detected species.

| Common Name | *Scientific Name* | Total Detections | % Frequency |
|---|---|---|---|
| Sweetgum | *Liquidambar styraciflua* | 86 | 59.3 |
| Swamp laurel oak | *Quercus laurifolia* | 84 | 51.9 |
| Gum species | *Nyssa* species | 66 | 27.8 |
| Red maple | *Acer rubrum* | 38 | 27.8 |
| Baldcypress | *Taxodium distichum* | 31 | 20.4 |
| Willow oak | *Quercus phellos* | 24 | 20.4 |
| Water oak | *Quercus nigra* | 21 | 20.4 |
| Winged elm | *Ulmus alata* | 17 | 20.4 |
| American hornbeam | *Carpinus caroliniana* | 13 | 13.0 |
| Water hickory | *Carya aquatica* | 7 | 11.1 |
| American elm | *Ulmus americana* | 7 | 9.3 |
| River birch | *Betula nigra* | 6 | 9.3 |
| Overcup oak | *Quercus lyrata* | 5 | 9.3 |
| Swamp chestnut oak | *Quercus michauxii* | 5 | 7.4 |
| Cherrybark oak | *Quercus pagoda* | 5 | 5.6 |
| Loblolly pine | *Pinus taeda* | 4 | 5.6 |
| Hawthorne species | *Crateagus* species | 3 | 5.6 |
| Spruce pine | *Pinus glabra* | 3 | 5.6 |
| Water elm | *Planera aquatica* | 3 | 3.7 |
| Southern red oak | *Quercus falcata* | 3 | 3.7 |
| Mockernut hickory | *Carya tomentosa* | 2 | 3.7 |
| Carolina ash | *Fraxinus caroliniana* | 2 | 3.7 |
| Green ash | *Fraxinus pennslyvanica* | 2 | 3.7 |
| Live oak | *Quercus virginiana* | 2 | 1.9 |
| Maple species | *Acer* species *(not A. rubrum)* | 1 | 1.9 |
| Unknown 1 | -- | 1 | 1.9 |
| Unknown 2 | -- | 1 | 1.9 |
|  | Total Detections | 442 |  |

Table 4. Mean, standard error, minimum and maximum values for six habitat variables measured at stations in bottomland forests of the Altamaha River, Georgia.

| Habitat Variable | Mean | ± 1SE | Minimum | Maximum |
|---|---|---|---|---|
| Basal area, $m^2ha^{-1}$ | 92.83 | 0.27 | 88.02 | 96.1 |
| Canopy cover, % | 29.22 | 1.36 | 10 | 64 |
| Log tree density, $ha^{-1}$ | 337.6 | 32.56 | 48.4 | 1013.5 |
| DBH CV, % | 59.9 | 2.84 | 23.84 | 116.3 |
| Shrub density | 1127 | 212.4 | 0 | 8238 |
| Ground cover | 25.56 | 3.34 | 0 | 95 |

Table 5. Relationships between breeding bird density, breeding Neotropical migratory bird (NT) density variables and Avian Conservation Score (ACS) and each of six habitat variables from point-count stations (N=54) in bottomland hardwood forests of the Altamaha River, Georgia.

| | 20 species (10 NT) | | | | 33 Species (19 NT) | | | |
|---|---|---|---|---|---|---|---|---|
| | b | $R^2$ | $F_{1,53}$ | P | b | $R^2$ | $F_{1,53}$ | P |
| Breeding Bird Density | | | | | | | | |
| Basal area, $m^2ha^{-1}$ | -0.08 | 0.01 | 0.33 | 0.57 | -0.10 | 0.01 | 0.56 | 0.46 |
| Canopy cover, % | -0.09 | 0.01 | 0.45 | 0.50 | -0.13 | 0.02 | 0.83 | 0.37 |
| Log tree density, $ha^{-1}$ | -0.25 | 0.06 | 3.30 | 0.07 | -0.26 | 0.07 | 3.63 | 0.06 |
| DBH CV, % | -0.11 | 0.01 | 0.63 | 0.42 | -0.11 | 0.01 | 0.62 | 0.43 |
| Shrub density | -- | 0.03 | 0.85 | 0.44 | -- | 0.02 | 0.63 | 0.54 |
| Ground cover | -- | 0.10 | 2.68 | 0.08 | -- | 0.07 | 1.96 | 0.15 |
| NT Density | | | | | | | | |
| Basal area, $m^2ha^{-1}$ | -0.04 | <0.01 | 0.10 | 0.75 | -0.06 | <0.01 | 0.20 | 0.66 |
| Canopy cover, % | -0.04 | 0.01 | 0.07 | 0.80 | -0.07 | <0.01 | 0.24 | 0.63 |
| Log tree density, $ha^{-1}$ | -0.25 | 0.06 | 3.39 | 0.07 | -0.25 | 0.06 | 3.61 | 0.06 |
| DBH CV, % | -0.20 | 0.03 | 1.67 | 0.20 | -0.20 | 0.03 | 1.62 | 0.21 |
| Shrub density | -- | 0.06 | 1.51 | 0.23 | -- | 0.04 | 1.18 | 0.32 |
| Ground cover | -- | 0.08 | 2.10 | 0.13 | -- | 0.06 | 1.50 | 0.23 |
| ACS | | | | | | | | |
| Basal area, $m^2ha^{-1}$ | -0.07 | 0.01 | 0.27 | 0.60 | -0.15 | 0.02 | 1.16 | 0.29 |
| Canopy cover, % | -0.22 | 0.05 | 2.56 | 0.12 | -0.39 | 0.15 | 9.48 | <0.01 |
| Log tree density, $ha^{-1}$ | 0.01 | <0.01 | <0.01 | 0.95 | -<0.01 | <0.01 | <0.01 | 0.98 |
| DBH CV, % | 0.29 | 0.08 | 4.69 | 0.04 | 0.26 | 0.07 | 3.82 | 0.06 |
| Shrub density | -- | 0.03 | 0.82 | 0.45 | -- | 0.14 | 4.07 | 0.02 |
| Ground cover | -- | <0.01 | 0.04 | 0.97 | -- | <0.08 | 2.25 | 0.12 |

