BIRDS AND SMALL MAMMALS,

INTENSIVELY ESTABLISHED PINE PLANTATIONS,

AND LANDSCAPE METRICS OF THE COASTAL PLAIN

By

Brice Bond Hanberry

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Name: Brice Bond Hanberry

Date of Degree: December 15, 2007

Institution: Mississippi State University

Major Field: Forest Resources

Major Professors: Dr. Stephen Demarais and Dr. Jeanne C. Jones

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I evaluated effects of 5 treatments for pine plantation establishment on breeding and wintering birds and small mammals during years one through 5 post-treatment in the Lower Coastal Plain of Mississippi. I modeled the relationships between 8 vegetation variables and avian abundance to identify influential habitat components in pine plantations. At the landscape scale, I compared avian abundance of regionally important species with land class variables in the Coastal Plain of Georgia.

In pine plantations, species richness, total abundance, and 2 conservation bird metrics generally decreased with increasing intensity of stand establishment. Thus, this study suggests that increasing stand establishment intensity can reduce avian habitat quality in Coastal Plain pine plantations. Presence of residual trees retained after timber harvest was the most influential variable related to avian abundance, and tree retention may reduce the negative impacts of intensive stand establishment on avian communities. There were minimal treatment effects on common small mammals of young pine plantations. For the Coastal Plain landscape, a mixture of area and edge variables were influential in avian models for 10 species, although area or edge each were important for 2 species. Hardwood forests were important vegetation types for all but one modeled species. Assessment of habitat conditions that affect avifauna and small mammals on managed timber production lands can assist natural resource managers with integration of timber production and conservation of biological diversity.

Key words: birds, forest management, habitat, landscape, mammals, model, pine plantations, release, site preparation, snags, Southeast, stand establishment

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CHAPTER I

INTRODUCTION

The Coastal Plain of the United States is a physiographic region of minimal elevation that extends from eastern Texas across to the Atlantic Coast, with Virginia marking the northern boundary. Historically, frequent and predictable ground fires deterred hardwood establishment and allowed open pinelands to cover upwards of 37 million ha (Frost 1993). Fire-maintained longleaf pine (*Pinus palustris*) savannas in uplands interspersed with forested wetlands originally dominated the Atlantic and Lower Gulf Coastal Plain (Frost 1993, Ware et al. 1993). Longleaf forests alone comprised close to 23 million ha, thus equaling 35% of the southeastern region and 50% of uplands (Frost 1993). Pure stands of loblolly pine (*P. taeda*) composed a small fraction of southern forests, totaling 2 million ha (Shultz 1997). In the pine understory, there was extraordinarily high species richness and endemism of herbaceous vegetation, potentially rivaling for greatest floral diversity in a temperate zone (Means 1996). This vegetation type persisted for 5000 years (Ware et al. 1993).

After comprehensive timber harvesting around the turn of the twentieth century, there was limited natural longleaf pine regeneration (Williams 1989). With the advent of forestry as a profession in the United States and national legislation for land management (Williams 1989), cutover lands were re-forested by planted loblolly, shortleaf (*P. echinata*), and slash (*P. elliotti*) pines that grew well and easily. Forest industry invested in the long-term business of growing trees and thus a more responsible approach to forestry began. Unfortunately, less than 3% (Frost 1993) of the original landscape remained relatively intact, albeit fragmented.

Forested areas currently comprise about 87 million ha of the 137 million ha southeastern United States (USDA 1988, Conner and Hartsell 2002). Net land use distribution, including forest land, has remained stable since 1945. However, 810,000 to 1.2 million ha per year may change to or from a forest designation depending on timber and agricultural returns (Wear 2004). One third of the forested region is dominated by pine, one half is dominated by hardwoods, and the remainder is mixed pine/hardwood (Conner and Hartsell 2002). Moreover, without frequent fire or disturbance, natural pine forests are vulnerable to replacement by hardwoods due to succession (Baker and Hunter 2002). Pine tracts in later seral stages are rare, with pine forests older than 62 years comprising 930,000 ha. Ninety-four percent of planted pine is less than 33 years old, whereas 53% of natural pine is less than 33 years old. Approximately 9.5% of timberlands are publicly owned, in a patchwork of sizes and managed by various agencies (USDA 1988). Public land managers and private land owners are in position to maintain and develop older pine stands. However, individual land owners typically hold smaller sized tracts, which can generate landscape fragments.

Southeastern timber resources continue to supply wood products for the world. Southern pines produce one-third of the softwood lumber, one-half of plywood, and two-thirds of wood pulp nationally (USDA 1988). Wood is a multi-billion dollar industry, and production for pulp fiber in managed pine plantations is a substantial portion of the industry, accounting for almost half of harvested softwoods (USDA 1988). To meet market demand, fifty percent of southeastern pine stands now consist of planted pine, typically loblolly (Conner and Hartsell 2002, Baker and Hunter 2002).

Intensive management, including planting of genetically improved pines, herbicide application, mechanical site preparation, and fertilization, is common for plantation establishment. Herbicide application has intensified to include tank mixes of multiple herbicides during site preparation, followed by herbaceous release treatments one or more years following planting (Miller and Miller 2004). The primary objective of stand establishment is to reduce competition for pine seedlings, encouraging pine survival and growth. Herbicide applications during site preparation can increase loblolly pine yields more than five-fold (Glover and Zutter 1993).

Young pine plantations provide habitat for early successional species, but habitat quality and length of suitability differ with stand establishment methods. Herbicides and dense pine growth limit other forms of vegetation, altering habitat structure and composition. Intensity of vegetation disturbance, timing (at site preparation or as a later release), and treatment type (herbicide versus mechanical or both) should affect wildlife differentially.

In addition to stand composition and structure, landscape context, including habitat type area and isolation, are important determinants of species presence. Land use can reduce the areal extent of existing vegetation types, while often dividing previously contiguous areas into isolated fragments (Fahrig 1999) and producing edge at borders. When a landscape is modified, islands of original vegetation type may lose characteristic species (Opdam 1991). The primary explanation may be that habitat loss limits quantity of suitable breeding habitat. Also, patch quality may be impoverished due to missing stand elements, such as appropriate cavity trees or specialized microhabitat. Furthermore, because smaller areas have reduced species abundance, stochastic events increase probability of local extinction and decrease likelihood of colonization (Askins et al. 1987). Nest predation, and specifically for birds, brood parasitism can reduce reproductive success in small tracts to the point that communities are unlikely to be self-sustaining without immigration (Faaborg et al. 1998, Walters 1998).

Nonetheless, managed forests are better suited than other intensive land uses to provide biodiversity and wildlife habitat. This holds true particularly in the southeastern United States, where most biological diversity in forests historically was associated with the ground layer rather than old growth structure and the terrain allows harvest access without excessive soil damage (Simberloff 1993). In addition, favorable temperatures and precipitation permit rapid vegetation growth and the briefest timber rotations in the United States (Ware et al. 1993, Prestemon and Abt 2002). Increased productivity from intensive management holds the promise of conservation of natural forests.

There is a need to integrate intensive forest management with biological diversity (Sustainable Forestry Initiative 2005). Therefore, this project monitored responses of avian and mammalian assemblages to a gradient of pine plantation stand establishment intensities during 5 years post-treatment. I additionally addressed land use effects on bird species associated with a range of habitats by exploring correlations between landscape metrics and breeding bird abundance. Results from this study will help land managers make informed decisions when planning management regimes that integrate timber production with wildlife conservation in pine plantations of the Coastal Plain of the southeastern United States.

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CHAPTER II

AVIAN ASSEMBLAGES OF INTENSIVELY ESTABLISHED PINE PLANTATIONS IN COASTAL PLAIN MISSISSIPPI

Abstract: Pine plantations are a common vegetation type in southeastern United States. To expand knowledge of pine plantations as avian habitat, I evaluated effects of 5 pine plantation establishment intensities on breeding and wintering birds during years one through 5 post-treatment in the Coastal Plain of Mississippi. I detected 65 species with winter transects and spring point counts. I compared species richness, total bird abundance, individual species abundance, and 2 conservation metrics based on Partners in Flight species assessment using mixed models ANOVA. After 5 years, spring and winter species richness, total abundance, and 2 conservation assemblage metrics were greatest in a lower intensity treatment, consisting of herbicide-only site preparation with banded release treatment, compared to other stand establishment methods. In general, spring abundance of 22 species and winter abundance of 8 species also was greatest in the herbicide-only treatment. For 13 species there was a range in avian response to establishment intensity gradient, and abundance typically declined within mechanically-prepared treatments as herbicide intensity increased. Tree and snag retention combined with herbaceous and shrub cover in herbicide-only areas may have contributed to greatest avian abundance and richness. In this study, increasing stand establishment intensity appeared to reduce habitat quality for avian species in pine plantations of the Lower

Coastal Plain. Presence of residual trees and snags may reduce negative impacts of intensive stand establishment on bird communities in young pine plantations.

INTRODUCTION

The Southeast is the largest timber-producing region of the United States in area and volume (Haynes 2002). To meet demand for timber and fiber, southeastern pine plantation area increased from 810,000 ha during 1952 to 12 million ha by 1999 (Conner and Hartsell 2002, Prestemon and Abt 2002). In addition, intensive management of pine plantations can increase productivity and yield of southeastern plantations by up to 150% and shorten rotation lengths to less than 25 years (Wagner et al. 2004). Typical intensive stand establishment practices include herbicide use and mechanical treatments. The relatively recent development of multiple applications of several herbicide types broadcast over an entire stand may cause long-term vegetation suppression (Miller and Miller 2004).

Suppression of herbaceous vegetation and hardwoods through chemical and mechanical treatment can affect birds by altering structure, composition, and duration of early successional habitat (Lautenschlager 1993, Guynn et al. 2004, Miller and Miller 2004). Some herbicide release research shows reductions in avian abundance and richness (Savidge 1978, Santillo et al. 1989). Other studies of chemical and mechanical site preparation or release effects demonstrate few overall negative consequences for avifauna (Morrison and Meslow 1984, Kilgo et al. 2000). Instead, changes may be species-specific and subtle. For example, although relative abundance of males remained constant after mechanical or chemical release in spruce (*Picea*) plantations, Woodcock et al. (1997) recorded an increase in ratio of male to female birds captured in mist nets; males retained high site fidelity, but remained unmated.

Previous research in the Southeast investigating effects of pine plantation establishment on avian assemblages either used establishment techniques that are no longer current or produced equivocal results. However, chemical treatments may create habitat conditions that retain greater avian species abundance and richness than habitat created by mechanical treatments, likely due to tree retention. In east-central Mississippi loblolly pine (*Pinus taeda*) plantations less than 8 years old, habitat generated by herbicide site preparation supported greater bird diversity and abundance than mechanical site preparation areas during spring and winter (Darden 1980). Regression analysis indicated that snags had the greatest influence (40%) on species diversity. O'Connell and Miller (1994) documented greater bird diversity in hexazinone-prepared areas versus mechanically-prepared sites in South Carolina through 3 years post-treatment, but not through 5 years. Mihalco (2004) discerned few consistent differences in avian response to a stand establishment intensity gradient during 2 years post-treatment in eastern North Carolina. Plots with mechanical site preparation and a banded chemical release contained more neotropical migrants and Blue Grosbeaks (see Appendix 2.A for scientific names) than plots with herbicide site preparation with either banded or broadcast release during the second year.

Although young pine plantations provide early successional vegetation for wildlife, current intensive methods for pine plantation establishment may affect avian species differentially. The goal of this study was to explore breeding and wintering bird response to a wide spectrum of establishment intensities integrating mechanical and chemical site preparation and chemical release combinations in loblolly pine plantations. I monitored 5 establishment intensities on commercial pine plantations during years one through 5 post-establishment in Lower Coastal Plain Mississippi. I compared assemblage ordination, species richness, total bird abundance, individual species abundance, and 2 conservation metrics based on Partners in Flight (PIF) species assessment, a regionally important species score and total PIF score, among the 5 treatment intensities.

STUDY AREA

Mississippi has a humid, subtropical climate, with mild winters (240 frost-free days) and high annual precipitation (140 cm; Pettry 1977). Ultisols, acidic clays, mixed with sand sediments are prevalent (Pettry 1977, Martin and Boyce 1993). In Mississippi, 7.5 million hectares of forestlands cover over 62% of the state (Hartsell and London 1995). Approximately 2.5 million ha are softwoods, mostly loblolly pine, and 1.2 million hectares are pine plantations.

Study sites were 4 loblolly pine plantations in the lower Coastal Plain of Mississippi. These sites were owned and managed by Molpus Timberlands in Perry County, Plum Creek in George County, and Weyerhaeuser Company in Lamar County. All stands, averaging 66 ha, were previously loblolly or slash (*P. elliottii*) pine plantations harvested during summer 2000-winter 2001. Planting occurred during winter 2001-2002 with genetically-improved seedlings provided by each forest product industry cooperator. Tree spacing was 2.1 m between trees within a row and 3.0 m between rows, totaling 1,551 trees/ha. Two stands were machine planted and 2 stands were planted by hand because of greater logging debris loads. Banded herbaceous control treatments were applied with a band width of 1.5 m to every tree row, and broadcast herbicide applications were aerially applied. All treatments received a broadcast application of diammonium phosphate at 280 kg/ha during spring 2002.

Each site contained a randomized complete block, with 5 treatments that were at least 8 ha each per stand. Treatments levels incorporated a wide stand establishment intensity gradient. Establishment intensity, and thus anticipated vegetative alteration, increased from low for mechanical site preparation only and banded herbaceous release, MECH, to high for 2 years of broadcast herbaceous control following site preparation, BROAD2 (Table 2.1). Mechanical site preparation only, MECH, incorporated a combination plow to subsoil, disk, and bed, and a V-blade to clear debris during fall 2001, followed by a banded herbaceous control with 0.9 kg/ha of Oustar® (E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware; hexazinone and sulfometuron; 13 oz./acre) during spring 2002. Chemical site preparation only, CHEM, consisted of 2.4 L/ha Chopper® (BASF Corp., Research Triangle Park, North Carolina; imazapyr; 32 oz./acre), 3.5 L/ha Accord® (Dow AgroSciences LLC, Indianapolis, Indiana; glyphosate; 48 oz./acre), 3.5 L/ha Garlon 4 (Dow AgroSciences LLC, Indianapolis, Indiana; triclopyr; 48 oz./acre), and 1% Timberland 90® surfactant (UAP Timberland LLC, Monticello, Arkansas) during summer 2001 and the same banded herbaceous control as MECH. COMBO combined the mechanical and chemical site preparation of MECH and CHEM, along with the banded control. BROAD combined the same mechanical and chemical site preparation along with a single year of broadcast herbaceous control using 0.9 kg/ha of Oustar® during spring 2002. BROAD2 combined mechanical and chemical site preparation with the same broadcast herbaceous control during springs 2002 and 2003.

During 2004-2006, growth of pine trees by height averaged 1.36 m/yr across all treatments, however increasing treatment intensity increased height and diameter (Edwards 2004, P. Jones, Mississippi State University, unpublished data). CHEM had the lowest growth rate, while BROAD2 had the greatest, and the other treatments were intermediate. BROAD2 averaged 1.4 m taller and 2.4 cm greater in dbh than CHEM. Similarly, coverage of pine trees was associated with increased treatment intensity. Pine coverage was greatest in BROAD and BROAD2 and least in MECH and CHEM. Pine coverage increased in all treatments from 2004 to 2006. Coverage of understory herbaceous plants decreased with increasing intensity. BROAD2 averaged 65% of MECH. Coverage in all treatments declined from 85-125% during 2004 to 44-76% during 2006. Woody plant coverage, excluding pine trees, almost had a treatment effect ($F_{4,42} = 2.56$, $P = 0.053$), and coverage increased from 2004 to 2006. During 2002-2006, total vegetation generally was greatest in MECH and least in BROAD2, with COMBO, BROAD, and CHEM intermediate in vegetation coverage.

METHODS

Sampling

I surveyed breeding birds during mid-April through mid-June 2002-2006 with 10-minute point counts (Verner 1985). In each treatment, I established 3 point count stations as subsamples. Stations ranged from 150-230 m apart, and at least 50 m distant from treatment boundaries. Using a laser range finder to increase distance estimation accuracy when possible, I recorded birds within 75 m of the station. There were 3 survey repetitions during 2002 and 6 repetitions during 2003-2006 that occurred between sunrise and 1100 during optimal weather conditions (no rain or low cloud cover, and minimal wind and fog).

I also sampled 4 point count stations to a 75 m distance in each older stand surrounding treated stands 3 times per year during 2004-2005, to assess influence of nearby bird communities on treated plots. Tree composition at outside sampling points was heterogeneous, with 7 points in pre-thinned, closed canopy pine, 7 points in post-thinned open canopy pine, and 2 points in hardwoods.

I surveyed wintering birds during January-February of 2002-2006 with fixed width transects (Verner 1985). In each treatment, I established a transect ranging in length from 150-230 m, and walked transects at 1 minute per 15 m. I subsequently standardized bird abundance to shortest transect length. Transects were at least 50 m distant from treatment boundaries. I recorded birds that were within 30 m of each transect side, using a laser range finder to increase accuracy of distance estimation. I conducted 3-4 survey repetitions during 2002 and 6 repetitions during 2003-2006 that occurred between sunrise and 1000 hrs during conditions with no rain or low ceiling cloud cover, and minimal wind and fog.

Statistical Analyses

Inferential statistics.- - Partners in Flight formulated a system based on vulnerability factors to assess conservation status of North American bird species (Panjabi et al. 2005). Summation of vulnerability factor scores allows identification of priority species for physiographic regions. In general, species were of regional concern if they scored at least 14 in the revised version for breeding birds and 19 in the initial version for wintering birds. I calculated total PIF score by multiplying mean abundance of individual species by its PIF score and summing scores of all species across the entire treatment (Nuttle et al. 2003). The regionally important species score was similar, however, only the regionally important species were summed within a treatment.

I used a repeated measures, mixed model analysis of variance to test year effects, treatment effects, and year × treatment interactions for species richness, regionally important species score, total PIF score, total bird abundance, and individual species abundance (SAS Proc MIXED; SAS Institute 2002-2003). Year was a repeated measure and site was a random effect. Using least AIC_c (Akaike's Information Criterion corrected for small sample size) value, I selected the covariance structure with the best fit from autoregressive, compound symmetry, autoregressive heterogeneous, and compound symmetry heterogeneous (Gutzwiller and Riffell 2007). I then assessed model fit with and without the random statement, and retained site location (i.e., the random statement) based on lesser AIC_c value. I examined residuals and used either square root transformations or a change in covariance structure to improve model fit. I used the kenwardroger adjustment in denominator degrees of freedom for repeated measures and small sample sizes (Gutzwiller and Riffell 2007, Littell et al. 2006). I compared means with the LSMEANS PDIFF option. Differences were considered significant when $P \leq 0.05$.

Data analysis incorporated means of repetition, site, and during spring, point count stations. To present larger numerical values, table values equal bird abundance per 1 km transect length during winter and total of all point count stations per treatment during spring. In addition, 2 species present during spring, Palm Warbler and Sedge

Wren, were late spring migrants rather than breeding birds. These species plus Killdeer did not have PIF breeding scores, and thus I did not include them in the spring PIF conservation metrics. Likewise, for the winter, I excluded Hooded Warbler from PIF conservation metrics. I used Program Distance (Thomas et al. 2006) for species with greater than 40 observations per year in each treatment (Buckland et al. 2001), to determine if detectability remained similar among treatments, despite dynamic changes in vegetation. I chose model types based on lowest AIC value.

Assemblage ordination.- - Nonmetric multidimensional scaling (NMS) presents a graphical representation of community relationships through ordination (McCune and Grace 2002). Ordination places species composition along axes, using a dissimilarity matrix. Distance between points, or treatments for this analysis, in the ordination scatter plot represents degree of similarity. Stress is a measure of distance between original space and ordination space. There is greater stress when points depart from a monotonic line, that is, when there is plot dissimilarity of ordination space vs. original space. Stress should be less than 15 (McCune and Grace 2002). Monte Carlo tests compare real data stress with randomly re-arranged data. Small *P*-values signify stronger patterns than expected by chance alone.

To examine ordinal spacing among treatments, I converted bird sampling data with a square root transformation, so that abundant species did not dominate analysis. With PC-ORD version 4, I selected the Sorensen/Bray-Curtis distance measure for the NMS (Kruskal 1964, Mather 1976, McCune and Mefford 1999). I chose a 6-dimensional solution, stepping down to 1-dimensional solution, instability criterion of 0.0001, 500 iterations, 50 runs with real data and 50 runs with randomized data for Monte Carlo significance tests, and a random starting configuration. Then, after examining various dimensions, I re-ran the NMS with the recommended number of dimensions, using the saved starting configuration for *n* dimensions, no dimensionality step-down, and one real run.

RESULTS

Breeding Birds

Species richness had treatment and year effects ($F_{4,11.8} = 17.57$, $P < 0.001$; $F_{4,26.1} = 13.62$, $P < 0.001$). Total PIF score ($F_{16,60} = 3.61$, $P < 0.001$), regionally important species score ($F_{16,35} = 4.29$, $P < 0.001$), and total bird abundance ($F_{16,33.5} = 4.77$, $P < 0.001$) all showed year × treatment interactions (Table 2.2). These 4 metrics were greatest in CHEM treatments during all years. Values overall decreased with increasing intensity, however it is possible to evaluate specific site preparation effects on avian richness and abundance, given that MECH, CHEM, and COMBO received a different site preparation while sharing the same release. Likewise, release effects on birds can be extracted from COMBO, BROAD, and BROAD2, which had the same site preparation but received an increasing intensity of herbicide release. Site preparation and release type influenced species richness, total PIF score, regionally important species score, and total bird abundance. Banded release treatments generally had greater values than broadcast release treatments, as over time the 2 banded release mechanical treatments separated from the broadcast release mechanical treatments. Species richness peaked during the middle years, and was least during 2002. The low species richness during the first year may have been due, in part, to lesser sampling intensity, however species richness during

2002 still had significantly fewer species when compared to 3 repetitions during the other years.

I detected 46 species during springs of 2002-2006 (Table 2.3). Of the 46 species, 6 species had a treatment effect, 7 species had treatment and year effects, 9 species had a year × treatment interaction, and 4 species had year effects only. On the whole, species abundance was greatest in CHEM and the other treatments maintained similar abundance. However, for 8 species, abundance generally declined within mechanically prepared treatments as herbicide intensity increased.

Treatment type influenced abundance of Brown Thrasher ($F_{4,38} = 10.12$, $P < 0.001$), Carolina Chickadee ($F_{4,37.3} = 3.46$, $P = 0.017$), Carolina Wren ($F_{4,16.8} = 3.04$, $P = 0.047$), Downy Woodpecker($F_{4,23.3} = 6.17$, $P = 0.002$), Great Crested Flycatcher ($F_{4,15.4} = 7.19$, $P = 0.002$), and Red-bellied Woodpecker ($F_{4,15.9} = 4.16$, $P = 0.017$), with greatest abundance in CHEM and similar abundance in the remaining treatments (see Appendix 2.A for scientific names). Treatment and year affected Eastern Kingbird ($F_{4,21} = 3.80$, $P = 0.018$; $F_{4,54.8} = 9.23$, $P < 0.001$), Eastern Towhee ($F_{4,14.8} = 4.80$, $P = 0.011$; $F_{4,34.4} = 26.73$, $P < 0.001$), Indigo Bunting ($F_{4,23.8} = 3.56$, $P = 0.021$; $F_{4,58.6} = 21.18$, $P < 0.001$), Northern Cardinal ($F_{4,20.1} = 3.33$, $P = 0.030$; $F_{4,31.1} = 3.89$, $P = 0.011$), Orchard Oriole ($F_{4,17.9} = 6.57$, $P = 0.002$; $F_{4,27.3} = 3.95$, $P = 0.012$), Prairie Warbler ($F_{4,15.6} = 6.86$, $P = 0.002$; $F_{4,32} = 49.52$, $P < 0.001$), and Ruby-throated Hummingbird ($F_{4,29.6} = 4.17$, $P = 0.009$; $F_{4,56.1} = 2.68$, $P = 0.041$). CHEM treatments generally had greatest abundance of these species. Eastern Towhees, Indigo Buntings, and Prairie Warblers demonstrated separation among treatments, decreasing in abundance with increasing treatment intensity. Eastern Towhees were more numerous in single site preparation treatments than combination site preparation. As for year effects, Eastern Kingbirds declined from 2003 to 2006. Although Eastern Towhees, Indigo Buntings, Orchard Orioles, and Prairie Warblers were more numerous during the middle years, particularly 2004, they were present throughout the study period. Ruby-throated Hummingbirds were present during 2003 and 2006. Northern Cardinal populations fluctuated over time.

