

ABSTRACT

AMACHER, ANDREW JAMES. Assessing 100-meter-wide loblolly pine corridors as breeding habitat for landbirds. (Under the direction of Richard A. Lancia.)

I evaluated the suitability of 100-meter-wide loblolly pine (*Pinus taeda*) plantation corridors as breeding habitat for landbirds. The study was located within the Lower Coastal Plain of South Carolina on land owned by Westvaco Timber Corporation. The typical rotation-age within the landscape was 20 years. Work was conducted within post-rotation-age (24-31 years) corridors (100-meter-wide linear loblolly pine plantation stands) and patches (typical Westvaco stands). Work was also conducted in rotation-age patches (18-22 years). Vegetation, point count and nest monitoring data were used to compare corridors against patches. Point count surveys were conducted from 1995-1999, and vegetation and nest surveys from 1997-2000.

Vegetation data was collected between 1997-2000 within post-rotation-age corridors and patches (24-31 years) and rotation-age patches (18-22 years). I used 10th acre plots to quantify the following variables: pine, hardwood, and snag basal area; pine, hardwood, and snag dbh; canopy cover (%) and shrub cover; overstory and midstory height; and cane and vine cover. Cluster analysis of individual plots found that post-rotation-age corridors and patches were not significantly different ($p = 0.1178$) from each other, but were significantly different from rotation-age stands ($p < 0.0001$). Individual comparisons between classifications (post-rotation corridors and patches, rotation-age patches) found most significant differences between post-rotation-age and rotation-age stands.

However, post-rotation-age corridors and patches differed significantly in pine basal area ($p < 0.0001$), pine DBH ($p < 0.0001$), hardwood basal area ($p = 0.0153$) and shrub percent cover ($p = 0.0358$).

Point count data was collected from 1996-1999 within post-rotation-age corridors and patches. A total of 94 corridor points and 116 patch points were surveyed from 1996-1999. Corridors had greater species richness ($N=44$) than patches ($N = 38$). However, species composition was similar between corridors and patches. For all species, the Spearman's rho correlation coefficient on species ranked abundance was highly correlated ($r = 0.7877$, $p < 0.0001$). In individual species comparisons, only the Red-eyed Vireo was found in lower abundance within corridors (0.213 birds/plot) compared to patches (0.440 birds/plot, $p = 0.0011$). The Brown-headed Cowbird and Blue-gray Gnatcatcher were significantly more abundant within corridors relative to patches.

Nest searching was conducted within post-rotation-age corridors and patches, and rotation-age patches from 1997-2000. Three species were compared: the Acadian Flycatcher ($n = 132$), Hooded Warbler ($n = 37$), and Northern Cardinal ($n = 52$). Across all years, no significant difference in nest survival was found between nests within post-rotation-age corridors and nests within post-rotation-age patches for all 3 species. However, when compared to rotation-age patches, Acadian Flycatchers had significantly higher nest survival in both post-rotation-age corridors and patches ($p < 0.05$). Hooded Warblers had marginally higher nest success in both post-rotation-age corridors and patches relative to rotation-age patches ($p = 0.05-0.10$).

Nest survival was also compared by distance to edge (with loblolly stands aged 0-5 years), distance to road, and distance to edge+road. No significant differences were found in nest survival for the Acadian Flycatcher, Hooded Warbler, and Northern Cardinal based on a nest's distance to edge, road, or road+edge. The Hooded Warbler had 10 out of 37 nests (27%) parasitized by the Brown-headed Cowbird. Nine were within patches and 1 within a corridor. Parasitized nests were not significantly different from non-parasitized nests based on distance to edge ($p = 0.7100$), distance to road ($p = 0.2111$), or distance to edge+road ($p = 0.2492$).

**ASSESSING 100-METER-WIDE LOBLOLLY PINE CORRIDORS
AS BREEDING HABITAT FOR LANDBIRDS**

by

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BIOGRAPHY

Andrew James Amacher was born in Sunnyvale, California on July 14, 1974, the son of Jean and Wayne Amacher. Andrew obtained his high school diploma from Homestead High School in 1992. He obtained a B.S. in Environmental Science, Policy and Management (ESPM) from U.C. Berkeley in 1997. The fancy title of ESPM forever will confuse people, so his true degree was in Forestry and Wildlife Ecology.

Growing up in a suburban strip-mall jungle, Andrew has always had a keen interest in all things wild. Much of his youth was spent in front of the television watching programs such as "Wild, Wild, World of Animals", "Mutual of Omaha's Wild Kingdom", "Nature", "Wild America" and even "Cosmos". Once he could drive, Andrew often explored California on fishing expeditions designed to survey various habitats. After discovering that Astronomers only get to look through a telescope 1-2 days a year, Andrew switched his focus to obtaining a career that would allow him to explore and learn about the wild world. Early in high school, he saw a picture of California State Biologists fly-fishing in a pristine alpine lake as part of work. That sealed it.

Andrew has never had a desk job in his life. Summers early in college were spent house painting and he obtained a lab job assisting in wheat genetics research during the semester. Lab work was interesting, but the smell and harsh chemicals turned him off to it as a career. Andrew's first field job was under the supervision of Professor Reginald Barrett at U.C. Berkeley's Blodgett Forest

Research Station in 1996. It was a hearty experience, involving surveying all local flora and fauna. Andrew also learned that the Swainson's Thrush has the most hauntingly beautiful song that exists upon this planet. In 1997, Andrew took a field job with graduate student John Sabo from U.C. Berkeley's Integrative Biology Department. It was a beautiful summer in old growth redwoods along the Eel River in Northern California. Work involved a lot of noosing of lizards and construction of en/exlosures in order to determine the amount of riverine "subsidy" into the old growth food web system. In 1998, Andrew left California to work for Professor Richard A. Lancia at North Carolina State University. Summers from 1998-2000 were spent in the Lower Coastal Plain of South Carolina studying the effects of corridors on avian species. The result of this work is in your hand.

After finally acclimating to heat with humidity, Andrew will be returning to California to pursue a Ph.D. project with Professor Reginald Barrett at U.C. Berkeley. Work will involve assessing the impacts of prescribed burning and mechanical treatments on avian and mammal assemblages. Hopefully, the forests will not burn down before he returns...

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Special thanks go to Westvaco Timber Corporation for allowing us to conduct research upon their land. Thanks goes to Mac Baughman, head Westvaco wildlife biologist, who has helped us in many ways by being the point-man between Westvaco and NCSU. Chris Muckenfuss, another Westvaco wildlife biologist, has also helped the project. Foresters Karen Priestly, Alex Singleton, and Chris Vaughn helped by maintaining stands past rotation when possible. Mike Hunter supplied ArcView coverages, maps, and technical help. He also helped get technicians out of ditches with a smile. I also would like to thank receptionist Roseanne Meyer for being very helpful in coordinating keys, housing, and facilitating weekend off-season excursions on Westvaco property. Ronnie White, Alan Ilderton, and Joe Blume kept our vehicles in tip-top shape

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Special thanks goes to John Gerwin at the N.C. State Museum of Natural Sciences. He has been the resident ornithologist on the project since 1994. He also conducted and maintained all of our point count plots. His guidance and knowledge in the field helped this project immensely. I would also like to thank Becky Browning from the Museum for helping us out in 1998 and 1999.

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Also, a thank you must go to Wayne Amacher, whose engineering skills designed artificial nest timers that I unfortunately ran out of time to implement.

Next time, Dad!

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GENERAL PROJECT OVERVIEW, 1995-2000

As part of its Multiple-Use Ecosystem-Based Management Plan, Westvaco Timber Corporation is in the process of implementing an extensive corridor system across its managed landbase, which is composed primarily of loblolly pine (*Pinus taeda*) plantations. Westvaco has designated approximately 25% of its landbase to be maintained as forest corridors. These "corridors" are 100-meter-wide strips of relatively mature forest that provide connectivity across the landscape as timber stands are harvested. In 1994, a cooperative effort was undertaken by Westvaco, the National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI), and North Carolina State University (NCSU) to document the effects of habitat corridors on bird diversity, abundance, and productivity in an intensively managed forest landscape. The National Fish and Wildlife Foundation and the National Science Foundation provided additional support. Research was conducted from 1994-2000 within Westvaco Timber Corporation's Southern Woodlands in the South Carolina Lower Coastal Plain province. This short summary of previous work is focused on aspects that relate to my research conducted from 1999-2000.

After a pilot study in 1994, research from 1995-1996 focused on breeding bird assemblage diversity and abundance within hardwood and loblolly pine plantation stands across Westvaco's Ashley and Edisto Management Districts (Turner 1998). Approximately 350 50-meter fixed radius point counts were established across all age classes and stand sizes within the landscape. Many

of these plots continued to be censused until 1999, when the point count monitoring was terminated. The research conducted between 1995-1996 found that "bird community compositions in pine stands of rotation-age were a subset of those communities found in mature hardwood habitats due not only to basic similarities in stand structure, but also as a result of a high degree of large-scale interspersions of pine stands with hardwood stands of various sizes" (Turner 1998). There was a large degree of overlap of species between rotation-age loblolly stands (approximately 20 years) and mature hardwood stands (greater than 40 years). Small (0.5 - 5 ha) hardwood depressions called "gumponds" within pine stands were found to help increase diversity within pine stands. Also, the hardwood midstory within the loblolly stands, though more dispersed, was structurally similar to hardwood stands. The presence of this midstory was responsible for the presence of species commonly associated with bottomland hardwood forests (Turner 1998).

By 1997, corridors were beginning to become "installed" within the landscape through harvesting of adjacent stands. This began the corridor phase of the project. An experimental unit (corridors) and a control unit were setup within the Edisto and Ashley Districts, respectively. Experimental units consisted of post-rotation age (ages 24-27) loblolly pine corridors and adjacent "patches" (non-linear stands typical of Westvaco's stand delineations). The control unit consisted of large blocks of rotation-age loblolly pine (ages 18-20). Research focused on nesting success of 2 Neotropical migrants, the Acadian Flycatcher

(*Empidonax virescens*) and Hooded Warbler (*Wilsonia citrina*, Hazler 1999). Hazler (1999) found lower nesting success and nest density for the Acadian Flycatcher in the control unit versus the experimental unit. Within the experimental unit, nesting success for the Acadian Flycatcher was higher within post-rotation age corridors than in post-rotation patches. Results across all sites also showed increasing nesting success with increasing canopy height for both the Acadian Flycatcher and Hooded Warbler. Canopy height was correlated with age, hence because control units were younger than experimentals, nesting success was lower in control units. Aside from stand age, both vegetation surveys and Westvaco stand level data (site index, basal area, and trees per acre) indicated that the control and experimental units were structurally different. The control and experimental units were also spatially separated into 2 different management districts separated by a possible barrier, the Edisto River.

To focus on post-rotation age corridors, I concentrated on the Edisto District in 1999. All corridors and patches from the experimental unit continued to be surveyed where possible (2 patches were burned in 1999 and 2000). The agreement with Westvaco was for "management as usual" and consequently new patches had to be added to compensate for management activities. All corridors surveyed in the 1997 and 1998 field seasons continued to be surveyed in 1999 and 2000.

This thesis compares post-rotation age (24-31 years) corridors and patches with similar stand structure to determine: 1. if species diversity and

abundance differs between patches or corridors and 2. if nest productivity differs between patches and corridors. To analyze species abundance, point count plots within post-rotation age loblolly pine patches and corridors were used. All plots had 3 or 4 years of data from 1996-1999, and the points encompass more stands than the nest productivity study sites. To analyze nest productivity, nest productivity study stands within post-rotation loblolly pine corridors and patches were surveyed.

Rotation-age stands (20-21 years) continued to be surveyed from 1999-2000. These were new stands selected from the Edisto management district. Reference will be made to these stands as it applies to management; however, no rotation-age stands were included in the analysis of corridors and patches due to structural and successional differences. Rotation-age stands were treated separately throughout this thesis.

STUDY GOALS

The study was conducted in post-rotation-age loblolly pine corridors and patches (ages 24-30 for point counts, 24-31 for nest searching stands). This habitat-type is fragmented relative to rotation-age or younger stands. The overall goal of this analysis is to determine if corridors and patches were different in suitability as habitat for breeding landbirds. I also investigated edge effects in general to determine if high-edge to area ratio stands such as corridors are expected to function differently than regular stands.

The study uses point count and nest survival data to compare avian distribution and productivity within post-rotation-age loblolly corridors and patches. Avian species may respond to fragmentation in several ways, they may: 1. Avoid patches of certain sizes or shapes, 2. Occur in lower abundance within differing patch types, 3. Occur in similar abundance between patch types, but suffer greater nest mortality, or 4. Have similar abundance and nesting success between patch types.

If birds are avoiding certain patches or edges, differences may exist between abundance and distribution between corridors and patches. Analysis of point count data addresses species distribution and abundance within post-rotation loblolly corridors and patches. However, density is not necessarily correlated with habitat quality or suitability (Van Horne 1983). Nest survival analysis addresses if differences in nest productivity exist between corridors and patches, and if edge effects are operational within the landscape. The overall goal of this analysis is to determine if 100-meter wide loblolly pine corridors function as suitable breeding bird habitat relative to patches.

The chapters within this thesis are not stand-alone chapters designed for publication. Chapter 1 analyzes vegetation and avian abundance between post-rotation and rotation-age stands to determine if inclusion of rotation-age stands in subsequent analyses (Chapters 2 and 3) is warranted. Chapter 2 examines avian diversity and abundance within post-rotation age corridors and patches.

Chapter 3 examines nest survival within corridors and patches, and in relation to distance to edge types.

STUDY AREA

The study was located in the Lower Coastal Plain Province of South Carolina, approximately 20 miles west of Charleston on land owned and managed by Westvaco Timber Corporation. Westvaco owns approximately 200,000 hectares within this region. About one-half of their landbase is intensively managed loblolly pine, about one-quarter is hardwood ranging from small isolated gumponds (small isolated hardwood depressions within loblolly stands) to large, contiguous stands, and the remainder in various land use categories. Loblolly pine plantations are managed primarily on a 20-25 year rotation for fiber production. Private forestry is the dominant land use and the region can be visualized predominately as a shifting mosaic of loblolly pine stands (10 - 100 hectares) in various stages of regeneration.

Mature loblolly pine plantations consist of a dominant loblolly overstory with a substantial hardwood midstory and patchy cover of understory. Within loblolly pine plantations, the dominant overstory is almost entirely composed of loblolly pine (*Pinus taeda*). However, within isolated gumponds, common overstory hardwood species were laurel oak (*Quercus laurifolia*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*) and blackgum (*Nyssa sylvatica*). Sweetgum was the dominant midstory species across all sites, with laurel oak, red maple, blackgum, water oak (*Quercus nigra*), willow oak (Q.

phellos) southern red oak (*Q. falcata*), ashes (*Fraxinus spp.*), winged elm (*Ulmus alata*), American elm (*Ulmus americana*), and hickories (*Carya spp.*) comprising most of the midstory. Common shrub layer species included saplings of tree species above, switchcane (*Arundinaria gigantea*), wax myrtle (*Myrica cerifera*), devil's walking stick (*Aralia spinosa*), blueberries (*Vaccinium spp.*), and blackberries (*Rubus spp.*). The shrub layer was patchy and varied between stands; however, switchcane, wax myrtle, and devil's walking stick were common within this patchy structure. Understory species were composed of herbs, forbs and vine species such as poison ivy (*Toxicodendron radicans*), trumpet creeper (*Campsis radicans*), wild grape (*Vitis rotundifolia*) and peppervine (*Ampelopsis arborea*).

Westvaco has adopted an "Ecosystem-Based Multiple-Use Management Plan," part of which includes managing about one-fifth of its landbase as a "corridor" network. These 100-meter-wide strips of pines and hardwoods are intended to provide connectivity among the surrounding forest stands. At the landscape scale, point count plots were surveyed across all loblolly age classes and habitat types within the landscape. Approximately 54 point counts in post rotation age loblolly pine stands (24-30 years) within the Edisto District were used in this analysis. At the stand level, after 1997 in which 1 corridor and 1 patch were surveyed for nests, 3-4 corridors were surveyed from 1998-2000 and 3 patches from 1998-2000. All study stands were as closely matched as possible based on stand characteristics such as: age, basal area, trees per acre, site

index, soil type, prescribed burn year and the surrounding forest stand composition.

Literature Cited

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Turner, J.C. 1998. Influences of hardwood stand size and adjacency of breeding bird communities in an intensively managed pine landscape in the South Carolina lowcountry. Master's thesis. North Carolina State University.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *J. of Wildl. Manage.* 47: 893-901.