Table 6. Multiple regression model of breeding bird density (calculated from 20 and 33 species) and habitat variables from stations (N=54) in bottomland hardwood forests of the Altamaha River, Georgia.

| | $R^2$ | b | df | F | P |
|---|---|---|---|---|---|
| Whole Model, 20 Species | 0.40 | -- | 10,53 | 2.85 | 0.01 |
| Total basal area $m^2ha^{-1}$ | -- | 0.09 | 1 | 0.51 | 0.48 |
| Canopy cover (%) | -- | -0.25 | 1 | 4.04 | 0.05 |
| Log tree density ($ha^{-1}$) | -- | -0.33 | 1 | 6.39 | 0.02 |
| DBH CV | -- | -0.02 | 1 | 2.46 | 0.12 |
| Shrub density (0, low) | -- | -0.07, 0.27 | 2 | 2.06 | 0.14 |
| Ground Cover (0, low) | -- | 0.36, -0.33 | 2 | 2.99 | 0.06 |
| Whole Model, 33 Species | 0.40 | -- | 10,53 | 2.85 | 0.01 |
| Total basal area $m^2ha^{-1}$ | -- | 0.08 | 1 | 0.34 | 0.57 |
| Canopy cover (%) | -- | -0.29 | 1 | 5.01 | 0.03 |
| Log tree density ($ha^{-1}$) | -- | -0.35 | 1 | 7.11 | 0.01 |
| DBH CV | -- | -0.22 | 1 | 3.01 | 0.09 |
| Shrub density (0, low) | -- | -0.09, 0.27 | 2 | 2.12 | 0.13 |
| Ground Cover (0, low) | -- | 0.32, -0.30 | 2 | 2.37 | 0.11 |

Table 7. Multiple regression model of Neotropical migratory breeding bird density (calculated from 10 and 19 species) and habitat variables from stations (N=54) in bottomland hardwood forests of the Altamaha River, Georgia.

| | $R^2$ | b | df | F | P |
|---|---|---|---|---|---|
| Whole Model, 10 species | 0.35 | -- | 10,53 | 2.34 | 0.03 |
| | | | | | |
| Total basal area $m^2ha^{-1}$ | -- | 0.08 | 1 | 0.33 | 0.57 |
| Canopy cover (%) | -- | -0.19 | 1 | 2.18 | 0.15 |
| Log tree density ($ha^{-1}$) | -- | -0.35 | 1 | 6.62 | 0.01 |
| DBH CV | -- | -0.30 | 1 | 4.72 | 0.03 |
| Shrub density (0, low) | -- | -0.01, 0.31 | 2 | 2.79 | 0.07 |
| Ground Cover (0, low) | -- | 0.26, -0.23 | 2 | 1.88 | 0.06 |
| | | | | | |
| Whole Model, 19 species | 0.35 | -- | 10,53 | 2.29 | 0.03 |
| | | | | | |
| Total basal area $m^2ha^{-1}$ | -- | 0.07 | 1 | 0.24 | 0.63 |
| Canopy cover (%) | -- | -0.22 | 1 | 2.85 | 0.10 |
| Log tree density ($ha^{-1}$) | -- | -0.37 | 1 | 7.07 | 0.01 |
| DBH CV | -- | -0.31 | 1 | 5.21 | 0.03 |
| Shrub density (0, low) | -- | -0.03, 0.31 | 2 | 2.66 | 0.08 |
| Ground Cover (0, low) | -- | 0.21, -0.27 | 2 | 1.43 | 0.25 |

Table 8. Multiple regression model of Avian Conservation Scores (calculated from 20 and 33 species) and habitat variables from stations (N=54) in bottomland hardwood forests of the Altamaha River, Georgia.

| | $R^2$ | b | df | F | P |
|---|---|---|---|---|---|
| Whole Model, 20 Species | 0.22 | -- | 10, 53 | 1.23 | 0.30 |
| Whole Model, 33 Species | 0.33 | -- | 10,53 | 2.12 | 0.04 |
| Total basal area $m^2ha^{-1}$ | -- | -0.01 | 1 | 0.01 | 0.93 |
| Canopy cover (%) | -- | -0.33 | 1 | 5.95 | 0.02 |
| Log tree density ($ha^{-1}$) | -- | -0.03 | 1 | 0.03 | 0.85 |
| DBH CV | -- | 0.14 | 1 | 0.98 | 0.33 |
| Shrub density (0, low) | -- | -0.30, 0.07 | 2 | 2.15 | 0.13 |
| Ground Cover (0, low) | -- | -0.14, 0.01 | 2 | 0.50 | 0.61 |

Table 9. Results of logistic regressions, including Chi-square values ($x^2$) and unit odds ratios (OR), for 5 breeding bird species using 6 habitat variables from stations (N=54) in bottomland hardwood forests of the Altamaha River, Georgia. The 5 bird species were Prothonotary Warbler (PROW), White-eyed Vireo (WEVI), Hooded Warbler (HOWA), Yellow-throated Vireo (YTVI), and Kentucky Warbler (KEWA).