Abundance of Brown-headed Nuthatch ($F_{16,61.7} = 2.97$, $P = 0.001$), Common Yellowthroat ($F_{16,57.7} = 1.85$, $P = 0.046$), Field Sparrow ($F_{16,59.9} = 6.61$, $P < 0.001$), Hooded Warbler ($F_{16,39.6} = 2.71$, $P = 0.006$), Mourning Dove ($F_{16,37.2} = 2.02$, $P = 0.038$), Northern Flicker ($F_{16,61.4} = 2.92$, $P = 0.001$), Red-headed Woodpecker ($F_{16,51.1} = 6.69$, $P < 0.001$), White-eyed Vireo ($F_{16,54.9} = 3.07$, $P = 0.001$), and Yellow-breasted Chat ($F_{16,32.6} = 2.36$, $P = 0.018$) had varying treatment effects over time. Although for most species, abundance simply was greatest in CHEM treatments during years with treatment effects, there was a range of site preparation and release effects for 5 species. Abundance of Common Yellowthroats was greater in single site preparation treatments than sites receiving broadcast release treatment during 2003 and 2004, but during 2006, all treatments exhibited greater abundance than BROAD2 treatments. Field Sparrows decreased with increasing treatment intensity during 2003. Field Sparrows were most abundant in CHEM treatments and also more numerous in banded release treatments than broadcast release treatments. There were more Hooded Warblers in either site preparation alone versus combination of mechanical and chemical site preparation during 2006. White-eyed Vireo abundance decreased with increasing intensity during 2005, and the following year abundance in MECH and CHEM separated from the combination site preparation treatments. Conversely, there were more Yellow-breasted Chats during 2004 in all treatments except for the greatest intensity treatment, and during 2005, there were more chats in the lesser intensity treatments.

Species affected by year alone included Blue Grosbeak ($F_{4,30.7} = 5.85$, $P < 0.001$), Eastern Bluebird ($F_{4,45.4} = 4.50$, $P = 0.002$), Gray Catbird ($F_{4,26.2} = 2.98$, $P = 0.037$), and Northern Mockingbird ($F_{4,25.3} = 14.66$, $P = 0.001$). Blue Grosbeaks were more common during 2003 and 2004. Eastern Bluebird and Northern Mockingbird abundance diminished after 2002-2003, whereas Gray Catbird numbers increased during the study.

Only Indigo Bunting during spring 2004 had the necessary number of observations in each treatment to meet the adequate minimum of 40 for Program Distance (Buckland et al. 2001). Detection probabilities for uniform models ranged from 0.41 in MECH to 0.59 in COMBO and BROAD, and coefficient of variation varied from 10 to 79%. Although this was one species during one year, detection probabilities indicated that detectability was similar enough among treatments to not influence treatment differences.

Wintering Birds

Species richness had a year × treatment interaction (Table 2.4; $F_{16,60} = 28.96$, $P =$ 0.012). Species richness was greatest in CHEM compared to the other treatments during all years. During 2003-2005, all other treatments contained similar species richness, but species richness diverged during 2006, decreasing with increasing treatment intensity. Total PIF score ($F_{4,23.2} = 12.06$, $P < 0.001$; $F_{4,57.4} = 8.13$, $P < 0.001$), regionally important species score ($F_{4,}$ 21.3 $= 4.24$, $P = 0.011$; $F_{4,29.9} = 9.92$, $P < 0.001$), and total bird abundance ($F_{4,18.1} = 9.52$, $P < 0.001$; $F_{4,54.7} = 14.54$, $P < 0.001$) differed by treatment and year, however all were greatest in CHEM treatments.

I detected 45 species during winters 2002-2006 (Table 2.5). Species abundance tended to be greatest in CHEM treatments. In general, abundance in the other treatments either was equally low or showed treatment separation as intensity increased. Of the 45 species, 2 species exhibited treatment and year effects, 6 species exhibited a year × treatment interaction, and 9 species exhibited year effects only.

Species with treatment and year effects had greatest abundance in CHEM treatments: Carolina Chickadees ($F_{4, 33.1} = 9.13$, $P < 0.001$; $F_{4, 27.9} = 4.00$, $P = 0.011$) and Carolina Wren ($F_{4,15} = 5.22$, $P = 0.008$; $F_{4,60} = 5.26$, $P = 0.001$). Carolina Chickadee abundance increased over time. Carolina Wrens were absent during 2002, but were present during the rest of the study. For year × treatment interactions, Northern Cardinals ($F_{16,55.2} = 2.37$, $P = 0.009$) and Red-bellied Woodpeckers ($F_{16,37.1} = 2.01$, $P = 0.040$) typically had their greatest abundance in CHEM treatments during all years with treatment effects. Common Yellowthroats ($F_{16,60.4} = 1.93$, $P = 0.035$) had greater abundance in the lesser intensity treatments during 2004, and abundance decreased with increasing intensity. During 2005, Common Yellowthroat abundance was greatest in MECH treatments. Although Eastern Towhees ($F_{16,60} = 3.04$, $P = 0.001$) were most numerous in CHEM treatments, towhee abundance in MECH separated from the combination site preparation treatments over time. Ruby-crowned Kinglets ($F_{16,55.7} = 2.20$, $P = 0.016$) were most common in CHEM treatments during 2006, but were equally abundant in all treatments except BROAD2 during 2005. Song Sparrows ($F_{16,60} = 3.77$, P

< 0.001) were more numerous in CHEM and MECH treatments during 2003, and abundance of these sparrows declined with increasing intensity.

Year influenced American Woodcock ($F_{4,42.1} = 2.86$, $P = 0.035$), Dark-eyed Junco ($F_{4,60.5} = 3.84$, $P = 0.008$), Eastern Bluebird ($F_{4,27.9} = 3.86$, $P = 0.013$), Eastern Phoebe ($F_{4,57.6} = 2.98$, $P = 0.026$), Field Sparrow ($F_{4,60.8} = 4.61$, $P = 0.003$), Sedge Wren ($F_{4,61.9} = 7.80$, $P < 0.001$), Swamp Sparrow ($F_{4,60} = 6.20$, $P < 0.001$), Winter Wren ($F_{4,60} = 5.19$, $P = 0.001$), and Yellow-rumped Warbler ($F_{4,28.6} = 16.03$, $P < 0.001$). Dark-eyed Juncos were present during years 2003 and 2004, Sedge Wrens were present after 2003, American Woodcocks were present after 2004, and Winter Wrens were present during 2003 and 2006. Eastern Bluebirds and Eastern Phoebes were more common during initial years, whereas Field Sparrows peaked in the middle years, and Swamp Sparrows increased over time. Yellow-rumped Warbler abundance fluctuated throughout the study period.

Assemblage Ordination

The simplest relationships were in breeding season data that included information from point count stations in older plantations surrounding study sites during 2004-2005 (Figure 2.1; note each point designates treatment type followed by year, either 04 or 05). There were 45 bird species. The Monte Carlo test *P*-value was 0.02 for a 1-dimensional solution. Final stress was 7.95 and final instability was 0.0056 for 500 iterations. The coefficient of determination for correlations between ordination distances and distances in the original n-dimensional space was 0.940. There was a well-established pattern created by the treatment intensity gradient: BROAD2, BROAD, COMBO, MECH, CHEM, and lastly the outside points (OUT). The outside points were most dissimilar from other treatments, followed by CHEM. There was a similar pattern between years, as evidenced by repetition of the same treatment in the figure.

Spring 2002-2006 treatment relationships were more complex (Figure 2.2), with ordination required a 2-dimensional final solution. The Monte Carlo test *P*-value was 0.02, final stress was 6.06, and final instability was 0.0053 for 500 iterations. Coefficient of determination was 0.62 for axis 1 and 0.34 for axis 2, a cumulative total of 0.96. There were 46 bird species. Over time, treatments funneled from a dispersed pattern to a clustered pattern, therefore becoming more similar. The pattern was CHEM, MECH, COMBO, BROAD, and BROAD2. CHEM remained most internally consistent over the study period, whereas the other treatments became more similar to CHEM during the first 3 years. The 2 broadcast treatments, BROAD and BROAD2, remained dissimilar from CHEM.

Winter 2002-2006 treatment relationships were dynamic, particularly among years (Figure 2.3). There were 45 species present. Ordination used a 3-dimensional final solution. The Monte Carlo test *P*-value was 0.02, final stress was 11.09, and final instability was 0.0268 for 500 iterations. The coefficient of determination was 0.09 for axis 1, 0.45 for axis 2, and 0.34 for axis 3, cumulative total of 0.88. Because axis 1 was relatively weak, I presented only the second and third axes. For the first 2 years (2002-2003), treatments were very dissimilar, whereas in the last 3 years (2004-2006), there was less movement as treatments stabilized. Coordinates for CHEM were more tightly grouped over the years, indicating greater consistency. MECH and COMBO treatments were most similar within the same year. The other treatments appeared to be lagging behind the trajectory of CHEM. There may be a BROAD2, BROAD/COMBO/MECH cluster, CHEM pattern establishing, but the bird assemblages continued to fluctuate.

DISCUSSION

Breeding Birds

The greater species richness and total bird abundance in CHEM corresponded with Darden's (1980) Mississippi loblolly site preparation study, which documented greater avian diversity and abundance in areas of herbicide-only treatments than mechanically-treated areas. O'Connell and Miller (1994) also recorded greater diversity, but not abundance, in chemically-prepared sites compared to mechanically-prepared sites through 3 years post-treatment. However, treatment effects disappeared after 5 years, unlike in this study. Mihalco (2004) found no richness and total abundance differences between chemically and mechanically-prepared sites in eastern North Carolina.

Assemblage ordination produced a CHEM, MECH, COMBO, BROAD, and BROAD2 gradient, thus complementing expected treatment intensity gradient and community metrics. Furthermore, MECH and COMBO merged in space, which reinforces results from statistical metrics. However, the ordination pattern revealed that the treatments overall were becoming more similar, which was not apparent from the inferential statistical results.

O'Connell and Miller (1994) detected differences for only 6 avian species when comparing chemical and mechanical site preparation. This study shared 3 of these species, and for both studies, Mourning Dove and Carolina Wren abundance was greater in the chemical treatment. Yellow-breasted Chats were more common in the mechanical treatment for O'Connell and Miller (1994), whereas this species was more common in the lesser intensity treatments in this study. Again, differences for O'Connell and Miller (1994) did not persist past 3 years, whereas the treatment effects continue through 5 years in this study. My species-specific findings differed from those of Mihalco (2004), who found treatment differences in Blue Grosbeaks, whereas I found only a suggestion of a treatment difference. Similarly to this study, greater species diversity in Darden's (1980) herbicide-only treatment meant that some species, such as Brown-headed Nuthatch and Great Crested Flycatcher, were present only in that area.

Contrary to the intended intensity continuum, in which stand establishment would produce a range in vegetation suppression and consequently in avian abundance, there was complete partitioning of CHEM from the other treatments for more than half of affected species. This may be due to presence of leave trees in non-mechanical treatments, as mechanical site preparation virtually eliminates residual trees. Residual trees add an attractive stand element, particularly for birds that use trees as their primary substrate. In this study, residual trees explain the presence of tree foragers, including Brown-headed Nuthatch, Carolina Chickadee, Downy Woodpecker, and Red-bellied Woodpecker, in CHEM compared to all other treatments. Brown Thrashers, Eastern Kingbirds, Great Crested Flycatchers, Mourning Doves, Northern Cardinals, Northern Flickers, Orchard Orioles, Red-headed Woodpeckers, and Ruby-throated Hummingbirds also may benefit by tree presence (Mirarchi and Baskett 1994, Moore 1995, Robinson et al. 1996, Scharf and Kren 1996, Halkin and Linville 1999, Cavitt and Haas 2000, and Smith et al. 2000). Carolina Wren abundance in CHEM treatments did not completely separate from the other banded release treatments, and this species may select scattered trees and dense brushy cover (Haggarty and Morton 1995).

Other researchers have recognized the importance of residual tree presence for avian assemblages during intensive stand establishment. Darden (1980) found that residents typical of more mature stands were present only in the chemical treatments, and determined that snags were a contributing factor to greater species diversity. The ordination of treatments with surrounding plantations showed that CHEM treatments were more similar to older stands than the other treatments in terms of avian assemblages of older stands. O'Connell and Miller (1994) noted that presence or absence of structural elements, such as snags, probably created differences in avian diversity on sites treated with either chemical or mechanical site preparation. For example, 3 woodpecker species were present only in the hexazinone treatments. Brooks et al. (1994) attributed the greater abundance of forest birds in one treatment to the number of snags left after harvest, when comparing plots treated with different herbicide types.

Species that exhibited an abundance gradient congruent with intensity were more likely to be responding to vegetation suppression resulting from intensive vegetation control. Species most common in CHEM or MECH treatments, including Common Yellowthroat, Eastern Towhee, Field Sparrow, Hooded Warbler, Indigo Bunting, Prairie Warbler, White-eyed Vireo, and Yellow-breasted Chat inhabit dense, low growing, shrubby vegetation (Payne 1992, Carey et al. 1994, Ogden and Stutchbury 1994, Hopp et al. 1995, Greenlaw 1996, Guzy and Ritchison 1999, Nolan et al. 1999, Eckerle and Thompson 2001).

While treatment differences affected 6 species during winter and spring, there were 7 species present during both seasons that displayed only spring treatment effects. During spring, Brown-headed Nuthatch, Brown Thrasher, Downy Woodpecker, Field Sparrow, Mourning Dove, and Northern Flicker abundance was greatest in CHEM treatments, while White-eyed Vireos tended to be most numerous in the 2 lesser intensity treatments. One possible explanation is that sampling intensity was greater during spring than winter, resulting in more detections, particularly for species that primarily may be using treatments for foraging, such as Brown-headed Nuthatch, Downy Woodpecker, and Northern Flicker. Interestingly, a cavity nesting bird, Eastern Bluebird, which definitively nested within treatments, exhibited no treatment differences. For other species, breeding requirements may restrict habitat selection to areas with perches for song and display and appropriate nest site characteristics. Nest sites that are located in or near trees or else in thick, brushy vegetation, may account for greater Brown Thrasher, Field Sparrow, Mourning Dove, and White-eyed Vireo abundance in lesser intensity treatments during breeding season. Moreover, it is possible that invertebrate abundance was greater in CHEM and MECH, due to increased vertical heterogeneity and horizontal density, and thus these treatments would provide more food during breeding season. Red-headed Woodpecker abundance differed among treatments during spring; however this woodpecker was not detected during winter, even though they are present year-round in southern Mississippi (Smith et al. 2000). Red-headed Woodpeckers have a winter diet of hard mast (Smith et al. 2000), which is not readily available in the study sites.

Wintering Birds

Few studies have explored site preparation and release treatment effects on wintering birds. Darden (1980) found that herbicide site preparation resulted in greater avian abundance and diversity than did mechanically-prepared areas. Brooks et al. (1994) did not detect any differences among sites prepared with varying herbicide types. In this study, spring and winter results were similar, albeit with alternative species. CHEM treatments had greatest species richness, total bird abundance, and conservation metrics throughout the study period. During 2006, species richness among treatments differentiated by stand establishment intensity, demonstrating a complete continuum. Despite variation over time, toward the end of the study period, assemblage ordination illustrated that CHEM and BROAD2 treatments were most distant, whereas MECH, COMBO, and BROAD were comparable and intermediate between 2 isolated extremes. This agreed reasonably well with the inferential statistics.

Three species exhibited a simple pattern of increased abundance in CHEM. The distinctive division of CHEM from the other treatments probably was due to tree retention, an uncontrolled side effect of herbicide-only treatments. This would explain presence of birds associated with trees, including Carolina Chickadees and Red-bellied Woodpeckers. Carolina Wrens, in addition, may select open tree canopy or scattered trees (Haggarty and Morton 1995). Moreover, 4 species (American Woodcock, Downy Woodpeckers, Sedge Wren, Yellow-rumped Warbler) were most common in CHEM treatments although detected abundance for these species did not differ at the 0.05 significance level. Different analyses or a study design that yielded a larger sample size could have potentially detected a treatment effect at the 0.05 significance level for abundance of these species. Nevertheless, 5 other species varied with the intensity gradient. Bird species with abundance levels that decreased with intensity probably were reacting to vegetation density control by site preparation and release. This trend occurred with Common Yellowthroats, Eastern Towhees, and Song Sparrows, which often occupy thick, shrubby vegetation (Greenlaw 1996, Guzy and Ritchison 1999, Arcese et al. 2002).

MANAGEMENT IMPLICATIONS

For spring and winter bird species, the primary habitat feature that influenced bird abundance appeared to be residual trees. Moreover, herbicide-only treatments might have separated even further from the other treatments if all 4 sites had residual trees, yet only 3 of the 4 sites contained trees after harvesting. Tree retention may have been more beneficial than the vegetation characteristics resulting from intensive stand establishment, although certainly dense, shrubby vegetation determined abundance of some species. It was not possible with the experimental design of the study to definitively differentiate between relative impact of residual trees and vegetation structure, or determine if there was a synergistic effect. However, models of vegetation variables that predicted bird abundance (see chapter 3) tended to match results from this study. That is, residual trees occurred as a model variable for species that had greatest abundance in CHEM treatments, and a mixture of variables were present in models for species that varied in abundance with the intensity spectrum.

CHEM treatments also supported greater species richness and assemblages with greater PIF values. Partners in Flight confers a greater conservation score to declining species (e.g. Prairie Warbler) than abundant increasing bird species (e.g. American

Robin) or common birds that are detrimental to other species (e.g. Brown-headed Cowbird). Thus, metrics based on avian conservation status are more informative than simple, unweighted species richness. Bird assemblage composition that includes declining species may be more important than overall abundance of common species for management assessment.

This study occurred on a relatively small spatial scale, but results do not appear to be short-lived. After 5 years, avian metrics in treatments remained different. Variation in stand establishment intensity produced significant differences for 24 out of 65 bird species. Although stand establishment effects should be minimal after all treatments reach canopy closure, clearly establishment intensity had significant long term effects on avian assemblages.

The southeastern United States has an ideal climate for producing wood fiber. Managed forests nevertheless can contribute to wildlife, particularly compared with other land uses. Fortunately, no matter how intensely established, minor modifications can enhance habitat for birds. Young pine plantations provide early successional habitat, but the habitat quality and length of suitability may differ due to site preparation and release methods, which can simplify vegetation structure and composition. Short rotations of approximately 25 years can prevent development of mature forest characteristics, such as snags (Harlow and Guynn 1983, McComb et al. 1986, Moorman et al. 1999), however trees retained after harvest can integrate vertical structure and complexity into regenerating stands (Franklin et al. 1997). Regenerating stands with residual trees may provide a partial habitat substitute for bird species associated with mature, open forests (Baker and Hunter 2002), and thereby tree retention can enrich avian assemblages in young, intensively established pine plantations. Trees are attractive to a variety of songbirds for perching, singing, and mating display posts, and feeding and nesting opportunities. Another option includes wider initial spacing of pine seedlings within and between rows to offset rapid canopy closure. This will delay crop trees shading out understory vegetation, thus maintaining dense herbaceous and shrubby vegetation for a greater length of time. Alternatively, applications of chemicals banded along the pine tree rows instead of broadcast over the site can provide for avian species that use dense vegetation.

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Table 2.1. Five stand establishment treatments varying from low (MECH) to high (BROAD2) intensity in the Mississippi Lower Coastal Plain.

	Treatment				
	MECH	CHEM	COMBO	BROAD	BROAD2
Site Preparation	Mechanical	Chemical	Mechanical and Chemical	Mechanical and Chemical	Mechanical and Chemical
Release	Banded - 2002	Banded - 2002	Banded - 2002	Broadcast - 2002 & 2003	Broadcast - 2002 & 2003

Table 2.2. Avifauna species richness, total Partners in Flight (PIF) score[a], regionally important species score[a], and total bird abundance[a] for 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[b] during years 1-5 post-treatment (April - June 2002 - 2006) in the Mississippi Lower Coastal Plain[c].

	Treatment																	
	MECH[d]			CHEM[e]			COMBO[f]			BROAD[g]			BROAD2[h]			*P* -value		
	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	Yr	Trt	Yr*Trt
Species Richness																		
2002	6.5		2.1	14.5		3.4	5.5		1.8	4.8		1.7	4.0		1.7			
2003	10.8		1.2	19.8		2.4	10.3		1.2	10.5		1.3	8.5		1.8			
2004	12.5		1.0	20.5		3.9	10.3		1.8	9.3		1.8	7.5		1.9			
2005	10.0		1.1	19.0		2.2	10.8		0.9	8.8		1.0	7.3		1.7			
2006	10.5		0.9	14.0		1.8	10.5		0.9	8.3		0.8	7.0		0.9			
Combined	10.1	A	0.7	17.6	B	1.3	9.5	A	0.7	8.3	AC	0.7	6.9	C	0.7	< 0.001	< 0.001	0.300
Total PIF Score																		
2002	69.4		35.6	200.6		27.0	70.5		23.3	60.0		21.5	42.9		20.3		0.067	
2003	358.3	A	43.4	626.8	B	107.7	266.9	AC	60.1	184.8	CD	20.4	109.8	D	32.5		< 0.001	
2004	487.3	A	33.6	751.6	B	92.8	406.6	AC	52.9	303.8	CD	57.2	216.2	D	61.6		< 0.001	
2005	387.8	A	46.7	616.7	B	66.8	364.5	A	18.8	237.5	C	36.7	160.0	C	49.3		< 0.001	
2006	421.3	A	54.0	582.0	B	72.4	410.2	A	35.7	260.0	C	53.1	169.0	C	53.2		< 0.001	< 0.001
Regionally Important Species Score																		
2002	28.8	A	12.9	117.9	B	19.7	35.0	A	9.4	13.2	A	11.5	13.6	A	7.9		< 0.001	
2003	222.9	A	23.8	382.0	B	64.3	152.0	AC	24.4	103.2	C	21.5	57.3	C	21.2		< 0.001	
2004	297.0	A	13.3	474.8	B	53.3	260.6	AC	38.0	186.0	C	19.4	160.7	D	38.7		< 0.001	
2005	225.7	A	20.7	398.1	B	32.6	209.3	AC	16.4	145.3	C	10.8	105.9	D	25.5		< 0.001	
2006	227.1	A	15.9	353.4	B	49.2	214.6	AC	21.8	138.1	C	19.1	100.3	D	22.5		< 0.001	< 0.001
Total Bird Abundance																		
2002	5.3	A	2.7	15.0	B	1.7	5.5	A	1.8	4.9	A	1.7	3.4	A	1.5		< 0.001	
2003	25.5	A	3.2	45.5	B	7.8	19.8	AC	4.6	13.8	AC	1.5	8.3	C	2.4		< 0.001	
2004	33.9	A	2.7	53.4	B	7.2	28.3	AC	3.8	21.6	CD	4.3	15.0	D	4.4		< 0.001	
2005	27.3	A	3.5	43.5	B	5.3	26.0	A	1.3	17.0	C	2.8	11.1	C	3.4		< 0.001	
2006	30.6	A	4.5	41.5	B	5.7	29.7	A	2.8	18.9	C	4.1	12.1	C	3.9		< 0.001	< 0.001

Table 2.2. Continued

[a] total PIF score = $\sum$ (mean abundance of all species in a treatment * Partners in Flight priority score)
regionally important species score = $\sum$ (mean abundance of species with Partners in Flight score $\geq$ 19 in a treatment * Partners in Flight priority score)
total bird abundance = mean total number of birds

[b] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[c] Values within rows followed by the same letter do not differ ($P > 0.05$); values are point count station totals averaged across repetitions and sites

[d] Within-treatment year effect ($P < 0.001$): Total PIF Score, Regionally Important Species Score, Total Bird Abundance

[e] Within-treatment year effect ($P < 0.001$): Total PIF Score, Regionally Important Species Score, Total Bird Abundance

[f] Within-treatment year effect ($P < 0.001$): Total PIF Score, Regionally Important Species Score, Total Bird Abundance

[g] Within-treatment year effect ($P < 0.001$): Total PIF Score, Regionally Important Species Score, Total Bird Abundance

[h] Within-treatment year effect ($P < 0.001$): Regionally Important Species Score; ($P < 0.01$): Total PIF Score, Total Bird Abundance

Table 2.3. Bird species abundance for 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] during years 1-5 post-treatment (April - June 2002 - 2006) in the Mississippi Lower Coastal Plain[b].