Chapter 1: Assessing vegetation and avian species abundance differences between rotation-age and post-rotation-age loblolly stands

Introduction

In my study, stands of rotation-age (18-22 years) and post-rotation-age (24-31 years) loblolly pine (*Pinus taeda*) plantations were surveyed from 1995-2000. Both point counts (1995-1999) and nest surveys (1997-2000) were conducted within rotation-age patches ("RA" hereafter) and post-rotation-age ("PR" hereafter) patches and corridors. Work was conducted in two different Westvaco management districts, the Ashley (33,200 ha) and Edisto (83,000 ha) management districts. Point counts were conducted within both the Ashley and Edisto districts from 1995-1999. All nest-searching PR corridors and patches were located in the Edisto District (1997-2000), whereas RA patches were located within the Ashley District in 1997-1998 and Edisto District in 1999-2000.

If PR corridors and patches were vegetatively similar to RA stands within the Ashley and Edisto Districts, RA stands could be used as patches in subsequent comparisons of avian abundance and nest productivity between corridors and patch stands (Chapters 2 and 3). However, there is reason to believe that RA stands were dissimilar to PR stands. Previous work conducted from 1997-1998 found significantly lower nesting success for both Acadian Flycatchers (*Empidonax virescens*) and Hooded Warblers (*Wilsonia citrina*) in RA-Ashley stands compared to Edisto District PR corridors and patches (Hazler

1999). Acadian Flycatcher territory and nest density were also lower in RA-Ashley stands (Hazler 1999).

As a result, I concentrated my efforts within the Edisto District from 1999-2000. Three new RA-Edisto stands were added (2 patches and 1 corridor), and surveys continued within the same PR corridors and patches surveyed between 1997-1998. However, these stands RA-Edisto stands were wetter, had a denser hardwood midstory component, and denser vine coverage (personal observation). Acadian Flycatcher territory density also appeared to be lower within these RA-Edisto Stands. One 18.1 ha RA-Edisto stand contained only one singing Acadian Flycatcher male in both 1999 and 2000 (0.06 birds/ha), and only one nest was found within this stand between 1999-2000 (Amacher, unpublished nest data). Whereas, Acadian Flycatcher territory density ranged from 0.26-0.36 birds/ha within PR corridors and patches in 1998 (Hazler 1999, p. 71). These results suggest that RA-Edisto stands surveyed from 1999-2000 were possibly dissimilar to PR corridors and patches.

In a landscape that undergoes turnover every 20-25 years, the age differences between PR and RA stands may have significant effects on avian species abundance. The Acadian Flycatcher is an open-cup tree-nesting species commonly associated with hardwood forests (Ehrlich et al. 1988). Responses of other hardwood associated species or tree-nesting guilds may be similar.

Other studies have demonstrated that successional age differences within the same habitat type can affect avian abundance. A 30-year study in relatively mature temperate deciduous forest stand (10 ha) found that the most important local factor affecting bird abundance was temporal change in forest vegetation structure, resulting from natural forest succession and local disturbances (Holmes and Sherry 2001). Along a northern hardwood forest successional gradient, American Redstarts (*Setophaga ruticilla*) were found to have higher densities and mating success, and lower territory sizes within earlier successional stands (Hunt 1996). In a study involving small mammals, Knight and Morris (1996) used density-dependent habitat selection to delineate 3 habitat types when only 2 were assumed to exist.

My analysis tests the hypothesis that 3 distinct stand vegetation types exist: 1. PR corridors and patches combined 2. RA-Ashley stands and 3. RA-Edisto stands. PR corridors and patches were assumed to be similar due to similar ages and locality (Edisto district). RA stands were assumed to be different from PR stands due to age and previous work (Hazler 1999). RA Ashley and Edisto stands were assumed different due to spatial separation in different management districts.

Cluster analysis (Tongeren 1995) was used to group individual vegetation plots from the 4 stand type classifications (PR-corridors, PR-patches, RA-Ashley, and RA-Edisto) into 3 cluster groups based on the assumptions above. Avian species abundance changes across an age gradient of 15-28 years were

analyzed using logistic regression to determine if avian species were responding to the assumed successional changes within the midstory.

Methods

Vegetation data consist of plot-level data from nest-searching stands. PR corridors, PR patches, and RA patches were searched for nests from 1997-2000 (Table 1, Appendix-Map 1). During this same period, random vegetation plots were surveyed within the nest-searching stands. Nest-searching stands were gridded with flagging at 25m intervals. Vegetation plots were randomly sampled at grid points subject to the restriction that no point could be located within 50m of another sampled point. Effort was consistent, 1 vegetation plot/ha was sampled across nest searching stands.

Random vegetation plots were a modified protocol from James and Shugart (1970). At each plot, the following variables were measured: canopy cover (%), pine, hardwood and snag basal area (ft²/acre); pine, hardwood and snag diameter at breast height (DBH, in cm); canopy and subcanopy height (m); scaled measures of vine and cane in the understory (scaled 1-5, 1=high coverage, 5= no or little coverage); and shrub cover (%).

Canopy cover was estimated using a convex densiometer and averaging the values obtained from the 4 cardinal directions. Basal area for pines, hardwoods and snags was estimated using a BAF-10 prism. Depending upon whether it was within the prism plot or not, pine, hardwood, and snag DBH were measured using a metric DBH-tape. Overstory (loblolly pine) and midstory

(hardwood) heights were measured using a clinometer. Shrub-layer cover was estimated using a cover board, 2.5 m high by 10cm wide, subdivided into 5 equal sections. The board was placed 11.5m from the plot center, and the observer at the plot center visually estimated the percentage of each board section that was blocked from view by leafy vegetation. This was repeated in each cardinal direction and averaged to obtain a single value for each plot.

Avian abundance was estimated from point count plots located within both the Ashley and Edisto Districts in loblolly pine patches aged 15-28 years. Because the majority of RA plots were patches, all plots occurring within corridors were not used in my analysis to guard against possible shape effects. Data consisted of 167 points surveyed from 1995-1999 (n=539 plots across years). Point count plots had a fixed radius of 50m and were visited once during the field season (Ralph et al. 1993). Individual point counts were located at least 150m apart from the outer radius to ensure independence. Surveys began around sunrise and ended no later than 10 am each day. Point counts were 5 minutes in duration, and all individual birds detected within as well as outside the 50m radius were recorded. Only within-plot detections were used in analysis.

Statistical Analysis

Cluster analysis was performed on all individual vegetation plots using Ward's standardized hierarchical method using JMP 4.02 statistical software (SAS Institute). Vegetation variables included all variables except pine, hardwood and snag DBH. This was because of cases in which a plot had either

no pine, hardwood or snag within the plot ("0" DBH is meaningless). Cluster analysis required values for all variables within each plot.

Results from cluster analysis were aggregated into 3 cluster groups based on the plot-level vegetation data. The 4 stand classifications (PR-corridor, PR-patch, RA-Ashley, and RA-Edisto) were compared against each other based on the distribution of cluster types within each classification. The distribution of the percentage of cluster types within each stand classification was compared using the Chi-square test statistic.

Cluster analysis was performed across all stand classifications (PR-corridor, PR-patch, RA-Ashley, and RA-Edisto) from plot-level vegetation data obtained from 1997-2000. However, because RA-Ashley and RA-Edisto stands were surveyed only from 1997-1998 and 1999-2000, respectively, RA-Ashley stands were compared separately against PR corridors and patches using only data from 1997-1998, and likewise RA-Edisto compared against PR stands using only 1999-2000 data. This approach controlled for possible temporal vegetative growth effects.

After cluster analysis, vegetation data based on stand classifications (PR-corridor, PR-patch, RA-Ashley, and RA-Edisto) were compared against each other. Based on cluster analysis results, PR-corridors and patches were combined prior to this analysis. Individual comparisons of vegetation variables were tested using t-tests for normally distributed data, and the Wilcoxon rank-

sum test for non-normally distributed data. Canopy cover (%) and shrub cover (%) were arcsine transformed prior to analysis.

Avian presence/absence data collected between 1995-1999 were analyzed using logistic regression across ages 15-28. The data were modeled as presence/absence because in almost all cases 1 bird/plot/species were detected in individual point count plots. The age interval was chosen to screen for both species increasing with age and possibly declining with stand age. Age was the independent variable and species-specific abundance by age the dependent variable. Only species with greater than 0.05 mean abundance (birds/plot) were included in the analysis (n=19 species). Mean abundance and model significance were reported for each species.

Results

Vegetation Cluster Analysis

Cluster analysis was used to form 3 distinct cluster groupings. Results for all classification types (PR-corridors, PR-patches, RA-Ashley, RA-Edisto) indicate that post rotation-age corridors and patches had similar structure (Figure 1). The distribution of cluster groupings for PR patch and corridor classifications were not significantly different ($\text{Prob} > \text{ChiSq} = 0.1178$). The distribution of clusters for RA patches from both the Ashley and Edisto Districts were both significantly different from each other as well as from PR corridors and patches (Figure 1, $\text{Prob} > \text{ChiSq} < 0.0001$ for all comparisons).

Because RA patches within the Ashley District were surveyed from 1997-1998 (Table 1), cluster analysis was compared for PR patches and corridors and RA-Ashley, using data from 1997-1998 (Figure 2). PR patches and corridors were not significantly different ($\text{Prob}>\text{ChiSq} = 0.4425$). RA-Ashley patches were significantly different from both PR patches and corridors (Figure 2, $\text{Prob}>\text{ChiSq} < 0.0001$ for both comparisons).

Because RA patches within the Edisto District were surveyed from 1999-2000 (Table 1), cluster analysis was compared for PR patches and corridors and RA patches, Edisto District, using data from 1999-2000 (Figure 3). PR patches and corridors were not significantly different ($\text{Prob}>\text{ChiSq} = 0.4789$). RA patches, Edisto District, were significantly different from both PR patches and corridors (Figure 3, $\text{Prob}>\text{ChiSq} < 0.0001$ for both comparisons).

Vegetation Stand Classification Analysis

Comparisons by stand classification were made between PR patches and corridors, 1997-2000 (Table 2). Significant differences were found between pine basal area ($p < 0.0001$), pine DBH ($p < 0.0001$), hardwood basal area ($p = 0.0153$), hardwood DBH ($p = 0.0247$), and percent shrub cover ($p = .0358$).

Based on cluster analysis results (Figures 1-3), PR corridors and patches were combined for analysis against RA patches (Tables 3 and 4). For the comparison of PR stands vs. RA patches, Ashley District, data from 1997-1998 were used (Table 3). Significant differences were found between overstory height ($p < 0.0001$), midstory height ($p < 0.0001$), pine DBH ($p < 0.0001$), hardwood

DBH ($p = 0.0434$), snag DBH ($p < 0.0001$), vine cover ($p = 0.0082$), and cane cover ($p < 0.0001$).

For the comparison of PR stands vs. RA patches, Edisto District, data from 1999-2000 were used (Table 4). Significant differences were found between percent canopy cover ($p < 0.0001$), overstory height ($p < 0.0001$), midstory height ($p < 0.0001$), pine basal area ($p < 0.0001$), hardwood basal area ($p = 0.0022$), snag basal area ($p = 0.0023$), vine cover ($p < 0.0001$), cane cover ($p < 0.0001$), and shrub percent cover ($p < 0.0001$).

Point count data were analyzed across loblolly pine patches aged 15-28 years (Table 5). Ten out of 19 species showed significant increases in abundance with age, 6 showed no significant change, and 3 significantly declined in abundance with stand age (Table 5).

Discussion

Results from cluster analysis confirm: 1. that PR patches and corridors were similar in vegetative structure (Figures 1-3), 2. PR patches and corridors were different in vegetative structure relative to both RA-Ashley and RA-Edisto patches (Figures 1-3), and 3. RA-Ashley and RA-Edisto were different in vegetative structure against each other (Figure 1). Thus for assessing differences in avian abundance and nest productivity between corridors and patches, inclusion of RA patches was not warranted.

Analysis of vegetative differences between stand classifications (PR-corridor, PR-patch, RA-Ashley, and RA-Edisto) demonstrated significant

differences across all comparisons. Although cluster analysis demonstrated similarity between PR patches and corridors, significant differences were found between pine and hardwood basal area, pine and hardwood DBH, and percent shrub cover. Difference in shrub cover is most likely due to the increased solar penetration along edges within the 100-meter-wide corridors. All corridor plots were within at least 50m of an edge. In regards to pine and hardwood DBH, results were unlikely to be biologically significant. The actual differences between PR patch and corridor pine and hardwood DBH were 1.8 and 2.6 cm, respectively. The significant difference between hardwood DBH is lessened by that fact that the difference in midstory height was 0.2 m between PR corridors and patches. This indicates that although midstory DBH was dissimilar, midstory tree structure between stand types was similar.

The significant differences between pine and hardwood basal area between PR corridors and patches were most likely due the imprint of management practices. Corridors were designed to encompass wetter areas across the landscape. Since corridors will persist in the landscape 40-60 years, and harvesting is sometimes more difficult in wetter soils, Westvaco purposely designated some corridors to encompass wetter sites where possible. However, at the vegetation plot level, the difference in basal area translates to an average density of 1 more hardwood tree/plot within corridors.

Significant differences between PR stands (PR corridors and patches combined) and RA patches indicate the imprint of age. Across all comparisons,

overstory and midstory height were significantly different. However RA-Ashley stands had similar pine and hardwood basal area compared to PR stands. RA-Edisto stands had significantly lower pine basal area and significantly higher hardwood basal area than both PR stands and RA-Ashley stands ($p < 0.0001$ and $p = 0.0020$ respectively for the RA-Edisto and RA-Ashley comparison). These results indicate that RA-Edisto stands were more of a mixed pine-hardwood stand whereas RA-Ashley patches were simply younger versions of loblolly pine stands with respect to PR stands.

Avian abundance changes across loblolly pine patches aged 15-28 years (Table 5) indicate that significant changes occurred for 13 out of 19 species. Of those species increasing with loblolly stand age, 5 were tree-nesting species: Acadian Flycatcher, Blue-gray Gnatcatcher (*Polioptila caerulea*), Pine Warbler (*Dendroica pinus*), Red-eyed Vireo (*Vireo olivaceus*), and Summer Tanager (*Piranga rubra*). Four were cavity nesting species: Carolina Chickadee (*Poecile carolinensis*), Eastern Tufted Titmouse (*Baeolophus bicolor*), Great-crested Flycatcher (*Myiarchus crinitus*), and Red-bellied Woodpecker (*Melanerpes carolinus*). One was a ground-nesting species, the Kentucky Warbler (*Oporornis formosus*). The tree-nesting species were most likely responding to increasing suitable nest sites, foraging sites, or characteristics related to foliage-height diversity (Mills et al. 1991). Cavity nesting species most likely were responding to increases in snag size and production with stand age.

Of the 6 species showing no significant changes in abundance with age, 5 were habitat generalists or edge associated species: Carolina Wren (*Thryothorus ludovicianus*), Common Yellowthroat (*Geothlypis trichas*), Eastern Towhee (*Pipilo erythrophthalmus*), Northern Cardinal (*Cardinalis cardinalis*), and White-eyed Vireo (*Vireo griseus*). The Northern Parula (*Parula americana*) was the only tree nesting species (the Northern Cardinal is both a shrub and tree nesting species across the study area). The Northern Parula requires Spanish Moss as nesting substrate, and its distribution may be more tied to this limiting resource.

Three species declined with age, the Hooded Warbler, Ovenbird (*Seiurus aurocapillus*), and Worm-eating Warbler (*Helmitheros vermivorus*). All 3 are Neotropical migrants that nest either in shrubs (Hooded Warbler) or on the ground (Ovenbird and Worm-eating Warbler). The reasons for these declines were unclear. All 3 of these species are commonly associated with mature forest structure and considered possibly area-sensitive (Whitcomb et al. 1981). Most RA plots were within the Ashley district, which is less fragmented compared to the Edisto district. The location of points within the Ashley District were amongst relatively large blocks of rotation-age stands, whereas both corridor and patch stands within the Edisto District were adjacent to loblolly stands aged 0-5 years. It is possible that these species were sensitive to stand area within the landscape.

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Table 1. Stand-level forestry data for nest searching corridors, patches, and rotation-age patches 1997-2000.

Stand Type	Years Surveyed	Age	Area (ha)	Site Index ¹	Basal Area (ft ² /acre)	Trees/ acre	Prescribed Burn Year	District	Classification ²
<u>Corridors</u>									
C1	1997-2000	25-28	20.7	75	152	249	1993	Edisto	PR-C
C2	1998-2000	27-29	30.0	83	186	238	1996	Edisto	PR-C
C3	1998-2000	26-28	10.6	72	125	255	1994	Edisto	PR-C
C4	1999-2000	27-28	9.4	75	121	206	1993	Edisto	PR-C
<u>Patches</u>									
P1	1997-2000	25-28	38.0, 12.4 ³	80	164	264	1993	Edisto	PR-P
P2	1998-1999	27-28	20.2	96	179	212	1992	Edisto	PR-P
P3	1998	24	22.5	77	142	237	1993	Edisto	PR-P
P4	1999-2000	24-25	32.0	78	192	302	1997	Edisto	PR-P
P5	2000	31	16.1	72	125	255	1994	Edisto	PR-P
<u>Rotation-age</u>									
R1	1997-1998	19-20	22.1	81	160	331	1995	Ashley	R-A
R2	1997-1998	19-20	18.5	84	173	444	1991	Ashley	R-A
R3	1998	18	39.1	72	154	618	1996	Ashley	R-A
R4	1999-2000	20-21	18.1	68	122	312	1995	Edisto	R-E
R5	1999-2000	21-22	20.3	81	139	201	1996	Edisto	R-E
R6 ⁴	1999-2000	21-22	7.1	82	172	266	1996	Edisto	R-E

¹ - Site index, loblolly pine, base age 50 (total expected height in feet at age 50).