| | | PROW | WEVI | HOWA | YTVI | KEWA |
|---|---|---|---|---|---|---|
| Whole Model | $x^2_{54}$ | 17.50 | 20.52 | 27.42 | 27.17 | 17.84 |
| | $R^2$ | 0.32 | 0.54 | 0.61 | 0.36 | 0.54 |
| | P | 0.03 | 0.01 | 0.01 | 0.01 | 0.02 |
| Effect Likelihood Ratio Tests | | | | | | |
| Tree density ($ha^{-1}$) | $x^2$ | 0.01 | 0.75 | 3.40 | 0.13 | 1.93 |
| | P | 0.92 | 0.38 | 0.07 | 0.71 | 0.16 |
| | OR | 1.00 | 1.00 | 0.99 | 1.00 | 1.01 |
| Basal area ($m^2 ha^{-1}$) | $x^2$ | 3.63 | 3.77 | 0.13 | 5.02 | 0.07 |
| | P | 0.06 | 0.05 | 0.72 | 0.03 | 0.79 |
| | OR | 1.14 | 0.86 | 1.03 | 0.90 | 0.96 |
| Canopy cover (%) | $x^2$ | 0.05 | 11.49 | 4.17 | 12.19 | 0.05 |
| | P | 0.82 | <0.01 | 0.04 | <0.01 | 0.82 |
| | OR | 0.95 | 8.59 | 0.46 | 0.49 | 0.90 |
| Shrub density ($ha^{-1}$) | $x^2$ | 0.68 | 3.74 | 0.53 | 0.002 | 8.79 |
| | P | 0.41 | 0.05 | 0.47 | 0.96 | <0.01 |
| | OR | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| DBH CV | $x^2$ | 9.37 | 2.52 | 0.19 | 1.47 | 7.41 |
| | P | <0.01 | 0.11 | 0.66 | 0.23 | 0.01 |
| | OR | 1.08 | 1.08 | 0.98 | 0.98 | 0.81 |
| Ground cover (%) | $x^2$ | 0.19 | 0.67 | 3.46 | 1.56 | <0.01 |
| | P | 0.67 | 0.41 | 0.06 | 0.21 | 0.99 |
| | OR | 0.99 | 0.96 | 1.07 | 1.02 | 1.00 |
| Mean time of day | $x^2$ | 7.46 | 2.56 | 4.77 | 0.08 | 0.09 |
| | P | 0.23 | 0.01 | 0.11 | 0.029 | 0.77 |
| | OR | <0.01 | -- | -- | <0.01 | <0.01 |
| Mean date | $x^2$ | 3.56 | 0.13 | 16.23 | 1.07 | 0.07 |
| | P | 0.06 | 0.71 | <0.001 | 0.30 | 0.78 |
| | OR | 0.56 | 1.13 | 16.97 | 1.24 | 0.82 |

Table 10. Results of logistic regressions for 5 breeding bird species using 6 habitat variables from stations (N=54) in bottomland hardwood forests of the Altamaha River, Georgia. The 5 species are Swainson's Warbler (SWWA), Summer Tanager (SUTA), Yellow-throated Warbler (YTWA), Wood Thrush (WOTH) and Ruby-throated Hummingbird (RTHU).

| | | SWWA | SUTA | YTWA | WOTH | RTHU |
|---|---|---|---|---|---|---|
| Whole Model | $x^2_{54}$ | 14.42 | 8.59 | 12.02 | 8.63 | 8.91 |
| | $R^2$ | 0.25 | 0.19 | 0.21 | 0.12 | 0.17 |
| | P | 0.07 | 0.38 | 0.15 | 0.15 | 0.35 |

Figure 1.  Examples of typical mature bottomlands found along the Altamaha River, Georgia.

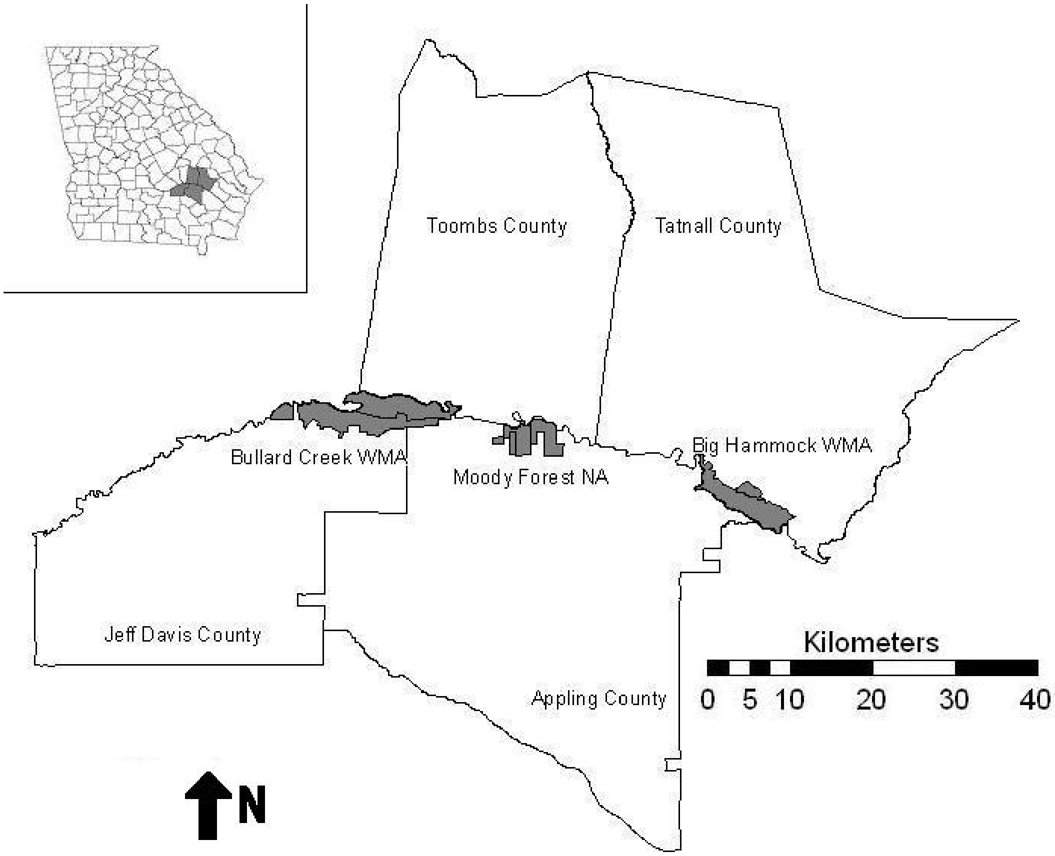

Figure 2. Locations of three study sites along the Altamaha River, Georgia: Georgia Department of Natural Resources' Bullard Creek and Big Hammock Wildlife Management Areas (WMA) and The Nature Conservancy's Moody Forest Natural. Inset map shows location of these counties within the state of Georgia.