	Treatment										*P* -value		
	MECH[c]		CHEM[d]		COMBO[e]		BROAD[f]		BROAD2				
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Yr	Trt	Yr*Trt
American Crow													
2002	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.4	0.2			
2004	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.142	0.558	0.198
Barn Swallow													
2002	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.1			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.141	0.544	0.680
Black Vulture													
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	0.0			
2006	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.399	0.336	0.438
Blue-gray Gnatcatcher													
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2004	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.423	0.413	0.485
Blue Grosbeak													
2002	0.2	0.1	0.2	0.1	0.4	0.2	0.6	0.2	0.0	0.0			
2003	1.7	0.5	1.9	0.4	3.3	0.8	1.2	0.3	0.6	0.2			
2004	0.6	0.3	1.7	0.8	0.8	0.4	0.3	0.1	0.1	0.1			
2005	0.0	0.0	0.4	0.2	0.5	0.2	0.3	0.3	0.2	0.1			
2006	0.0	0.0	1.2	0.5	0.8	0.5	0.2	0.2	0.3	0.1	0.001	0.094	0.225

Table 2.3. Continued

Blue Jay																		
2002	0.3		0.2	0.5		0.3	0.0		0.0	0.0		0.0	0.1		0.1			
2003	0.1		0.1	0.5		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.335	0.139	0.369
Brown-headed Cowbird																		
2002	0.0		0.0	0.2		0.1	0.0		0.0	0.1		0.1	0.0		0.0			
2003	0.0		0.0	0.8		0.3	0.0		0.0	0.1		0.1	0.0		0.0			
2004	0.3		0.1	1.0		0.3	0.2		0.1	0.3		0.2	0.3		0.3			
2005	0.3		0.1	0.7		0.3	0.3		0.2	0.3		0.1	0.0		0.0			
2006	0.9		0.3	0.3		0.3	0.6		0.3	0.4		0.2	0.1		0.1	0.152	0.173	0.898
Brown-headed Nuthatch																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2005	0.0	A	0.0	0.2	B	0.1	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0		< 0.001	
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	0.001
Brown Thrasher																		
2002	0.2		0.1	0.6		0.2	0.0		0.0	0.1		0.1	0.0		0.0			
2003	0.0		0.0	1.0		0.5	0.0		0.0	0.1		0.1	0.0		0.0			
2004	0.4		0.2	1.3		0.4	0.5		0.3	0.3		0.2	0.5		0.3			
2005	0.4		0.3	0.5		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.4		0.2	0.1		0.1	0.1		0.1	0.0		0.0			
Combined	0.2	A	0.1	0.8	B	0.1	0.1	A	0.1	0.1	A	0.1	0.1	A	0.1	0.079	< 0.001	0.938
Carolina Chickadee																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.7		0.3	0.1		0.1	0.0		0.0	0.1		0.1			
2004	0.4		0.2	1.6		0.7	0.0		0.0	0.0		0.0	0.2		0.2			
2005	0.3		0.2	0.5		0.2	0.2		0.2	0.1		0.1	0.3		0.1			
2006	0.1		0.1	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
Combined	0.2	A	0.1	0.6	B	0.2	0.1	A	0.0	0.0	A	0.0	0.1	A	0.0	0.149	0.017	0.639
Carolina Wren																		
2002	0.3		0.3	0.4		0.2	0.1		0.1	0.3		0.2	0.1		0.1			
2003	1.6		0.5	1.2		0.4	1.8		0.6	0.5		0.2	0.1		0.1			
2004	0.2		0.1	0.8		0.3	0.3		0.2	0.1		0.1	0.1		0.1			
2005	0.1		0.1	1.0		0.6	0.2		0.1	0.0		0.0	0.1		0.1			
2006	0.3		0.1	0.7		0.3	0.2		0.1	0.0		0.0	0.0		0.0			
Combined	0.5	AB	0.1	0.8	B	0.2	0.5	AB	0.2	0.2	A	0.1	0.1	A	0.0	0.065	0.047	0.917

Table 2.3. Continued

Chipping Sparrow																		
2002	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.4		0.2	0.2		0.1	0.2		0.1	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.071	0.051	0.589
Common Ground Dove																		
2002	0.0		0.0	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.3		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0	0.909	0.298	0.782
Common Nighthawk																		
2002	0.0		0.0	0.1		0.1	0.0		0.0	0.1		0.1	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.138	0.543	0.774
Common Yellowthroat																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	2.4	A	0.3	3.4	A	0.8	1.5	AB	0.5	0.2	B	0.1	0.1	B	0.1		0.004	
2004	4.7	A	0.6	4.8	A	0.5	3.5	AB	0.8	2.0	BC	0.6	1.5	C	0.4		0.002	
2005	3.6		0.7	3.6		0.5	4.7		0.9	3.3		0.9	1.7		0.5		0.057	
2006	5.6	A	0.9	5.4	A	0.7	4.8	A	0.6	3.9	A	1.0	1.3	B	0.3		< 0.001	0.046
Downy Woodpecker																		
2002	0.0		0.0	0.2		0.1	0.0		0.0	0.0		0.0	0.1		0.1			
2003	0.0		0.0	0.5		0.2	0.0		0.0	0.0		0.0	0.1		0.1			
2004	0.0		0.0	0.7		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.5		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
Combined	0.0	A	0.0	0.4	B	0.1	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0	0.306	0.002	0.204
Eastern Bluebird																		
2002	0.4		0.3	1.5		0.7	0.2		0.2	0.8		0.4	0.7		0.3			
2003	0.1		0.1	1.8		0.4	1.0		0.4	1.0		0.3	1.4		0.4			
2004	0.0		0.0	1.5		0.6	0.1		0.1	0.0		0.0	0.1		0.1			
2005	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.004	0.262	0.748

Table 2.3. Continued

Eastern Kingbird																		
2002	0.3		0.2	1.0		0.3	0.3		0.3	0.4		0.3	0.0		0.0			
2003	1.8		0.5	2.1		0.8	1.0		0.3	0.6		0.2	0.8		0.2			
2004	0.0		0.0	0.9		0.4	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.8		0.4	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
Combined	0.4	A	0.1	1.0	B	0.2	0.3	A	0.1	0.2	A	0.1	0.2	A	0.1	< 0.001	0.018	0.609
Eastern Towhee																		
2002	0.3		0.2	0.8		0.4	0.0		0.0	0.0		0.0	0.1		0.1			
2003	2.0		0.4	3.6		0.7	0.8		0.4	0.8		0.2	0.4		0.2			
2004	5.2		0.9	4.6		1.0	2.6		0.5	1.9		0.5	1.0		0.4			
2005	2.6		0.5	3.8		0.8	2.4		0.4	1.3		0.3	1.3		0.4			
2006	3.4		0.9	3.9		0.7	1.9		0.4	1.8		0.5	1.3		0.5			
Combined	2.7	AB	0.3	3.3	B	0.4	1.5	A	0.2	1.2	C	0.2	0.8	C	0.2	< 0.001	0.011	0.376
Field Sparrow																		
2002	0.0		0.0	0.2		0.2	0.3		0.3	0.0		0.0	0.0		0.0		0.508	
2003	2.1	A	0.4	2.8	B	0.4	1.5	AC	0.3	0.4	C	0.2	0.1	C	0.1		<.0001	
2004	0.6		0.2	0.9		0.4	0.2		0.1	0.2		0.1	0.1		0.1		0.119	
2005	0.0		0.0	0.8		0.2	0.3		0.2	0.1		0.1	0.3		0.2		0.188	
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	< 0.001
Gray Catbird																		
2002	0.0		0.0	0.1		0.1	0.0		0.0	0.1		0.1	0.0		0.0			
2003	0.0		0.0	0.3		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.6		0.3	2.3		0.9	0.3		0.1	0.1		0.1	0.3		0.1			
2005	0.8		0.4	2.3		0.8	0.5		0.3	0.5		0.3	0.3		0.1			
2006	2.1		1.2	3.8		1.1	3.4		1.7	1.8		1.0	1.6		0.8	0.037	0.426	0.820
Great Crested Flycatcher																		
2002	0.0		0.0	0.4		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.6		0.2	0.0		0.0	0.1		0.1	0.0		0.0			
2004	0.0		0.0	0.5		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.7		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
Combined	0.0	A	0.0	0.5	B	0.1	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0	0.445	0.002	0.600
Hooded Warbler																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2005	0.2		0.1	0.2		0.1	0.0		0.0	0.0		0.0	0.0		0.0		0.965	
2006	1.6	A	0.6	1.7	A	0.6	0.1	B	0.1	0.1	B	0.1	0.0	B	0.0		< 0.001	0.006

Table 2.3. Continued

Indigo Bunting																		
2002	0.5		0.2	1.8		0.5	1.2		0.3	0.0		0.0	0.3		0.1			
2003	4.6		0.6	4.9		0.8	4.1		0.6	2.5		0.5	1.8		0.6			
2004	5.8		0.7	7.5		0.7	7.6		1.1	6.4		0.8	5.9		0.6			
2005	3.8		1.1	5.0		0.8	5.3		1.1	4.8		1.0	3.0		0.6			
2006	2.4		0.5	4.7		0.6	4.2		0.8	3.2		0.7	2.5		0.7			
Combined	3.4	AC	0.4	4.8	B	0.4	4.5	AB	0.5	3.4	AC	0.4	2.7	C	0.3	< 0.001	0.021	0.894
Killdeer																		
2002	0.0		0.0	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.551	0.522	0.457
Loggerhead Shrike																		
2002	0.0		0.0	0.0		0.0	0.3		0.2	0.0		0.0	0.3		0.3			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.112	0.567	0.722
Mourning Dove																		
2002	0.5		0.2	0.3		0.2	0.3		0.2	0.0		0.0	0.1		0.1		0.383	
2003	0.1	A	0.1	2.3	B	0.8	0.0	A	0.0	0.0	A	0.0	0.1	A	0.1		0.013	
2004	0.0		0.0	0.3		0.1	0.1		0.1	0.2		0.2	0.0		0.0		0.426	
2005	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.1		0.1		0.574	
2006	0.3		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		0.079	0.038
Northern Bobwhite																		
2002	0.1		0.1	0.4		0.2	0.1		0.1	0.0		0.0	0.0		0.0			
2003	0.2		0.1	1.8		0.7	0.3		0.2	1.3		0.4	0.1		0.1			
2004	0.1		0.1	0.2		0.2	0.3		0.3	0.0		0.0	0.1		0.1			
2005	0.0		0.0	0.3		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0	0.161	0.129	0.546
Northern Cardinal																		
2002	0.5		0.2	0.6		0.2	0.2		0.1	0.1		0.1	0.0		0.0			
2003	0.0		0.0	0.5		0.3	0.0		0.0	0.0		0.0	0.1		0.1			
2004	0.0		0.0	0.7		0.4	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.8		0.4	1.4		0.5	0.2		0.1	0.1		0.1	0.1		0.1			
2006	0.3		0.1	0.2		0.1	0.3		0.2	0.0		0.0	0.1		0.1			
Combined	0.3	A	0.1	0.7	B	0.1	0.1	A	0.1	0.0	A	0.0	0.1	A	0.0	0.011	0.030	0.224

Table 2.3. Continued

Northern Flicker																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2004	0.0	A	0.0	0.3	B	0.1	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0		< 0.001	
2005	0.0	A	0.0	0.3	B	0.2	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0		< 0.001	
2006	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0		0.673	0.001
Northern Mockingbird																		
2002	1.4		0.5	2.6		0.6	1.8		0.6	2.3		0.4	1.4		0.5			
2003	1.3		0.5	3.3		0.6	0.5		0.2	2.4		0.6	1.5		0.4			
2004	0.6		0.3	1.8		0.4	0.4		0.1	1.1		0.4	0.6		0.3			
2005	0.1		0.1	0.3		0.1	0.2		0.1	0.0		0.0	0.3		0.2			
2006	0.0		0.0	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	< 0.001	0.273	0.351
Orchard Oriole																		
2002	0.2		0.1	0.2		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.7		0.3	3.0		0.6	0.2		0.1	0.5		0.3	0.2		0.1			
2004	1.0		0.3	3.2		0.9	0.3		0.3	0.4		0.2	0.0		0.0			
2005	0.9		0.5	2.8		0.8	0.2		0.1	0.3		0.1	0.0		0.0			
2006	0.5		0.3	1.6		0.7	0.3		0.2	0.1		0.1	0.0		0.0			
Combined	0.7	A	0.1	2.1	B	0.3	0.2	A	0.1	0.3	A	0.1	0.0	A	0.0	0.012	0.002	0.144
Palm Warbler																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.420	0.413	0.479
Pileated Woodpecker																		
2002	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0	0.500	0.193	0.627
Pine Warbler																		
2002	0.0		0.0	0.8		0.7	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.3		0.3	0.0		0.0	0.2		0.1			
2006	0.1		0.1	0.2		0.1	0.0		0.0	0.0		0.0	0.1		0.1	0.527	0.402	0.496

Table 2.3. Continued

Prairie Warbler																		
2002	0.2		0.1	0.6		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2003	1.8		0.6	2.3		0.3	0.8		0.3	0.2		0.1	0.3		0.3			
2004	4.5		0.6	6.0		0.6	4.8		0.6	2.7		0.5	2.7		0.6			
2005	3.4		0.8	5.8		0.5	3.1		0.4	2.5		0.5	1.8		0.5			
2006	2.9		0.9	5.3		1.0	5.3		0.5	2.1		0.7	1.7		0.5			
Combined	2.6	AC	0.3	4.0	B	0.4	2.8	A	0.3	1.5	CD	0.2	1.3	D	0.2	< 0.001	0.002	0.126
Red-bellied Woodpecker																		
2002	0.0		0.0	0.2		0.1	0.2		0.1	0.1		0.1	0.0		0.0			
2003	0.1		0.1	0.8		0.2	0.0		0.0	0.1		0.1	0.0		0.0			
2004	0.0		0.0	1.1		0.4	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.7		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
Combined	0.0	A	0.0	0.6	B	0.1	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0	0.176	0.017	0.081
Red-headed Woodpecker																		
2002	0.0	A	0.0	0.6	B	0.2	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0		< 0.001	
2003	0.0		0.0	0.2		0.1	0.0		0.0	0.0		0.0	0.0		0.0		0.851	
2004	0.0		0.0	0.2		0.1	0.0		0.0	0.0		0.0	0.0		0.0		0.851	
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	< 0.001
Red-winged Blackbird																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.420	0.413	0.479
Red-tailed Hawk																		
2002	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.453	0.413	0.541
Ruby-throated Hummingbird																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.2		0.1	0.0		0.0	0.1		0.1	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.2		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
Combined	0.0	A	0.0	0.1	B	0.0	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0	0.041	0.009	0.079

Table 2.3. Continued

Sedge Wren																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.1		0.1	0.1		0.1	0.1		0.1	0.0		0.0			
2005	0.0		0.0	0.3		0.1	0.0		0.0	0.3		0.1	0.0		0.0			
2006	0.1		0.1	0.2		0.1	0.3		0.2	0.1		0.1	0.0		0.0	0.153	0.431	0.681
Summer Tanager																		
2002	0.0		0.0	0.1		0.1	0.0		0.0	0.1		0.1	0.0		0.0			
2003	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0	0.249	0.622	0.755
White-eyed Vireo																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2004	0.8		0.3	1.3		0.4	0.3		0.1	0.3		0.2	0.0		0.0		0.243	
2005	3.0	A	0.6	2.4	AB	0.5	1.8	B	0.7	0.3	C	0.1	0.0	C	0.0		< 0.001	
2006	3.6	A	0.5	3.9	A	0.8	1.5	B	0.3	1.8	B	0.4	0.9	B	0.3		< 0.001	0.001
Wild Turkey																		
2002	0.1		0.1	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.453	0.413	0.541
Yellow-breasted Chat																		
2002	0.0		0.0	0.3		0.1	0.1		0.1	0.0		0.0	0.2		0.1		0.256	
2003	5.0		0.5	4.4		0.9	2.9		0.8	1.5		0.6	0.3		0.2		0.068	
2004	7.9	A	0.5	8.0	A	1.1	6.1	A	0.9	5.4	A	0.9	1.7	B	0.5		0.005	
2005	7.3	A	0.8	8.0	A	1.3	5.8	AB	0.8	2.8	BC	0.7	1.8	C	0.6		0.005	
2006	6.4		0.5	7.3		1.3	5.8		0.7	3.5		0.8	2.3		0.7		0.064	0.018

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Values within rows followed by the same letter do not differ ($P > 0.05$); values are point count station totals averaged across repetitions and sites

Table 2.3. Continued

[c] Within-treatment year effect (*P* < 0.001): Common Yellowthroat, Field Sparrow, Hooded Warbler, White-eyed Vireo, Yellow-breasted Chat; (*P* < 0.05): Mourning Dove

[d] Within-treatment year effect (*P* < 0.001) Brown-headed Nuthatch, Common Yellowthroat, Field Sparrow, Hooded Warbler, Northern Flicker, Red-headed Woodpecker, White-eyed Vireo, Yellow-breasted Chat; (*P* < 0.01): Mourning Dove

[e] Within-treatment year effect (*P* < 0.001): Common Yellowthroat, Field Sparrow, Yellow-breasted Chat; (P < 0.01): White-eyed Vireo

[f] Within-treatment year effect (*P* < 0.001): Yellow-breasted Chat; (P < 0.01): Common Yellowthroat, White-eyed Vireo

Table 2.4. Avifauna species richness, total Partners in Flight (PIF) score[a], regionally important species score[a], and total bird abundance[a] for 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[b] during years 1-5 post-treatment (February 2002, January - February 2003 - 2006) in the Mississippi Lower Coastal Plain[c].

	Treatment															*P* -value		
	MECH[d]			CHEM[e]			COMBO[f]			BROAD[g]			BROAD2					
	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	Yr	Trt	Yr*Trt
Species Richness																		
2002	2.3		0.6	2.8		0.6	0.3		0.3	0.8		0.5	1.3		1.3		0.365	
2003	5.3	A	0.5	9.0	B	1.4	5.5	A	2.0	5.3	A	0.5	4.0	A	0.4		0.010	
2004	4.8	A	1.1	10.3	B	1.5	3.8	A	0.5	3.0	A	0.7	3.8	A	1.4		< 0.001	
2005	6.5	A	0.6	9.8	B	1.7	6.3	A	0.9	5.0	A	0.7	4.3	A	0.9		0.003	
2006	8.3	A	1.0	13.3	B	1.0	6.5	AC	1.0	5.0	CD	0.7	2.5	D	0.3		< 0.001	0.012
Total PIF Score																		
2002	18.6		9.5	29.4		11.7	1.1		1.1	13.5		10.2	7.8		7.8			
2003	40.5		7.8	74.6		10.9	29.6		9.0	29.9		11.0	20.4		7.6			
2004	17.8		1.1	47.5		9.6	14.0		4.7	12.5		3.8	25.8		9.2			
2005	42.6		13.0	52.9		11.0	21.3		7.3	25.8		8.2	25.9		14.5			
2006	25.4		3.8	77.9		17.3	18.5		3.0	15.6		1.1	8.7		2.2			
Combined	29.0	A	4.1	56.5	B	6.4	16.9	A	3.1	19.5	A	3.5	17.7	A	4.1	< 0.001	< 0.001	0.204
Regionally Important Species Score																		
2002	1.5		1.5	10.5		5.5	0.0		0.0	0.0		0.0	2.5		2.5			
2003	4.6		1.7	16.0		5.0	1.8		1.2	6.3		3.3	4.0		3.3			
2004	13.6		0.9	26.5		8.7	8.6		5.4	5.6		2.2	22.2		9.5			
2005	28.2		16.3	27.5		5.1	14.5		5.8	15.0		9.6	21.1		14.9			
2006	14.0		2.3	31.1		4.6	8.8		1.9	7.7		1.5	4.2		2.9			
Combined	12.4	A	3.7	22.3	B	3.0	6.7	A	1.9	6.9	A	2.2	10.8	A	3.8	< 0.001	0.011	0.357
Total Bird Abundance																		
2002	1.2		0.6	1.8		0.7	0.1		0.1	1.0		0.8	0.5		0.5			
2003	2.4		0.5	4.5		0.7	1.8		0.5	1.8		0.7	1.3		0.6			
2004	0.9		0.1	2.6		0.5	0.7		0.2	0.7		0.2	1.3		0.4			
2005	2.3		0.5	3.1		0.7	1.1		0.4	1.4		0.3	1.4		0.7			
2006	1.4		0.2	4.8		1.2	1.1		0.2	0.9		0.1	0.5		0.1			
Combined	1.6	A	0.2	3.4	B	0.4	1.0	A	0.2	1.2	A	0.2	1.0	A	0.2	< 0.001	< 0.001	0.429

Table 2.4. Continued

[a] total PIF score = ∑ (mean abundance of all species in a treatment * Partners in Flight priority score)
regionally important species score = ∑ (mean abundance of species with Partners in Flight score $\geq$ 19 in a treatment * Partners in Flight priority score)
total bird abundance = mean total number of birds

[b] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[c] Values within rows followed by the same letter do not differ ($P > 0.05$); values are standardized to 1000 m length transect and averaged across sites

[d] Within-treatment year effect ($P < 0.01$): Species Richness

[e] Within-treatment year effect ($P < 0.001$): Species Richness

[f] Within-treatment year effect ($P < 0.001$): Species Richness

[g] Within-treatment year effect ($P < 0.01$): Species Richness

Table 2.5. Bird species abundance for 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] during years 1-5 post-treatment (February 2002, January - February 2003 -2006) in the Mississippi Lower Coastal Plain[b].

	Treatment												
	MECH[c]		CHEM[d]		COMBO[e]		BROAD[f]		BROAD2		*P* -value		
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Yr	Trt	Yr*Trt
American Goldfinch													
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	1.0	0.6	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.164	0.164	0.073
American Robin													
2002	0.0	0.0	0.7	0.5	0.0	0.0	0.0	0.0	0.6	0.6			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	2.5	1.6			
2004	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0			
2005	1.7	0.7	3.1	1.2	0.8	0.4	0.2	0.2	0.2	0.2			
2006	0.4	0.3	6.4	4.3	0.6	0.3	0.0	0.0	0.0	0.0	0.178	0.184	0.161
American Woodcock													
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.2	0.2	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.035	0.076	0.054
Black Vulture													
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.453	0.413	0.541
Blue Jay													
2002	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.461	0.481	0.313

Table 2.5. Continued

Brown-headed Nuthatch																		
2002	0.0		0.0	0.4		0.4	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.453	0.413	0.541
Brown Thrasher																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.4		0.3	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.420	0.413	0.479
Carolina Chickadee																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	1.2		1.2			
2003	0.0		0.0	0.6		0.5	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.4		0.4	1.1		0.5	0.0		0.0	0.0		0.0	0.4		0.4			
2005	0.0		0.0	1.5		0.6	0.2		0.2	0.0		0.0	0.0		0.0			
2006	0.4		0.3	4.7		1.2	0.4		0.3	0.3		0.3	1.1		0.9			
Combined	0.2	A	0.1	1.7	B	0.3	0.1	A	0.1	0.1	A	0.2	0.5	A	0.1	0.011	< 0.001	0.083
Carolina Wren																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.9		0.4	2.6		1.0	1.0		0.4	0.7		0.5	0.3		0.3			
2004	0.2		0.2	1.1		0.4	0.4		0.3	0.0		0.0	0.4		0.4			
2005	0.2		0.2	0.4		0.3	0.0		0.0	0.9		0.5	0.2		0.2			
2006	0.9		0.4	1.8		0.5	0.4		0.3	0.2		0.2	0.3		0.3			
Combined	0.5	A	0.1	1.3	B	0.3	0.4	A	0.1	0.4	A	0.2	0.2	A	0.1	0.001	0.008	0.259
Cedar Waxwing																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	1.6		1.6	0.0		0.0	0.0		0.0	0.0		0.0	0.467	0.188	0.570
Chipping Sparrow																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	1.1		1.1	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.545	0.268	0.567

Table 2.5. Continued

Common Ground Dove																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.4		0.3	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.534	0.547	0.420
Common Snipe																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.2		0.2	1.4		1.4	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.322	0.504	0.532
Common Yellowthroat																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2004	0.9	AB	0.4	1.5	B	0.6	0.2	AC	0.2	0.0	C	0.0	0.0	C	0.0		< 0.001	
2005	1.7	A	0.8	0.4	B	0.4	0.8	B	0.4	0.2	B	0.2	0.2	B	0.2		0.002	
2006	0.4		0.4	0.4		0.4	0.0		0.0	0.0		0.0	0.0		0.0		0.629	0.035
Dark-eyed Junco																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	1.7		1.0	4.4		3.7	4.2		1.9	0.9		0.9	0.0		0.0			
2004	0.0		0.0	1.6		1.6	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.008	0.351	0.836
Downy Woodpecker																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.4		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.8		0.4	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.320	0.056	0.294
Eastern Bluebird																		
2002	4.1		2.1	5.6		2.7	0.6		0.6	1.1		1.1	1.2		1.2			
2003	0.2		0.2	3.3		1.0	0.0		0.0	2.6		1.2	2.7		1.0			
2004	0.0		0.0	1.5		0.7	0.6		0.5	2.1		1.2	0.2		0.2			
2005	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.4		0.3	0.0		0.0	0.0		0.0	0.0		0.0	0.013	0.272	0.440