² - PR-C = Post rotation-age Corridor, PR-P = Post-rotation age patch, R-A = Rotation-age patch, Ashley District, R-E Rotation-age patch, Edisto District.

³ - P1 was cut in 1999 to form C4, leaving a 12.4 ha patch (P1) and new 9.4 ha corridor (C4)

⁴ - This was a corridor, included as a RA patch in vegetation analysis

Table 2. Vegetation comparisons between post-rotation-age patches and corridors, 1997-2000. Data were from random vegetation plots within nest searching stands. Data are presented as mean and (standard deviation). Significant differences are in bold ($p < 0.05$)

Habitat Variable	Corridor	Patch	p-value
Canopy Cover (%) ¹	1.15 (0.11)	1.16 (0.11)	0.3101
Overstory Height (m)	26.0 (3.20)	26.1 (3.11)	0.7703
Midstory Height (m)	12.8 (2.86)	13.0 (2.75)	0.4660
Pine Basal Area (ft ² /acre)	139.0 (59.74)	165.9 (59.33)	<0.0001
Pine DBH (cm)	34.5 (4.45)	32.7 (4.26)	<0.0001
Hardwood Basal Area (ft ² /acre)	30.2 (33.0)	23.2 (31.0)	0.0153^a
Hardwood DBH (cm)	18.1 (10.15)	15.5 (8.62)	0.0247
Snag Basal Area (ft ² /acre)	6.4 (9.80)	5.8 (8.16)	0.9146 ^a
Snag DBH (cm)	19.2 (8.23)	18.3 (6.61)	0.4398
Vines	4.4 (0.96)	4.5 (0.89)	0.0517 ^a
Cane	4.2 (1.00)	4.2 (1.15)	0.3934 ^a
Shrub Cover (%) ¹	0.53 (0.24)	0.47 (.25)	0.0358

¹ - Data are arcsine transformed

^a - Wilcoxon Rank Sum Test

Table 3. Vegetation comparisons between post-rotation-age patches and corridors, 1997-1998, and RA Ashley. Data were from random vegetation plots within nest searching stands. Data are presented as mean and (standard deviation). Significant differences are in bold ($p < 0.05$)

Habitat Variable	Post-rotation-age corridors and patches	Rotation-age patches, Ashley District	p-value
Canopy Cover (%) ¹	1.10 (0.10)	1.11 (0.08)	0.4454
Overstory Height (m)	26.3 (3.13)	20.8 (2.94)	<0.0001
Midstory Height (m)	12.5 (2.96)	9.9 (2.01)	<0.0001
Pine Basal Area (ft ² /acre)	159.3 (64.15)	147.1 (59.00)	0.2336
Pine DBH (cm)	32.7 (3.83)	22.9 (4.22)	<0.0001
Hardwood Basal Area (ft ² /acre)	26.8 (3.22)	22.4 (2.80)	0.5239 ^a
Hardwood DBH (cm)	15.0 (7.39)	11.7 (10.20)	0.0434
Snag Basal Area (ft ² /acre)	5.6 (8.34)	4.91 (7.91)	0.5182 ^a
Snag DBH (cm)	18.2 (0.81)	11.4 (1.28)	<0.0001
Vines	4.4 (0.84)	4.0 (1.10)	0.0082^a
Cane	4.1 (1.00)	4.9 (0.37)	<0.0001^a
Shrub Cover (%) ¹	0.52 (0.23)	0.52 (0.25)	0.9491

¹ - Data are arcsine transformed

^a - Wilcoxon Rank Sum Test

Table 4. Vegetation comparisons between post-rotation-age patches and corridors combined, and rotation-age patches, Edisto District, 1999-2000. Data were from random vegetation plots within nest searching stands. Data are presented as mean and (standard deviation). Significant differences are in bold ($p < 0.05$)

Habitat Variable	Post-rotation-age corridors and patches	Rotation-age patches, Edisto District	p-value
Canopy Cover (%)¹	1.17 (0.10)	1.26 (0.09)	<0.0001
Overstory Height (m)	26.0 (2.90)	21.3 (3.16)	<0.0001
Midstory Height (m)	13.1 (2.72)	11.0 (2.74)	<0.0001
Pine Basal Area (ft²/acre)	148.1 (59.29)	97.20 (57.03)	<0.0001
Pine DBH (cm)	34.1 (4.64)	33.6 (3.17)	0.3061
Hardwood Basal Area (ft²/acre)	27.0 (32.29)	35.6 (31.86)	0.0022^a
Hardwood DBH (cm)	17.7 (10.29)	17.2 (10.79)	0.6832
Snag Basal Area (ft²/acre)	6.3 (9.38)	3.40 (6.85)	0.0023^a
Snag DBH (cm)	19.0 (7.97)	17.1 (14.64)	0.5379
Vines	4.4 (0.97)	3.1 (1.41)	<0.0001^a
Cane	4.3 (1.11)	4.8 (0.45)	<0.0001^a
Shrub Cover (%)¹	0.49 (0.26)	0.39 (.20)	<0.0001

¹ - Data were arcsine transformed

^a - Wilcoxon Rank Sum Test

Table 5. Bird abundance by loblolly pine stand ages 15-28. Data were from 1995-1999 point count data, Ashley and Edisto Districts (n= 167 distinct points, n = 539 sampled across years). Corridor plots were omitted from this analysis. Species abundance was analyzed using nominal logistic regression for each species with greater than .05 mean abundance (birds/plot) across the age interval 15-28 years.

Species	Mean Abundance	p-value (Age)
<u>Species Increasing with Age</u>		
Acadian Flycatcher	0.2245	<0.0001
Blue-Gray Gnatcatcher	0.1762	<0.0001
Carolina Chickadee	0.1224	0.0288
Eastern Tufted Titmouse	0.2096	0.0008
Great-crested Flycatcher	0.1948	<0.0001
Kentucky Warbler	0.0538	0.0121
Pine Warbler	0.5117	<0.0001
Red-bellied Woodpecker	0.0538	0.0039
Red-eyed Vireo	0.2616	<0.0001
Summer Tanager	0.1206	0.0020
<u>Species Unchanging with Age</u>		
Carolina Wren	0.1058	0.9398
Common Yellowthroat	0.0853	0.9258
Eastern Towhee	0.1113	0.2238
Northern Cardinal	0.1670	0.6984
Northern Parula	0.1020	0.5500
White-eyed Vireo	0.1020	0.3008
<u>Species Decreasing with Age</u>		
Hooded Warbler	0.2078	0.0308
Ovenbird	0.0742	0.0004
Worm-eating Warbler	0.1243	0.0171

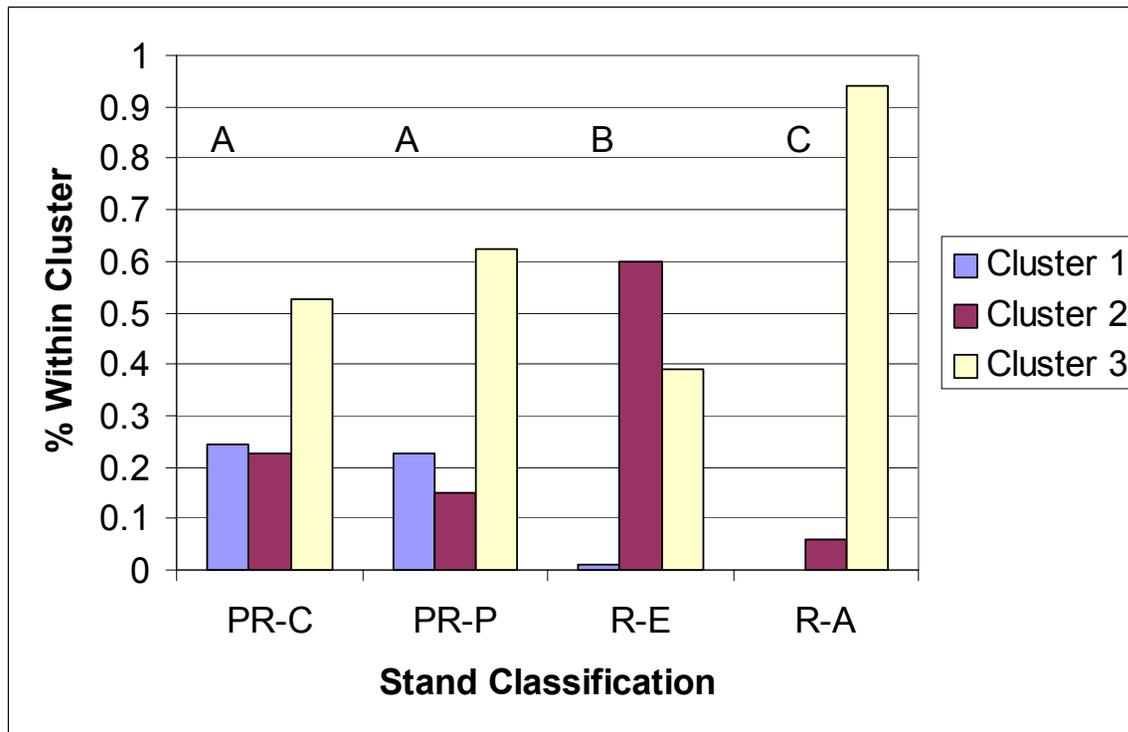


Figure 1. Cluster analysis results between post-rotation-age corridors (PR-C), post-rotation-age patches (PR-P), and rotation-age patches, Ashley district (R-A), and rotation-age patches, Edisto District (R-E), 1997-2000. Data for PR-C and PR-P span 1997-2000, data for R-A span 1997-1998, and data for R-E span 1999-2000. Letters denote significant differences among distributions between classifications ($p < 0.0001$ for all significant differences, Chi-Sq test)

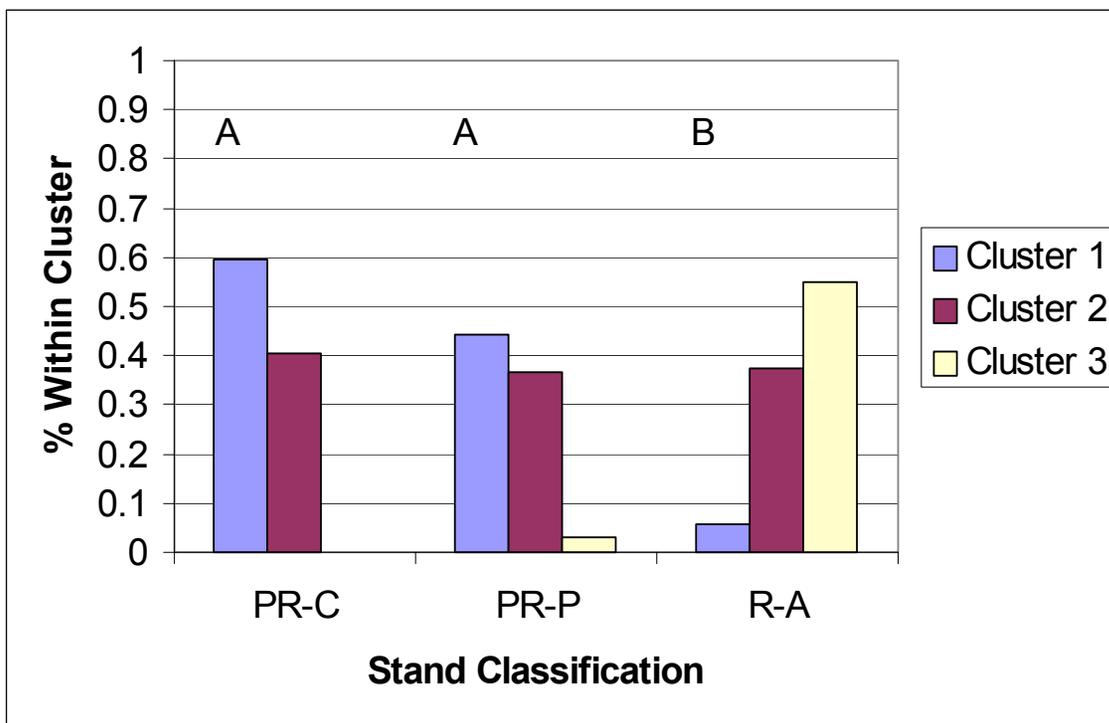


Figure 2. Cluster analysis results between post-rotation-age corridors (PR-C), post-rotation-age patches (PR-P), and rotation-age patches, Ashley district (R-A), 1997-1998. Letters denote significant differences among distributions between classifications ($p < .0001$ for all significant differences, Chi-Sq test)

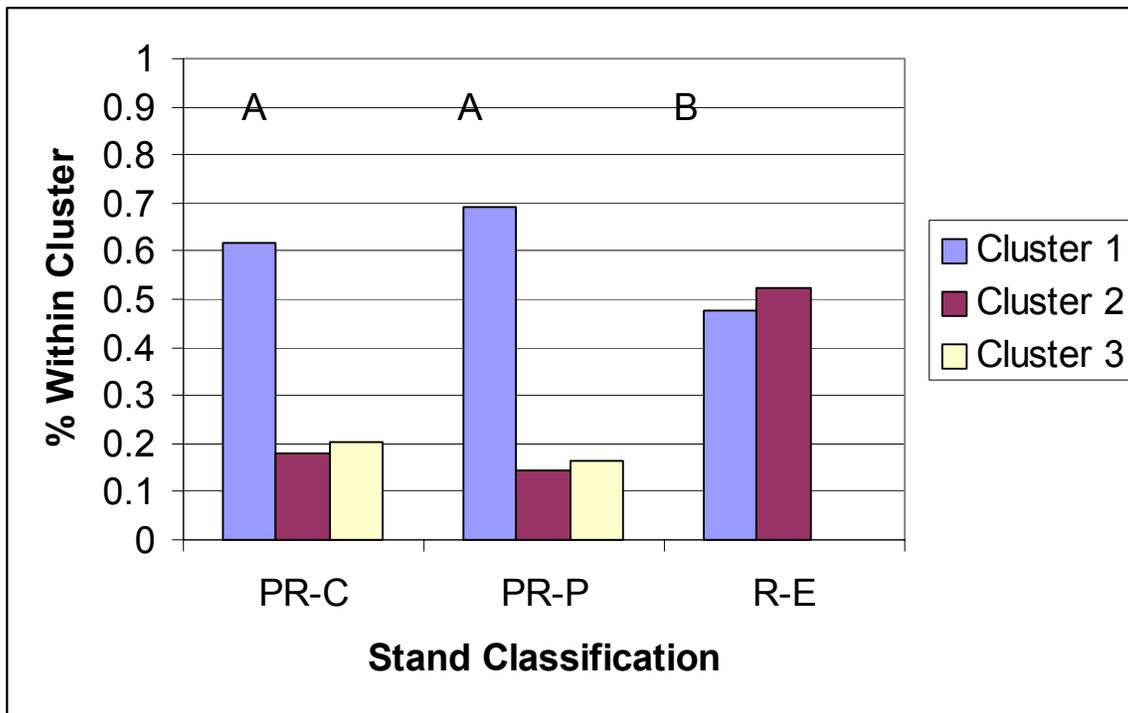


Figure 3. Cluster analysis results between post-rotation-age corridors (PR-C), post-rotation-age patches (PR-P), and rotation-age patches, Edisto district (R-E), 1999-2000. Letters denote significant differences among distributions between classifications ($p < .0001$ for all significant differences, Chi-Sq test)

Chapter 2: Avian diversity and abundance within loblolly pine plantation corridors and patches

Introduction

Populations of some forest bird species have been declining over the past decades, including forest interior Neotropical migrant species (Askins 1993, Peterjohn et al. 1995, Holmes and Sherry 2001). Habitat loss, fragmentation and isolation have been cited as major causes for these declines (Walters 1998). Loss of breeding habitat affects the overall population negatively if remaining habitat does not compensate for the lost breeding opportunities. For forest interior bird species, fragmentation and isolation might induce negative "edge effects" on the population (McCollin 1998). Increased nest predation and brood parasitism near edges might limit reproductive success (Wilcove 1985, Donovan et al. 1995, Robinson et al. 1995). Species may also avoid habitat of insufficient size or occur in lower abundance (Roberts and Norment 1999).

Several studies have investigated fragmentation of forests and its effect on forest-associated bird species abundance and distribution. In a continental-wide analysis, Neotropical migrants as a group were found to be more sensitive to landscape structure, being more abundant in larger forest patches and less fragmented forested landscapes, and less abundant in edge habitats (Flather and Sauer 1996). In a continental study on tanagers, species exhibited strong negative responses to habitat fragmentation and local sensitivity to fragmentation was lower in regions with greater overall forest cover (Rosenberg et al. 1999).