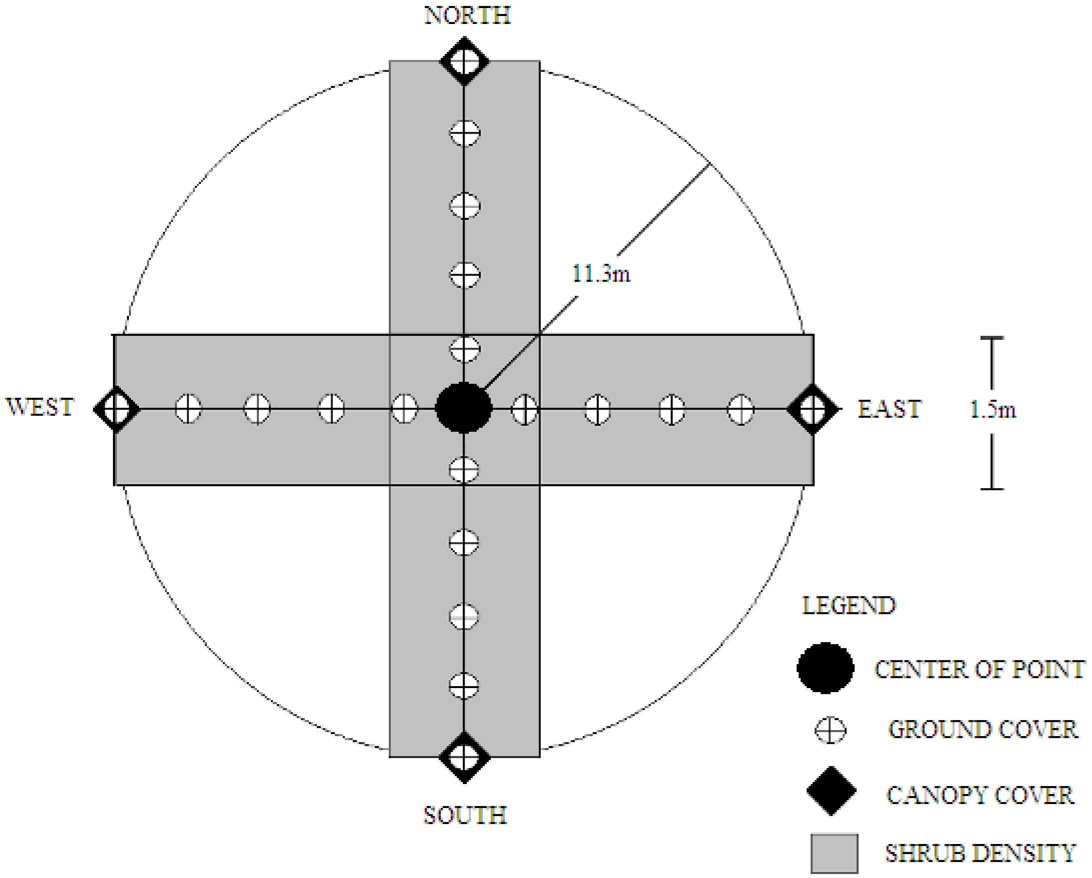

Figure 3. Schematic illustration of plots for measuring canopy cover, shrub density, and ground cover from survey plots (N=54) in bottomland hardwood forests of the Altamaha River, Georgia in 2007.