Table 2.5. Continued

Eastern Phoebe																		
2002	0.6		0.4	0.0		0.0	0.0		0.0	0.0		0.0	0.6		0.6			
2003	0.4		0.4	0.0		0.0	0.4		0.3	0.4		0.3	0.6		0.4			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.2		0.2	0.0		0.0	0.4		0.3	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.026	0.768	0.689
Eastern Towhee																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.5	A	0.3	3.4	B	0.8	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0		< 0.001	
2004	0.4	A	0.3	2.8	B	0.7	0.0	A	0.0	0.0	A	0.0	0.7	A	0.7		0.001	
2005	1.9	AB	0.7	2.9	B	0.8	1.2	AC	0.5	0.7	AC	0.5	0.0	C	0.0		0.003	
2006	2.3	A	0.6	4.2	B	0.7	0.8	C	0.4	0.3	C	0.3	0.3	C	0.3		< 0.001	0.001
Field Sparrow																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.4		0.3	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.9		0.5	1.6		0.8	1.0		0.5	0.7		0.5	3.0		2.1			
2005	0.0		0.0	1.3		1.1	0.4		0.4	2.2		1.6	1.9		1.3			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.003	0.506	0.813
Golden-crowned Kinglet																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.3		0.3			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.420	0.413	0.479
Gray Catbird																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.4		0.4			
2005	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.551	0.537	0.430
Hairy Woodpecker																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.423	0.413	0.485

Table 2.5. Continued

Hooded Warbler																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.2		0.2	0.5		0.5			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.172	0.507	0.655
Loggerhead Shrike																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.2		0.2	0.4		0.4	0.0		0.0	0.6		0.6	0.0		0.0			
2004	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.076	0.471	0.840
Mourning Dove																		
2002	1.1		1.1	0.0		0.0	0.0		0.0	5.8		5.8	1.2		1.2			
2003	0.0		0.0	0.3		0.3	1.0		0.6	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.3		0.3			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.6		0.6			
2006	0.0		0.0	0.7		0.6	0.0		0.0	0.2		0.2	0.0		0.0	0.470	0.594	0.379
Northern Bobwhite																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	1.3		1.3	0.0		0.0	1.8		1.8	0.7		0.7	2.6		1.8			
2005	7.2		5.0	0.0		0.0	2.4		2.4	0.0		0.0	4.0		4.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.085	0.605	0.892
Northern Cardinal																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.0	A	0.0	1.5	B	0.7	0.4	AC	0.4	1.0	BC	0.7	0.0	A	0.0		< 0.001	
2004	0.0		0.0	0.9		0.5	0.0		0.0	0.0		0.0	0.0		0.0		0.133	
2005	0.0		0.0	0.3		0.3	0.0		0.0	0.0		0.0	0.3		0.3		0.901	
2006	0.0	A	0.0	2.4	B	0.8	0.4	A	0.3	0.3	A	0.3	0.0	A	0.0		< 0.001	0.009
Northern Flicker																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.2		0.2			
2006	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.574	0.556	0.429

Table 2.5. Continued

Northern Harrier																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.3		0.3	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.420	0.413	0.479
Northern Mockingbird																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.4		0.3	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.2		0.2	1.5		0.6	0.2		0.2	0.4		0.3	0.0		0.0			
2005	0.0		0.0	2.6		0.6	0.2		0.2	0.0		0.0	0.0		0.0			
2006	0.0		0.0	4.3		2.3	0.0		0.0	0.0		0.0	0.0		0.0	0.477	0.156	0.620
Palm Warbler																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.3		0.3	0.7		0.7			
2005	0.2		0.2	0.2		0.2	0.0		0.0	0.0		0.0	0.2		0.2			
2006	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.313	0.468	0.721
Pine Warbler																		
2002	0.7		0.7	3.6		1.8	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.3		0.3	0.2		0.2	0.4		0.4	1.8		1.6			
2004	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.8		0.4	1.3		0.5	0.4		0.3	0.7		0.4	0.0		0.0	0.276	0.327	0.336
Red-bellied Woodpecker																		
2002	0.0		0.0	0.7		0.7	0.0		0.0	0.0		0.0	0.0		0.0		0.414	
2003	0.0	A	0.0	1.7	B	0.5	0.0	A	0.0	0.0	A	0.0	0.0	A	0.0		0.003	
2004	0.0		0.0	1.3		0.9	0.0		0.0	0.0		0.0	0.0		0.0		0.181	
2005	0.0		0.0	0.4		0.3	0.0		0.0	0.0		0.0	0.0		0.0		0.065	
2006	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0		0.414	0.040
Red-shouldered Hawk																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.420	0.413	0.479

Table 2.5. Continued

Ruby-crowned Kinglet																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	0.0		0.0	0.0		0.0	0.2		0.2	0.0		0.0	0.0		0.0		0.997	
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2005	2.5	A	0.5	2.6	A	0.7	1.8	A	0.6	1.8	A	0.7	0.3	B	0.3		0.003	
2006	0.8	A	0.4	3.5	B	1.3	1.0	A	0.4	0.7	A	0.4	0.5	A	0.4		<.0001	0.016
Savannah Sparrow																		
2002	0.0		0.0	0.00		0.00	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.00		0.00	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.66		0.48	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.00		0.00	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.00		0.00	0.0		0.0	0.0		0.0	0.0		0.0	0.423	0.413	0.485
Sedge Wren																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	1.5		0.6	2.3		0.6	0.6		0.5	0.6		0.4	0.0		0.0			
2005	0.9		0.5	2.7		0.9	0.6		0.3	1.2		0.5	0.0		0.0			
2006	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	< 0.001	0.101	0.149
Song Sparrow																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0		1.000	
2003	13.0	A	2.6	11.3	A	2.5	6.0	B	1.1	4.0	BC	1.7	1.7	C	0.6		< 0.001	
2004	0.8		0.4	0.5		0.4	1.4		0.8	1.0		0.7	0.8		0.8		0.988	
2005	0.6		0.5	0.2		0.2	0.0		0.0	0.6		0.4	0.5		0.3		0.995	
2006	0.4		0.3	1.2		0.5	0.6		0.3	0.2		0.2	0.0		0.0		0.963	< 0.001
Swamp Sparrow																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.9		0.6	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.6		0.3	1.3		0.8	0.0		0.0	0.0		0.0	1.2		0.6			
2005	0.4		0.3	2.2		0.9	1.2		0.5	2.1		0.8	2.5		1.0			
2006	2.1		0.5	2.0		0.6	2.3		0.6	2.2		0.6	0.5		0.3	< 0.001	0.951	0.549
Turkey Vulture																		
2002	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2003	0.2		0.2	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2004	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2005	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0			
2006	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.420	0.413	0.4792

Table 2.5. Continued

White-eyed Vireo													
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.423	0.413	0.4847
White-throated Sparrow													
2002	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.4	0.3	0.4	0.4	0.2	0.2	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.325	0.633	0.6669
Winter Wren													
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2003	0.2	0.2	0.0	0.0	0.6	0.3	0.0	0.0	0.0	0.0			
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
2006	0.5	0.3	0.5	0.3	0.8	0.4	0.2	0.2	0.0	0.0	0.001	0.339	0.596
Yellow-rumped Warbler													
2002	3.1	2.4	3.2	2.5	0.0	0.0	0.5	0.5	0.0	0.0			
2003	1.7	0.8	7.1	2.6	0.0	0.0	3.4	1.5	2.1	1.5			
2004	0.0	0.0	1.1	0.9	0.0	0.0	0.3	0.3	0.4	0.4			
2005	1.6	0.9	3.8	2.2	0.4	0.3	2.0	0.7	0.0	0.0			
2006	2.3	0.5	5.0	0.7	1.9	0.6	2.6	0.9	1.9	0.7	< 0.001	0.133	0.287

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM =chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Values within rows followed by the same letter do not differ ($P > 0.05$); values are standardized to 1000 m length transect and averaged across sites

[c] Within-treatment year effect ($P < 0.001$): Common Yellowthroat, Eastern Towhee, Ruby-crowned Kinglet, Song Sparrow

[d] Within-treatment year effect ($P < 0.001$): Eastern Towhee, Northern Cardinal, Red-bellied Woodpecker, Ruby-crowned Kinglet, Song Sparrow; ($P < 0.01$): Common Yellowthroat

[e] Within-treatment year effect ($P < 0.05$): Ruby-crowned Kinglet; ($P < 0.01$): Song Sparrow

[f] Within-treatment year effect ($P < 0.05$): Ruby-crowned Kinglet

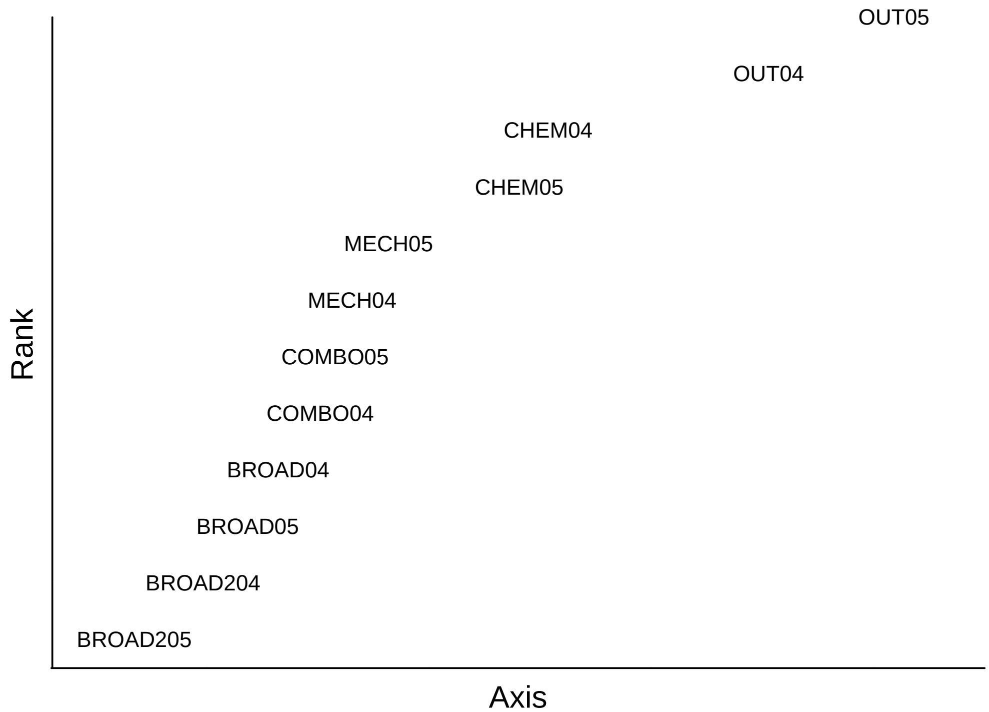

Figure 2.1. NMS ordination for breeding season avian assemblages of 5 pine plantation establishment treatments increasing in intensity from MECH, CHEM, COMBO, BROAD, to BROAD2 and surrounding plantation points (OUT) during years 3-4 post-treatment (April-June 2004 -2005) in the Mississippi Lower Coastal Plain. Each point is represented by treatment code followed by year, and distance represents dissimilarity.

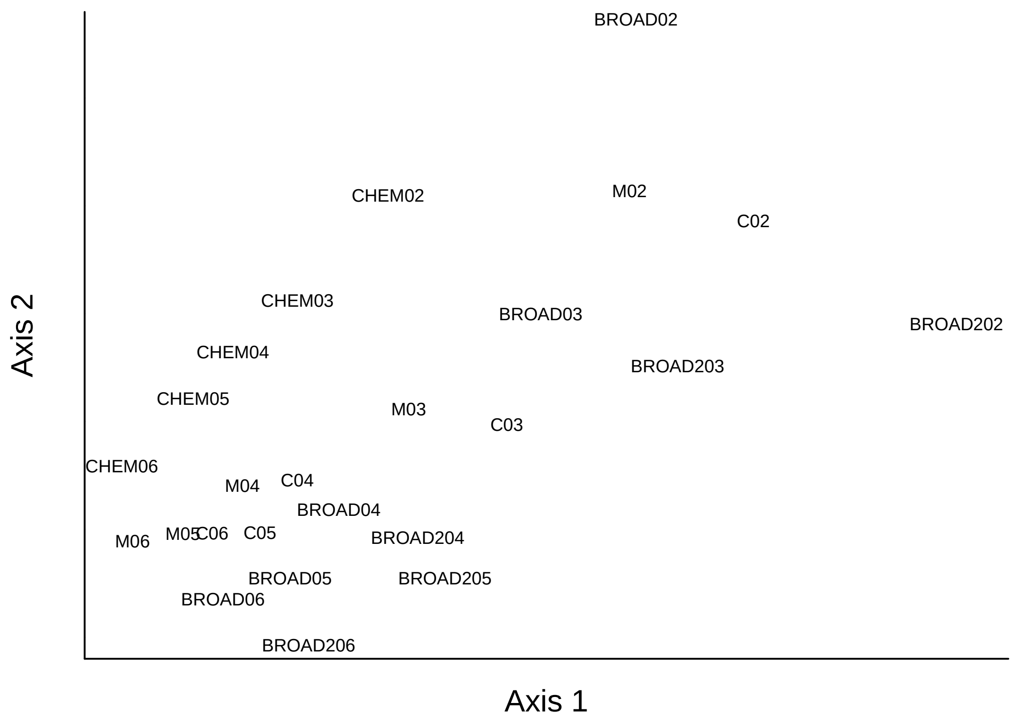

Figure 2.2. NMS ordination for breeding season avian assemblages of 5 pine plantation establishment treatments increasing in intensity from MECH (M), CHEM, COMBO (C), BROAD, to BROAD2 during years 1-5 post-treatment (April-June 2002 -2006) in the Mississippi Lower Coastal Plain. Each point is represented by treatment code followed by year, and distance represents dissimilarity. Treatments MECH and COMBO were shortened to M and C to minimize overlap.

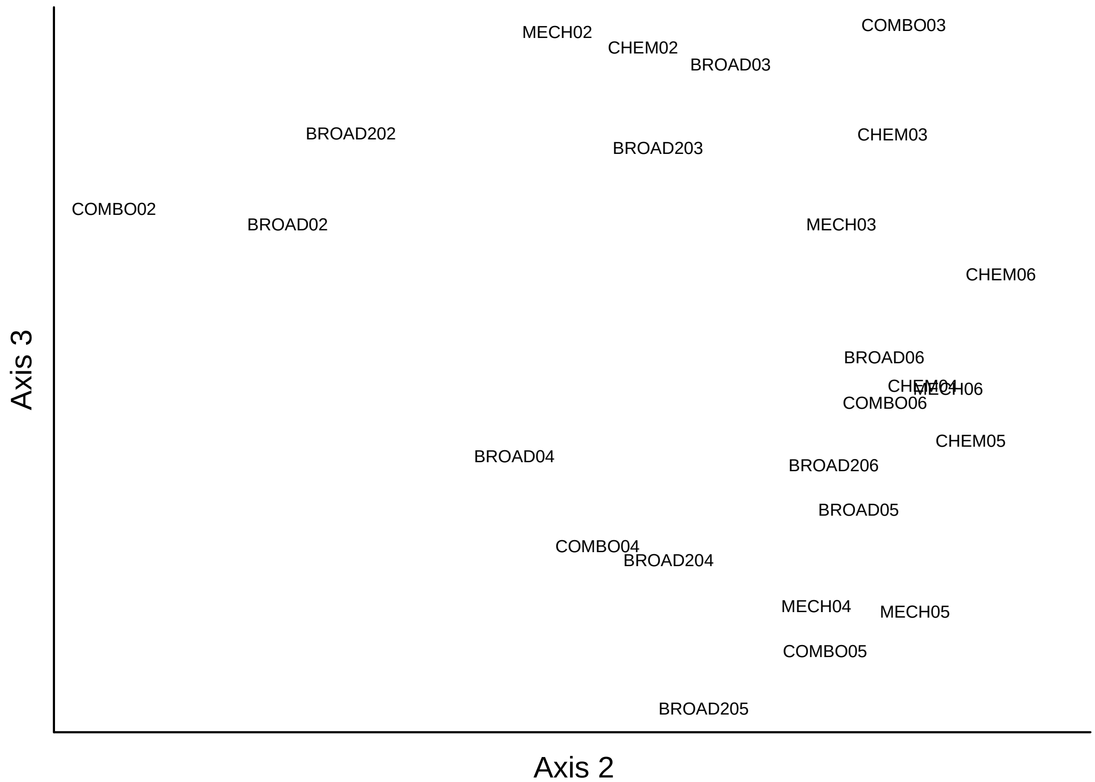

Figure 2.3. NMS ordination for wintering avian asssemblages of 5 pine plantation establishment treatments increasing in intensity from MECH, CHEM, COMBO, BROAD, to BROAD2 during years 1-5 post-treatment (February 2002, January-February 2003-2006) in the Mississippi Lower Coastal Plain. Each point is represented by treatment code followed by year, and distance represents dissimilarity.

Appendix 2.A. Common and scientific names of bird species in 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] during years 1 - 5 post-treatment (2002 - 2006) in the Mississippi Lower Coastal Plain.

Common Name	Scientific Name
American Crow	*Corvus brachyrhynchos*
American Goldfinch	*Carduelis tristis*
American Robin	*Turdus migratorius*
American Woodcock	*Scolopax minor*
Barn Swallow	*Hirundo rustica*
Black Vulture	*Coragyps atratus*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Blue Grosbeak	*Guiraca caerulea*
Blue Jay	*Cyanocitta cristata*
Brown-headed Cowbird	*Molothrus ater*
Brown-headed Nuthatch	*Sitta pusilla*
Brown Thrasher	*Toxostoma rufum*
Carolina Chickadee	*Poecile carolinensis*
Carolina Wren	*Thryothorus ludovicianus*
Cedar Waxwing	*Bombycilla cedrorum*
Chipping Sparrow	*Spizella passerina*
Common Ground Dove	*Columbina passerina*
Common Nighthawk	*Chordeiles minor*
Common Snipe	*Gallinago gallinago*
Common Yellowthroat	*Geothlypis trichas*
Dark-eyed Junco	*Junco hyemalis*
Downy Woodpecker	*Picoides pubescens*
Eastern Bluebird	*Sialia sialis*
Eastern Kingbird	*Tyrannus tyrannus*
Eastern Phoebe	*Sayornis phoebe*
Eastern Towhee	*Pipilo erythrophthalmus*
Field Sparrow	*Spizella pusilla*
Golden-crowned Kinglet	*Regulus satrapa*
Gray Catbird	*Dumetella carolinensis*
Great Crested Flycatcher	*Myiarchus crinitus*
Hairy Woodpecker	*Picoides villosus*
Hooded Warbler	*Wilsonia citrina*
Indigo Bunting	*Passerina cyanea*
Killdeer	*Charadrius vociferus*
Loggerhead Shrike	*Lanius ludovicianus*
Mourning Dove	*Zenaida macroura*
Northern Bobwhite	*Colinus virginianus*
Northern Cardinal	*Cardinalis cardinalis*
Northern Flicker	*Colaptes auratus*
Northern Harrier	*Circus cyaneus*
Northern Mockingbird	*Mimus polyglottos*
Orchard Oriole	*Icterus spurius*
Palm Warbler	*Dendroica palmarum*
Pileated Woodpecker	*Dryocopus pileatus*
Pine Warbler	*Dendroica pinus*
Prairie Warbler	*Dendroica discolor*

Red-bellied Woodpecker	*Melanerpes carolinus*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Red-shouldered Hawk	*Buteo lineatus*
Red-tailed Hawk	*Buteo jamaicensis*
Red-winged Blackbird	*Agelaius phoeniceus*
Ruby-crowned Kinglet	*Regulus calendula*
Ruby-throated Hummingbird	*Archilochus colubris*
Savannah Sparrow	*Passerculus sandwichensis*
Sedge Wren	*Cistothorus platensis*
Song Sparrow	*Melospiza melodia*
Summer Tanager	*Piranga rubra*
Swamp Sparrow	*Melospiza georgiana*
Turkey Vulture	*Cathartes aura*
White-eyed Vireo	*Vireo griseus*
White-throated Sparrow	*Zonotrichia albcollis*
Wild Turkey	*Meleagris gallopavo*
Winter Wren	*Troglodytes troglodytes*
Yellow-breasted Chat	*Icteria virens*
Yellow-rumped Warbler	*Dendroica coronata*

[a] MECH = mechanical site preparation with banded chemical control during 2002,
CHEM = chemical site preparation with banded chemical control during 2002,
COMBO = mechanical and chemical site preparation with banded chemical control during 2002,
BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002,
BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

CHAPTER III

BIRD-HABITAT MODELS OF INTENSIVELY ESTABLISHED PINE PLANTATIONS IN COASTAL PLAIN MISSISSIPPI

Abstract: Pine plantation establishment methods can alter vegetation composition and structure, thus affecting wildlife habitat. I evaluated 8 vegetation variables, which were generated by a range of plantation establishment methods, to identify variables most closely associated with breeding bird abundance in the Lower Coastal Plain of Mississippi. Presence of residual trees and snags was important for 16 of 21 species. Woody vegetation and pine trees were relatively common model variables. However, pine trees primarily had negative relationships with avian abundance. Influence of residual trees illustrates that knowledge of habitat elements affecting birds on intensively established pine plantations can aid managers in integrating pine plantation establishment with avifauna conservation.

INTRODUCTION

The South is the largest national source of timber, supported by the growth of intensively managed pine plantations (Haynes 2002). Common stand establishment procedures incorporate herbicide applications and mechanical site preparation to control hardwood and herbaceous plant growth, consequently modifying vegetation structure and composition. Suppression of herbaceous and non-merchantible hardwoods through herbicide and mechanical treatment after harvest may affect wildlife by altering critical early successional habitat (Lautenschlager 1993). Intensity of vegetation disturbance timing (at site preparation or as a later release), and treatment type (herbicide versus mechanical or both) affect wildlife differentially. Furthermore, insects, the primary food source for birds during breeding season, may fluctuate in abundance and composition in response to vegetative changes (Santillo et al. 1989).

Vegetation provides nesting sites, foraging opportunities, cover from predators, and perches for song and display (Martin 1988, Steele 1993, Holmes and Schultz 1988). There has been some question about greater importance of vegetative structure or composition, primarily of tree species, driven by the contrasting processes of nest predation and food limitation (Robinson and Holmes 1984, Orians and Wittenberger 1991, Martin 1995, Nagy and Holmes 2004). Composition may be nested within structure, resulting in avian species-specific balances between both features.

The range of intensive pine plantation establishment may affect vegetation characteristics important to bird species. The purpose of this study was to assess breeding bird response to vegetation variables generated by a stand establishment intensity continuum, which increased in intensity due to combinations of mechanical and chemical site preparation and chemical release. I modeled relationships of 8 habitat variables to abundance of avian species of concern in the Lower Coastal Plain of Mississippi.

STUDY AREA

The 4 study sites, which averaged 66 ha, were loblolly pine plantations in lower Coastal Plain Mississippi. These sites were owned and managed by Molpus Timberlands in Perry County, Plum Creek in George County, and Weyerhaeuser Company in Lamar County. All stands were previously loblolly (*Pinus taeda*) or slash (*P. elliottii*) pine plantations, harvested during summer 2000-winter 2001 and planted with loblolly pine during winter 2001-2002. Each forest product industry cooperator provided proprietary genetically-improved seedlings. Tree spacing was 3.0 m between rows and 2.1 m between trees within a row, totaling 1,551 trees/ha. Two stands were machine planted and 2 stands were planted by hand, due to greater post-harvest debris loads. Banded herbaceous control treatments were applied with a band width of 1.5 m to every tree row, and broadcast herbicide applications were applied by helicopter. All treatments received a broadcast application of diammonium phosphate at 280 kg/ha during spring 2002.

Each site contained 5 treatment levels, representing a range of operational stand establishment intensities. Each treatment was assigned randomly to a minimum of 8-ha per stand, in a randomized complete block design. Management intensity, and thus expected vegetative impact, increased from low for mechanical site preparation only and banded herbaceous release, MECH, to high for 2 years of broadcast herbaceous control following site preparation, BROAD2 (Table 3.1). MECH consisted of mechanical site preparation only (via a combination plow to subsoil, disk, and bed, as well as a V-blade to clear debris) during fall 2001 and a banded herbaceous control with 0.9 kg/ha of Oustar® (E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware; hexazinone and sulfometuron; 13 oz./acre) during spring 2002. CHEM consisted of chemical site preparation only, including 2.4 L/ha Chopper® (BASF Corp., Research Triangle Park, North Carolina; imazapyr; 32 oz./acre), 3.5 L/ha Accord® (Dow AgroSciences LLC, Indianapolis, Indiana; glyphosate; 48 oz./acre), 3.5 L/ha Garlon 4 (Dow AgroSciences LLC, Indianapolis, Indiana; triclopyr; 48 oz./acre), and 1% Timberland 90® surfactant (UAP Timberland LLC, Monticello, Arkansas) during summer 2001 and the same banded herbaceous control as MECH. A combined mechanical site preparation of MECH and chemical site preparation of CHEM, along with the banded control, was COMBO. The first broadcast treatment, BROAD, combined the same mechanical and chemical site preparation with a single year of broadcast herbaceous control using 0.9 kg/ha of Oustar®. The second broadcast treatment, BROAD2, combined the same mechanical and chemical site preparation with the same broadcast herbaceous control during springs 2002 and 2003.