In a study involving 33 experimental landscapes and 15 bird species, Villard et al. (1999) found that the presence of only 3 species was not significantly related to either cover or configuration of the woodland. The authors concluded that landscape structure was an important predictor of species distribution, that both forest cover and configuration were important predictors of species presence, and that responses were species specific. The type of landscape matrix has also been investigated. Urban and agricultural landscapes have been found to accumulate species more slowly with area than landscapes that retained more natural habitats (Flather 1996).

In a review of fragmentation studies on birds and mammals from different landscapes, Andren (1995) found that with suitable habitat of >30% of the landscape, fragmentation effects were best modeled as simple habitat loss. Below this 30% threshold, patch size and isolation complemented the effect of habitat loss and the decline in population size was greater than expected from habitat loss alone.

These studies indicate, at the landscape, stand or patch level, that overall availability of suitable habitat and its configuration may affect species distribution and abundance. With regards to the studies mentioned above, my study site is represented by fragmented, post-rotation-age (24-31 years of age) loblolly pine (*Pinus taeda*) plantation habitat within a forested landscape. Across Westvaco's Edisto Management District, loblolly pine comprises 50% of the land area, with 4% represented by post-rotation stands (Figure 1). The remainder of the

landbase is comprised of hardwood stands (23%), non-forested land (25%) and gumponds (2%). Thus, following from Andren (1995), patch size and isolation may have significant effects on avian diversity and abundance. Corridors are 100-meter-wide linear patches of loblolly pine, whereas patches are typical Westvaco stand configurations. The high-edge to area ratio within corridors may induce greater negative edge effects on certain forest interior avian species in comparison to patches.

Although post-rotation loblolly pine comprises only 4% of the landscape, the corridor system provides connectivity between post-rotation-age patches and corridors and to mature hardwood stands as well. The connectivity of these post-rotation stands, as well as the lack of agricultural land within the matrix, may mitigate fragmentation effects. Schmiegelow et al. (1997) studied bird responses to experimentally fragmented 1, 10, 40 and 100-hectare forest patches in boreal mixed-wood forest connected with 100-meter-wide riparian buffer strips. Neotropical migrant species declined both in connected and isolated fragments, while resident species declined in isolated fragments. However, corridors were cited as mitigating declines in comparison with isolated fragments.

Corridors can potentially serve 2 main functions in the maintenance of species populations (Nichols and Margules, 1991): 1. corridors may facilitate movement between patches of similar habitat, and 2. corridors may act as suitable habitat in their own right. This project investigated the value of loblolly corridors as breeding habitat for landbirds. If edge effects are prevalent within

my study area, corridors may function as population "sinks" (Pulliam, 1988) or ecological "traps" (Gates and Gysel, 1978) relative to patches. A habitat is termed a "sink" if reproductive output is insufficient to maintain positive population growth within the habitat. A habitat is termed a "trap" if characteristics of the habitat attract species in high densities, and such species experience greater mortality or lower reproductive success than in other habitat patches.

Linear habitat structures such as corridors, shelterbelts and hedgerows have been studied over the past decades (for a review see Beier and Noss 1998). Research has focused on the effects of fragmenting and linearizing habitat on various species or species communities. Few studies have directly assessed mature forest corridors in relation to avian species (Haas 1996, Machtans et. al 1996, Bentley and Catterall 1997, Schmiegelow et. al 1997, Major et. al 1999, Lambert and Hannon, 2000).

In a study examining the frequency of bird movements in riparian buffer strips between forest reserves in a mixed wood boreal forest, Machtans et. al (1996) found that riparian buffer strips enhanced juvenile bird movements and that adult bird species maintained territories within the strips. The authors also found that there was a threshold distance between forest reserves beyond which birds rarely flew across forest openings. In a study of tropical bushland rainforest remnant patches and linear bushland corridors, Bentley and Catterall (1997) found that spatial characteristics were a better predictor of bird abundance than habitat characteristics. Bushland-dependent residents were more abundant in

continuous bushland than in linear remnants. However, many species used both continuous and linear bushland. Lambert and Hannon (2000) studied the behavioral responses of Ovenbirds (*Seiurus aurocapillus*) to 20, 100 and 200-meter-wide riparian buffer strips in a boreal mixed-wood forest in Alberta. Ovenbirds were not found in 20m strips but were found in both 100 and 200m strips both before and after harvesting of the surrounding area.

One study compared plots near the edge of 8, 16, and 23-meter-wide forest-dividing corridors (unpaved and paved roads, and power line rights-of-way, respectively) with interior plots away from disturbance (Rich et al. 1994). High abundances of Brown-headed Cowbirds (*Molothrus ater*) and avian nest-predators were found near even the smallest forest-dividing corridor. Overall relative abundance of Neotropical migrants did not differ significantly between forest-edge and interior plots for unpaved roads, but was greater for interior plots in comparisons between paved roads and power-line rights-of-way. However, the authors concluded that lower abundances were a result of lack of habitat near these edge points (paved roads and power-lines), and that forest interior species were not avoiding narrow-forest dividing corridors. They concluded that narrow forest dividing corridors have the potential to act as "ecological traps" (Gates and Gysel 1978) due to the high abundance of Brown-headed Cowbirds and nest predators, and the lack of edge avoidance in nesting forest-interior songbirds.

My analysis investigates whether bird diversity or abundance differs between post-rotation-age corridors and patches, and whether edge effects are operational within the landscape. Species diversity, similarity, and abundance were compared between post-rotation corridors and patches. To investigate possible edge effects, species abundance was also examined for three stand classifications: corridors, points within patches within 80m of an edge (P-edge), and points within patches greater than 80m from an edge (P-interior).

Methods

Approximately 350 point count plots were established in 1994 across all loblolly and hardwood stand ages based on available habitat age and type. During the course of the study, 54 plots (Appendix -Map 2) within the Edisto district were within post-rotation age stands similar to and including nest searching stands (Chapter 3, Appendix-Map 1, ages 24-31). Only point count plots with 3 or more years of sampling from 1996-1999 were included in the analysis. Counts before 1996 were not used because the corridor system was largely installed via harvesting of adjacent stands between 1995-1996. Point counts used within this analysis include nest searching stands (corridors and patches) and other corridor and patch stands of similar age and stand structure.

For species diversity, only corridors and patches were compared (Table 1). Diversity was compared for all species, all Neotropical migrants, and all forest-associated Neotropical migrants. Because there has been much debate over interpretation of diversity measures (Krebs 1989), several measures were

employed. The following measurements of species diversity were used: species richness (N), Shannon's Index (H'), Simpson's Index (1-D), the Morisita-Horn measure of overlap (C), and Spearman's rho rank-order correlation coefficient (r).

For analysis of individual species abundance, corridor and patch points were compared, and points were also divided into 3 classifications to account for possible edge effects: 1. corridor points, 2. patch points located within 80m to an edge (aged 0-5 years), 3. patch points located greater than 80m to an edge aged 0-5 years. Distances were chosen to equalize sample sizes between both types of patch distance to edge classifications (Table 2). In almost all cases, the closest edge to any point count plot was a loblolly pine stand aged 0-5 years (Appendix-Map 2). This was due to the high frequency of harvesting of adjacent stands to both corridors and post-rotation-age patches.

Point count plots had a fixed radius of 50m and were visited once during the field season (Ralph et al. 1993). Individual point counts were located at least 150m apart from the outer radius to ensure independence. Surveys began around sunrise and ended no later than 10 am each day. Point counts were 5 minutes in duration, and all individual birds detected within as well as outside the 50m radius were recorded. Only within-plot detections were used in analysis.

Point count plot vegetation was characterized using available Westvaco stand level data (Tables 1 and 2). Variables included: age, basal area of pines, trees per acre, site index, and years since prescribed burn. These data were for the stand level only; thus plots within the same stand had the same values.

However, this is a realistic representation of stand data commonly available in Forestry operations.

For analysis of possible edge effects, linear distances to edges aged 0-5 years were measured using ArcView. All point count plots were recorded using a global positioning system (GPS). Point count locations were entered as a layer within Westvaco's stand layer in ArcView (ArcView GIS, ESRI). These were overlaid upon the stand layer and linear distance to edge calculations were measured.

Statistical Analysis

Species diversity formulations were calculated using Bio-Dap software, with formulations from Magurran (1988). Species relative abundance was used in all diversity calculations (n individuals of species x / N total individuals for the patch type). The total number of individuals was 473 for corridors and 475 for patches, 1996-1999. Shannon's index is weighted more toward rare species, whereas Simpson's index is weighted more toward common species (Krebs 1989). Both indices are scales, higher numbers indicate greater diversity. The Morisita-Horn measure compares species overlap (similarity) between corridors and patches. C ranges from 0 to 1, with 0 being no overlap and 1 being complete overlap in habitat use. Spearman's rho calculates the correlation (r) between the rank order of species relative abundance between corridors and patches.

Point count data for individual species were compared for patches and corridors; and the 3 spatial groupings: "corridor" points, "edge" points (patches in which the plot was < 80m to an edge aged 0-5 years) and "interior" points (patches in which the plot was >80m from an edge aged 0-5years). The data were modeled as presence/absence because in almost all cases at most 1 bird/plot/species were detected in individual point count plots (data were almost entirely 0 or 1 for each species per point count plot). Abundance in this analysis is thus measured as birds/plot within patch type point count plots within each classification (presence/absence).

Data for avian abundance were analyzed using contingency tables tested against the Chi-square statistic. This analysis tests the null hypothesis that each avian species was distributed equally among corridors and patches or spatial group classifications (corridor points, patch points <80m to an edge, and patch points >80m from an edge). Only species with > 0.10 birds/plot overall were used in the analysis, except for the Brown-headed Cowbird (*Molothrus ater*), a brood parasite.

Results

Vegetation characteristics

Tables 1 and 2 summarize the both the sampling effort and stand level data for corridor/patch comparisons (Table 1) and distance to edge comparisons (Table 2), 1996-1999. For corridor/patch comparisons (Table 1), significant differences existed between stand size (ha), distance to edge, site index, and

stand basal area. For edge comparisons (corridor, patch-edge, patch-interior points, Table 2) significant differences between corridor/patch-edge points were between stand size, distance to road and site index. For corridor/patch interior comparisons, significant differences were between stand size, distance to edge, site index, and basal area. For patch edge/interior stand level comparisons, significant differences were found between distance to edge, distance to road, and basal area.

Species Diversity

Species relative abundance and diversity were compared only between corridors and patches. Table 3 ranks the relative abundance of all species detected within corridors and patches, 1996-1999 (Appendix-Table 1 lists common and scientific names). Figure 2 graphically displays corridor species relative abundance against ranked patch species relative abundance within patches. Eleven species were unique to corridors: American Crow (*Corvus brachyrhynchos*), Eastern Bluebird (*Sialia sialis*), White-Breasted Nuthatch (*Sitta carolinensis*), Blue Grosbeak (*Guiraca caerulea*), Common Grackle (*Quiscalus quiscula*), Fish Crow (*Corvus ossifragus*), Little-blue Heron (*Egretta caerulea*), Mourning Dove (*Zenaida macroura*), Northern Bobwhite Quail (*Colinus virginianus*), Wild Turkey (*Meleagris gallopavo*), and Yellow-throated Warbler (*Dendroica dominica*). None of these species occurred at greater than 1.3% relative abundance. Five species were unique to patches: Prairie Warbler (*Dendroica discolor*), Wood Thrush (*Hylocichla mustelina*), Black and White

Warbler (*Mniotilta varia*), Ovenbird (*Seiurus aurocapillus*), and Ruby-throated Hummingbird (*Archilochus colubris*). None of these species occurred at greater than 0.4% relative abundance.

Table 4 summarizes species diversity metrics between corridors and patches for: 1. all species detected, 2. Neotropical migrants, and 3. forest-associated Neotropical migrants. For all species detected, species richness was greater within corridors (44 vs. 38). For Neotropical migrant species, species richness was greater in patches (21 vs. 25 for all Neotropical migrants, and 15 vs. 17 for all forest-associated Neotropical migrants).

Species diversity measured using the Shannon and Simpson indices (Table 4) showed greater diversity in corridors for comparisons over all species ($H' = 3.27$ for corridors and 3.04 for patches, $1-D = 0.952$ for corridors and 0.938 for patches) and for comparisons of all Neotropical migrant species ($H' = 2.62$ for corridors and 2.55 for patches, $1-D = 0.912$ for corridors and 0.901 for patches). Comparisons for Neotropical forest-associated species were virtually equivalent ($H' = 2.35$ for both corridors and patches, $1-D = 0.888$ for corridors and 0.887 for patches).

The Morisita-Horn measure of overlap (C) compared similarity between corridors and patches. Results indicate a high degree of overlap across all species (0.925), Neotropical migrants (0.934), and forest-associated Neotropical migrants (0.944). Spearman's correlation coefficient (ρ) compared the rank order of species relative abundance between corridors and patches.

Correlations were significant for all species ($r = 0.7877$, $p < 0.0001$), for all Neotropical migrants ($r = 0.8160$, $p < 0.0001$), and forest-associated Neotropical migrants ($r = 0.8985$, $p < 0.0001$).

Species Abundance

Comparisons of species-specific abundance between stand type (corridor and patch) and edge categories (corridor, patch-edge plot, and patch-interior plot) are displayed in Table 5. For corridor/patch comparisons, 3 species showed significant differences, both the Blue-gray Gnatcatcher (*Polioptila caerulea*) and Brown-headed Cowbird occurred in higher abundance in corridors ($p = 0.0343$ and $p = 0.0093$, respectively). The Red-eyed Vireo (*Vireo olivaceus*) occurred in higher abundance within patches ($p = 0.0011$).

For corridor vs. patch-edge comparisons (Table 5), both the Great-crested Flycatcher (*Myiarchus crinitus*) and Brown-headed Cowbird occurred in higher abundance within corridors ($p = 0.0019$ and $p = 0.0338$, respectively). The Red-eyed Vireo occurred in higher abundance within patch-edge plots ($p = 0.0471$).

For corridor vs. patch-interior comparisons, 7 species differed significantly in abundance between types (Table 5). Six of the 7 species were found in higher abundance within corridors: Blue-gray Gnatcatcher, Brown-headed Cowbird, Carolina Wren (*Thryothorus ludovicianus*), Eastern Towhee (*Pipilo erythrophthalmus*), Red-bellied Woodpecker (*Melanerpes carolinus*), and White-eyed Vireo (*Vireo griseus*). The only species found at higher abundance within patch-interior plots relative to corridors was the Red-eyed Vireo ($p < 0.0001$).

The final comparison was between patch-edge and patch-interior plots (Table 5). Six species showed significant differences in abundance. Five species occurred in greater abundance within patch-edge plots: the Blue-gray Gnatcatcher, Carolina Wren, Eastern Towhee, Red-bellied Woodpecker, and White-eyed Vireo. The only species found in significantly greater abundance within patch-interior plots was the Great-crested Flycatcher.

Across a gradient of edge to interior conditions, only 2 species significantly increased in abundance (Figure 3). The Red-eyed Vireo increased significantly in the corridor/patch (0.213 vs. 0.440, $p = 0.0011$), corridor/p-edge (0.213 vs. 0.364, $p = 0.0471$), and corridor/p-interior comparisons (0.213 vs. 0.510, $p < 0.0001$). The Great-crested Flycatcher increased in abundance within the p-edge/p-interior comparison (0.182 vs. 0.377, $p = 0.0186$). The remaining 6 species were higher in abundance within more edge-like conditions in at least 1 of the comparisons (Figure 3, Table 5).

Discussion

Species diversity was greater within corridors than patches. Although patch plots were sampled more ($n=116$ vs. $n=94$, Table 1), corridors contained 44 species whereas patches had 38. Both Shannon and Simpson's diversity indices indicated greater diversity within corridors. Although greater in diversity, the Morisita-Horn measure indicated that corridors and patches were similar in species overlap ($C = 0.925$, Table 4). Most of the differences in diversity were due to rare species (Table 3). Of species occurring only in one patch type, none

were greater than 1.3% relative abundance in corridors and 0.40% in patches. The Spearman's rank correlation on species ranks between corridors and patches was high (0.7877, $p < 0.0001$), indicating that most species had similar relative abundance by rank-order between patch types.

These results indicate that corridors and patches were similar in avian assemblage composition. Greater diversity and species richness within corridors was most likely due to habitat heterogeneity. Point counts located within corridors were proximal to 2 edges, whereas patch plots were proximal to one. Since Leopold (1933) edge habitats have been noted for their generally high concentration of wildlife species. Eight of the 11 species occurring only within corridors (Table 3) were edge associated species: American Crow, Eastern Bluebird, White-breasted Nuthatch, Blue Grosbeak, Common Grackle, Fish Crow, Mourning Dove, and Northern Bobwhite Quail (Ehrlich et al. 1988). Of the 5 species occurring only in patches, 3 were forest-associated species: Wood Thrush, Black and White Warbler, and Ovenbird.