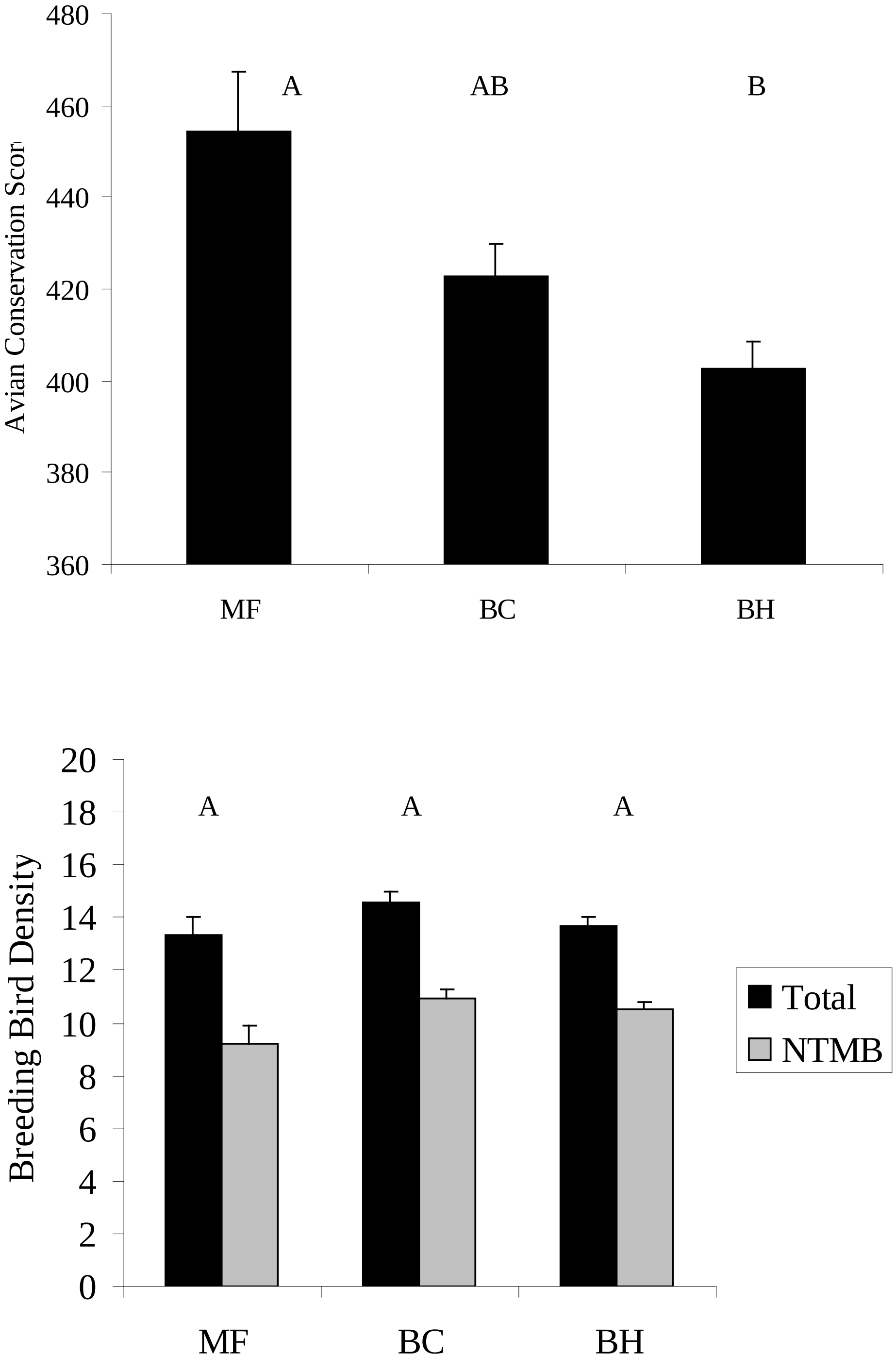

Figure 4. Mean Avian Conservation Score (above) and Breeding Bird Density and NT density (below) from point counts in three bottomland hardwood forest sites along the Altamaha River, Georgia, Moody Forest (MF), Bullard Creek (BC) and Big Hammock (Big Hammock). Sites with different letters above columns have significantly different means.

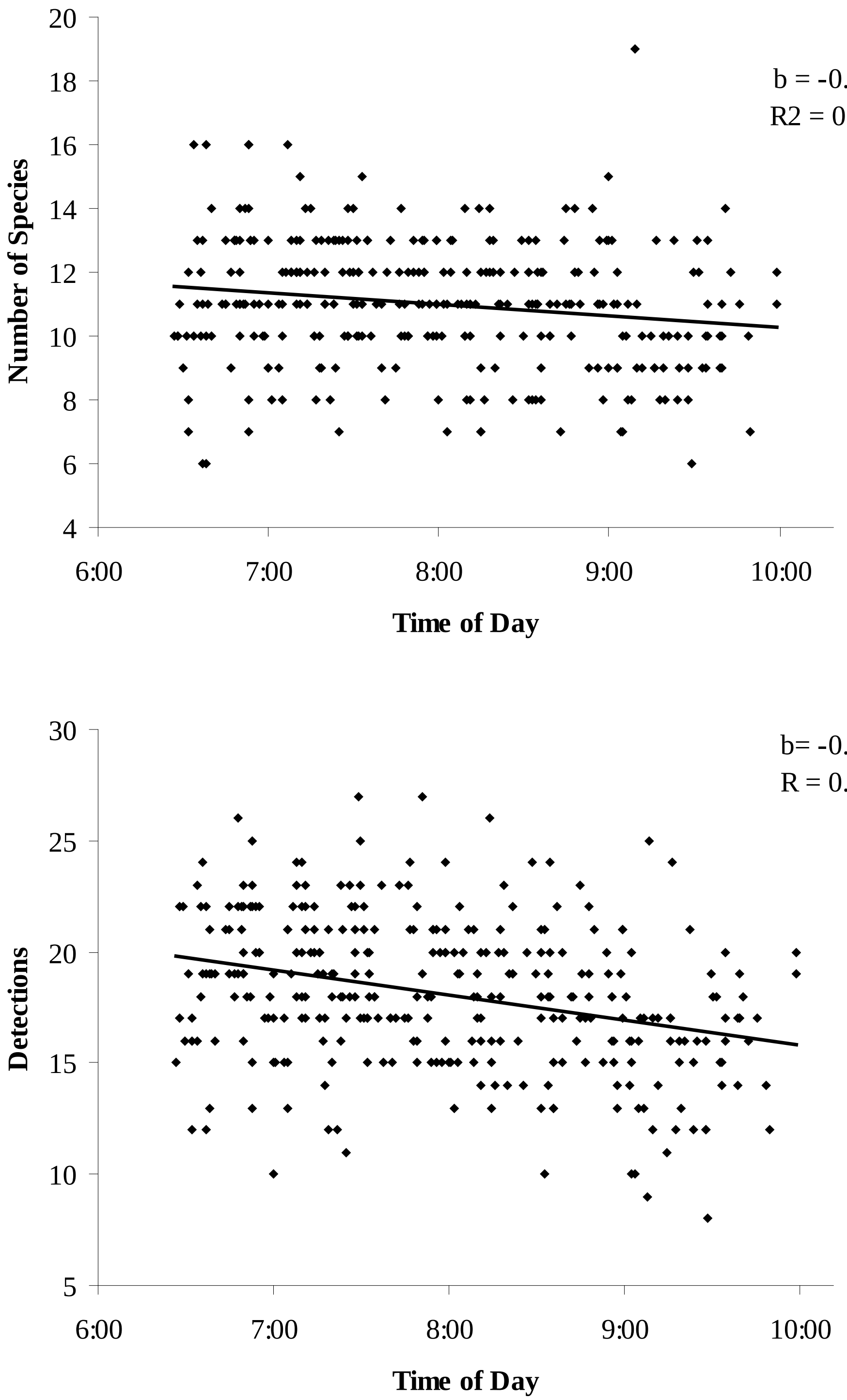

Figure 5. Relationship between the number of species detected (above) and number of detections (below) to the time of day of point counts (N=323) in bottomland hardwood forests of the Altamaha River, Georgia.