Vegetation was sampled in a companion study (Edwards 2004, P. Jones, Mississippi State University, unpublished data). During 2004-2006, increasing treatment intensity increased pine tree height and diameter. CHEM had the lowest growth rate, while BROAD2 had the greatest, and the other treatments were intermediate. BROAD2 averaged 1.4 m taller and 2.4 cm greater in dbh than CHEM. Growth of pine trees by height averaged 1.36 m/yr across all treatments. Correspondingly, coverage of pine trees was associated with increased treatment intensity. Pine coverage was greatest in BROAD and BROAD2 and least in MECH and CHEM. Pine coverage increased in all treatments from 2004 to 2006. Coverage of understory herbaceous plants decreased with increasing intensity. BROAD2 averaged 65% of MECH. Coverage in all treatments declined from 85-125% during 2004 to 44-76% during 2006. Woody plant coverage, excluding pines, almost had a treatment effect ($F_{4,42} = 2.56$, $P = 0.053$), and coverage increased from 2004 to 2006. During 2002-2006, total vegetation generally was greatest in MECH and least in BROAD2, with COMBO, BROAD, and CHEM intermediate in vegetation coverage.

METHODS

Sampling

I surveyed breeding birds during mid-April through mid-June 2002-2006 with 10-minute point counts (Verner 1985). In each treatment, I established 3 point count stations ranging from 150-230 m apart, and at least 50 m distant from treatment boundaries. Using a laser range finder to increase distance estimation accuracy, I recorded birds that were within 75 m of each station. I completed 3 survey repetitions during 2002 and 6 repetitions during 2003-2006 that occurred between sunrise and 1100 during optimal weather conditions: no rain or low cloud cover, minimal wind and fog. I selected for modeling those birds that indicated a treatment difference (P value < 0.2; see chapter 2), were regionally less common according to Partners in Flight (Panjabi et al. 2005), and were not rare observations in the study sites. This produced a set of 21 birds, after including Brown-headed Cowbird, a nest parasite (scientific names listed in Appendix 3.A).

Vegetation was sampled in a companion study on all sites during June 2002-2006 (Appendix 3.B; Edwards 2004, P. Jones, Mississippi State University, unpublished data). Within each treatment, 10 transects of 30 m were established to assess vegetation characteristics. Percent coverage of understory herbaceous species, woody species, and debris was recorded using a modification of Canfield's (1941) line-intercept method. Plants were identified to species and then grouped by growth form type. Additionally, I counted any residual or hardwood trees > 2 m in height or > 10 cm in diameter within 10 m along one side of an established belt transect for winter bird surveys.

Statistical Analyses

I used canonical correspondence analysis (CCA; McCune and Mefford 1999, McCune and Grace 2002), which combines ordination and multiple regression, for comparison of bird abundance to vegetation variables. I retained variables of biological importance and grouped variables based on similar bird response. Final vegetation variables consisted of coverage of bare ground and debris (BGandD), grass and grass-like (GandGL), forbs excluding legumes, legumes, pine trees, woody non-pine shrubs and trees, vines, and number of residual trees and snags (Snag).

I used a repeated measures, mixed model analysis of variance to model bird abundance and vegetation using all possible combinations of vegetation through 5 variables (Proc MIXED; SAS Institute 2002-2003). Site was a random effect and year was a repeated measure. To account for time, year was a variable in all models. Using least AIC_c (Akaike's Information Criterion corrected for small sample size) value, I selected the covariance structure with the best fit from autoregressive, compound symmetry, autoregressive heterogeneous, and compound symmetry heterogeneous options (Gutzwiller and Riffell 2007). The models were ranked by AIC_c from least to greatest value, followed by calculation of differences among models (ΔAIC_c) and their Akaike weights. For models within 2 AIC_c units of the top model, I calculated a Pearson correlation coefficient (Proc CORR; SAS Institute 2002-2003) by comparing observed bird abundance to predicted bird abundance based on the model for every sample point. Because many of the bird species had models of approximately equal weight and correlation, I removed models with more variables when there was a nested reduced model. I retained the global model and the model with the greatest r^2 value if it was greater by 0.05 than the reduced model (Table 3.2). For all competing models within 2 AIC_c units of the top model, I weighted importance of each variable by summing model weights for all models in which the variable occurred (Appendix 3.C). This provides a complete description of variables before taking into account their contribution to prediction rates.

RESULTS

Bird species that had models with relatively high prediction rates ($r > 0.70$) were Yellow-breasted Chat, Common Yellowthroat, Prairie Warbler, White-eyed Vireo, Indigo Bunting, Great Crested Flycatcher, Eastern Towhee, Downy Woodpecker, and Red-bellied Woodpecker (Table 3.2). Yellow-breasted Chat abundance was associated positively with bare ground and debris, residual trees, vines, woody vegetation, and negatively associated with pine trees. The Common Yellowthroat model incorporated positive relationships with grasses, residual trees, vines, and negative relationships with legumes and pine trees. The model for Prairie Warbler was positive for residual trees and negative for pine trees. For White-eyed Vireo, the model consisted of positive associations with woody vegetation and negative association with pine trees. Indigo Bunting abundance was related positively to residual trees, and negatively to bare ground and debris and woody vegetation. The best models for Great Crested Flycatcher and Downy Woodpecker indicated positive relationships with number of residual trees. Eastern Towhee numbers increased with increased woody vegetation and residual trees, and decreased with increased forb cover. Red-breasted Woodpecker abundance was influenced positively by residual trees, and negatively by woody vegetation and legumes.

Red-headed Woodpecker, Field Sparrow, Brown-headed Cowbird, Brown Thrasher, Eastern Kingbird, and Carolina Wren had borderline models with r values of 0.59 – 0.70 (Table 3.2). Red-headed Woodpecker abundance increased with residual trees and decreased with bare ground and debris. The Field Sparrow model included positive relationships with grasses and residual trees. Brown-headed Cowbirds were associated positively with residual trees, and negatively with grasses and pine trees. The model for Brown Thrasher had woody vegetation and residual trees as positive variables and for Eastern Kingbird and Carolina Wren, it was presence of residual trees as a positive variable.

Vegetation explained little variation for Hooded Warbler and Blue Jay, which had models with r values of 0.50 – 0.55 (Table 3.2). The Hooded Warbler model incorporated vines and negatively, pines. Blue Jays were influenced positively by grasses, pine trees, and residual trees, and negatively by forbs. Blue Grosbeak, Carolina Chickadee, Orchard Oriole, and Northern Bobwhite had very weak models ($r < 0.50$).

The most frequently represented variable was residual trees, which were in models for 16 species. Woody vegetation and pine trees were relatively common in models, however pine tree primarily had negative associations. Bare ground and debris, and the herbaceous variables of grasses and grass-like, legumes, forbs, and vines were less common in models.

DISCUSSION

Tree retention was not a planned part of the establishment intensity gradient, but residual trees were an outcome from the chemical-only treatment and skipped areas in other treatments. Mature trees with large diameter and height, potential cavity sites, and well-developed bark are important for primary and secondary cavity nesters (Conner 1978, Davis 1983). Although retained trees all had diameters less than 23 cm, appearance of residual trees in models for cavity nesters was not surprising. Residual trees were influential for Downy, Red-bellied, and Red-headed Woodpeckers, which use snags for nesting, foraging, and mate attraction (drumming). Secondary cavity nesters, including Carolina Wrens, Carolina Chickadees, and Great Crested Flycatchers, also had models containing residual trees. Previous research has found that cavity nesters may extend their home range to include young plantations when snags and nest sites were available (Dickson et al. 1983, Caine and Marion 1991). Lohr et al. (2002) reported that snag removal reduced abundance of Red-headed Woodpecker, Great Crested Flycatcher, and Carolina Wren, but not Red-bellied Woodpecker or Carolina Chickadee in loblolly forests of South Carolina.

Although there is an obvious relationship between primary and secondary cavity nesters to snags, few studies emphasize importance of retained trees for other breeding birds. Many bird species also use larger trees for nest sites, perches, singing or display posts, sighting prey, and foraging. Snags in regenerating pine plantations may increase abundance and species richness of avian species (Johnson and Landers 1982, Dickson et al. 1983, Caine and Marion 1991). Additionally, snag removal may reduce substrate for some insects, possibly reducing prey sources for insectivorous birds. Dickson et al. (1983) noted increased presence of Blue Jays, Yellow-breasted Chats, Carolina Wrens, and Brown-headed Cowbirds in plots with snags versus snag-less plots in an East Texas clearcut. In contrast to my models, Dickson et al. (1983) found that Blue Grosbeak, Field Sparrows, and Prairie Warblers were more abundant on plots devoid of standing snags, whereas Indigo Buntings and Common Yellowthroats probably did not differ between snag and snag-less plots.

Woody shrubs and deciduous and broadleaf evergreen trees, herbaceous vegetation, bare ground and debris, and pine trees also were model variables, and their proportions were altered by the establishment gradient. Woody and/or herbaceous vegetation cover, along with amount of bare ground and debris, are vegetative associations for early successional species, and thus produced a mix of generally positive but some negative relationships. For example, woody vegetation was important for Brown Thrasher, Eastern Towhee, White-eyed Vireo, and Yellow-breasted Chats, which prefer thickets (Hopp et al. 1995, Greenlaw 1996, Cavitt and Haas 2000, Eckerle and Thompson 2001). Grasses were model variables for Common Yellowthroat and Field Sparrow, which can be found in dense low vegetation (Guzy and Ritchison 1999) and grassy fields (Carey et al. 1994). Grasses were negative in the Brown-headed Cowbird model, but total bird abundance excluding Brown-headed Cowbirds had a greater and significant correlation to woody vegetation compared to grasses. Bare ground and debris were positive variables for Yellow-breasted Chats, which can tolerate disturbed sites when shrubs are present (Eckerle and Thompson 2001), and Eastern Towhees, which forage on a well-developed litter layer (Greenlaw 1996). In contrast to other variables, pine trees were almost always negative variables. Growing pine trees tended to replace other vegetation over time, so negative associations may result from vegetation displacement rather than pine tree presence. Pine trees positively influenced Blue Jays, which are found in forested edges and lawns (Tarvin and Woolfenden 1999). Forbs and legumes also produced negative associations. Forbs and legumes, similarly to pine trees, may have negative associations because they displace vegetation that is more directly beneficial.

One limitation to modeling in this study is that abundance is not an equivalent measure to demographic metrics. Although density is generally a good predictor of reproductive success (Bock and Jones 2004), higher quality habitat does not always equal greater density, and likewise, greater density does not necessarily equal higher quality habitat. Density and habitat quality can be decoupled by at least 1) territoriality and other social interactions, 2) source-sink dynamics, 3) ecological traps, 4) migrant deception, or site tenacity after habitat change, and 5) patchy resources. In species with strong social interactions, particularly generalists with high reproduction rates, dominant individuals can force subdominants into marginal habitat to the extent that density is greater in lower quality habitats (Van Horne 1983). Density also can be inflated artificially in low quality population sinks that are supported by regional population sources (Pulliam 1988). Animals correctly evaluate habitat quality, yet source habitat is limited. Anthropogenic disturbance can disconnect habitat preference and reproduction (Bock and Jones 2004) in the overlapping cases of ecological traps and migrant deception. Density can be high yet reproductive success low in sink habitat that is preferred (Dwernychuk and Boag 1972, Battin 2004). For example, ecological traps can occur in locations with elevated numbers of nest predators or brood parasites, specifically in areas that historically contained reduced levels (Robertson and Hutto 2006), or grassland species can lose nests to early mowing. Disturbance-dependent species particularly may be vulnerable to ecological traps, mistaking artificial disturbance for natural disturbance (Weldon and Haddad 2005). Overstocking also may develop when birds settle in a previously successful breeding site, without recognizing recent habitat modification, whether from natural disturbance or land use and management (Wiens et al. 1986, Lautenschlager 1993). Density undersaturation can occur in high quality habitat when resources fluctuate spatially or temporally, due to factors such as weather, disturbance, or vegetation ecology (Wiens 1981, Van Horne 1983).

In this study, I modeled effects from chemical and mechanical alteration of vegetation and avian abundance. Many of the problems associated with count data were reduced by a randomized block design, where all sites contain every treatment. Adjacent treatments therefore were affected equally by outside and historical events, negating regional source/sink influences and reducing differential migrant deception, patchiness, and exposure to ecological traps. I also estimated associations within a similar, albeit modified, vegetation type, which again minimized differences. Furthermore, I modeled rare and declining bird species, which were less constrained by social interactions. In addition, modeling during breeding season avoided a heavy influx of juveniles.

MANAGEMENT IMPLICATIONS

Residual trees appeared to be a critical stand element for many bird species in the study sites. Tree retention may enrich avian assemblages in young, intensively established pine plantations. Furthermore, a variety of small mammals, including bats, reptiles, and amphibians use mature trees and snags for foraging, nesting, roosting, and denning. Therefore, retaining trees at harvest is the primary management recommendation. Tree retention requires knowledge of number, species, size, and spatial distribution of trees to most efficiently benefit birds and other wildlife. This information currently is undeveloped, particularly in the southeastern United States, and will require experimental manipulation along with model development.

Woody and herbaceous vegetation are important to birds, but the preferred combinations of various growth forms of woody and herbaceous vegetation differ by species. Therefore, across a landscape, a variety of management prescriptions can provide the range of vegetation structure and composition to provide for a complete set of avian species. Future research should explore if grass cover is preferable to forb cover for selected bird species, as suggested by the models in this study.

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Table 3.1. Five stand establishment treatments varying from low (MECH) to high (BROAD2) intensity in the Mississippi Lower Coastal Plain.

	Treatment				
	MECH	CHEM	COMBO	BROAD	BROAD2
Site Preparation	Mechanical	Chemical	Mechanical and Chemical	Mechanical and Chemical	Mechanical and Chemical
Release	Banded - 2002	Banded - 2002	Banded - 2002	Broadcast - 2002 & 2003	Broadcast - 2002 & 2003

Table 3.2. Avian models from 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] during years 1-5 post-treatment (April - June 2002 - 2006) in the Mississippi Lower Coastal Plain.

Species	Model[bc]	K	AICc	ΔAICc	Weight	r[d]	r^2
Brown-headed Cowbird	Woody(+) Snag(+)	9	-224.2	0.80	0.12	0.58	0.33
Brown-headed Cowbird	GandGL(-) Pine(-) Snag(+)	10	-223.9	1.10	0.10	0.63	0.39
Brown-headed Cowbird	GandGL(-) Legume(-) Snag(+)	10	-223.4	1.60	0.08	0.58	0.34
Brown-headed Cowbird	Global	15	-217.9	7.10	0.00	0.64	0.41
Blue Grosbeak	Woody(-)	8	-85.2	0.50	0.15	0.47	0.22
Blue Grosbeak	Global	15	-75.0	10.70	0.00	0.49	0.24
Blue Jay	Forb(-) GandGL(+) Pine(+) Snag(+)	11	-474.7	0.00	0.52	0.51	0.26
Blue Jay	Global	15	-466.0	8.70	0.01	0.54	0.29
Brown Thrasher	Woody(+) Snag(+)	9	-222.0	1.60	0.31	0.60	0.36
Brown Thrasher	Global	15	-209.8	13.80	0.00	0.62	0.39
Carolina Chickadee	Snag(+)	8	-175.2	0.00	0.09	0.39	0.15
Carolina Chickadee	BGandD(+) GandGL(+) Woody(+) Snag(+)	11	-174.4	0.80	0.06	0.45	0.20
Carolina Chickadee	Global	15	-164.3	10.90	0.00	0.46	0.21
Carolina Wren	Snag(+)	8	-171.2	0.00	0.28	0.59	0.35
Carolina Wren	Global	15	-160.2	11.00	0.00	0.58	0.33
Common Yellowthroat	Pine(-)	8	17.9	1.00	0.07	0.80	0.64
Common Yellowthroat	GandGL(+) Legume(-) Pine(-) Vine(+) Snag(+)	12	18.8	1.90	0.04	0.84	0.70
Common Yellowthroat	Global	15	22.8	5.90	0.01	0.84	0.70
Downy Woodpecker	Snag(+)	8	-389.9	0.50	0.14	0.71	0.50
Downy Woodpecker	Global	15	-378.8	11.60	0.00	0.74	0.54
Eastern Kingbird	Snag(+)	8	-121.4	0.00	0.54	0.60	0.36
Eastern Kingbird	Global	15	-105.5	15.90	0.00	0.61	0.38
Eastern Towhee	Forb(-) Woody(+) Snag(+)	10	-24.2	0.00	0.54	0.71	0.50
Eastern Towhee	BGandD(+) Woody(+) Snag(+)	10	-22.2	2.00	0.20	0.67	0.45
Eastern Towhee	Global	15	-12.6	11.60	0.00	0.74	0.55
Field Sparrow	GandGL(+) Snag(+)	9	-159.0	1.50	0.17	0.69	0.48
Field Sparrow	Global	15	-148.8	11.70	0.00	0.71	0.51
Great Crested Flycatcher	Snag(+)	8	-351.5	0.30	0.17	0.75	0.56
Great Crested Flycatcher	Global	15	-341.1	10.70	0.00	0.75	0.56

Table 3.2. Continued

Hooded Warbler	Woody(+)	8	-197.8	1.50	0.19	0.53	0.28
Hooded Warbler	Pine(-) Vine(+)	9	-197.5	1.80	0.17	0.55	0.30
Hooded Warbler	Global	15	-186.4	12.90	0.00	0.58	0.33
Indigo Bunting	BGandD(-) Woody(-) Snag(+)	10	43.6	1.40	0.21	0.77	0.60
Indigo Bunting	Global	15	50.5	8.30	0.01	0.80	0.64
Northern Bobwhite	Pine(-) Woody(-)	9	-288.6	0.00	0.24	0.33	0.11
Northern Bobwhite	Legume(-) Woody(-)	9	-287.6	1.00	0.15	0.31	0.10
Northern Bobwhite	Global	15	-279.0	9.60	0.00	0.13	0.02
Orchard Oriole	BGandD(+) Forb(+)	9	-71.8	0.00	0.38	0.31	0.10
Orchard Oriole	BGandD(+) Forb(+) Pine(-)	10	-71.5	0.30	0.33	0.45	0.21
Orchard Oriole	Global	15	-59.1	12.70	0.00	0.31	0.10
Prairie Warbler	Pine(-) Snag(+)	9	-31.0	0.00	0.40	0.81	0.65
Prairie Warbler	Global	15	-19.3	11.70	0.00	0.83	0.69
Red-bellied Woodpecker	Legume(-) Woody(-) Snag(+)	10	-352.7	1.20	0.11	0.73	0.53
Red-bellied Woodpecker	GandGL(+) Snag(+)	9	-352.7	1.20	0.11	0.71	0.51
Red-bellied Woodpecker	Global	15	-346.6	7.30	0.01	0.71	0.50
Red-headed Woodpecker	BGandD(-) Snag(+)	9	-367.7	0.00	0.44	0.68	0.47
Red-headed Woodpecker	Global	15	-355.2	12.50	0.00	0.70	0.49
White-eyed Vireo	Pine(-) Woody(+)	9	-103.7	0.00	0.19	0.78	0.61
White-eyed Vireo	Global	15	-94.1	9.60	0.00	0.81	0.66
Yellow-breasted Chat	BGandD(+) Pine(-) Vine(+) Woody(+) Snag(+)	12	-1.6	0.00	0.56	0.84	0.71
Yellow-breasted Chat	BGandD(+) Pine(-) Vine(+) Snag(+)	11	0.3	1.90	0.22	0.80	0.65
Yellow-breasted Chat	Global	15	4.4	6.00	0.03	0.86	0.73

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Year is a variable in all models and produces 5 additonal parameters

[c] Snag is residual trees, BGandD is bare ground and debris, GandGL is grass and grass-like

[d] r is correlation between observed bird abundance and predicted bird abundance based on model for 100 sample points

Appendix 3.A. Common and scientific names, and 2007 Southeastern Coastal Plain Partners in Flight conservation score, of bird species in 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] during years 1 - 5 post-treatment (2002 - 2006) in the Mississippi Lower Coastal Plain.

Common Name	Scientific Name	Conservation Score
Blue Grosbeak	*Guiraca caerulea*	12
Blue Jay	*Cyanocitta cristata*	14
Brown-headed Cowbird	*Molothrus ater*	8
Brown Thrasher	*Toxostoma rufum*	15
Carolina Chickadee	*Poecile carolinensis*	16
Carolina Wren	*Thryothorus ludovicianus*	13
Common Yellowthroat	*Geothlypis trichas*	13
Downy Woodpecker	*Picoides pubescens*	14
Eastern Kingbird	*Tyrannus tyrannus*	15
Eastern Towhee	*Pipilo erythrophthalmus*	16
Field Sparrow	*Spizella pusilla*	15
Great Crested Flycatcher	*Myiarchus crinitus*	12
Hooded Warbler	*Wilsonia citrina*	14
Indigo Bunting	*Passerina cyanea*	14
Northern Bobwhite	*Colinus virginianus*	16
Orchard Oriole	*Icterus spurius*	16
Prairie Warbler	*Dendroica discolor*	18
Red-bellied Woodpecker	*Melanerpes carolinus*	13
Red-headed Woodpecker	*Melanerpes erythrocephalus*	15
White-eyed Vireo	*Vireo griseus*	14
Yellow-breasted Chat	*Icteria virens*	13

[a] MECH = mechanical site preparation with banded chemical control during 2002,
CHEM = chemical site preparation with banded chemical control during 2002,
COMBO = mechanical and chemical site preparation with banded chemical control during 2002,
BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002,
BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

Appendix 3.B. Vegetation variables from 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] during years 1-5 post-treatment (2002 - 2006) in the Mississippi Lower Coastal Plain[b].

	BGandD[c] (cm)		Forb (cm)		GandGL[c] (cm)		Legume (cm)		Pine (cm)		Snag[c]		Vine (cm)		Woody (cm)	
Treatment	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
MECH	7606.5	1213.4	3478.7	554.9	7637.7	801.1	342.2	93.4	4314.0	808.3	2.8	1.2	14546.8	1594.1	8758.1	1169.1
CHEM	9612.9	1310.4	5034.9	1003.8	9011.6	1130.9	249.9	72.0	3951.3	761.5	56.8	8.9	7424.1	1118.0	6274.5	1194.7
COMBO	9170.7	1560.7	4972.7	821.6	7632.2	1073.7	321.5	90.9	5253.9	960.7	2.9	1.4	10342.2	1545.3	4297.3	807.8
BROAD	11371.5	1979.6	4374.5	880.6	7092.3	1189.4	532.7	143.9	6228.9	1195.0	1.6	0.9	8210.0	1178.5	5170.3	1160.8
BROAD2	16261.9	1838.5	2140.7	573.3	5953.8	1331.8	211.7	74.3	6689.9	1336.6	1.1	0.7	4733.0	925.1	4590.9	1120.5

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Modified from Edwards (2004) and Jones (in progress)

[c] BGandD is bare ground and debris, GandGL is grass and grass-like, Snag is residual trees

Appendix 3.C. Variables for avian models from 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] during years 1-5 post-treatment (April - June 2002 - 2006) in the Mississippi Lower Coastal Plain.