When diversity of only Neotropical migrants was compared, species richness was greater in patches. This was true for all Neotropical migrants and forest-associated Neotropical migrants (Table 4). Forest associated Neotropical migrant diversity measures were almost identical, and both similarity measures, Morisita-Horn (0.944) and Spearman's rho (0.8985) were high. However, because patch points were sampled more, these results may be an artifact of sample size.

Analysis of diversity and similarity between corridors and patches indicate that avian assemblages within corridors and patches were very similar. This was true across all species, Neotropical migrants, and forest-associated Neotropical migrants. In general, abundant species were abundant, and rare species were rare within both patch types. Major changes in avian assemblages were not apparent between corridors and patches in this analysis.

Although both avian diversity and assemblages were similar between patches and corridors, understanding the spatial distribution of avian species within corridors and patches is essential to determining if edge effects are affecting species abundance. Analysis of individual avian abundance (birds/plot) between corridors and patches examined the following 4 comparisons: 1. corridors and patches outright, 2. corridors and all point counts within 80m of a patch edge (edge points), 3. corridors and all point counts >80m from an edge (interior points), and 4. patch edge and interior points.

Eight out of 17 species occurring with > 0.10 abundance (birds/plot) showed significant differences between either patch type or spatial classification (Table 5). Only 2 of these species, the Red-eyed Vireo and Great-crested Flycatcher demonstrated possible sensitivity to edge conditions. The Great-crested Flycatcher was significantly more abundant within patch-interior points compared to patch-edge points (0.377 vs. 0.182). However, it did not significantly differ between patch-interior points and corridor points (0.377 vs.

0.340). This may indicate a preference for interior conditions when available, but lack of avoidance of edge conditions.

The Red-eyed Vireo was the only species to show consistently lower abundance within more edge-like conditions. Across a gradient of edge-like conditions from corridors to patch-edge to patch-interior, the Red-eyed Vireo increased in abundance (0.213, 0.364, and 0.508, respectively). The Red-eyed Vireo has been considered a forest-area sensitive species (Whitcomb et al. 1981). However, the Red-eyed Vireo is not listed as a species high priority by Partners in Flight for the South Carolina Coastal Plain, or of moderate priority nationally (Carter et al., in press). Kilgo et al. (1998), in a study of South Carolina bottomland hardwood strips ranging from <50m to >1000m in width enclosed by pine forested habitat, found that Red-eyed Vireos were actually significantly more abundant within smaller width classes. However, within our study area, both corridors and patches were surrounded by loblolly stands aged 0-5, and this edge may be a much sharper contrast for Red-eyed Vireos.

Although stand level vegetation between patches and corridors were similar (Tables 1 and 2), it is possible that Red-eyed Vireos were responding to specific microsite habitat requirements. This is unlikely because plot-level vegetation characteristics (Chapter 1) were similar between patches and corridors. The Red-eyed Vireo is also considered a hardwood-associated species (Ehrlich et al. 1988, Kilgo et al. 1998), and corridors have significantly greater hardwood basal area than patches (Chapter 1). Another explanation is

that territory sizes within corridors were larger or more dispersed than within patches. For a nesting species, central place foraging theory predicts circular territories to be optimal. Within corridors, certain avian species may have to increase territory size in order to forage and raise broods successfully. However, Hazler (1999) did not find differential territory size for Acadian Flycatchers within post-rotation-age corridors and patches within the study site.

The Brown-headed Cowbird, a brood parasite, was found at significantly higher abundance within corridors than in patch, patch-edge and patch-interior points (Table 5). Two known nest predators, the American and Fish Crow, were found in corridors but not in patches (Table 3). These 3 species are difficult to census using point counts, so their abundance may be best interpreted as a potential greater use of corridors for movements or foraging. If the Brown-headed Cowbird and avian nest predators use corridors more often than patches, corridors have the potential to act as "ecological traps" (Gates and Gysel 1978, Rich et al. 1994) relative to patches. Of all forest-associated species, only the Red-eyed Vireo showed preference for more interior-like conditions. If nest mortality is greater within corridors, corridors may act as traps for those species occurring in similar abundance between corridors and patches.

In conclusion, species richness, diversity and community overlap were similar between post-rotation-age corridors and patches. Abundant species were abundant and rare species were rare between both types. Analysis of abundance for edge effects revealed 2 species possibly preferring interior

conditions to edge conditions, the Great-crested Flycatcher and Red-eyed Vireo. All other species showing significant differences in abundance, including the Brown-headed Cowbird, favored more edge-like conditions.

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Table 1. Stand level vegetation data for point count plots, 1996-1999. Forestry data based on Westvaco stand-level data from ArcView database files. Data are average value for each grouping with (standard deviation). All differences were tested using the Tukey Kramer statistic. Results with different letters denote significant differences ($p < 0.05$) between corridors and patches.

Stand Data	Corridor	Patch
# distinct points	26	33
# distinct stands	10	15
Sample size (1996-1999)	94	116
Stand size (ha)	20.5 (9.17)A	28.4 (9.93)B
Distance to edge (m)	50.4 (14.12)A	122.5 (99.6)B
Distance to road (m)	131 (96.07)A	119.5 (73.5)A
Distance to Gumpond (m)	149.1 (135.47)A	150.2 (124.68)A
Site Index (base age 50)	78.3 (3.80)A	82.1 (2.26)B
Stand Age	26.5 (1.49)A	26.6 (1.66)A
Basal Area (ft ² /acre)	159 (24.43)A	171 (25.32)B
Trees per Acre	232.1 (34.05)A	233.4 (42.48)A
Years since burn	4.5 (3.27)A	4.3 (3.24)A

Table 2. Stand level vegetation data for point count plots, 1996-1999. Forestry data based on Westvaco stand-level data from ArcView database files. Data are average value for each grouping with (standard deviation). All differences were tested using the Tukey Kramer statistic. Results with different letters denote significant differences ($p < 0.05$) between corridors, patch-edge and patch-interior point count plots.

Stand Data	Corridor	Edge	Interior
# distinct points	26	17	17
# distinct stands	10	9	9
Sample size (1996-1999)	94	55	61
Stand size (ha)	20.5 (9.17)A	27.9 (10.53)B	28.1 (9.43)B
Distance to edge (m)	50.4 (14.12)A	58.3 (14.72)A	180.4 (107.81)B
Distance to road (m)	131 (96.07)A	99.4 (50.81)B	137.7 (85.53)A
Distance to Gumpond (m)	149.1 (135.47)A	164.2 (121.08)A	137.5 (127.50)A
Site Index (base age 50)	78.3 (3.80)A	81.6 (2.38)B	82.6 (2.04)B
Stand Age	26.5 (1.49)A	26.9 (1.72)A	26.3 (1.57)A
Basal Area (ft ² /acre)	159 (24.43)A	168 (27.83)A	175 (22.54)B
Trees per Acre	232.1 (34.05)A	228.0 (40.82)A	238.2 (43.67)A
Years since burn	4.5 (3.27)A	5.0 (3.65)A	3.7 (2.70)A

Table 3. Relative abundance of species in corridors and patches, 1996-1999. See Appendix- Table 1 for species names. Relative abundance calculated here as # species x/ N individuals sampled within each type. Species in bold occur only in within the grouping.

Corridors			Patches		
Rank	Species	Relative Abundance	Rank	Species	Relative Abundance
1	PIWA	0.114165	1	PIWA	0.122105
2	BGGN	0.082452	2	REVI	0.111579
3	ACFL	0.073996	3	ACFL	0.098947
4	GCFL	0.069767	4	GCFL	0.071579
5	ETTI	0.052854	5	BGGN	0.067368
6	REVI	0.042283	6	ETTI	0.061053
7	NOCA	0.040169	7	HOWA	0.046316
8	CACH	0.038055	8	SUTA	0.046316
9	SUTA	0.038055	9	NOCA	0.044211
10	WEVI	0.038055	10	CARW	0.033684
11	COYE	0.035941	11	EATO	0.033684
12	HOWA	0.035941	12	CACH	0.027368
13	CARW	0.031712	13	COYE	0.027368
14	EATO	0.031712	14	KEWA	0.027368
15	BHCO	0.027484	15	WEVI	0.025263
16	RBWO	0.027484	16	RBWO	0.023158
17	INBU	0.021142	17	DOWO	0.016842
18	KEWA	0.021142	18	YTVI	0.014737
19	YBCH	0.021142	19	NOPA	0.012632
20	DOWO	0.019027	20	YBCU	0.012632
21	EAWP	0.014799	21	BLJA	0.010526
22	AMCR	0.012685	22	WEWA	0.010526
23	BHNU	0.012685	23	BHNU	0.008421
24	NOPA	0.012685	24	BACS	0.004211
25	YTVI	0.012685	25	GRCA	0.004211
26	EABL	0.010571	26	HAWO	0.004211
27	WBNU	0.008457	27	INBU	0.004211
28	YBCU	0.008457	28	PRAW	0.004211
29	RHWO	0.006342	29	RHWO	0.004211
30	BACS	0.004228	30	WOTH	0.004211
31	GRCA	0.004228	31	BAWW	0.002105
32	PIWO	0.004228	32	BHCO	0.002105
33	BLGR	0.002114	33	EAWP	0.002105
34	BLJA	0.002114	34	OROR	0.002105
35	COGR	0.002114	35	OVEN	0.002105
36	FICR	0.002114	36	PIWO	0.002105
37	HAWO	0.002114	37	RTHU	0.002105
38	LBHE	0.002114	38	YBCH	0.002105
39	MODO	0.002114			
40	NOBO	0.002114			
41	OROR	0.002114			
42	WEWA	0.002114			
43	WITU	0.002114			
44	YTWA	0.002114			

Table 4. Species diversity indices for comparison of patches and corridors.

<u>Diversity Index</u>	<u>Corridor</u>	<u>Patch</u>	<u>Interpretation</u>
All Species			
Species Richness (N)	44	38	N of species observed in patch type
Shannon Index (H')	3.27	3.04	Index of diversity, higher values are more diverse
e ^{H'}	26.3113	20.9052	Number of equally common species that would produce the same diversity as H'
Simpson's index (1-D)	0.952	0.938	Probability that two individuals selected randomly belong to different species
1/ Simpson's Index	20.932	16.189	Number of equally common species required to generate the observed heterogeneity of the sample
Morisita-Horn Measure (C)		0.925	Index of overlap (similarity) between corridors and patches
Spearman's Rho (r)		0.7877 (p < 0.0001)	Correlation coefficient (r) for comparison of species by rank-order
Neotropical Migrants			
Species Richness (N)	21	25	
Shannon Index (H')	2.62	2.55	
e ^{H'}	13.73	12.81	
Simpson's index (1-D)	0.912	0.901	
1/ Simpson's Index	11.397	10.084	
Morisita-Horn Measure (C)		0.934	
Spearman's rho (r)		0.8160 (p < 0.0001)	
Forest Associated Neotropical Migrants			
Species Richness (N)	15	17	
Shannon Index (H')	2.35	2.35	
e ^{H'}	10.48	10.48	
Simpson's index (1-D)	0.888	0.887	
1/ Simpson's Index	8.947	8.854	
Morisita-Horn Measure (C)		0.944	
Spearman's rho (r)		0.8985 (p < 0.0001)	

Table 5. Chi-square tests for point count plots based on distance to edge, 1996-1999. Only species with > 0.10 birds/plot overall were included (except for Brown-headed Cowbird).

Species	Distance Category Frequency (% detected)				Significant Differences Between Groupings (Prob < ChiSq)			
	<u>Corridor</u>	<u>Patch</u>	<u>Edge</u>	<u>Interior</u>	<u>Corridor vs. Patch</u>	<u>Corridor vs. Edge</u>	<u>Corridor vs. Interior</u>	<u>Edge vs. Interior</u>
Acadian Flycatcher	.372	.405	.382	.426				
Blue-gray Gnatcatcher	.415	.276	.382	.180	0.0343		0.0018	0.0149
Brown-headed Cowbird	.106	.009	0	.016	0.0093	0.0019	0.0192	
Carolina Chickadee	.181	.112	.109	.115				
Carolina Wren	.160	.138	.236	.049			0.0271	0.0027
Common Yellowthroat	.181	.112	.127	.098				
Eastern Towhee	.160	.138	.255	.039			0.0078	0.0003
Eastern Tufted Titmouse	.255	.250	.236	.262				
Great-crested Flycatcher	.340	.285	.182	.377		0.0338		0.0186
Hooded Warbler	.170	.190	.236	.148				
Kentucky Warbler	.106	.112	.146	.082				
Northern Cardinal	.202	.181	.236	.131				
Pine Warbler	.543	.483	.510	.459				
Red-bellied Woodpecker	.138	.095	.164	.033			0.0201	0.0134
Red-eyed Vireo	.213	.440	.364	.508	0.0011	0.0471	< 0.0001	
Summer Tanager	.192	.181	.200	.164				
White-eyed Vireo	.192	.143	.182	.033			0.0018	0.0065

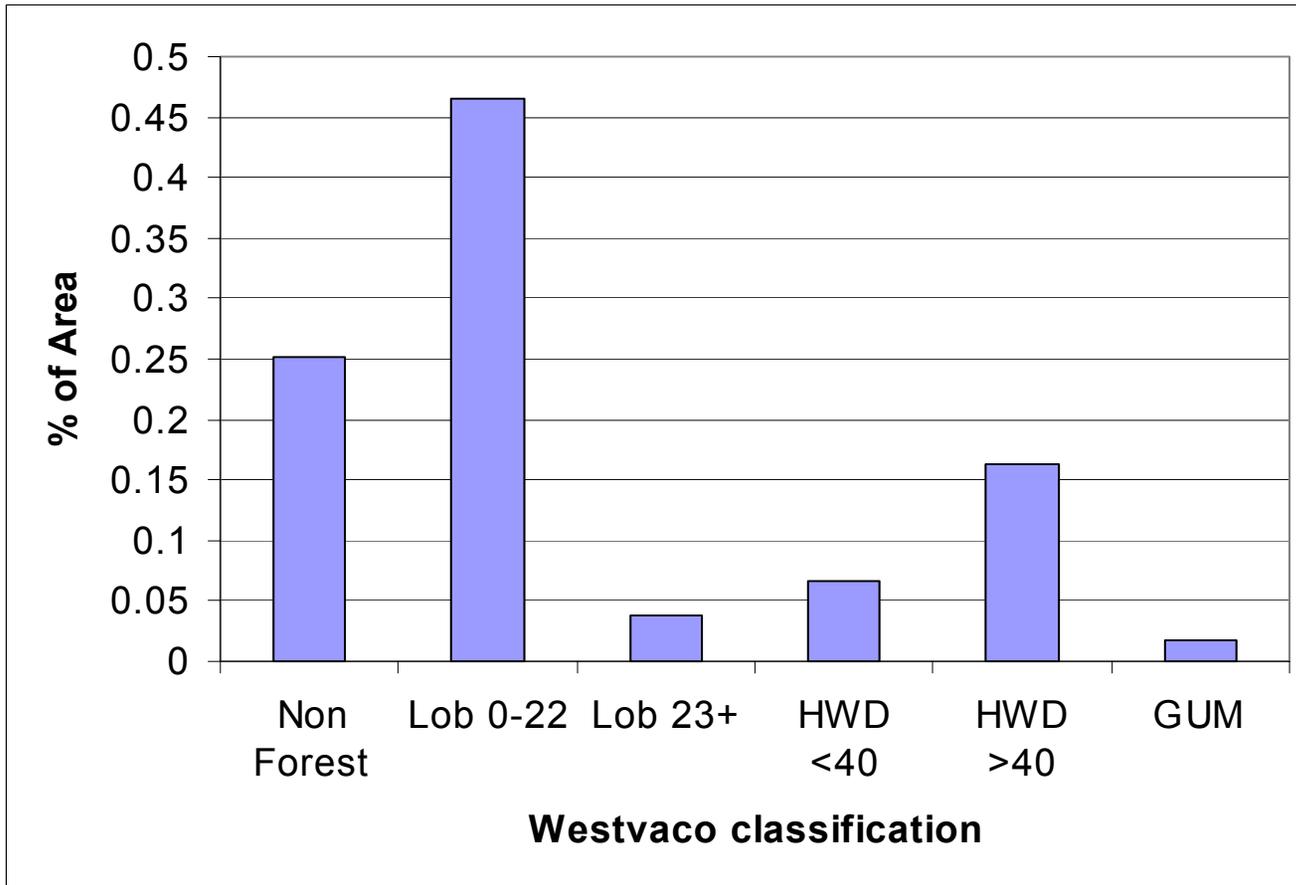


Figure 1. Proportion on habitat types and age classes across Westvaco's Edisto Management District. Non-Forest = roads and non-forest property, Lob 0-22 = loblolly 0-22 years, Lob 23+ = loblolly 23+ years, HWD = different hardwood age groups, GUM= gumponds, small 0.5-2 ha hardwood depressions within loblolly stands.