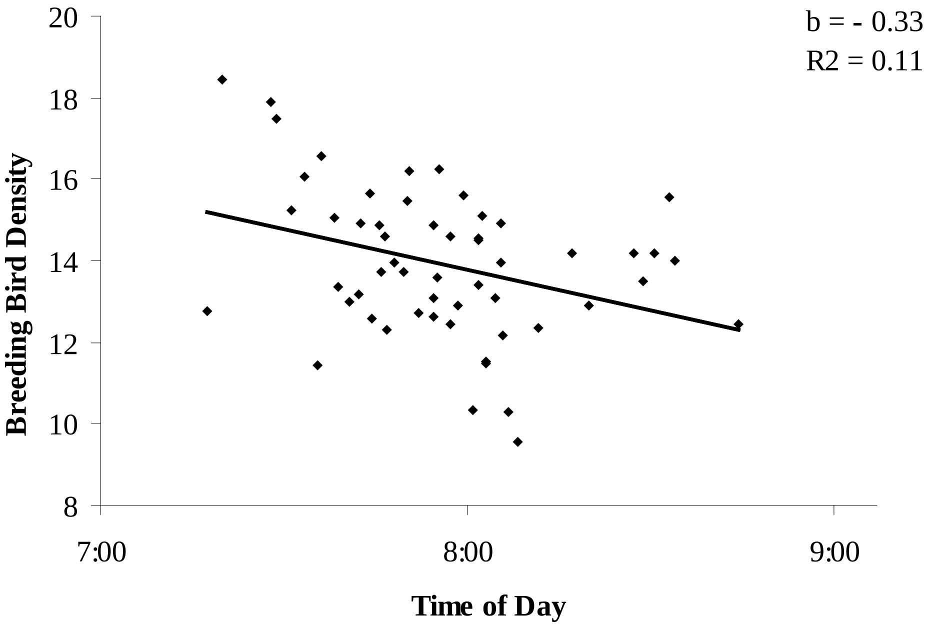

Figure 6. Relationship between breeding bird density and mean time of day of six point counts at each point (N=54) from bottomland hardwood forests of the Altamaha River, Georgia.

# APPENDIX A.

## COMPLETE LIST OF BIRD SPECIES DETECTED

Table A1. List of bird species with number of detections from 361 point counts (10-minute duration, 150-meter radius) performed in 2007 and 2008 in bottomland forests of the upper Altamaha River, Georgia.

| Common Name (*Scientific Name*) | CODE | Status | # |
|---|---|---|---|
| Great Egret (*Ardea alba*) | GREG | B, C, E | 11 |
| Yellow-crowned night heron (*Nyctanassa violacea*) | YCNH | B, C | 11 |
| White Ibis (*Eudocimus albus*) | WHIB | B, C | 8 |
| Wood Stork (*Mycteria americana*) | WOST | B, C, E | 3 |
| Canada Goose (*Branta canadensis*) | CAGO | D | 1 |
| Wood Duck (*Aix sponsa*) | WODU | A, B | 11 |
| Turkey Vulture (*Cathartes aura*) | TUVU | B, C, E | 1 |
| Osprey ( *Pandion haliaetus*) | OSPR | A, B, C | 1 |
| Swallow-tailed kite (*Elanoides forficatus*) ** | SWTK | A, B, C | ** |
| Mississippi Kite (*Ictinia mississippiensis*) | MIKI | A, B | 2 |
| Red-Shouldered Hawk (*Buteo lineatus*) | RSHA | B, C | 116 |
| Wild Turkey (*Meleagris gallopavo*) | WITU | B, C | 23 |
| Northern Bobwhite (*Colinus virginianus*) | NOBO | B | 1 |
| Sora (*Porzana carolina*) | SORA | B | 1 |
| Limpkin (*Aramus guarauna*) ** | LIMP | C, D | ** |
| Mourning Dove (*Zendaida macroura*) | MODO | B | 82 |
| Yellow-billed Cuckoo (*Coccyzus americanus*) | YBCU | A, B | 328 |
| Barred Owl (*Strix varia*) | BAOW | B, C | 45 |
| Chimney Swift (*Chaetura pelagica*) | CHSW | A, B, E | 36 |
| Ruby-throated Hummingbird (*Archilochus colubris*) | RTHU | A, B | 11 |
| Belted Kingfisher (*Megaceryle alcyon*) | BEKI | B, C | 1 |
| Red-bellied Woodpecker (*Melanerpes carolinus*) | RBWO | B | 214 |
| Downy Woodpecker(*Picoides pubescens*) | DOWO | B | 89 |
| Hairy Woodpecker(*Picoides villosus*) | HAWO | B | 14 |
| Pileated Woodpecker (*Dryocopus pileatus*) | PIWO | B | 169 |
| Acadian Flycatcher (*Empidonax virescens*) | ACFL | A, B | 683 |
| Great Crested Flycatcher (*Myiarchus crinitus*) | GCFL | A, B | 183 |
| White-eyed Vireo (*Vireo griseus*) | WEVI | A, B | 355 |
| Red-eyed Vireo (*Vireo olivaceus*) | REVI | A, B | 840 |
| Yellow-throated Vireo (*Vireo flavifrons*) | YTVI | A, B | 78 |
| Blue Jay(*Cyanocitta cristata*) | BLJA | B | 172 |
| American Crow (*Corvus brachyrhynchos*) | AMCR | B, C | 131 |
| Fish Crow (*Corvus ossifragus*) | FICR | B, C | 6 |
| Purple Martin (*Progne subis*) | PUMA | A, B, E | 2 |
| Carolina Chickadee(*Poecile carolinensis*) | CACH | B | 83 |
| Tufted Titmouse (*Baeolophus bicolor*) | TUTI | B | 452 |
| Carolina Wren(*Thryothorus ludovicianus*) | CAWR | B | 498 |
| Blue-gray Gnatcatcher (*Polioptila caerulea*) | BGGN | A, B | 362 |
| Swainson's Thrush (*Catharus ustulatus*) | SWTH | A, D | 2 |
| Wood Thrush (*Hylocichla mustelina*) | WOTH | A, B | 29 |
| Gray Catbird (*Dumetella carolinensis*) | GRCA | A, B | 3 |

Table A1. Continued.