Species	Variable[bc]	Variable Weight
Blue Grosbeak	Woody(-)	1.00
Blue Grosbeak	GandGL(-)	0.74
Blue Grosbeak	Pine(-)	0.40
Blue Grosbeak	BGandD(-)	0.36
Blue Grosbeak	Vine	0.11
Blue Grosbeak	Forb	0.08
Blue Jay	Forb(-)	1.00
Blue Jay	GandGL	1.00
Blue Jay	Pine	1.00
Blue Jay	Snag	1.00
Blue Jay	BGandD(-)	0.29
Blue Jay	Vine	0.19
Brown Thrasher	Woody	1.00
Brown Thrasher	Snag	1.00
Brown Thrasher	Forb(-)	0.69
Brown-headed Cowbird	Snag	1.00
Brown-headed Cowbird	Woody	0.82
Brown-headed Cowbird	Legume(-)	0.49
Brown-headed Cowbird	GandGL(-)	0.48
Brown-headed Cowbird	Pine(-)	0.45
Brown-headed Cowbird	BGandD	0.16
Carolina Chickadee	Snag	1.00
Carolina Chickadee	GandGL	0.42
Carolina Chickadee	Pine(-)	0.25
Carolina Chickadee	Forb(-)	0.24
Carolina Chickadee	BGandD	0.22
Carolina Chickadee	Woody	0.21
Carolina Chickadee	Legume(-)	0.14
Carolina Chickadee	Vine(-)	0.08
Carolina Wren	Snag	1.00
Carolina Wren	Woody(-)	0.32
Carolina Wren	Legume(-)	0.29
Carolina Wren	GandGL	0.29
Carolina Wren	Pine(-)	0.11
Common Yellowthroat	Pine(-)	1.00
Common Yellowthroat	Vine	0.66
Common Yellowthroat	Snag	0.55
Common Yellowthroat	Forb	0.28
Common Yellowthroat	Legume(-)	0.28
Common Yellowthroat	Woody	0.14
Common Yellowthroat	GandGL	0.09
Common Yellowthroat	BGandD(-)	0.04
Downy Woodpecker	Snag	1.00

Appendix 3.C. Continued

Downy Woodpecker	GandGL	0.50
Downy Woodpecker	BGandD	0.36
Downy Woodpecker	Forb(-)	0.31
Downy Woodpecker	Legume(-)	0.14
Downy Woodpecker	Vine	0.11
Eastern Kingbird	Snag	1.00
Eastern Kingbird	Vine	0.25
Eastern Kingbird	Forb(-)	0.21
Eastern Towhee	Snag	1.00
Eastern Towhee	Woody	1.00
Eastern Towhee	Forb(-)	0.80
Eastern Towhee	Pine(-)	0.26
Eastern Towhee	BGandD	0.20
Field Sparrow	GandGL	1.00
Field Sparrow	Snag	1.00
Field Sparrow	Vine	0.83
Field Sparrow	Forb(-)	0.17
Field Sparrow	Legume(-)	0.15
Field Sparrow	BGandD	0.14
Great Crested Flycatcher	Snag	1.00
Great Crested Flycatcher	GandGL	0.60
Great Crested Flycatcher	Pine	0.32
Great Crested Flycatcher	Forb(-)	0.21
Great Crested Flycatcher	Woody(-)	0.16
Great Crested Flycatcher	Vine(-)	0.08
Hooded Warbler	Woody	0.83
Hooded Warbler	Pine(-)	0.81
Hooded Warbler	Vine	0.40
Indigo Bunting	BGandD(-)	1.00
Indigo Bunting	Snag	1.00
Indigo Bunting	Woody(-)	1.00
Indigo Bunting	GandGL(-)	0.59
Indigo Bunting	Legume	0.21
Indigo Bunting	Pine	0.17
Northern Bobwhite	Woody(-)	1.00
Northern Bobwhite	Pine(-)	0.85
Northern Bobwhite	Snag(-)	0.45
Northern Bobwhite	Legume(-)	0.44
Northern Bobwhite	BGandD	0.16
Orchard Oriole	BGandD	1.00
Orchard Oriole	Forb	1.00
Orchard Oriole	Pine(-)	0.48
Orchard Oriole	Woody(-)	0.29
Prairie Warbler	Pine(-)	1.00
Prairie Warbler	Snag	1.00
Prairie Warbler	Forb(-)	0.22
Prairie Warbler	Legume	0.19
Prairie Warbler	Woody(-)	0.18
Red-bellied Woodpecker	Snag	1.00

Appendix 3.C. Continued

Red-bellied Woodpecker	GandGL	0.89
Red-bellied Woodpecker	Legume(-)	0.78
Red-bellied Woodpecker	Pine	0.56
Red-bellied Woodpecker	Woody(-)	0.50
Red-bellied Woodpecker	Forb(-)	0.08
Red-headed Woodpecker	BGandD(-)	1.00
Red-headed Woodpecker	Snag	1.00
Red-headed Woodpecker	Pine	0.22
Red-headed Woodpecker	Woody(-)	0.19
Red-headed Woodpecker	Forb	0.16
White-eyed Vireo	Pine(-)	1.00
White-eyed Vireo	Woody	1.00
White-eyed Vireo	Snag	0.50
White-eyed Vireo	Legume	0.32
White-eyed Vireo	GandGL(-)	0.15
White-eyed Vireo	Vine	0.08
Yellow-breasted Chat	BGandD	1.00
Yellow-breasted Chat	Pine(-)	1.00
Yellow-breasted Chat	Snag	1.00
Yellow-breasted Chat	Vine	1.00
Yellow-breasted Chat	Woody	0.56
Yellow-breasted Chat	Forb	0.23

[a] MECH = mechanical site preparation with banded chemical control during 2002,
CHEM = chemical site preparation with banded chemical control during 2002,
COMBO = mechanical and chemical site preparation with banded chemical control during 2002,
BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002,
BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Year is a variable in all models and produces 5 additonal parameters

[c] Snag is residual trees, BGandD is bare ground and debris, GandGL is grass and grass-like

CHAPTER IV

SMALL MAMMAL ASSEMBLAGES DURING INTENSIVE PINE PLANTATION ESTABLISHMENT IN COASTAL PLAIN MISSISSIPPI

***Abstract*:** There is a wide intensity range of pine plantation establishment in the southeastern United States. To investigate small mammal habitat quality along a gradient of pine plantation establishment intensities, I monitored small mammal response for 5 years in pine plantations established with chemical and mechanical site preparation with chemical release treatments in the Lower Coastal Plain of Mississippi. I captured small mammals for 5 nights at each of 4 study sites during February using 100 station trapping grids in each of 5 treatments. I caught 2,476 individuals of 6 species during 100,000 trap nights. There were minimal treatment effects on small mammal assemblages. The highest intensity treatment created habitat conditions that supported more white-footed mice (*Peromyscus leucopus*) adults and males. Total small mammal abundance excluding *Peromyscus leucopus* was greater in the lower intensity treatments. Abundance of 5 captured small mammal species appeared adaptable to the full range of stand establishment intensity in the Lower Coastal Plain. Future research should focus on areas containing species of conservation concern, such as vulnerable subspecies with limited geographic range.

INTRODUCTION

Pine plantations comprise 12 million hectares of southeastern forestlands, compared to 810,000 ha in 1952. (Prestemon and Abt 2002, Wear 2002). Intensive site preparation and early herbicide release in pine plantations can suppress herbaceous and shrubby vegetation while removing stand elements, such as coarse woody debris and leaf litter (Lautenschlager 1993, Smith et al. 1996). Consequent modification of stand structure, particularly foliage density, may impact small mammal populations by altering moist microhabitats, foraging opportunities, cover, nest sites, and travel routes (Langley and Shure 1980, Loeb 1996, Bowman et al. 2001, Mengak and Guynn 2003). Furthermore, successional stage may affect small mammal abundance (Atkeson and Johnson 1979, Mengak et al. 1989), and intensive silvicultural management can abbreviate the length of high quality habitat by hastening canopy closure.

Research has demonstrated differences in small mammal communities between sites receiving chemical or mechanical release treatments, perhaps due to greater vegetation suppression or presence of mammals less adaptable to disturbance (Borrecco et al. 1979, Ritchie et al. 1987, Santillo et al. 1989, Lautenschlager et al. 1997). In contrast, there are studies that indicate minimal release treatment differences (Freedman et al. 1988, Sullivan 1990, Runciman and Sullivan 1996, Cole et al. 1998). Studies in the Southeast involving effects of establishment treatments on small mammal communities tend to detect temporary differences. O'Connell and Miller (1994) chronicled greater abundance at 2 years post-treatment and greater species diversity at 3 years post-treatment in sites managed with mechanical treatments versus hexazinone treatments in South Carolina. Brooks et al. (1994), in a Georgia pine site preparation study contrasting effects of 3 different herbicide treatments, detected no treatment effects apart from oldfield mice (*Peromyscus polionotus*) during one trapping period. Mihalco (2004), studying an establishment intensity gradient for 2 years after treatment in North Carolina pine plantations, found that total captures of small mammals were greatest in mechanically prepared treatments with banded release during the second year.

Small mammal populations may react differentially to intensive pine plantation establishment, depending on mammal species, severity of vegetation removal and site disturbance, and time length of vegetation alteration. Therefore, I investigated small mammal response to a wide establishment intensity gradient incorporating both chemical and mechanical site preparation along with chemical release. The study objective was to quantify effects of pine plantation establishment intensities on small mammal assemblages through year 5 post-treatment in lower Coastal Plain Mississippi. I compared species richness, total abundance, and for each common species, abundance by species, gender class, and age class among the 5 treatments.

STUDY AREA

The 4 study sites, averaging 66 ha, were located in George, Lamar, and Perry counties of Lower Coastal Plain Mississippi. These sites were owned and managed by Molpus Timberlands (Perry County), Plum Creek (George County), and Weyerhaeuser Company (Lamar County). Soils generally consisted of ultisols, acid clays which are highly leached and low in organic matter, along with sandy sediments (Pettry 1977, Martin and Boyce 1993). Stands were previously loblolly (*Pinus taeda*) or slash (*P. elliottii*) pine plantations that were harvested during summer 2000-winter 2001.

All stands were planted with loblolly pine during winter 2001-2002. Each forest product industry cooperator provided proprietary genetically-improved seedlings. Tree spacing was 3.0 m between rows and 2.1 m between trees within a row, totaling 1,551 trees/ha. Two stands were machine planted and 2 stands were planted by hand due to greater harvest debris loads. Banded herbaceous control treatments were applied to every tree row with a band width of 1.5 m, and broadcast herbicide applications were applied by helicopter. All treatments received a broadcast application of diammonium phosphate at 280 kg/ha during spring 2002.

Each site contained 5 treatment levels, representing a range of operational intensities in stand establishment techniques. The experimental design included a randomized complete block, so that each treatment was assigned randomly to a minimum of 8 ha per stand. Management intensity, and thus expected vegetative impact, increased from "low" for MECH to "high" for BROAD2 (Table 4.1). MECH consisted of mechanical site preparation only, via a combination plow to subsoil, disk, and bed, as well as a V-blade to clear debris, during fall 2001 and a banded herbaceous control with 0.9 kg/ha of Oustar® (E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware; hexazinone and sulfometuron; 13 oz./acre) during spring 2002. CHEM consisted of chemical site preparation only, involving 2.4 L/ha Chopper® (BASF Corp., Research Triangle Park, North Carolina; imazapyr; 32 oz./acre), 3.5 L/ha Accord® (Dow AgroSciences LLC, Indianapolis, Indiana; glyphosate; 48 oz./acre), 3.5 L/ha Garlon 4 (Dow AgroSciences LLC, Indianapolis, Indiana; triclopyr; 48 oz./acre), and 1% Timberland 90® surfactant (UAP Timberland LLC, Monticello, Arkansas) during summer 2001 and the same banded herbaceous control as MECH. COMBO combined the mechanical site preparation of MECH with the chemical site preparation of CHEM, along with the banded control. BROAD combined the same mechanical and chemical site preparation with a broadcast herbaceous control using 0.9 kg/ha of Oustar® during spring 2002. BROAD2 combined the same mechanical and chemical site preparation with the same broadcast herbaceous control during springs 2002 and 2003.

Vegetation was sampled in a companion study (Edwards 2004, Jones unpublished data, Mississippi State University), and the establishment intensity gradient generated treatment differences in vegetation. During 2004-2006, increasing treatment intensity increased pine tree height and diameter. CHEM had the lowest growth rate, while BROAD2 had the greatest, and the other treatments were intermediate. BROAD2 averaged 1.4 m taller and 2.4 cm greater in dbh than CHEM. Growth of pine trees by height averaged 1.36 m/yr across all treatments. Correspondingly, coverage of pine trees was associated with increased treatment intensity. Pine coverage was greatest in BROAD and BROAD2 and least in MECH and CHEM. Pine coverage increased in all treatments from 2004 to 2006. Coverage of understory herbaceous plants decreased with increasing intensity. BROAD2 averaged 65% of MECH. Coverage in all treatments declined from 85-125% during 2004 to 44-76% during 2006. Woody plant coverage, excluding pines, almost had a treatment effect ($F_{4,42} = 2.56$, $P = 0.053$), and coverage increased from 2004 to 2006. During 2002-2006, total vegetation generally was greatest in MECH and least in BROAD2, with COMBO, BROAD, and CHEM intermediate in vegetation coverage.

METHODS

I trapped small mammals during February for 5 nights per site from 2002-2006. Within each treatment, there was a 10 x 10 trapping grid, with stations approximately 10 m distant from other stations. Stations contained 2 Victor® traps (Woodstream Corporation, Lititz, Pennsylvania), one mouse and one rat, baited with peanut butter. Every treatment had 200 total traps and thus each site had 1000 traps. Trapping grids were at least 50 m away from treatment boundaries. I recorded and weighed mammals in the field, and later determined species, gender, and reproductive status. Age was either juvenile or adult based on size and coloration of testes in males (Jameson 1950) and by uterine horn development in females. Results for 2002-2003 were reported previously by Edwards (2004). MSU Institutional Animal Care and Use Committee approved trapping and handling procedures as Protocol 04-002.

I used a repeated measures, mixed model analysis of variance to test year effects, treatment effects, and year × treatment interactions for small mammal species richness, relative abundance of individuals by species, and gender and age classes (SAS Proc MIXED; SAS Institute 2002-2003). Year was a repeated measure and site was a random effect. Using least AIC_c (Akaike's Information Criterion corrected for small sample size) value, I selected the covariance structure with the best fit from autoregressive, compound symmetry, autoregressive heterogeneous, compound symmetry heterogeneous, and toeplitz heterogeneous (Gutzwiller and Riffell 2007). I then assessed model fit with and without the random statement, and retained site based on lesser AIC_c value. I examined residuals and used either square root transformations or a change in covariance structure to improve model fit when indicated. I used the kenwardroger adjustment in denominator degrees of freedom for repeated measures and small sample sizes (Gutzwiller and Riffell 2007, Littell et al. 2006). I compared means with Fisher's least significant difference, using the LSMEANS PDIFF option. Differences were considered significant when $P \leq 0.05$.

RESULTS

I captured 2,476 individuals during 100,000 trap nights. I caught 5 species every year: southern short-tailed shrew (*Blarina carolinensis*), wood rat (*Neotoma floridana*), white-footed mouse (*Peromyscus leucopus*), fulvous harvest mouse (*Reithrodontomys fulvescens*), and cotton rat (*Sigmodon hispidus*). In 2005 and 2006, 4 golden mice (*Ochrotomys nuttalli*) were captured and I included this species only for species richness.

I detected few treatment effects for small mammal abundance (Table 4.2). Male *Peromyscus leucopus* ($F_{4,17.1} = 2.97$, $P = 0.049$) were most common in BROAD2 and least in CHEM. Adult *Peromyscus leucopus* ($F_{4,16.7} = 3.08$, $P = 0.045$) were most numerous in BROAD2. Species richness nearly showed a year × treatment interaction ($F_{16,37.6} = 1.90$, $P = 0.053$; Table 4.3). During 2003, richness was greatest in CHEM, followed by MECH, COMBO and BROAD2, and lastly, BROAD.

Year effects were frequent, and whether total abundance or abundance by species, gender class or age class, generally reflected a sharp increase from 2002 to 2003 followed by a decline by 2006 (Table 4.4). Total small mammal, *Peromyscus leucopus*, and *Sigmodon hispidus* abundance peaked during 2003, and *Blarina carolinensis* and *Reithrodontomys fulvescens* peaked during 2005. By 2006, total abundance was similar to the first year, which was due in part to a great decrease in *Peromyscus leucopus*.

To determine if the most abundant species, *Peromyscus leucopus*, were masking a treatment effect for total abundance of the other small mammal species, I excluded *Peromyscus leucopus*. Total abundance excluding *Peromyscus leucopus* had a treatment and year effect ($F_{4,18.8} = 3.29$, $P \le 0.033$; $F_{4,25} = 60.07$, $P \le 0.001$; Table 4.5). There were more individuals in the lower intensity treatments, MECH and CHEM, than the highest intensity treatment, BROAD2.

DISCUSSION

Treatment differences in small mammals were minimal after 5 years of monitoring, despite some vegetation dissimilarities, including generally greater herbaceous and woody coverage in the lesser intensity treatments (vegetation described in companion study by Edwards 2004 and P. Jones, Mississippi State University, unpublished data). These results were consistent with prior southeastern research investigating intensive stand establishment effects on small mammals.

Adult male *Peromyscus leucopus* were more common in the relatively open plantation conditions during initial years and highest intensity treatment during all years. One cause may be intersexual differences in habitat use. There is little evidence for this in small mammals, despite greater home range of males and territoriality by females, because there is overlap between female and male home ranges (Wolff 1989). However, Seagle (1985) found that female *Peromyscus leucopus* resided in better protective cover than males in deciduous forest. This agrees with my results, where male *Peromyscus leucopus* were more frequent in sparse cover. Furthermore, stronger presence of *Peromyscus leucopus* in open vegetation corresponded with the “sparse ground cover” that Mengak and Guynn (2003) characterized for white-footed mice but contrasted with the dense foliage profile that M'Closkey and LaJoie (1975) and Adler and Wilson (1987) described. If *Peromyscus leucopus* use a range of vegetation density, then their distribution may have coincided with areas of limited inhabitation by other species. Displacement of *Peromyscus leucopus* into BROAD2 could have caused a balance of total small mammal abundance among treatments, thus total abundance without this species contained more individuals in the lowest intensity treatments. The lower intensity treatments provided the densest cover while BROAD2 had the least total vegetation, during 3 years post-establishment (Edwards 2004, Jones unpublished data, Mississippi State University). This preferred habitat (Goertz 1964, M'Closkey and LaJoie 1975) may be claimed by other small mammal species, perhaps demonstrated by greater species richness in the lower intensity treatments during 2003, resulting in the exclusion of adult male *Peromyscus leucopus*.

Plantations supported greatest number of small mammals during years 2-4 post-establishment. During the first year, this may be due to limited time for small mammal colonization and initial lack of vegetation. By 2006, tree canopy development and consequent understory suppression may have reduced habitat quality.

Several factors could have influenced lack of treatment effects on small mammals. Most small mammals are readily able to exploit resources through flexible foraging and rapid reproduction (Bourlière 1975). They tend to be omnivorous rather than specialists, allowing for greater food opportunities (Golley et al. 1975). Additionally, most species may not require specific habitat beyond broad vegetation type and successional stage (Sullivan 1979, Van Horne 1981). For example, Goertz (1964,

1970) concluded that for *Sigmodon hispidus* and *Neotoma floridana*, plant taxa were interchangeable as long as basic requirements of grasslands or woodlands were present. Principal small mammal species present in this study were habitat generalists that are common to abundant in the southeastern United States (Goertz 1964, Packard 1968, Goertz 1970, Adler and Wilson 1987, Brown 1997, Peles et al. 1999).

Small mammal populations present in the study sites therefore may respond more to biological interactions than habitat changes. There are numerous studies attributing small mammal distribution to tight internal regulation and powerful social interactions, that is, by adults causing 1) juvenile emigration or mortality through aggression or 2) suppression of subadult reproduction or recruitment (Harland et al. 1979, Sullivan 1979, Nadeau et al. 1981, Van Horne 1981, Adler and Tamarin 1984, Bowers and Dooley 1999). Dispersal may counteract any divergence in abundance resulting from habitat quality variation. In my study, each site had at least 2 adjacent trapping grids that were within 150 m of each other. Small mammals frequently disperse from their natal home range, although dispersal distances typically tend to be less than 200 m (Bowers and Dooley 1999). Nonetheless, home range for *Peromyscus* spp. can reach 3,000 square meters (Wolff 1989). In addition, small mammals may not maintain home ranges, for example *Peromyscus* spp. exhibit substantial amount of year-round movement. Moreover, reported prevalence of juvenile and adult transience combined with fast turnover of small mammals suggests that captured animals may not represent the treatment of origin.

Trapping can produce misleading results. Bait may be more attractive in habitats with low food abundance, and thus animal captures may reflect food abundance rather than species abundance. Differential trapping can occur, as males, older individuals, and socially dominant species are more likely to be caught (Smith et al. 1975). This factor is a particular shortcoming of kill-trapping. Social interactions can be disrupted by mammal removal, leading to changes in social structure such as breeding, behavior, age, and recruitment. In particular, after 3 days of continuous trapping, immigrants instead of residents may be caught, distorting results (Sullivan et al. 2003). Lautenschlager (1993) found that of 14 studies, conifer release treatments displayed differences only with removal trapping, perhaps due to removal of the animals tolerant of disturbance or dominant species.

MANAGEMENT IMPLICATIONS

Judging by the first 5 years, and previous studies, captured small mammals appeared adaptable to the full range of stand establishment intensity in the Lower Coastal Plain. Establishment that at least initially suppressed foliage density did not suppress abundance of small mammal populations. This suggested that increasing plantation establishment intensity in the southeastern Coastal Plain will not be detrimental to species that currently are abundant in young plantations. However, richness and abundance may be incomplete metrics that do not assess population-level impacts. There was not enough information to evaluate reproduction of trapped animals (only 23 individuals contained embryos; B. Hanberry, Mississippi State University, unpublished data), and I did not evaluate survival during the trapping period, or reproductive metrics and survival during another season.

One concern is that overall plantation trends indicated small mammal populations were declining after reaching a peak during years 2 to 4. The plantations may be providing quality habitat for small mammal species only during a very young early successional stage. The faster growth toward pine tree dominance and canopy closure due to intense stand establishment may limit the duration and diversity of non-pine vegetation (Zobrist et al. 2005), and consequently reduce small mammal abundance (Atkeson and Johnson 1979, Mengak et al. 1989).

The design of my study did not address whether increased intensity of pine plantation establishment could impact declining small mammal species. Thus, future research should be conducted where vulnerable species occur. Studies should concentrate on plantation establishment in locations containing rare small mammal species, such as Florida mouse (*Podomys floridanus*). However, pine plantations in most instances are established in plantation forests or agricultural fields, which are not likely to contain rare species, and sustainable forestry certification programs require protection of sensitive species and communities (Sustainable Forestry Initiative 2005).

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Table 4.1. Five stand establishment treatments varying from low (MECH) to high (BROAD2) intensity in the Mississippi Lower Coastal Plain.

	Treatment				
	MECH	CHEM	COMBO	BROAD	BROAD2
Site Preparation	Mechanical	Chemical	Mechanical and Chemical	Mechanical and Chemical	Mechanical and Chemical
Release	Banded - 2002	Banded - 2002	Banded - 2002	Broadcast - 2002 & 2003	Broadcast - 2002 & 2003

Table 4.2. Mean abundance of small mammals captured by treatment in 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] at years 1-5 post-treatment (February 2002-2006) in the Mississippi Lower Coastal Plain[b].

	Treatment																
	MECH			CHEM			COMBO			BROAD			BROAD2			*P* -value	
Species	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	Trt	Yr*trt
Blarina carolinensis	0.9		0.3	1.0		0.4	0.9		0.5	1.2		0.5	0.7		0.4	0.977	0.836
Female	0.5		0.2	0.6		0.3	0.3		0.2	0.5		0.2	0.3		0.1	0.942	0.754
Male	0.4		0.2	0.5		0.2	0.6		0.3	0.7		0.3	0.4		0.3	0.794	0.571
Adult	0.4		0.1	0.4		0.2	0.4		0.2	0.3		0.2	0.1		0.1	0.853	0.799
Juvenile	0.5		0.2	0.7		0.3	0.5		0.3	0.9		0.4	0.6		0.3	0.799	0.591
Neotoma floridana	0.6		0.2	0.7		0.2	0.5		0.2	0.4		0.2	0.4		0.2	0.188	0.576
Female	0.3		0.1	0.3		0.1	0.3		0.1	0.3		0.1	0.2		0.1	0.578	0.293
Male	0.4		0.1	0.4		0.2	0.3		0.1	0.1		0.1	0.2		0.1	0.210	0.575
Adult	0.5		0.1	0.5		0.2	0.3		0.1	0.2		0.1	0.2		0.2	0.381	0.717
Juvenile	0.2		0.1	0.2		0.1	0.2		0.1	0.2		0.1	0.2		0.1	0.997	0.650
Ochrotomys nuttalli	0.1		0.1	0.1		0.1	0.0		0.0	0.0		0.0	0.1		0.1	N/A	N/A
Peromyscus leucopus	8.7		1.9	7.9		2.2	11.3		2.9	8.3		1.9	13.6		2.1	0.139	0.912
Female	3.9		1.1	4.0		1.4	4.9		1.4	3.6		1.0	5.8		1.0	0.509	0.810
Male	4.9	AB	0.9	3.9	A	0.9	6.4	BC	1.6	4.7	AB	1.0	7.9	C	1.1	0.049	0.814
Adult	4.5	A	0.9	3.6	A	0.8	4.8	A	1.4	4.6	A	1.1	8.3	B	1.2	0.045	0.803
Juvenile	4.3		1.4	4.3		1.8	6.5		2.1	3.7		1.0	5.4		1.6	0.477	0.718
Reithrodontomys fulvescens	3.5		1.0	4.6		1.1	3.8		1.1	3.9		1.0	2.9		0.8	0.833	0.872
Female	1.9		0.6	3.0		0.9	1.7		0.5	2.1		0.6	1.2		0.4	0.486	0.857
Male	1.6		0.5	1.6		0.4	2.1		0.6	1.8		0.6	1.7		0.5	0.957	0.924
Adult	0.8		0.4	1.6		0.5	0.8		0.3	1.4		0.4	0.9		0.3	0.094	0.515
Juvenile	2.7		0.7	3.0		0.7	3.1		0.9	2.5		0.8	2.0		0.6	0.815	0.866
Sigmodon hispidus	13.5		4.3	12.1		2.8	9.0		1.8	7.8		1.6	6.0		1.3	0.141	0.255
Female	7.2		2.4	4.6		1.0	4.4		0.8	4.0		0.8	2.8		0.6	0.108	0.507
Male	6.4		2.0	7.5		1.9	4.6		1.0	3.8		0.8	3.3		0.7	0.144	0.289
Adult	5.3		1.4	7.7		1.9	5.6		1.2	4.8		1.1	3.4		0.9	0.230	0.453
Juvenile	8.2		3.2	4.5		1.2	3.5		0.8	3.0		0.9	2.6		0.6	0.128	0.065
Total Abundance	27.3		5.5	26.3		4.2	25.4		4.0	21.4		2.9	23.6		2.7	0.633	0.398

Table 4.2. Continued

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Values within rows followed by the same letter do not differ ($P > 0.05$); values are number of individuals per 1000 trap nights averaged across sites

Table 4.3. Small mammal species richness in 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity at years 1-5 post-treatment (February 2002 - 2006) in the Mississippi Lower Coastal Plain[b].