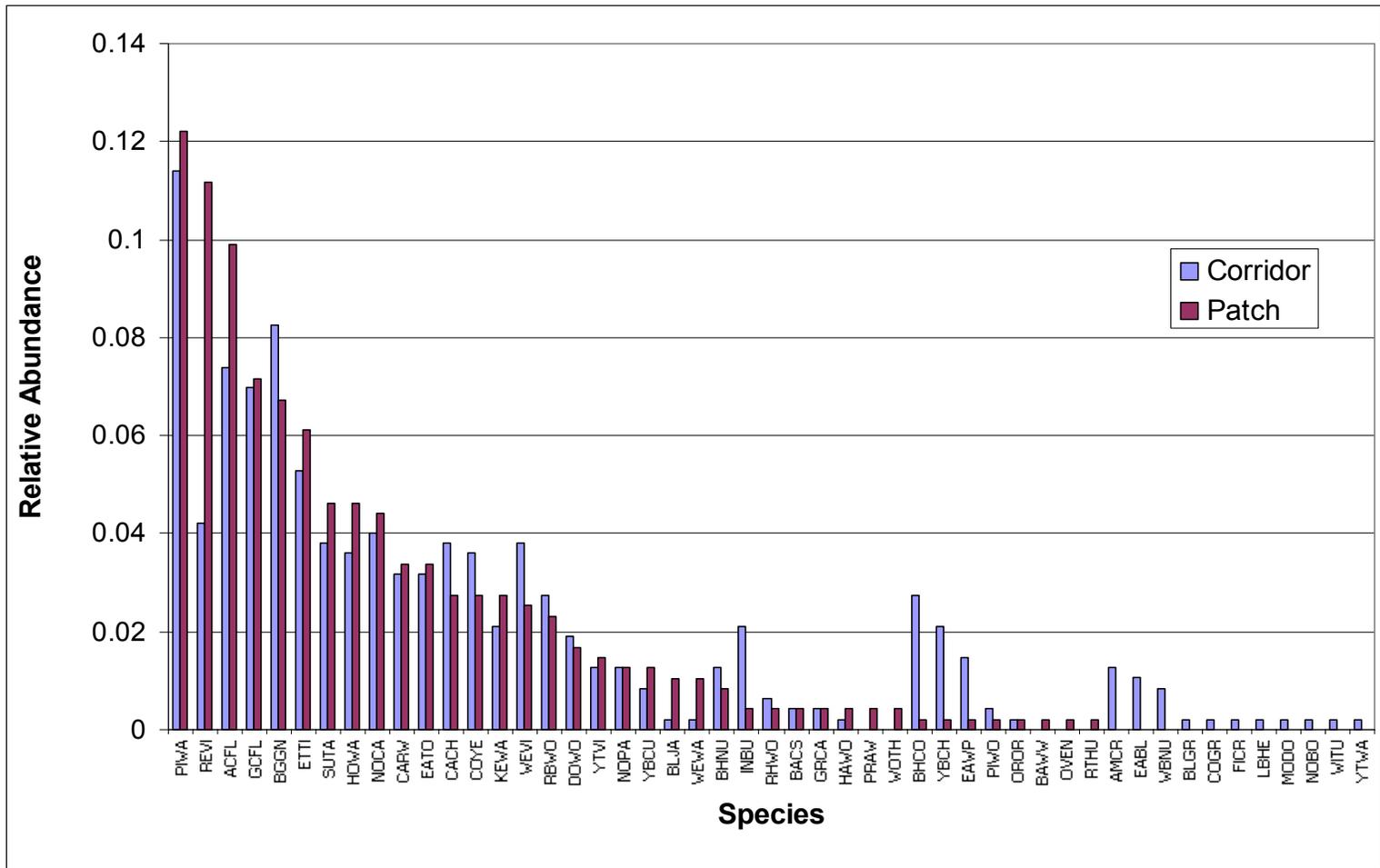


Figure 2. Avian relative abundance for corridors and patches. Patch relative abundance is ranked greatest to least.

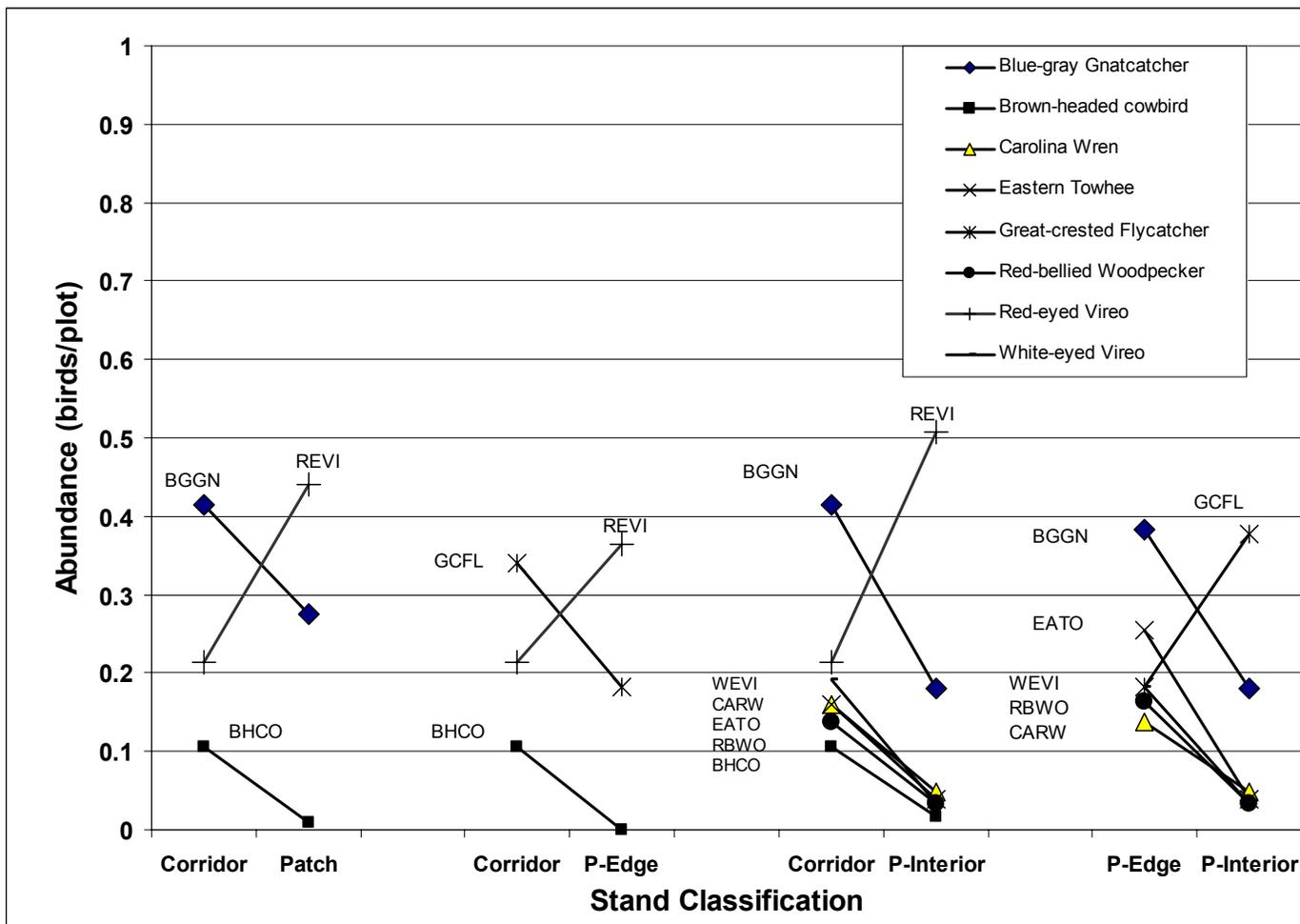


Figure 3. Avian species showing significant changes between stand types and stand classifications.

Chapter 3: Avian nest survival within post-rotation loblolly pine plantation corridors and patches

Introduction

Research on forest bird distribution is useful for analyzing distribution, abundance and probability of occurrence within habitat or patch types. However, density is not necessarily correlated with habitat quality (Van Horne 1983). Nest predation is a major factor affecting the fitness of most passerine birds (Martin 1995). Birds may occur in similar abundance between habitat types, but suffer differential nest predation rates. Research on forest bird species has focused on nest survival in various contexts of forest fragmentation. Previous research indicates higher nest predation and brood-parasitism rates in more fragmented or edge-like habitat configurations (Paton 1994, Andren 1995).

Decreasing forest cover within a 10-km radius of sites was strongly related to increased nest mortality in the Midwestern United States (Robinson et al. 1995). Another Midwestern study found that reproductive success for Ovenbirds (*Seiurus aurocapillus*), Red-eyed Vireos (*Vireo olivaceus*) and Wood Thrush (*Hylocichla mustelina*) was lower in smaller forest fragments relative to contiguous forest (Donovan et al. 1995). Decreased nest survival was attributed to greater nest predation within fragments and the authors concluded that fragments were acting as population sinks (Pulliam 1988). A study on Scarlet Tanagers (*Piranga olivacea*) within 10-1,000 ha stands found that fledging success increased significantly with stand area (Roberts and Norment 1999).

Tanagers were absent from stands less than 10 ha in size. Forest area was also found to best explain greater Wood Thrush nest survival in contiguous stands and large fragments relative to smaller fragments (Hoover et al. 1995). In a meta-analysis of forest cover, edge effects and artificial nest predation rates, Hartley and Hunter (1998) found that daily nest predation rates decreased as forest cover increased.

Research has also focused on stand-level edge effects in general. Such studies have revealed elevated nest predation, brood parasitism, and loss of diversity in small or linear habitat fragments (for review see Paton 1994 and Andrén 1995). Paton (1994) concluded, "current evidence, although equivocal, suggests that predation and parasitism rates are often significantly greater within 50 meters of an edge." However, edge effects are not universal. Andrén (1995) in a review of 40 papers concluded, "edge related increase in predation seems to be most commonly found inside forests surrounded by farmland and was rarely found in forest mosaics."

Many of the initial forest fragmentation studies were conducted within the highly fragmented landscapes of the Midwest. Forest stands often were remnant habitat patches amidst an established, permanent agricultural matrix. However, impacts of fragmentation in forested landscapes through periodic harvesting introduce dynamic disturbances that change through time.

Recent work in primarily forested timber landscapes has revealed a lack of consistent negative effects of fragmentation on avian species. A study involving

8 forested landscapes and 8 agricultural landscapes found that nest predation was greater within unfragmented forest (Tewksbury et al. 1998). Increased predation was attributed to an established nest predator community within forested landscapes. In a managed forest landscape, distance to forest edge had no effect on nesting success within forested and open habitats and nest predation was higher within forested habitats (Hanski et al. 1996). Brood-parasitism rates were low within the landscape (9.7%). In a boreal coniferous forest landscape, artificial nest predation rates were not related edge or stand size (Huhta et al. 1998). The authors concluded that findings from agricultural areas might not be directly applicable to forested landscapes.

Additionally there are few studies of bird populations within private industrial timber landscapes (Hagan et al. 1997). My study site is a forested, privately owned loblolly pine (*Pinus taeda*) plantation landscape. The study area is a dynamic landscape in which loblolly pine plantations are harvested on a 20-year rotation. My analysis examines the effects of 100-meter-wide linear loblolly pine habitat patches ("corridors" hereafter) vs. non-linear patches ("patches" hereafter) on breeding bird nest productivity within a fragmented industrial forestry landscape.

Corridors and patches were post-rotation-age stands (24-31 years). In regards to the landscape, post-rotation age stands were fragmented. Only 4% of loblolly pine stands were older than 23 years across the landscape. Within my study area, corridors and patches were adjacent or near two main habitat

disturbances, clearcuts aged 0-5 years of age and an extensive forestry road network (unpaved and gravel). The proximity of 0-5-year-old loblolly stands was due to both harvesting of adjacent stands to create corridors and harvesting blocks of stands. Due to logistics, remnant post-rotation-age patches were not always harvested as scheduled. Such stands may persist within the landscape for years until harvesting is scheduled in close proximity to the remnant patch.

This analysis compares nest survival of avian species between corridors and patches, focusing on the Acadian Flycatcher (*Empidonax vireescens*), Hooded Warbler (*Wilsonia citrina*), and Northern Cardinal (*Cardinalis cardinalis*). Both the Acadian Flycatcher and Hooded Warbler are Neotropical migrants, while the Northern Cardinal is a resident species. All are open-cup nesting passerines, the Acadian Flycatcher nests in trees, the Hooded Warbler within the shrub layer, and the Cardinal within both the shrub and tree layer. In addition to comparisons of nest survival between corridors and patches, edge effects in general were investigated. Nest survival was compared to distance to edge (loblolly aged 0-5 years), distance to road, and a linear combination of distance to edge and road (edge+road, an index of summed distance to road and edge).

Methods

Nest searching stands included in this analysis include post-rotation age stands within the Edisto Management District (Appendix-Map 1). After 1997 in which 1 corridor and patch were surveyed, 3-4 corridors and 3 patches were surveyed annually from 1998-2000 (Table 1). Rotation-age stands (18-21 years)

were also surveyed from 1997-2000. Two patches were surveyed in 1997, 3 in 1998, and 2 in 1999 and 2000 (Table 1). These stands were structurally different in vegetation, and avian species data from point counts suggest them to be an earlier successional stage (Chapter 1). These rotation-age stands were referred to separately in the patch/corridor comparisons and were not included in nest edge effect analysis.

All nest-searching stands were gridded with brightly colored flagging at 25-50m intervals to aid in locating nests. Nest-searching was conducted from mid-April through the end of July from 1997-2000. Each stand was surveyed at least once a week, and hour's searched/hectare calculated to ensure that each stand received the same search effort. Searching protocol was adapted after Martin and Geupel (1993). Nest searchers used visual cues and followed females to determine nest location. Stands were also systematically searched to ensure equal coverage of the entire stand.

Once located, initial nest contents were checked and nests were revisited an average of every 3 days until failure or fledging was documented. Nest were checked more frequently (1-2 days) near the estimated hatching or fledging dates to ensure an accurate estimate of nest daily survival (Mayfield 1975). Contents were checked using an 18-foot telescoping pole mounted with a mirror. Technicians took care not to disturb the nest and to avoid leaving "dead-end" tracks at the nest-site. Nests too high to be checked were monitored for activity for at least 15 minutes. Nests with uncertain fates were not included in analysis.

Nests abandoned before being found, or failing for known causes other than predation were not included in analysis. A nest was considered successful if it fledged at least one hatchling.

Nest searching stands were both characterized by Westvaco stand level data (Table 1) and more comprehensive data obtained from random vegetation plots modified from the protocol of James and Shugart (1970). Vegetation plots were sampled from 1997-2000 by randomly selecting grid points within each stand. Effort was consistent, and 1 random vegetation plot per hectare of each individual stand was completed each year. Nest sites also were sampled using the same protocol. For nest sites, vegetation plots were centered at the nest.

At each plot, the following variables were measured: canopy cover, pine, hardwood and snag basal area; pine, hardwood and snag diameter at breast height (DBH); canopy and subcanopy height; scaled measures of vine and cane in the understory (scaled 1-5, 1=high coverage, 5= no or little coverage); and percent shrub cover. For nest sites, height of the nest, nest plant height, DBH, and species were also recorded.

For analysis of possible edge effects, linear distances to edges aged 0-5 years and roads were measured using ArcView. Many grid and nest locations were recorded using a global positioning system (GPS). All non-GPS'ed locations were located by distance and azimuth from referenced points. Both nest-sites and grid locations were entered as a layer within Westvaco's stand layer in ArcView (ArcView GIS, ESRI). These were overlaid upon the stand layer

and linear distance to edge type calculations were estimated. In almost all cases the closest habitat edge to both patches and corridors were loblolly stands aged 0-5 years (Appendix-Map 1). This was due to the high frequency of harvest around corridors and post-rotation age remnant stands.

Statistical Analysis

All nesting data were analyzed using the Mayfield daily survival rate (Mayfield 1975). All interval estimations used the midpoint method (Mayfield 1975). The Mayfield method estimates a daily nest survival rate that is assumed constant from nest initiation to fledging. Mayfield values were also calculated for the egg and hatchling stage for all species. There was a general trend of higher survival in the egg stage, but because no significant differences were found, single overall Mayfield values were reported in analyses.

The Mayfield formulation is:

$$1 - [(nest failures)/(total observation days)]$$

Standard errors were calculated from Johnson (1979). Significance tests between groups used the z-test statistic from Johnson (1979).

The Mayfield estimate taken to the exponent of species-specific days required to successfully fledge a nest gives the % of successful nests:

$$P (\text{success}) = (\text{Mayfield daily survival rate})^{\text{total nest days}}$$

Nest survival between patches and corridors was compared for the Acadian Flycatcher (29 days), Hooded Warbler (21 days), Northern Cardinal (22 days), White-eyed Vireo (*Vireo griseus*, 24 days), Eastern Towhee (*Pipilo*

erythrophthalmus, 23 days) and Summer Tanager (*Piranga rubra*, 22 days). The Mayfield analysis is sensitive to small sample sizes (Hensler and Nichols 1980) and only data for the Acadian Flycatcher could be analyzed between years.