| | | | |
|---|---|---|---|
| Northern Parula (*Parula americana*) | NOPA | A, B | 498 |
| Black-throated Blue Warbler (*Dendroica caerulescens*) | BTBW | A, D | 7 |
| Pine Warbler (*Dendroica pinus*) | PIWA | B | 6 |
| Blackpoll Warbler (*Dendroica striata*) | BLPW | A, D | 5 |
| Yellow-throated Warbler (*Dendroica dominica*) | YTWA | A, B | 39 |
| Black-and-white Warbler (*Mniotilta varia*) | BAWW | A, B | 3 |
| American Redstart (*Setophaga ruticilla*) | AMRE | A, D | 2 |
| Prothonotary Warbler ( *Protonitaria citrea*) | PROW | A, B | 267 |
| Common Yellowthroat (*Geothlypis trichas*) | COYE | A, B | 2 |
| Kentucky Warbler (*Oporonis formosus*) | KEWA | A, B | 9 |
| Northern Waterthrush (*Seiurus noveboracensis*) | NOWA | A, B | 1 |
| Louisiana Waterthrush (*Seiurus motacilla*) | LOWA | A, D | 1 |
| Swainson's Warbler (*Lymnothylpis swainsonii*) | SWWA | A, D | 23 |
| Hooded Warbler (*Wilsonia citrina*) | HOWA | A, B | 11 |
| Scarlet Tanager (*Piranga olivacea*) | SCTA | A, D | 1 |
| Summer Tanager (*Piranga rubra*) | SUTA | A, B | 114 |
| Blue Grosbeak (*Guiraca caerulea*) | BLGR | A, B | 1 |
| Indigo Bunting (*Passerina cyanea*) | INBU | A, B | 5 |
| Northern Cardinal (*Cardinalis cardinalis)* | NOCA | B | 473 |
| Eastern Towhee (*Pipilo erythrophthalmus*) | EATO | B | 1 |
| Common Grackle (*Quiscalus quiscula*) | COGR | B | 4 |
| Brown-headed cowbird (*Molothrus ater*) | BHCO | B | 106 |
| Total | | | 6639 |

*Species status: A = Neotropical migratant, B = breeding regionally, C = wide-ranging, D = transient, and E = flyover

** = species detected at study sites but not during point counts

# APPENDIX B

## RESULTS FROM PROGRAM DISTANCE

Table B1. Densities (D) with coefficients of variation (CV), degrees of freedom (df), and 95% confidence limits (CL) from point counts of breeding birds in bottomland hardwood forests of the Altamaha River, Georgia.

| SPECIES | D | CV | df | 95% CL Low | 95% CL High |
|---|---|---|---|---|---|
| ACFL | 1.28 | 5.57 | 821.81 | 1.15 | 1.43 |
| BGGN | 4.15 | 6.51 | 563.21 | 3.65 | 4.71 |
| BHCO | 0.27 | 14.48 | 210.66 | 0.20 | 0.36 |
| BLJA | 0.17 | 10.56 | 302.27 | 0.13 | 0.20 |
| CACH | 0.19 | 17.14 | 180.70 | 0.14 | 0.26 |
| CAWR | 0.59 | 14.57 | 557.90 | 0.44 | 0.78 |
| DOWO | 0.47 | 16.51 | 188.69 | 0.34 | 0.65 |
| GCFL | 0.33 | 11.01 | 339.62 | 0.27 | 0.42 |
| MODO | 0.07 | 13.65 | 173.27 | 0.05 | 0.09 |
| NOCA | 0.59 | 4.86 | 477.42 | 0.54 | 0.65 |
| NOPA | 0.88 | 13.53 | 561.85 | 0.68 | 1.15 |
| PIWO | 0.26 | 19.85 | 208.43 | 0.18 | 0.38 |
| PROW | 0.52 | 9.10 | 381.36 | 0.43 | 0.62 |
| RBWO | 0.24 | 7.74 | 372.41 | 0.21 | 0.28 |
| REVI | 1.29 | 9.93 | 928.45 | 1.06 | 1.56 |
| SUTA | 0.15 | 10.54 | 222.98 | 0.12 | 0.19 |
| TUTI | 0.62 | 7.26 | 637.27 | 0.54 | 0.71 |
| WEVI | 0.62 | 16.04 | 404.86 | 0.45 | 0.84 |
| YBCU | 0.90 | 7.22 | 518.76 | 0.78 | 1.04 |
| YTVI | 0.16 | 16.84 | 151.62 | 0.12 | 0.23 |

Table B2. Effective detection radius (EDR) values with coefficients of variation (CV), degrees of freedom (df), and 95% confidence limits (CL) from point counts of breeding birds in bottomland hardwood forests of the Altamaha River, Georgia.

| **SPECIES** | **EDR** | **CV** | **df** | **95% CL Low** | **95% CL High** |
|---|---|---|---|---|---|
| ACFL | 68.54 | 2.48 | 654 | 65.29 | 71.96 |
| BGGN | 28.34 | 2.68 | 361 | 26.88 | 29.87 |
| BHCO | 57.86 | 5.70 | 98 | 51.68 | 64.79 |
| BLJA | 97.92 | 3.21 | 172 | 91.90 | 104.33 |
| CACH | 63.56 | 6.33 | 82 | 56.05 | 72.07 |
| CAWR | 88.66 | 7.06 | 498 | 77.18 | 101.84 |
| DOWO | 41.52 | 6.36 | 87 | 36.59 | 47.11 |
| GCFL | 70.90 | 4.41 | 182 | 64.99 | 77.34 |
| MODO | 102.58 | 4.91 | 81 | 93.04 | 113.09 |
| NOCA | 85.60 | 1.70 | 472 | 82.79 | 88.51 |
| NOPA | 71.96 | 6.53 | 494 | 63.31 | 81.79 |
| PIWO | 77.43 | 9.37 | 168 | 64.38 | 93.13 |
| PROW | 67.31 | 3.90 | 255 | 62.33 | 72.69 |
| RBWO | 89.68 | 2.46 | 213 | 85.43 | 94.14 |
| REVI | 77.52 | 4.82 | 838 | 70.53 | 85.20 |

Table B2 Continued.