	Treatment															P-value	
	MECH			CHEM			COMBO			BROAD			BROAD2					
Species Richness	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	Yr	Trt	Yr*trt
2002	2.5		0.5	2.3		0.5	1.5		0.3	1.3		0.3	1.3		0.3		0.213	
2003	4.0	AB	0.4	4.5	A	0.3	3.3	BC	0.3	3.0	C	0.4	3.3	BC	0.3		0.008	
2004	3.8		0.6	3.8		0.6	4.3		0.3	4.0		0.4	3.3		0.3		0.626	
2005	3.5		0.3	3.8		0.3	3.3		0.5	3.5		0.7	4.0		0.6		0.771	
2006	2.8		0.5	2.3		0.3	3.0		0.0	2.5		0.3	2.8		0.3		0.307	0.053

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Values within rows followed by the same letter do not differ (P > 0.05); values are number of individuals per 1000 trap nights averaged across sites

Table 4.4. Mean abundance of small mammals captured by year in 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] at years 1-5 post-treatment (February 2002-2006) in the Mississippi Lower Coastal Plain[b].

	Year																
	2002			2003			2004			2005			2006			*P* -value	
Species	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	Yr	Yr*trt
Blarina carolinensis	0.1		0.1	1.0		0.3	1.0		0.3	2.1		0.7	0.4		0.2	0.054	0.836
Female	0.1	A	0.1	0.6	BC	0.2	0.5	C	0.1	1.1	C	0.4	0.1	AB	0.1	0.029	0.754
Male	0.0	A	0.0	0.5	AB	0.2	0.6	AB	0.2	1.1	B	0.4	0.4	A	0.2	0.032	0.571
Adult	0.1		0.1	0.3		0.1	0.3		0.1	0.8		0.3	0.2		0.1	0.111	0.799
Juvenile	0.0	A	0.0	0.7	AB	0.3	0.8	BC	0.3	1.4	B	0.5	0.3	AC	0.2	0.005	0.591
Neotoma floridana	0.3		0.1	0.6		0.2	0.9		0.2	0.5		0.2	0.3		0.1	0.059	0.576
Female	0.1		0.1	0.3		0.1	0.4		0.1	0.3		0.1	0.2		0.1	0.117	0.293
Male	0.2		0.1	0.3		0.1	0.5		0.2	0.2		0.1	0.2		0.1	0.306	0.575
Adult	0.2		0.1	0.5		0.2	0.6		0.2	0.2		0.1	0.2		0.1	0.175	0.717
Juvenile	0.1		0.1	0.1		0.1	0.4		0.1	0.3		0.1	0.2		0.1	0.254	0.650
Ochrotomys nuttalli	0.0		0.0	0.0		0.0	0.0		0.0	0.1		0.1	0.2		0.1	N/A	N/A
Peromyscus leucopus	14.8	A	1.5	22.5	B	2.6	6.6	C	1.0	3.3	D	0.7	2.6	D	0.7	< 0.001	0.912
Female	6.3	A	0.7	11.1	B	1.5	2.4	C	0.4	1.3	D	0.3	1.0	D	0.2	< 0.001	0.810
Male	8.5	A	0.9	11.4	A	1.3	4.2	B	0.7	2.1	C	0.4	1.6	C	0.4	< 0.001	0.814
Adult	10.3	A	1.4	7.4	A	0.9	4.0	B	0.8	2.1	C	0.6	1.9	C	0.5	< 0.001	0.803
Juvenile	4.5	A	0.4	15.1	B	2.2	2.6	C	0.6	1.3	CD	0.4	0.7	D	0.3	< 0.001	0.718
Reithrodontomys fulvescens	0.2	A	0.1	4.1	B	0.8	6.3	C	1.0	7.0	BC	1.2	1.1	D	0.3	< 0.001	0.872
Female	0.1	A	0.1	2.2	B	0.5	3.4	B	0.8	3.7	B	0.7	0.6	C	0.2	< 0.001	0.857
Male	0.1	A	0.1	1.9	B	0.4	2.9	B	0.6	3.3	B	0.6	0.6	A	0.2	< 0.001	0.924
Adult	0.0	A	0.0	0.5	A	0.2	1.8	B	0.4	2.4	B	0.5	0.9	A	0.3	< 0.001	0.515
Juvenile	0.2	A	0.1	3.6	B	0.7	4.6	B	0.7	4.6	B	0.8	0.3	A	0.1	< 0.001	0.866
Sigmodon hispidus	0.5	A	0.2	19.1	B	4.6	10.9	C	1.3	13.1	BC	1.1	4.9	D	1.0	< 0.001	0.255
Female	0.2	A	0.1	8.8	B	2.4	4.7	BC	0.6	6.4	B	0.6	2.9	C	0.6	< 0.001	0.507
Male	0.3	A	0.1	10.3	B	2.4	6.2	B	0.9	6.8	B	0.7	2.0	C	0.4	< 0.001	0.289
Adult	0.2	A	0.1	8.5	B	2.1	6.9	B	1.0	7.9	B	0.9	3.2	C	0.7	< 0.001	0.453
Juvenile	0.3	A	0.1	10.6	B	3.1	4.0	C	0.5	5.2	C	0.9	1.7	D	0.4	< 0.001	0.065
Total Abundance	15.8	A	1.5	47.2	B	5.3	25.6	C	1.8	26.0	C	1.6	9.4	D	1.2	< 0.001	0.398

Table 4.4 Continued

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Values within rows followed by the same letter do not differ ($P > 0.05$); values are number of individuals per 1000 trap nights averaged across sites

Table 4.5. Total abundance of small mammals, excluding *Peromyscus leucopus* , captured in 5 pine plantation establishment treatments varying from low (MECH) to high (BROAD2) intensity[a] at years 1-5 post-treatment (February 2002-2006) in the Mississippi Lower Coastal Plain[b].

	Treatment																
	MECH			CHEM			COMBO			BROAD			BROAD2			*P* -value	
Species	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	$\bar{x}$		SE	Yr	Trt	Yr*trt
Total without *Peromyscus leucopus*																		
2002	2.0		0.6	1.8		1.0	0.5		0.3	0.3		0.3	0.3		0.3			
2003	50.5		13.1	31.5		10.1	19.3		5.4	13.5		6.6	8.5		3.6			
2004	15.0		3.5	26.0		4.0	21.5		5.6	19.5		4.9	13.3		1.9			
2005	19.8		4.1	25.3		2.2	21.8		4.3	24.0		1.4	22.5		4.4			
2006	5.5		1.6	7.3		2.3	7.8		3.2	8.3		2.1	5.3		1.4			
Combined	18.6	A	4.7	18.4	A	3.3	14.2	AB	2.6	13.1	AB	2.5	10.0	B	2.1	< 0.001	0.033	0.215

[a] MECH = mechanical site preparation with banded chemical control during 2002, CHEM = chemical site preparation with banded chemical control during 2002, COMBO = mechanical and chemical site preparation with banded chemical control during 2002, BROAD = mechanical and chemical site preparation with broadcast chemical control during 2002, BROAD2 = mechanical and chemical site preparation with broadcast chemical control during 2002 and 2003

[b] Values within rows followed by the same letter do not differ (P > 0.05); values are number of individuals per 1000 trap nights averaged across sites

CHAPTER V

BREEDING BIRD RELATIONSHIPS TO LANDSCAPE METRICS IN COASTAL PLAIN GEORGIA

Abstract: Some avian species in the southeastern United States are declining, and population decreases may arise from changes in area, abundance, or stage class of vegetation types. My objective was to compare abundance of conservation priority bird species with landscape variables in the Coastal Plain of Georgia. I used the Georgia Gap Analysis land cover grid buffered at 0.5, 1, 2, and 4-km extents along North American Breeding Bird Survey (BBS) routes. I applied logistic regression and Akaike's Information Criteria for model fitting and then retained models based on external validation and overall accuracy. Acadian Flycatcher (*Empidonax virescens*) and Field Sparrow (*Spizella pusilla*) had models that incorporated area variables. Downy Woodpecker (*Picoides pubescens*), Eastern Kingbird (*Tyrannus tyrannus*), Eastern Wood-pewee (*Contopus virens*), Northern Parula (*Parula americana*), Orchard Oriole (*Icterus spurius*), Pileated Woodpecker (*Dryocopus pileatus*), Prairie Warbler (*Dendroica discolor*), Summer Tanager (*Piranga rubra*), and 2 potential nuisance species, Blue Jay (*Cyanocitta cristata*) and Brown-headed Cowbird (*Molothrus ater*), had models that included area and edge associations with varying scales and vegetation types. Edge appeared to be important for Red-bellied Woodpecker (*Melanerpes carolinus*) and Carolina Chickadee (*Poecile carolinensis*). Eastern Towhee (*Pipilo erythrophthalmus*),

Northern Bobwhite (*Colinus virginianus*), and Pine Warbler (*Dendroica pinus*) did not have models that incorporated area or edge and 7 species did not have models that met prediction or accuracy thresholds. Each buffer extent included models for 8-10 species, an even distribution among the scales. Hardwood forests were important vegetation types for all but one modeled species. Systematic assessment of area requirements for declining species can provide information for management, conservation, and research.

INTRODUCTION

Populations of certain bird species are declining, particularly disturbance-dependent species associated with grasslands, shrublands, and open forests (Hunter et al. 2001). Population trends may arise from land use changes in vegetation type area, abundance, or stage class. Stand elements, including vegetation composition and structure, can affect a variety of bird species, such as cavity nesters that require older trees or early successional species that need an open canopy and midstory.

Most bird-landscape studies have taken place outside of the Southeast. Compared to regions fragmented by agriculture and urbanization, Coastal Plain landscape research on breeding birds has been equivocal, perhaps because many patches of one forest type are enclosed within forest of another type (Sallabanks et al. 2000, Turner et al. 2002). Such studies include Krementz and Christie (2000), who detected no effect of clearcut size on species richness or juvenile to adult ratios in birds captured in mist nets. In investigations of bottomland hardwood widths, Hodges and Krementz (1996) and Kilgo et al. (1998) found species richness increased with riparian width. Aquilani and Brewer (2004) determined that Wood Thrush (*Hylocichla mustelina*) nest success was greatest in large fragments and least near clearcut edges, primarily due to varying predation levels. Edge increased nest predation and negatively affected Indigo Bunting (*Passerina cyanea*) nesting success (Weldon and Haddad 2005), but edge did not depress Acadian Flycatcher nest survival (Hazler et al. 2006).

Given that there is incomplete regional knowledge about avian habitat requirements, models can contribute valuable information about landscape metrics associated with avian presence for conservation management and research. Habitat selection involves multiple scales, or at least changes depending on observation scale, and may vary by region (Wiens et al. 1987, Orians and Wittenberger 1991). Regional habitat modeling at different scales for birds that are declining may help establish area sensitivity classifications. My objective was to determine land class variables at varying scales that predict abundance of priority avian species in Coastal Plain Georgia.

STUDY AREA

Southeastern Georgia is in the Coastal Plain, a low, flat physiographic region. Coastal Plain vegetation consists of upland forests interspersed with wetlands and poorly drained flatwoods. Land use consists of row crop agriculture and intensively managed pine forest, with urbanization along the coast (Kramer et al. 2003). In 1999, Georgia had 9.5 million ha of timberlands, 60 - 65% of the state's total area, including 2.5 million ha in planted pine and 1.85 million ha in natural pine (Conner and Hartsell 2002). Forested areas are young; 3.3 million ha are in the seedling sapling stage (less than 12.7 cm dbh; Conner and Hartsell 2002). Disturbance agents include fire, hurricanes, tornadoes, floods, and ice storms.

METHODS

Data Sets

I combined the North American Breeding Bird Survey (BBS; Sauer et al. 2004), coordinated by USGS Patuxent Wildlife Research Center, with the Georgia Gap Analysis land cover grid (GA-GAP; Kramer et al. 2003), to correlate bird species abundance with spatial metrics. Breeding Bird Survey routes are approximately 40 km long and consist of 50 points that are 0.8 km apart. Volunteers record birds within a 400 m radius during 3 minutes at each point. One bias of BBS is that surveys occur alongside roads. However, there are roads throughout Georgia, where roadless areas may be limited (Trani 2002). The GA-GAP classified 30 meter resolution Landsat Thematic Mapper satellite imagery, using 1996-1998 imagery. There are 44 land cover classes with an overall accuracy of 75.5%. The satellite imagery occurred before the accuracy assessment, which contributed to error rate.

From the BBS database, I selected all routes in Georgia's Coastal Plain and Flatwoods with 3 survey years under approved conditions during 1995 to 1999 (n = 27 routes). I divided the routes into 5, 10-stop partial routes about 8 km in length, and selected the straightest (i.e. the least overlapping) partial route from each end (i.e. not the middle partial route). I placed buffered extents of 0.5, 1, 2, and 4-km around each partial route. I eliminated 2 partial routes, due to overlap at the 4 km buffer extent, leaving 52 routes. For all these operations, I used ArcGIS 9.0 (ESRI 2005).

I retained, with some reclassification, 8 GA-GAP land cover classes for analysis: 1) Hardwood forests 2) Hydric hardwoods (bottomland hardwood, cypress-gum swamp, evergreen forested wetland), 3) Clearcut (recent clearcuts, sparse vegetation, and other early successional areas, 4) Pasture/hay, 5) Mixed forest, 6) Managed pine (loblolly-shortleaf, loblolly-slash), 7) Longleaf pine), and 8) Shrub (sandhill, shrub wetland). I clipped the reclassified grid using the buffered partial route shapes, creating grids of each partial route at 4 buffer distances.

I used FRAGSTATS (McGarigal et al. 2002) to compute 7 spatial metrics for each class type. Metrics for modeling included area (AREA; mean patch area, depends on patch size and number), core area (CORE; mean core area of patch, excludes 90 m buffer from edge), cohesion (COHESION; connectivity of class type), edge density (ED; edge length of patch standardized by area), and the interspersion and juxtaposition index (IJI; class type intermixing). Additionally, for landscape descriptive statistics (Appendix E), I calculated percentage of landscape (PLAND; proportional abundance of class type, standardized by area) and core percentage landscape (CPLAND; proportional abundance of class type core area, excludes 90 m buffer from edge).

I chose 22 bird species, scored as regionally important by Partners in Flight for the southeastern Coastal Plain region (Panjabi 2005; Appendix F). I also included Brown-headed Cowbird, a nest parasite, and Blue Jay, a nest predator, because of their possible impact on declining species. Then, I averaged BBS counts for each species by year (i.e., mean of 3 years) and partial route, to calculate a species mean. Routes were categorized as low abundance for less than the mean and higher abundance for greater than or equal to the mean.

Statistical Analyses

I used 37 partial routes for modeling, while reserving 15 partial routes for validation. Although there was little correlation, I removed one variable for each pair that was at least 70% correlated (Proc CORR; SAS Institute 2002-2003) based on the following order to retain: AREA, CORE, ED, COHESION, IJI. Then, for each species and extent, I selected the 5 best fitting, one to 4 variable models, using logistic regression with score selection (Proc LOGISTIC; SAS Institute 2002-2003). I evaluated these candidate models with Akaike's Information Criteria corrected for small sample size (AIC_c).

To assess model accuracy, I used all models, including model coefficients, within 2 AIC_c units of the least AIC_c value to predict lesser or greater abundance for 15 model validation routes (Proc LOGISTIC; SAS Institute 2002-2003). I classified model fit as correct for a route if predicted probability was greater than or equal to 50% and bird abundance mean fell within the greater abundance category, or alternatively if probability was less than 50% and bird abundance mean was within the lesser abundance category. Final best model selection incorporated models with the greatest prediction rate from models that correctly predicted at least 10 out of 15 routes at each buffer extent. I removed models with more variables if there was a nested smaller model that predicted equally well at the same extent. Lastly, I used the *c* statistic, which measures model accuracy, to determine how well the models fit all 52 routes, and I eliminated any models with a *c* statistic below 0.75. For models that appeared to have unusual positive or negative associations, I checked the variance inflation factor using Proc REG (SAS Institute 2002-2003).

To determine if model fit would increase by adjusting for spatial variability, I compared the final model with the least AIC_c at the greatest extent for each species using GLIMMIX (SAS Institute 2002-2003) with and without a spatial covariance structure. To check that the GLIMMIX covariance parameter estimates were accurate, I also evaluated estimates with a variogram for each model, using the residuals from Proc LOGISTIC (SAS Institute 2002-2003).

RESULTS

Ten species had models that contained a mixture of area and edge variables (Table 5.1). Downy Woodpeckers were associated positively with hardwood area and interspersion, pasture edge density at 0.5, 2, and 4 km, shrub interspersion at 0.5 and 4 km, hydric hardwood connectivity, and clearcut area. Mixed forest interspersion and managed pine area were negative model variables. Eastern Kingbirds were associated positively with pasture edge density and core area, hardwood and managed pine area, and clearcut connectivity. Negative model variables incorporated clearcut and pasture area and managed pine edge density. Eastern Wood-pewee models included positive model variables of hardwood and hydric hardwood area and pasture edge density and interspersion. Hardwood interspersion and hydric hardwood edge density constituted negative associations. Northern Parula models combined positive variables of hydric hardwood edge density with mixed forest area at 0.5, 1, and 2 km extents along with clearcut area at 1 and 2 km. Negative associations included area of both types of hardwoods and shrub interspersion. Orchard Oriole models consisted of positive variables that included pasture edge density at 0.5, 1, and 4 km, hydric hardwood edge density and area, and core area of mixed forest and longleaf pine. Negative relationships encompassed hardwood core and interspersion, along with clearcut and managed pine interspersion. Pileated Woodpeckers were associated positively with hydric hardwood and managed pine edge density and mixed forest area. Prairie Warbler models encompassed positive variables of hydric hardwood area at 0.5 and 1 km mixed forest core, shrub edge, and managed pine connectivity. Negative associations were with hydric hardwood edge density, clearcut area, and mixed forest interspersion. Summer Tanager was linked to positive model variables of pasture edge density at all extents, longleaf pine area and edge density, and managed pine area. Model variables that were negative consisted of clearcut connectivity, mixed forest area, and interspersion of hydric hardwoods, mixed forest, longleaf pine, and shrub. Blue Jays were related positively to mixed forest core and pasture edge density, as well as hardwood forest interspersion. Negative relationships included hydric hardwood and managed pine connectivity, clearcut interspersion, and shrub edge density. Brown-headed Cowbirds were associated positively with hardwood area and hydric hardwood connectivity, clearcut connectivity, shrub area, and longleaf pine edge density. Negative associations consisted of clearcut area and interspersion, pasture area, hydric hardwood interspersion and edge density, managed pine edge density, and longleaf pine area and cohesion.

Seven species had models that did not contain a mixture of area and edge variables, and generally involved only one model, and thus only one buffer extent (Table 5.1). Acadian Flycatchers were associated positively with mixed forest area and hydric hardwood connectivity at 1 and 2 km, and shrub interspersion. Clearcut edge density was a negative model variable at 1 and 2 km. Field Sparrow models also contained no edge density, but included positive model variables of shrub core, area, and interspersion at multiple extents, mixed forest core, hardwood area and interspersion, and interspersion of hydric hardwoods and managed pine. Pasture edge density and interspersion and clearcut interspersion were negative model associations. Two species had models that contained edge density but not area variables. The Carolina Chickadee model at 0.5 km consisted of positively, hydric hardwood edge density, hardwood interspersion, and negatively, managed pine area and clearcut interspersion. The Red-bellied Woodpecker model variables at 4 km were related positively to longleaf pine edge density, mixed forest interspersion and negatively to clearcut interspersion. Managed pine interspersion at 2 km was the only positive association for Eastern Towhee; longleaf pine and shrub edge density and hydric hardwood interspersion were negative model variables. The Northern Bobwhite model at 1 km included positively, hardwood interspersion, clearcut connectivity, and negatively, mixed forest area. The Pine Warbler model consisted of shrub interspersion as a positive relationship whereas hydric hardwood interspersion and connectivity and mixed forest interspersion produced negative relationships.

Brown-headed Nuthatch, Indigo Bunting, Red-headed Woodpecker and White-eyed Vireo did not have any models that correctly predicted the minimum 10 out of 15 on the validation routes, and Brown Thrasher, Carolina Wren, and Wood Thrush did not meet the threshold 0.75 for *c* statistic value. For all species, the selected model tested for spatial variability did not produce improved model fit using a spatial covariance structure.

DISCUSSION

Based on modeling results for the selected species, hardwood forests and hydric hardwoods were important vegetation types in Coastal Plain Georgia. Hardwoods of both classification types were present, and overall positive, in models for all species but Red-bellied Woodpecker. This is consistent with the Georgia Gap Analysis (Kramer et al. 2003), which found that bottomland hardwoods contained the greatest species richness (74 species), and other hardwood types also ranked highly. The 6 other vegetation types each generated positive models for about 5 species, even though analyzed landscape abundance ranging from 25% for managed pine to less than 5% for pasture, longleaf pine, mixed forest, and shrub. Longleaf pine and clearcuts, despite their importance regionally and for early successional species (Frost 1993, Hunter et al. 2001), produced models for the fewest species.

The models generally consisted of appropriate bird-vegetation type associations (Poole and Gill 1992-2003). There were some exceptions that seemed to arise from the clearcut vegetation type. Field Sparrows are associated with shrub/scrub (Carey et al. 1994), and although Field Sparrow models involved shrub, the models also contained hardwoods as a vegetation type instead of more probable clearcuts. Perhaps riparian zones in hardwoods provided enough brushy vegetation to account for the presence of this species. Conversely, mature forest Northern Parulas (Moldenhauer and Regelski 1996) had models containing clearcut as a vegetation type. Possibly this was due to vegetation type classification error in the Gap land cover grid or a problem resulting from modeling.

Brown-headed Cowbirds were not associated with their typical clearcuts or pasture (Lowther 1993), except indirectly, but they were related to hardwoods, which matched as a vegetation type common to many of the species modeled. Hardwoods may contain the greatest bird richness and abundance, providing more nesting opportunities. Donovan et al. (1997) suggested that cowbirds choose breeding areas that contain high host abundance in core habitats, perhaps because core area species have fewer defenses against brood parasitism and additionally core habitats in moderately fragmented landscapes provide a balance between breeding opportunities and access to feeding areas. Blue Jays were linked to mixed forest core and pasture edge density, and thus may be a problem for birds nesting in those vegetation types.

The combination of vegetation type with spatial metrics may complicate interpretation of both variables. For example, a species could have, as a model variable, edge density linked with a vegetation type that the species avoids, if the edge represented lower abundance of the vegetation type. Occurrence of area and edge of the same vegetation type may show more clearly that the species is responding directly to the vegetation type, rather than the particular metric. Orchard Oriole had models that included hydric hardwood edge density at 4 km and hydric hardwood area at 1 km, whereas Summer Tanager models incorporated longleaf pine area at 0.5, 1, and 2 km and longleaf pine edge density at 4 km. However, these are separate models, and thus could represent distinctive selection at different scales.

Although land class area means for partial routes were low (Appendix E), area was a model variable for Acadian Flycatchers, a species which may be area sensitive (Whitehead and Taylor 2002). Field Sparrows also appeared to respond to area, although

I could not find research that directly appeared to display area sensitivity for Field Sparrows.

A mixture of area and edge variables developed in most models, which may reflect that scale and vegetation type influence area relationships. Downy Woodpecker, Eastern Kingbird, Eastern Wood-pewee, Northern Parula, Orchard Oriole, Pileated Woodpecker, and Summer Tanager exhibited area as a model variable, which helps support positive area findings in previous studies (Freemark et al. 1995, Moldenhauer and Regelski 1996). In particular, the Prairie Warbler, Eastern Kingbird, and Eastern Wood-pewee models suggested area sensitivity, because models for the same vegetation type included area as a positive variable and edge as a negative variable. The 1 km Prairie Warbler model contained hydric hardwood area and negatively, edge density. At 2 km, Eastern Wood-pewees responded positively to hydric hardwood area and negatively to hydric hardwood edge density. Although different models and scales, Eastern Kingbirds were connected to managed pine area and negatively to managed pine edge density. Oddly, in the same model, Eastern Kingbirds showed positive pasture edge density and core area, but negative pasture area. Perhaps this species is benefiting from edge and interior.