Analysis of daily survival rate in relation to distance to edge, road, and road+edge were analyzed for the Acadian Flycatcher, Hooded Warbler and Northern Cardinal. Corridor and patch nests were combined and separated into bins of 2-5 groups of distance to edge or road or edge+road. The first bin contained all the nests closest to an edge for the bin interval. The bins were then aggregated into higher levels to determine if edge effects existed. Remainder nests were placed in the interval furthest from edge type. For example, 50 nests would be divided (10, 10, 10, 10, and 10) at the level of 5 bins, and (12, 12, 12, 14) at the level of 4 bins, and so on.

For nest site selection analysis, vegetation data and nest habitat data were analyzed using individual comparisons between different groups. Avian nest-site selection compared nest vegetation plots against combined corridor and patch random plots to determine if any significant differences existed.

Comparisons were t-tests corrected for unequal variances when applicable.

Non-normal distributions were analyzed using the Wilcoxon rank-sum test.

Results

Between 1997-2000, nesting surveys were conducted within rotation-age loblolly stands as well as post-rotation-age patches and corridors (Table 1).

Between 1997-98, rotation-age nest survey stands were located within a

separate district; the Ashley District. Between 1999-2000, all nest survey stands, including rotation-age stands, were located within the Edisto District (Table 1). Table 2 summarizes the effort for post-rotation-age patches and corridor nest searching stands from 1997-2000. Stand-level data between corridors and patches were similar (Table 1).

Vegetation comparisons from random plots between patches and corridors show significant differences between pine and hardwood basal area, pine and hardwood DBH, and shrub percent cover (Table 3). Corridors had greater average hardwood DBH and basal area relative to patches. Corridors had a greater average pine DBH than patches, but a lower pine basal area (Table 3). In all cases, rotation-age stands were statistically different between corridors or patches or both and were not included in nest site vegetation analysis.

Habitat variables for both post-rotation-age patches and corridors were combined from random sites and tested against nest sites for the Acadian Flycatcher, Hooded Warbler, Northern Cardinal, White-eyed Vireo, Eastern Towhee and Summer Tanager (Table 4). Acadian Flycatcher nest sites had a significantly greater hardwood basal area, lower hardwood DBH, and lower % shrub cover than random sites. Hooded Warbler nest sites had a greater amount of cane and shrub cover compared to random sites. Northern Cardinal nests had significantly lower hardwood basal area, greater vine cover, and greater shrub % cover than random sites. White-eyed Vireo nests had significantly greater shrub

% cover than random sites. Eastern Towhee nests had significantly lower % canopy cover, lower hardwood basal area, and greater shrub % cover than random sites. Summer Tanager nests had significantly lower hardwood basal area, lower hardwood DBH and lower shrub % cover than random sites.

Habitat variables were also tested separately between corridors and patches for the Acadian Flycatcher (Table 5). For comparisons between corridor nest and random sites, midstory height, hardwood basal area, canopy cover, shrub % cover and nest tree DBH were significantly different. For comparisons between patch nest and random sites, hardwood basal area and shrub % cover were significantly different (Table 5). For comparisons of corridor and patch nests against each other, midstory height, pine basal area, pine DBH, hardwood basal area, vine cover, nest tree height and nest tree DBH were significantly different (Table 5).

Corridor and Patch Nest Survival Comparisons

A total of 132 Acadian Flycatcher nests suitable for daily nest survival analysis were found between 1997-2000 for patches and corridors (Table 6, Figure 1). Corridors had significantly higher nest survival in 1998 than in 1999. Sample sizes were too small for reliable comparison, but nest survival was significantly lower in corridors than in patches in 2000. Over all years, nest survival was not significantly different between patches and corridors. Over all years, nest survival was significantly higher in corridors and patches compared to nests from rotation-age stands (n = 31).

A total of 63 Hooded Warbler nests were found from 1997-2000 (Table 7, Figure 2). Thirty-seven were found between corridors and patches and 26 within rotation-age stands. No significant differences existed between corridors and patches. Nest survival was marginally significant between rotation-age and corridor nests (18.9% vs. 38.9%, $p = 0.102$) and rotation-age and patch nests (18.9% vs. 42.6%, $p = 0.053$).

A total of 66 Northern Cardinal, 37 White-eyed Vireo, 25 Eastern Towhee, and 22 Summer Tanager nests were found between 1997-2000. No significant differences were found between patch comparisons for all species (Tables 8-11). Sample sizes for the White-eyed Vireo, Eastern Towhee, and Summer Tanager were small and were combined for corridors and patches to give a landscape nest survival estimate (Tables 9-11).

Nest Productivity Data in Relation to Edge

For Acadian Flycatchers, it was possible to group nests within both corridors and patches into 2 bins of distance to edge, road, and edge+road (Table 12). Half of all nests within the patch type that were closest to an edge were placed in one bin, and the remainder within the other bin. No significant differences were found in all comparisons within patch types, although the edge+road comparison was marginally significant for the comparison between corridors (Table 12, $p = 0.0571$). Nests within 10-110m distance from edge+road within corridors had marginally higher nest success (48.18%) than corridor nests 111-498m from edge+road (28.26%).

In order to determine if landscape-wide edge effects were operating, post-rotation age nests for the Acadian Flycatcher (n = 132), Hooded Warbler (n=37) and Northern Cardinal (n = 52) were combined for each species and nest survival compared among bins of distance to edge. Bins were aggregated into levels with greater nests in each bin. Nest survival was compared between each nest bin's distance to edge, road, and edge+road. For the Acadian Flycatcher, all bin levels were analyzed for significant differences. Due to low sample sizes, only the final bins (2 groupings) were analyzed for significant differences for the Hooded Warbler and Northern Cardinal.

For Acadian Flycatchers (Tables 13-15) no significant differences were found between distance to edge or road over all bins and levels of aggregation. For distance to edge+road, the interval of 98-111m had significantly greater nest survival than the interval of 112-168m (0.4934 vs. 0.3070, $p < 0.05$). This significant difference disappeared as bins were aggregated into higher levels. Examining the data, no apparent trend existed between distance to edge type for all comparisons.

For Hooded Warbler nest survival comparisons, no significant differences existed between the final 2 bins for distance to edge, road, and edge+road (Tables 16-18). For distance to road and edge+road no trend toward negative edge effects was apparent. For distance to edge, the interval closest to edge had consistently lower nesting success than other intervals (Table 16). Ninety-percent of brown-headed cowbird parasitism events occurred between the

interval of 0-99m to an edge (Table 16). 50% of all cowbird parasitism events occurred between 0-30m from a road (Table 17). 50% of all cowbird parasitism events occurred between the interval of 4-60m from an edge+road combined (Table 18).

Ten out of 37 Hooded Warbler nests were parasitized during the course of this study (27.0%). Only 1 out of 13 corridor nests were parasitized (7.7%) while 9 out of 27 patch nests were parasitized (33.3%). Four out of 10 parasitized nests also fledged at least one Hooded Warbler (40.0%). Kolmogorov-Smirnov tests were used to test whether parasitized nests ($n = 10$) and non-parasitized nests ($n = 27$) distributions by distance to edge, road, and road+edge were significantly different. Results were not significant for distance to edge ($p = 0.7100$), distance to road ($p = 0.2111$), and distance to edge+road ($p = 0.2492$).

For the Northern Cardinal distance to edge comparisons, no significant differences existed between the final two bins for distance to edge, road, and edge+road (Tables 19-21). As with the Hooded Warbler, the interval closest to edge had consistently lower nesting success than other intervals (Table 19). No trend was apparent in comparisons with distance to road and edge+road. Only 3% (2 out of 52) of Northern Cardinal nests were parasitized by the Brown-headed Cowbird.

Discussion

Nest-site Selection

Nest-site selection analysis found significant differences across all species. This result was not unexpected, as avian species select nest sites in accordance with life history requirements and selection pressure from nest predation (Martin 1995). For the Acadian Flycatcher, sample sizes were large enough to compare nest site selection between corridors and patches (Table 5). In both corridors and patches, Acadian Flycatcher nests differed from random plots significantly in both hardwood basal area and shrub % cover. For a hardwood nesting species such as the Acadian Flycatcher, preference for sites with greater hardwood basal area was most likely related to increases in suitable nest sites. It has been suggested that nesting in areas with a greater density of potential nest-sites is a positive strategy for minimizing nest predation (Martin 1993). The preference of Acadian Flycatchers for open areas under nests (lower shrub % cover) has been documented elsewhere (Mumford 1964). Significant differences between patch and corridor nest sites (Table 5) were most likely due to differences between patch types themselves (Table 3). Pine basal area and pine DBH were similar for nest sites when compared to values from random plots (Table 3), and the differences in hardwood basal area were both in the same direction for nest sites vs. their respective patch type. These results indicate that Acadian Flycatchers were most likely not selecting pine habitat features but were showing a preference for hardwoods within both patches and corridors.

For all other species, significant nest site selection variables were consistent with the species life history (Table 4). The Hooded Warbler nests and forages within the shrub layer, often within cane (43% of nests were in cane). The Northern Cardinal nests both within the shrub (47.2% of nests) and tree layer (41.2%), and some nests were in vine species (11.1%). The result of lower hardwood basal area was interesting since all Northern Cardinal tree nests were within hardwood trees. When shrub (n =17 nests) and tree nests (n =15 nests) were compared against each other, shrub nests had significantly higher shrub % cover ($p = 0.0014$, 58.2% vs. 30.2%) and significantly lower hardwood basal area ($p = 0.0244$, 10.0 vs. 28.0 ft²/acre). Thus Cardinal nests within trees were similar in hardwood basal area to random sites (27.0 vs. 28.0, Table 4) and were similar in shrub % cover (30.2% vs. 25.2%, Table 4). The differences between nest and random sites in hardwood basal area and shrub % cover were driven by Cardinal nests within shrubs. Samples sizes for the Eastern Towhee, White-eyed Vireo and Summer Tanager were most likely too small to be meaningful.

Corridor and Patch Nest Survival

No significant differences were found in nest survival between patches and corridors for the Hooded Warbler and Northern Cardinal. For the Acadian Flycatcher, overall nest survival did not differ between patches and corridors (1997-2000), but was significantly different from rotation-age patches (Table 6). Previous results show that within the study area, Acadian Flycatcher abundance (Chapter 1) and territory density (Hazler 1999) increased with stand age. These

results, along with nest survival data, strengthen the argument that rotation-age stands may be lower quality habitat for Acadian Flycatchers. In relation to post-rotation corridors and patches, rotation-age stands may be acting as population sinks (Pulliam 1988).

For years with adequate sample sizes (1998 and 1999), a significant year effect was found for Acadian Flycatcher nest survival. Corridors had significantly higher nesting success in 1998 compared to corridors in 1999. Patch nest survival also reached its lowest value in 1999 (30.9%), although this result was not significant in all 1998-1999 comparisons. In 1999, a severe region-wide drought occurred. Field sites were usually partially flooded at the start of the field season, and subject to partial flooding throughout the field season. However in 1999 all study stands were dry throughout the field season until the beginning of July.

It is likely that severe drought conditions affected Acadian Flycatcher nest survival. The Acadian Flycatcher forages on flying insects during the breeding season (Ehrlich 1988). The lack of standing water may have affected flying insect abundance; occurrence of flying insects was noticeably less in 1999 (personal observation). However since foraging observations and insect abundance data were not collected, evidence of a drought effect can only be inferred. An alternative hypothesis is that nest predator pressure may have been more intense during drought conditions. If food resources were scarce across the landscape, predators may have switched to nests. Even if nest predation

was a random event in space and time (Wilson and Cooper 1998a), random encounters may have been greater in 1999 if predators were spending more time searching.

For the Hooded Warbler, nest success was similar and not significant between corridors (38.9%) and patches (42.6%). However, nest success within both corridors and patches was marginally greater ($p = 0.05-0.10$) than within rotation-age stands. This result was interesting because Hooded Warblers were more abundant within rotation-age stands (Chapter 1, Table 5), and previous work (Hazler (1999) found greater territory density and smaller territory size within rotation-age stands (0.10-0.18 territories/ha, 1.49-2.10 ha in size) than in post-rotation corridors and patches (0.02-0.09 territories/ha, 2.93-5.08 ha in size). Similar results were found for the Northern Cardinal; non-significant nest survival within corridors (31.9%) and patches (28.6%), and lower nest survival, although not significant, within rotation-age patches (17.8%).

Consistently lower nesting success within rotation-age stands for the Acadian Flycatcher, Hooded Warbler and Northern Cardinal was interesting because rotation-age stands are less fragmented relative to post-rotation-age stands. Results for the Acadian Flycatcher can be explained by habitat quality, but the Hooded Warbler was more abundant within rotation-age stands, and the Northern Cardinal was found in similar abundance (Chapter 1). Tweksbury et al. (1998) found higher nest predation in unfragmented forest relative to fragmented forest due to an established nest predator community within unfragmented forest.

Our study site is a dynamic plantation landscape; loblolly stands typically turnover every 20 years. After harvest, loblolly stands undergo a period of major disturbances. After initial harvest, a stand may lay fallow for up to 3 years, after which it is plowed and bedded before planting. After planting, stands aged 0-5 years may be subjected to herbicide treatments to control shrubs and hardwoods. Edges next to both post-rotation-age corridors and patches were thus highly disturbed habitats, and may not have been attractive foraging sites for nest predators. In contrast, rotation-age stands consisted of large blocks of stands that had existed for longer periods without major local disturbance.

In 2000, 2 infra-red cameras monitored 10 nests within post-rotation corridors and patches. Four predation events were observed, and all were at Hooded Warbler nests. Two yellow rat snakes (*Elaphe obsoleta quadrivittata*), 1 black racer (*Coluber constrictor*), and a crow (*Corvus* sp.) were observed predated the nests. Additionally, through the course of the study, 2 snakes have been observed predated nests (a yellow rat snake and black racer), and evidence at one nest suggested predation by a Barred Owl (*Strix varia*).

Whereas crows are considered an edge species, the distribution of snakes within our study area is unknown. It is possible that snakes may reach higher densities within the less-disturbed rotation-age stands. Even if snakes randomly search for nests (Wilson and Cooper 1998a), greater densities may lead to greater nest predation.

Comparisons with Other Studies

Wilson and Cooper (1998b) found 601 Acadian Flycatcher nests in a large contiguous tract of bottomland forest in Arkansas from 1993-1995. Mayfield nest success ranged from 10-25%. Although hardwood forest is considered the preferred habitat type for Acadian Flycatchers (Ehrlich 1988), overall nest success from 1997-2000 was greater within corridors and patches (Table 6, 37.6% and 40.4% respectively). However, Wilson and Cooper's (1998b) site was described as a "long narrow fragment of bottomland forest surrounded by a large expanse of agriculture." The author's also found Brown-headed Cowbird parasitism rates of 21% (Wilson and Cooper 1998b). No Acadian Flycatcher nests (n =132) were parasitized within corridors or patches during the course of my study. These results were consistent with studies indicating that forested landscapes are not necessarily similar to agricultural landscapes (Hanski et al. 1996, Huhta et al. 1998, Tweksbury et al. 1998). However, Kilgo et al. (1998) studied avian abundance within bottomland hardwood forests enclosed by either agriculture or pine stands in South Carolina. Two species occurred in greater abundance within stands enclosed by agriculture, whereas no species occurred in greater abundance within pine enclosed stands. These results indicate that on a landscape level, agricultural landscapes may be ecological traps (Gates and Gysel 1978) relative to forested landscapes.

Sargent et al. (1997) studied nest survival for the Hooded Warbler within bottomland hardwood forests enclosed by pine stands within the Upper Coastal

Plain of South Carolina. Between 1993-1994, they found a Mayfield nest survival rate of 28.7% using a nesting interval of 20.5 days (Sargent et. al 1997). After adjusting the nesting interval (Table 7), patch and corridor nests had greater nest survival (43.5% and 38.8% respectively) than Sargent et al. (1997). Cowbird parasitism was greater within my study area (27.0% vs. 18.2%). In another study within a 362 ha bottomland hardwood forest in South Carolina, Moorman (1999) monitored 99 Hooded Warbler nests and documented a nest survival of 44.0% and parasitism rate of 13.0%. Adjusting for a nesting interval of 20 days, patch and corridor nest survival was similar (44.4% and 40.7% respectively) although parasitism rates were higher. Moorman (1999) also found no significant differences for Hooded Warbler nests in differing distance to edge classes. Gray rat snakes and black racers were also suspected dominant nest predators within the study site (Moorman 1999).