| | | | | | |
|---|---|---|---|---|---|
| SUTA | 82.62 | 2.97 | 112 | 77.89 | 87.64 |
| TUTI | 81.94 | 3.01 | 451 | 77.23 | 86.92 |
| WEVI | 72.78 | 7.73 | 353 | 62.53 | 84.70 |
| YBCU | 56.97 | 2.88 | 317 | 53.83 | 60.29 |
| YTVI | 66.46 | 6.60 | 77 | 58.28 | 75.79 |

Table B3. Detection probabilities (p) with coefficients of variation (CV), degrees of freedom (df), and 95% confidence limits (CL) calculated from point counts of breeding birds in bottomland hardwood forests of the Altamaha River.

| **SPECIES** | **p** | **CV** | **df** | **95% CL Low** | **95% CL High** |
|---|---|---|---|---|---|
| ACFL | 0.47 | 4.96 | 654 | 0.43 | 0.52 |
| BGGN | 0.32 | 5.36 | 361 | 0.29 | 0.36 |
| BHCO | 0.15 | 11.41 | 98 | 0.12 | 0.19 |
| BLJA | 0.43 | 6.43 | 172 | 0.38 | 0.48 |
| CACH | 0.18 | 12.65 | 82 | 0.14 | 0.23 |
| CAWR | 0.35 | 14.13 | 498 | 0.27 | 0.46 |
| DOWO | 0.17 | 12.73 | 87 | 0.13 | 0.22 |
| GCFL | 0.22 | 8.82 | 182 | 0.19 | 0.27 |
| MODO | 0.47 | 9.82 | 81 | 0.38 | 0.57 |
| NOCA | 0.33 | 3.40 | 472 | 0.30 | 0.35 |
| NOPA | 0.23 | 13.05 | 494 | 0.18 | 0.30 |
| PIWO | 0.27 | 18.75 | 168 | 0.18 | 0.38 |
| PROW | 0.45 | 7.81 | 255 | 0.39 | 0.53 |
| RBWO | 0.36 | 4.93 | 213 | 0.32 | 0.39 |
| REVI | 0.27 | 9.63 | 838 | 0.22 | 0.32 |
| SUTA | 0.30 | 5.95 | 112 | 0.27 | 0.34 |
| TUTI | 0.30 | 6.02 | 451 | 0.27 | 0.34 |
| WEVI | 0.24 | 15.45 | 353 | 0.17 | 0.32 |
| YBCU | 0.32 | 5.76 | 317 | 0.29 | 0.36 |
| YTVI | 0.20 | 13.21 | 77 | 0.15 | 0.26 |

# APPENDIX C

## GPS LOCATIONS OF STUDY SITES

Table C1. GPS locations in decimal degrees of stations (N=61) grouped by the study site in which they occurred.

| Study Site | Point ID # | Decimal Degrees North | Decimal Degrees West |
|---|---|---|---|
| Bullard Creek WMA | 5 | 31.94711 | 82.50027 |
| | 6 | 31.94616 | 82.49893 |
| | 7 | 31.94536 | 82.49681 |
| | 9 | 31.94555 | 82.49392 |
| | 10 | 31.94662 | 82.49192 |
| | 18 | 31.95471 | 82.52374 |
| | 19 | 31.95603 | 82.52204 |
| | 20 | 31.95584 | 82.51949 |
| | 23 | 31.95393 | 82.5211 |
| | 28 | 31.95661 | 82.52982 |
| | 32 | 31.96126 | 82.48281 |
| | 33 | 31.96214 | 82.48495 |
| | 35 | 31.96097 | 82.48749 |
| | 39 | 31.96090 | 82.45899 |
| | 40 | 31.95996 | 82.45522 |
| | 43 | 31.94984 | 82.42349 |
| | 45 | 31.95156 | 82.42669 |
| | 46 | 31.95520 | 82.42709 |
| | 47 | 31.94909 | 82.41857 |
| | 48 | 31.94851 | 82.41293 |
| Big Hammock WMA | 49 | 31.87646 | 82.10194 |
| | 50 | 31.87640 | 82.10434 |
| | 51 | 31.86650 | 82.09836 |
| | 52 | 31.86344 | 82.09483 |
| | 53 | 31.86119 | 82.09286 |
| | 85 | 31.86541 | 82.08336 |
| | 86 | 31.86469 | 82.07998 |
| | 88 | 31.86288 | 82.07550 |
| | 89 | 31.86032 | 82.07665 |
| | 91 | 31.85708 | 82.07098 |
| | 92 | 31.85580 | 82.06827 |
| | 93 | 31.85251 | 82.07112 |
| | 95 | 31.84699 | 82.07438 |
| | 96 | 31.84564 | 82.06925 |
| | 97 | 31.84441 | 82.06727 |
| | 98 | 31.84560 | 82.06448 |
| | 99 | 31.84317 | 82.07549 |
| | 100 | 31.84226 | 82.07008 |
| | 101 | 31.84174 | 82.06667 |
| | 102 | 31.84001 | 82.06255 |
| | 103 | 31.83677 | 82.05902 |

Table C1 Continued.

| | | | |
|---|---|---|---|
| | 104 | 31.83502 | 82.05566 |
| | 105 | 31.83811 | 82.05231 |
| | 108 | 31.83215 | 82.02320 |
| | 109 | 31.83328 | 82.02586 |
| | 110 | 31.83403 | 82.02823 |
| | 111 | 31.82991 | 82.03458 |
| | 112 | 31.82978 | 82.03725 |
| | 113 | 31.83127 | 82.04035 |
| | 114 | 31.84346 | 82.05004 |
| | 116 | 31.83168 | 82.01070 |
| | 117 | 31.83253 | 82.00826 |
| | 118 | 31.85485 | 82.06567 |
| | 119 | 31.83041 | 82.02131 |
| | 120 | 31.83072 | 82.01901 |
| TNC Moody Forest Preserve | 58 | 31.92470 | 82.27534 |
| | 60 | 31.92606 | 82.27377 |
| | 61 | 31.92813 | 82.27290 |
| | 62 | 31.92698 | 82.26748 |
| | 63 | 31.92776 | 82.26935 |
| | 64 | 31.92649 | 82.27063 |