Scale affects which variables will be represented, and therefore scale choice is important. Each buffer extent included models for about 8-10 species, an even distribution. Only Summer Tanager had models at each extent, whereas 7 species had a total of one model, thus one extent. Most of the models contained 4 variables, and there was variable overlap among extents, which may reflect continuity in habitat selection. However, multiple extents allowed expression of area and edge, a common occurrence.

For species that had limited model information, area and edge may be unimportant for habitat selection or depend on landscape context. Red-bellied Woodpecker and Carolina Chickadees may be area-sensitive (Freemark et al. 1995, Groom and Grubb 2006), yet edge appears to be important at some extents. Eastern Towhee, Northern Bobwhite, and Pine Warbler may have area or edge requirements (Freemark et al. 1995, Rodewald et al. 1999), but modeling did not reflect these metrics. Brown-headed Nuthatch, Brown Thrasher, Carolina Wren, Indigo Bunting, Red-headed Woodpecker, White-eyed Vireo, and Wood Thrush did not have models that met my criteria, and thus may be selecting sites based on different factors than modeled vegetation types or landscape metrics. Stand scale elements, such as vegetation structure and composition, may be particularly important for these species. Indeed, for intensively established pine plantations in Mississippi (see chapter 3), vegetation correlated reasonably well with abundance for some of these species, including woody vegetation and White-eyed Vireos, residual trees and Carolina Wrens, Indigo Bunting, and Red-Headed Woodpeckers, and both woody vegetation and residual trees with Brown Thrasher presence. However, species that are not selecting habitat at a landscape scale may be more at risk for landscape problems: predation and parasitism (Gates and Gysel 1978, Weldon and Haddad 2005).

Species that occur in smaller patches may have lesser pairing and reproductive success (Faaborg et al. 1995, Freemark et al. 2002). One explanation for this pattern is that biological interactions can escalate at edges, including increased predation of adults and young, avian brood parasitism by Brown-headed Cowbirds, and competition with edge and generalist species (Paton 1994). Edge effects may increase physical stress through a drier, more exposed microclimate, which additionally may reduce insect availability (Burke and Nol 1998). Exotic plant invasion can alter existing vegetation (Saunders et al. 1991). However, area sensitivity depends on patch context (Hunter et al. 2001), including the type and extent of landscape development (Rodewald and Yahner 2001). Furthermore, surrounding land suitability may mediate patch size effects (Andrén 1994, Lloyd et al. 2005).

MANAGEMENT IMPLICATIONS

Even though the Coastal Plain as a whole is forested, the analyzed landscape appeared to be comprised of edges, containing very little core area and small areal extents overall (Appendix E). Additionally, despite the limited area sizes, area was still prevalent in models for most bird species. One forest type adjacent to another forest type may expand the functional area of each forest, however there will be greater contrast at edges than unbroken areas would contain. Therefore, it seems sensible to maintain large tracts of currently contiguous habitat and to coordinate smaller tracts so that they occur in close proximity to a similar vegetation type.

Hardwood forests, according to model representation, are supporting a wide range of species, and should receive conservation priority. In contrast, this study suggested that longleaf pine and clearcuts, which should sustain at least Prairie and Pine Warblers, Northern Bobwhite, Red-headed Woodpecker, Brown-headed Nuthatch, Eastern Kingbird, Field Sparrow, Orchard Oriole, Eastern Towhee, and White-eyed Vireo, do not contain greater abundances of these species. Further research should explore if this indeed is occurring and what factors, potentially including replacement of the herbaceous ground layer and shrubby understory by a hardwood midstory, may reduce vegetation type quality.

Despite timber harvest, managed pine and pastures were present as land class models for an average number of species. Managed forests are better suited than other intensive land uses to provide wildlife habitat. This holds true particularly in the Southeast, where most forest biological diversity historically was associated with the ground layer rather than old growth structure and the terrain allows harvest access without excessive soil damage (Simberloff 1993). In addition, favorable temperatures and precipitation permit rapid vegetation growth and the shortest timber rotations in the United States. Increased productivity from intensive management holds the promise of allowing natural forests to be managed for wildlife.

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Table 5.1. Avian models with AICc value for modeling routes, prediction rate for validation routes, and *c* statistic for all selected Breeding Bird Survey partial routes in Coastal Plain Georgia during 1995-1999.

Species	Buffer (km)	Best Model(s)[ab]	AICc	Prediction Rate	*c* Statistic
Acadian Flycatcher	1	HH-COHESION (+) CL-ED (-) MF-AREA (+) SH-IJI (+)	43.85	11/15	0.78
Acadian Flycatcher	2	HH-COHESION (+) CL-ED (-) MF-AREA (+)	37.74	11/15	0.84
Blue Jay	0.5	HF-IJI (+) CL-IJI (-) MF-CORE (+)	42.65	10/15	0.79
Blue Jay	1	HF-IJI (+) HH-COHESION (-) CL-IJI (-) MP-COHESION (-)	31.85	10/15	0.88
Blue Jay	4	HH-COHESION (-) CL-IJI (-) PH-ED (+) SH-ED (-)	32.55	11/15	0.92
Brown-headed Cowbird	0.5	HH-IJI (-) CL-AREA (-) CL-COHESION (+) MP-ED (-)	41.43	10/15	0.80
Brown-headed Cowbird	2	HH-ED (-) HH-COHESION (+) CL-AREA (-) CL-IJI (-)	42.60	10/15	0.78
Brown-headed Cowbird	2	HF-AREA (+) HH-COHESION (+) CL-AREA (-) PH-AREA (-)	43.23	10/15	0.76
Brown-headed Cowbird	2	HF-AREA (+) CL-AREA (-) LP-AREA (-) SH-AREA (+)	43.98	10/15	0.77
Brown-headed Cowbird	4	HH-ED (-) PH-AREA (-) LP-ED (+) LP-COHESION (-)	41.51	11/15	0.83
Carolina Chickadee	0.5	HF-IJI (+) HH-ED (+) CL-IJI (-) MP-AREA (-)	47.57	10/15	0.80
Downy Woodpecker	0.5	HF-AREA (+) HH-COHESION (+) PH-ED (+) SH-IJI (+)	37.07	10/15	0.84
Downy Woodpecker	2	HF-IJI (+) PH-ED (+) MF-IJI (-) MP-AREA (-)	32.09	10/15	0.82
Downy Woodpecker	4	CL-AREA (+) PH-ED (+) MF-IJI (-) SH-IJI (+)	35.04	12/15	0.88
Eastern Kingbird	2	PH-ED (+) PH-AREA (-) PH-CORE (+) MP-ED (-)	32.23	10/15	0.80
Eastern Kingbird	4	HF-AREA (+) CL-AREA (-) CL-COHESION (+) MP-AREA (+	36.80	10/15	0.85
Eastern Towhee	2	HH-IJI (-) MP-IJI (+) LP-ED (-) SH-ED (-)	44.44	10/15	0.79
Eastern Wood-pewee	2	HF-IJI (-) HH-ED (-) HH-AREA (+) PH-ED (+)	46.54	10/15	0.78
Eastern Wood-pewee	2	HF-AREA (+) HF-IJI (-) PH-ED (+)	46.67	10/15	0.77
Eastern Wood-pewee	4	HF-AREA (+) PH-IJI (+)	42.65	10/15	0.75
Field Sparrow	0.5	HF-IJI (+) CL-IJI (-) PH-ED (-) SH-IJI (+)	32.53	12/15	0.93
Field Sparrow	0.5	HF-IJI (+) CL-IJI (-) SH-CORE (+) SH-IJI (+)	33.04	12/15	0.91
Field Sparrow	0.5	HF-IJI (+) HH-IJI (+) CL-IJI (-) SH-CORE (+)	33.60	12/15	0.89
Field Sparrow	0.5	HF-IJI (+) CL-IJI (-) PH-ED (-) SH-CORE (+)	33.87	12/15	0.91
Field Sparrow	1	CL-IJI (-) PH-IJI (-) MF-CORE (+) SH-IJI (+)	26.14	10/15	0.93
Field Sparrow	1	CL-IJI (-) PH-IJI (-) SH-CORE (+) SH-IJI (+)	26.31	10/15	0.93
Field Sparrow	4	CL-IJI (-) MP-IJI (+)	31.64	10/15	0.89
Field Sparrow	4	HF-AREA (+) PH-IJI (-) SH-AREA (+)	33.02	10/15	0.86
Northern Bobwhite	1	HF-IJI (+) CL-COHESION (+) MF-AREA (-)	47.09	10/15	0.76

Table 5.1. Continued

Northern Parula	0.5	HH-ED (+) MF-AREA (+) SH-IJI (-)	38.18	11/15	0.87
Northern Parula	1	HH-ED (+) CL-AREA (+) MF-AREA (+)	40.67	12/15	0.86
Northern Parula	2	HF-AREA (-) HH-ED (+) CL-AREA (+) MF-AREA (+)	34.29	13/15	0.91
Northern Parula	2	HH-ED (+) HH-AREA (-) CL-AREA (+) MF-AREA (+)	36.24	13/15	0.91
Orchard Oriole	0.5	HF-CORE (-) PH-ED (+) MF-CORE (+) MP-IJI (-)	22.51	10/15	0.85
Orchard Oriole	1	HF-IJI (-) HH-AREA (+) PH-ED (+) LP-CORE (+)	29.15	12/15	0.88
Orchard Oriole	4	HH-ED (+) CL-IJI (-) PH-ED (+) PH-IJI (+)	38.23	12/15	0.87
Pileated Woodpecker	1	HH-ED (+) MF-AREA (+) MP-ED (+)	28.14	10/15	0.87
Pine Warbler	1	HH-IJI (-) HH-COHESION (-) MF-IJI (-) SH-IJI (+)	42.45	11/15	0.83
Prairie Warbler	0.5	HH-AREA (+) MF-IJI (-) SH-ED (+)	25.31	12/15	0.82
Prairie Warbler	1	HH-ED (-) HH-AREA (+) CL-AREA (-) MP-COHESION (+)	12.78	10/15	0.90
Red-bellied Woodpecker	4	CL-IJI (-) MF-IJI (+) LP-ED (+)	45.76	12/15	0.80
Summer Tanager	0.5	CL-COHESION (-) PH-ED (+) MF-IJI (-) LP-AREA (+)	37.41	10/15	0.85
Summer Tanager	1	CL-COHESION (-) PH-ED (+) LP-AREA (+) SH-IJI (-)	40.99	11/15	0.86
Summer Tanager	2	HH-IJI (-) PH-ED (+) LP-AREA (+) LP-IJI (-)	33.52	11/15	0.92
Summer Tanager	4	PH-ED (+) MF-AREA (-) MP-AREA (+) LP-ED (+)	37.83	10/15	0.88

[a] HF = Hardwood forests, HH = Hydric hardwoods, CL = Clearcuts, PH = Pasture/hay, MF = Mixed forest, MP = Managed pine, LP = Longleaf pine, SH = Shrub

[b] AREA = mean patch area, COHESION = connectivity, CORE = mean core area, ED = edge length density, IJI = class type intermixing

Appendix 5.A. Landscape summary metrics[a] of each class type[b] for all selected Breeding Bird Survey partial routes in Coastal Plain Georgia during 1996-1998.

	Buffer	HF			HH			CL			PH			MF			MP			LP			SH		
Metric	(km)	$\bar{x}$	SE	Max[c]	$\bar{x}$	SE	Max[c]	$\bar{x}$	SE	Max[c]	$\bar{x}$	SE	Max[c]	$\bar{x}$	SE	Max[c]	$\bar{x}$	SE	Max[c]	$\bar{x}$	SE	Max[c]	$\bar{x}$	SE	Max[c]
PLAND	0.5	6.4	0.7	26.3	11.1	1.1	30.5	8.1	0.9	25.3	3.5	0.6	21.0	3.2	0.4	11.1	25.4	1.9	57.5	0.1	0.0	1.7	1.5	0.5	24.4
PLAND	1	6.9	0.8	26.7	13.1	1.3	38.3	8.3	0.8	24.0	3.3	0.5	16.6	3.4	0.5	11.7	25.8	1.7	54.0	0.1	0.1	3.7	1.7	0.5	24.4
PLAND	2	7.4	0.8	26.1	14.6	1.3	40.5	8.7	0.8	22.6	2.9	0.5	13.9	3.6	0.5	12.6	26.3	1.6	49.0	0.2	0.1	7.1	1.7	0.4	21.2
PLAND	4	7.5	0.8	28.7	15.9	1.4	37.9	8.7	0.7	22.4	2.7	0.4	9.5	3.5	0.4	13.5	26.5	1.4	48.2	0.4	0.3	13.2	1.7	0.4	20.1
AREA	0.5	0.4	0.0	1.3	0.9	0.1	6.0	0.9	0.1	4.8	1.0	0.2	7.2	0.3	0.0	0.9	2.4	0.3	16.7	0.2	0.1	1.1	0.8	0.1	3.3
AREA	1	0.4	0.1	1.7	1.1	0.1	5.6	1.0	0.1	5.7	0.9	0.1	2.6	0.4	0.0	0.8	2.6	0.3	15.8	0.3	0.1	1.2	0.9	0.1	3.7
AREA	2	0.5	0.1	2.0	1.3	0.1	5.8	1.1	0.1	5.6	1.0	0.1	2.7	0.4	0.0	0.9	2.7	0.3	11.7	1.0	0.4	5.5	1.0	0.1	4.0
AREA	4	0.5	0.1	2.0	1.6	0.1	5.5	1.1	0.1	4.5	1.0	0.1	2.9	0.4	0.0	0.8	2.6	0.2	6.9	8.0	6.0	119.8	0.9	0.1	2.6
CORE	0.5	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.5	0.1	0.1	2.0	0.0	0.0	0.0	0.3	0.1	6.0	0.0	0.0	0.0	0.0	0.0	0.6
CORE	1	0.0	0.0	0.1	0.1	0.0	1.2	0.1	0.0	0.8	0.0	0.0	0.6	0.0	0.0	0.0	0.4	0.1	7.0	0.0	0.0	0.0	0.0	0.0	0.4
CORE	2	0.0	0.0	0.1	0.1	0.0	1.1	0.1	0.0	0.9	0.0	0.0	0.2	0.0	0.0	0.0	0.4	0.1	4.8	0.0	0.0	0.1	0.0	0.0	0.6
CORE	4	0.0	0.0	0.0	0.2	0.0	1.2	0.1	0.0	0.6	0.0	0.0	0.2	0.0	0.0	0.0	0.4	0.1	2.3	3.2	3.1	61.9	0.0	0.0	0.5
CPLAND	0.5	0.0	0.0	0.2	0.3	0.1	3.1	0.4	0.1	2.6	0.1	0.0	2.2	0.0	0.0	0.0	2.5	0.4	20.4	0.0	0.0	0.0	0.1	0.1	4.5
CPLAND	1	0.0	0.0	0.8	0.6	0.1	4.9	0.4	0.1	3.5	0.1	0.0	1.3	0.0	0.0	0.4	3.2	0.5	23.9	0.0	0.0	0.0	0.1	0.1	3.2
CPLAND	2	0.0	0.0	0.6	0.9	0.2	6.4	0.5	0.1	3.4	0.1	0.0	1.1	0.0	0.0	0.4	3.4	0.4	18.3	0.0	0.0	0.6	0.1	0.1	3.3
CPLAND	4	0.0	0.0	0.4	1.3	0.2	7.0	0.5	0.1	3.0	0.1	0.0	0.5	0.0	0.0	0.3	3.6	0.3	11.5	0.1	0.1	2.7	0.1	0.1	3.1
ED	0.5	47.3	3.5	128.3	56.8	4.8	149.8	39.8	3.5	105.0	26.1	3.6	78.8	26.1	3.0	71.7	76.7	4.1	147.5	2.9	1.6	14.7	8.4	1.8	67.3
ED	1	49.7	3.5	125.2	60.7	4.6	144.7	40.4	3.2	93.8	23.0	3.1	68.1	28.0	3.2	80.8	77.9	3.8	150.2	3.8	2.5	24.2	8.9	1.8	76.5
ED	2	51.9	3.7	126.8	63.4	4.5	146.4	41.1	3.1	92.0	19.9	2.6	60.7	28.6	3.2	83.9	79.1	3.6	148.5	4.3	2.7	33.9	8.6	1.6	66.9
ED	4	52.3	3.8	132.2	64.1	4.2	134.8	41.1	2.9	87.6	17.0	2.2	50.7	28.4	3.2	91.7	79.4	3.2	132.5	3.9	2.3	46.0	8.6	1.6	65.0

[a] AREA (ha) = mean patch area, CORE (ha) = mean core area, CPLAND (%) = proportional abundance of class type core area, ED (m/ha) = edge length density, PLAND (%) = proportional abundance of class type

[b] HF = Hardwood forests, HH = Hydric hardwoods, CL = Clearcuts, PH = Pasture/hay, MF = Mixed forest, MP = Managed pine, LP = Longleaf pine, SH = Shrub

[c] Max equals the maximum mean for a partial route

Appendix 5.B. Common and scientific name, 2007 Southeastern Coastal Plain Partners in Flight conservation score, significant population trend during 1966-2005 for the Coastal Plain[a], and Breeding Bird Survey partial route mean abundance.

Common Name	Scientific Name	Conservation Score	Trend	Mean
Acadian Flycatcher	*Empidonax virescens*	15	+	0.28
Blue Jay	*Cyanocitta cristata*	14	-	4.46
Brown Thrasher	*Toxostoma rufum*	15	-	1.57
Brown-headed Cowbird	*Molothrus ater*	8	-	1.29
Brown-headed Nuthatch	*Sitta pusilla*	20	-	0.20
Carolina Chickadee	*Poecile carolinensis*	16	-	0.92
Carolina Wren	*Thryothorus ludovicianus*	13	0	5.21
Downy Woodpecker	*Picoides pubescens*	14	-	0.42
Eastern Kingbird	*Tyrannus tyrannus*	15	-	1.38
Eastern Towhee	*Pipilo erythrophthalmus*	16	-	5.50
Eastern Wood-pewee	*Contopus virens*	14	-	0.44
Field Sparrow	*Spizella pusilla*	15	-	0.94
Indigo Bunting	*Passerina cyanea*	14	0	3.22
Northern Bobwhite	*Colinus virginianus*	16	-	3.62
Northern Parula	*Parula americana*	15	0	0.94
Orchard Oriole	*Icterus spurius*	16	0	0.80
Pileated Woodpecker	*Dryocopus pileatus*	14	0	0.51
Pine Warbler	*Dendroica pinus*	14	+	1.18
Prairie Warbler	*Dendroica discolor*	18	-	0.26
Red-bellied Woodpecker	*Melanerpes carolinus*	13	0	3.44
Red-headed Woodpecker	*Melanerpes erythrocephalus*	15	0	0.31
Summer Tanager	*Piranga rubra*	16	0	0.84
White-eyed Vireo	*Vireo griseus*	14	0	1.63
Wood Thrush	*Hylocichla mustelina*	15	-	0.72

[a] Sauer, J. R., J. E. Hines, and J. Fallon. 2005. The North American Breeding Bird Survey, results and analysis 1966-2005. Version 6.2.2006. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

CHAPTER VI

SYNTHESIS AND IMPLICATIONS

Given limited resources, it is important to target declining species for research whenever possible. Species composition is more crucial than species number, and although any land use will benefit some species at the expense of others, rare species are are generally of greater conservation concern than abundant or common species. Research can identify factors that may contribute to population declines, with the hope that consequent management changes may help restore species of conservation concern, or at least mitigate losses. Furthermore, gaining knowledge about impacts of habitat modification on a diversity of game and nongame species can assist resource managers in developing pragmatic and proactive plans that may prevent today's common species from becoming rare in the future.

Some species may be declining because of land use, through changes that simplify vegetation either within a forest stand or across a landscape. For example, forest stands managed for commercial timber production may have diminished structural elements associated with mature seral stages, including large live trees with developed bark structure (Harlow and Guynn 1983, McComb et al. 1986, Moorman et al. 1999). At the landscape scale, representative vegetation types (e.g. grasslands and savannas) may be reduced and lack mature age classes and large contiguous areas.

Intensive site preparation and stand release treatments for establishment of pine plantations in the Lower Coastal Plain can reduce avian habitat quality. In this study, 4 metrics of species richness, total Partners in Flight score, Regionally Important Species score, and total abundance were greatest in CHEM, the herbicide-only treatment, during winter and spring. Importance of vegetation characteristics related to intensity of stand establishment treatments was especially evident during spring. Avifauna metric values for breeding birds decreased as intensity of site preparation and stand release treatments increased. Assemblage metrics in 2 banded release mechanical treatments became greater than in broadcast release mechanical treatments over time. On the whole, abundance of individual species was greatest in CHEM treatments and the other treatments supported similar abundance. However, for 13 species, abundance generally declined within mechanically prepared treatments as herbicide intensity increased.

This study helped substantiate that, at the stand scale, residual trees can enrich avian assemblages in intensively established pine plantations. There was greater abundance and richness – and particularly of species of greater conservation concern – in herbicide-only treatments. Frequently, bird species were more common, or only present, in CHEM sites while their abundance remained even in the other treatments, and residual trees were prevalent in models. This trend points toward influence of tree retention, rather than the specific combination of herbaceous and woody vegetation in CHEM sites. Depending on herbicide application, tree retention will continue to be beneficial throughout the rotation, supplying large, old trees to stands that otherwise may not develop mature forest characteristics.

Although tree retention incorporates live trees, it also involves snags, which are important for more than woodpeckers or cavity nesters. A variety of bird species, small mammals including bats, and herpetofauna use snags for foraging, perching, nesting, roosting, denning, and territorial and mating displays. The best management approach for tree retention requires further knowledge of number, species, size, and spatial distribution of trees to most efficiently benefit birds and other wildlife. This information currently is undeveloped, and will require experimental research. Based on my results, snag and live tree densities in the mechanical site preparation treatments were less than optimal for avian conservation in intensively established pine plantations in the Lower Coastal Plain of Mississippi.

The intensity establishment gradient in this study generated minimal differences for small mammals present at the study sites. Captured small mammal species were common to early successional habitats and were probably common because they are adaptable. An obvious stand element that might create a difference is coarse woody debris. Rodents, shrews, reptiles, and amphibians could benefit from coarse woody debris arising from trees and snags retained after harvest. Research should address availability of coarse woody debris over the rotation of commercial pine stands. However, it may be more judicious for future coarse woody debris research to target herpetofauna, which include many species of conservation concern and which may be more likely to require ground litter in regenerating stands.

At the landscape scale in Georgia's Coastal Plain, there appeared to be a surfeit of edges and negligible amounts of unfragmented area. The overall forest coverage, in combination, may extend effective area of individual forest types. However, because each forest type occurs generally as fragments, there may be sharp contrasts in age, structure, and composition at borders, which may not be acceptable to all species that are area sensitive or, in the case of herpetofauna, have limited dispersal ability. Therefore, it is reasonable to maintain large land tracts, or at least to keep vegetation types of similar composition and age in close proximity. Although harvest size is a controversial subject, it may be more beneficial to coordinate large clustered cuts than develop multiple dispersed clearings. Larger harvests will retain more extensive areas of similar vegetation age, from regeneration to harvest stages. Clearcut areas averaged 92 ha (20-600 ha) on commercial lands and 36 ha in public forests (Meyers and Johnson 1978) in the past, however more recent cut sizes may range from about 16 to 32 ha (Woodrey et al. 1998). The Sustainable Forestry Initiative requires the average size of cuts to not exceed 49 ha (Sustainable Forestry Initiative 2005), nevertheless large areas of similar stages can remain close through interspersion of harvests that are slightly offset in time.

Further research should continue to explore area-sensitivity in avian species in the Coastal Plain, at different scales, and seek consistent regional patterns. Additionally, in Georgia, research should investigate factors that may be allowing hardwood forests to support birds at a greater capacity than longleaf pine and clearcuts, which may not be functioning well to support bird species at greater abundances. Stand scale factors, such as an undesirable hardwood midstory (Conner and Hartsell 2002) may be pervasive across the region, producing problems throughout the landscape.

A variety of management prescriptions can provide the range of vegetation structure and composition needed for diverse communities of avifauna. Non-traditional silvicultural techniques can enhance stand internal heterogeneity through residual tree and coarse woody debris retention and establishment of skips and gaps between trees to open the understory, and wetland protection. Careful planning can help develop continuous expanses of similar vegetation types that have low contrast borders, minimizing edge effects. Lastly, achieving maximum diversity in local areas may not translate into maximum diversity in a regional landscape unless there is sufficient representation of currently rare vegetation types, in both early successional and mature forest stages.

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