In a study involving loblolly pine > 60 years of age and > 100 ha in size 1, 2, and 3 years after prescribed burning in the Georgia Piedmont, nest success for the Northern Cardinal (n = 29), Eastern Towhee (n = 33) and Summer Tanager (n =11) were 42%, 5%, and 12%, respectively (White et al. 1999). After adjusting for differing nest intervals, patch and corridor values were similar for the Northern Cardinal (38.2% within patches and 33.9% within corridors), and overall values for the Eastern Towhee and Summer Tanager were greater within patches and corridors combined (21.7% and 34.0% respectively).

These comparisons with studies conducted within similar locales indicate comparable or greater nest success within corridors and patches. However, the habitat types were dissimilar from my study site. There is a general dearth of information on avian productivity in Southeastern loblolly pine forests (White et al. 1999), and more research is needed. Given the growing importance of intensive loblolly management within the Southeast (Allen et al. 1996), reliable information is needed if land managers are to manage forests and promote wildlife diversity.

Nest Survival by Distance to Edge Types

For the Acadian Flycatcher, Hooded Warbler, and Northern Cardinal, nest survival was not dependent on a nest's distance to edge, road, and edge+road. The Acadian Flycatcher had consistently similar nest success in comparisons within corridors and patches (Table 12) and with corridor and patch nests combined (Tables 13-15). Sample sizes were too low for comparisons of more than the last 2 bins for both the Hooded Warbler and Northern Cardinal. For these comparisons, no significant differences were found for distance to edge, road and road+edge (Tables 16-21). However, in examining bins of 3 or greater, the bin closest to an edge had consistently lower nesting success for both species (Tables 16 and 19). It is possible that edge effects, in terms of greater nest predation, were occurring right at the edge interface for the Hooded Warbler and Northern Cardinal.

The Hooded Warbler was highly parasitized by the Brown-headed Cowbird. Ten out of 37 nests were parasitized (27.0%) during the course of this study. However, 4 of these 10 nests also fledged at least one Hooded Warbler (40%). The surprising result was that 9 out of the 10 parasitism events occurred within patches. In point count analysis between corridors and patches, Brown-headed Cowbirds were significantly more abundant within corridors than patches (10.6% vs. 0.9%, $p = 0.0093$, Chapter 2). Parasitism was also not related to distance to edge, road, or edge+road. Hahn and Hatfield (1995) found that Cowbird parasitism was not significantly higher near edges and that cowbirds invaded a large 1,300 ha forest stand. Within our study area, patches were often surrounded by roads or edges aged 0-5 years. It is likely that even if Cowbirds prefer edge conditions, enough edge conditions existed near patches to facilitate movements.

In conclusion, nesting success was similar between corridors and patches for the Acadian Flycatcher, Hooded Warbler, and Northern Cardinal. In comparisons with other studies, nesting success was similar or greater within corridors and patches. However, for the Hooded Warbler, parasitism rates were greater in comparisons. Analysis of edge effects (distance to loblolly pine age 0-5 years, distance to road, and distance to edge+road) did not find increased predation levels near edges. The most consistent result in this analysis was lower nest success within rotation-age stands for the Acadian Flycatcher,

Hooded Warbler, and Northern Cardinal. More research is needed to determine causal factors, especially research on nest predator distribution and abundance.

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Table 1. Stand-level forestry data for nest searching corridors, patches, and rotation-age patches 1997-2000.

Stand Type	Years Surveyed	Age	Area (ha)	Site Index ¹	Basal Area (ft ² /acre)	Trees/ acre	Prescribed Burn Year	District	Classification ²
<u>Corridors</u>									
C1	1997-2000	25-28	20.7	75	152	249	1993	Edisto	PR-C
C2	1998-2000	27-29	30.0	83	186	238	1996	Edisto	PR-C
C3	1998-2000	26-28	10.6	72	125	255	1994	Edisto	PR-C
C4	1999-2000	27-28	9.4	75	121	206	1993	Edisto	PR-C
<u>Patches</u>									
P1	1997-2000	25-28	38.0, 12.4	80	164	264	1993	Edisto	PR-P
P2	1998-1999	27-28	20.2	96	179	212	1992	Edisto	PR-P
P3	1998	24	22.5	77	142	237	1993	Edisto	PR-P
P4	1999-2000	24-25	32.0	78	192	302	1997	Edisto	PR-P
P5	2000	31	16.1	72	125	255	1994	Edisto	PR-P
<u>Rotation-age</u>									
R1	1997-1998	19-20	22.1	81	160	331	1995	Ashley	R-A
R2	1997-1998	19-20	18.5	84	173	444	1991	Ashley	R-A
R3	1998	18	39.1	72	154	618	1996	Ashley	R-A
R4	1999-2000	20-21	18.1	68	122	312	1995	Edisto	R-E
R5	1999-2000	21-22	20.3	81	139	201	1996	Edisto	R-E
R6	1999-2000	21-22	7.1	82	172	266	1996	Edisto	R-E

¹ - Site index, loblolly pine, base age 50 (total expected height in feet at age 50).

² - PR-C = Post rotation-age Corridor, PR-P = Post-rotation age patch, R-A = Rotation-age patch, Ashley District, R-E Rotation-age patch, Edisto District.

Table 2. Nest-searching stand-level and area effort, 1997-2000.

Year	# Patch Stands	Patch Area (ha)	# Corridor Stands	Corridor Area (ha)
1997	1	37.9	1	20.7
1998	3	80.7	3	61.3
1999	3	64.6	4	70.7
2000	3	60.5	4	70.7

Table 3. Vegetation characteristics of corridors, patches and rotation-age patches used for nest-searching, 1997-2000. Data come from random vegetation plots within stands (n = 376). Arithmetic means (and standard deviations) are reported.

Measure	Corridor	Patch	Absolute Difference	Rotation-age
Percent Canopy Cover (%)	82.2 (7.94)	83.1 (7.49)	0.9	86.5 (7.61) ^d
Overstory Height (m)	26.0 (3.20)	26.1 (3.11)	0.1	21.1 (2.92) ^d
Midstory Height (m)	12.8 (2.86)	13.0 (2.75)	0.2	10.6 (2.56) ^d
Pine Basal Area (ft ² /acre)	139.0 (59.74)	165.5 (59.30)	26.5 ^a	114.9 (62.33) ^d
Pine DBH (cm)	34.5 (4.45)	32.7 (4.26)	1.8 ^b	29.8 (6.25) ^d
Hardwood Basal Area (ft ² /acre)	30.2 (32.96)	23.2 (31.10)	7.0 ^c	30.9 (31.11) ^e
Hardwood DBH (cm)	18.1 (10.15)	15.5 (8.63)	3.0 ^c	15.5 (10.87) ^f
Snag Basal Area (ft ² /acre)	6.4 (9.80)	5.7 (8.18)	0.7	3.9 (7.25) ^f
Snag DBH (cm)	19.2 (8.23)	18.3 (6.64)	0.9	14.6 (1.30) ^d
Vines ¹	4.4 (0.96)	4.5 (0.90)	0.1	3.39 (1.37) ^d
Cane ¹	4.2 (1.00)	4.2 (1.15)	0.0	4.9 (.08) ^d
Shrub % Cover (%)	27.5 (19.88)	23.5 (21.12)	4.0 ^c	20.5 (18.30) ^f

^a - p < 0.0001

^b - p = 0.0002

^c - p < 0.05

^d - Significantly different from Corridors and Patches (p < 0.05)

^e - Significantly different from Patches (p < 0.05)

^f - Significantly different from Corridors (p < 0.05)

¹ - Based on a scale from 1 - 5 (1 = complete coverage, 5 = none or very sparse coverage)

Table 4. Significant variables between random and nest sites. Post-rotation age corridor and patch random and nest sites were combined for analysis. Nest vegetation data were collected from 1997-2000 for Acadian Flycatchers and Hooded Warblers, and 1999-2000 for the rest. Tests for the Acadian Flycatcher and Hooded Warbler use data from 1997-2000 (n=377 random plots). Tests for the Northern Cardinal, White-eyed Vireo, Eastern Towhee and Summer Tanager use data from 1999-2000 (n = 261 random plots). T-tests were performed for each variable and corrected when variances were unequal. Wilcoxon Rank-Sum tests were performed for vine and cane comparisons. Tests were performed on all habitat variables collected and only significant differences are reported.

Significant Habitat Variable	Nest Site	Random Site	p-value
<u>Acadian Flycatcher (n=141)</u>			
Hardwood Basal Area (ft ² /acre)	32.3	27.0	0.0443
Hardwood DBH (cm)	15.4	17.0	0.0413
Shrub % cover	12.9	25.6	<.0001
<u>Hooded Warbler (n=33)</u>			
Cane	3.5	4.2	0.0195
Shrub % Cover	55.4	25.7	<.0001
<u>Northern Cardinal (n=37)</u>			
Hardwood Basal Area (ft ² /acre)	17.3	27	0.0148
Vines	4	4.4	0.0083
Shrub % Cover	46.7	25.2	<.0001
<u>White-eyed Vireo (n=13)</u>			
Shrub % Cover	44.1	25.2	0.0015
<u>Eastern Towhee (n=17)</u>			
Canopy Cover (%)	80.4	84.3	0.0311
Hardwood Basal Area (ft ² /acre)	8.2	27	<.0001
Shrub % Cover	46.5	25.2	<.0001
<u>Summer Tanager (n=17)</u>			
Hardwood Basal Area (ft ² /acre)	15.3	27	0.0064
Hardwood DBH	11.5	17.7	0.0383
Shrub % Cover	14.1	25.2	0.0007

Table 5. Significant variables between random corridor and patch sites and nest sites for the Acadian Flycatcher. Nest vegetation data were collected from 1997-2000. Tests were performed on all habitat variables collected and only significant differences are reported, except for nest height.

Significant Habitat Variable	Nest Site	Random Site	p-value
<u>Corridor nests</u>	n = 70	n = 202	
Midstory Height (m)	13.71	12.8	0.0142
Hardwood Basal Area (ft ² /acre)	35.7	30.1	0.0119
Canopy Cover	84.5	82.2	0.0325
Shrub % cover	15.3	27.7	<0.0001
Nest tree DBH (cm)	13.1	18.0	0.0002
<u>Patch nests</u>	n = 69	n = 176	
Hardwood Basal Area (ft ² /acre)	29.1	23.2	0.0056
Shrub % Cover	15.3	23.5	<0.0029
<u>Patch vs. Corridor Nests</u>	<u>patch</u>	<u>corridor</u>	
Midstory Height (m)	12.9	13.7	0.0369
Pine Basal Area (ft ² /acre)	161.4	136.9	0.0089
Pine DBH (cm)	32.3	34.6	0.0004
Hardwood Basal Area (ft ² /acre)	29.1	35.7	0.0298
Vines	4.6	4.2	0.0003
Nest tree Height (m)	10.8	13.4	0.0003
Nest tree DBH (cm)	10.9	13.1	0.0106
Nest Height (m)	5.8	5.2	0.0984

Table 6. Acadian Flycatcher nesting success by patch type, 1997-2000. Rotation-age refers to stands surveyed from 1997-2000 between the ages of 18-21. Percent success based on nesting interval of 29 days. Statistical comparisons only made for 1998, 1999, and ALL.

Year and Type	# nests	#failures	Mayfield	SE	% Success
1997 Corridor	6.00	1	0.9922	0.0078	0.7973
1997 Patch	8.00	3	0.9783	0.0124	0.5287
1998 Corridor	27.00	10	0.9779	0.0069	0.5231
1998 Patch	23.00	11	0.9699	0.0089	0.4122
1999 Corridor	23.00	17	0.9504	0.0117	0.2285 ^a
1999 Patch	25.00	15	0.9603	0.0100	0.3091
2000 Corridor	11.00	7	0.9470	0.0195	0.2429
2000 Patch	9.00	2	0.9841	0.0111	0.6288
ALL, Corridor	67.00	35	0.9668	0.0055	0.3761
ALL, Patch	65.00	31	0.9692	0.0054	0.4040
ALL, Rotation-age	31.00	21	0.9403	0.0126	0.2743 ^b

^a - Significant difference ($p < .05$) between 1998 corridor and 1999 corridor

^b - Significant difference ($p < .05$) between rotation age vs. patch, ALL and corridor, ALL.

Table 7. Hooded Warbler nesting success by stand type, 1997-2000. Rotation-age refers to stands surveyed from 1997-2000 between the ages of 18-21. Percent success based on nesting interval of 21 days.

Stand Type	# nests	# failures	Mayfield	SE	% Success
Patch	24	9	0.9602	0.0130	0.4260
Corridor	13	6	0.9560	0.0175	0.3891
Rotation-age	26	16	0.9236	0.0183	0.1886 ^a

^a - Marginally significant vs. corridors (p = 0.102) and patches (p = 0.053)

Table 8. Northern Cardinal nesting success by stand type, 1997-2000. Rotation-age refers to stands surveyed from 1997-2000 between the ages of 18-21. Percent success based on nesting interval of 22 days.

Stand Type	# nests	# failures	Mayfield	SE	% Success
Patch	30	16	0.9494	0.0123	0.3194
Corridor	22	14	0.9447	0.0144	0.2858
Rotation-age	14	8	0.9245	0.0257	0.1779

Table 9. White-eyed Vireo nesting success by stand type, 1998-2000. Rotation-age refers to stands surveyed from 1997-2000 between the ages of 18-21. Percent success based on nesting interval of 24 days.

Stand Type	# nests	# failures	Mayfield	SE	% Success
Patches	6	4	0.9149	0.0407	0.1183
Corridors	11	5	0.9606	0.0173	0.3814
Corridors and Patches	17	9	0.9483	0.0168	0.2795
Rotation-age	17	8	0.9646	0.0123	0.4211

Table 10. Eastern Towhee nesting success by stand type, 1998-2000. Percent success based on nesting interval of 23 days.

Stand Type	# nests	# failures	Mayfield	SE	% Success
Corridors and Patches	25	15	0.9432	0.0142	0.2604
Corridors	13	9	0.9484	0.0167	0.2958
Patches	12	6	0.9330	0.0264	0.2027

Table 11. Summer Tanager nesting success by stand type, 1998-2000. Percent success based on nesting interval of 22 days.

Stand Type	# nests	# failures	Mayfield	SE	% Success
Corridors and Patches	22.00	10	0.9578	0.0131	0.3874
Corridor	7.00	4	0.9470	0.0258	0.3019
Patches	15.00	6	0.9628	0.0149	0.4348

Table 12. Acadian flycatcher nesting success by distance to edge type within patches and corridors, 1997-2000. Percent success based on nesting interval of 29 days. Statistical comparisons made only within patch type.

Distance to edge type	Patch Type	# nests	#failures	Mayfield	SE	% Success
<u>Edge</u>						
0-43m	Corridor	33	16	0.9703	0.0073	0.4170
43-175m	Corridor	34	19	0.9632	0.0083	0.3376
15-78m	Patch	32	14	0.9714	0.0075	0.4307
78-369m	Patch	33	17	0.9672	0.0078	0.3803
<u>Road</u>						
0-72m	Corridor	33	16	0.9692	0.0076	0.4033
73-344m	Corridor	34	19	0.9646	0.0080	0.3515
5-87m	Patch	32	16	0.9694	0.0075	0.4058
90-645m	Patch	33	15	0.9691	0.0079	0.4021
<u>Road and Edge</u>						
10-110m	Corridor	33	14	0.9751	0.0066	0.4818
111-498m	Corridor	34	21	0.9574	0.0091	0.2826 ^a
30-180m	Patch	33	16	0.9693	0.0075	0.4054
182-788m	Patch	32	15	0.9691	0.0079	0.4025

^a - Marginally significant difference ($p = 0.0571$) with 10-110m distance road + edge, corridor

Table 13. Acadian Flycatcher nesting success by distance to edge, 1997-2000. Nests from both corridors and patches combined (n = 132). Distance is to edge aged 0-5 years. Nests were grouped into bins, the first interval being the closest nests to edge within the bin. In cases where divisions were unequal, remaining nests were placed into the bin furthest from the edge.

Distance (m)	# nests	# failures	Mayfield	SE	% Success
<u>Bins of 5</u>					
4-31	26	13	0.9676	0.0088	0.3850
32-47	26	13	0.9678	0.0088	0.3873
47-65	26	13	0.9636	0.0099	0.3410
66-94	26	11	0.9779	0.0066	0.5225
96-369	28	16	0.9603	0.0097	0.3093
<u>Bins of 4</u>					
4-36	33	16	0.9689	0.0077	0.3997
36-52	33	18	0.9612	0.0090	0.3179
52-90	33	14	0.9760	0.0063	0.4948
91-369	33	18	0.9640	0.0083	0.3457
<u>Bins of 3</u>					
4-43	44	22	0.9699	0.0063	0.4117
43-75	44	23	0.9632	0.0075	0.3371
78-369	44	21	0.9703	0.0064	0.4176
<u>Bins of 2</u>					
4-52	66	34	0.9661	0.0057	0.3680
52-369	66	32	0.9698	0.0053	0.4109

Table 14. Acadian Flycatcher nesting success by distance to road, 1997-2000. Nests from both corridors and patches combined (n = 132). Distance is to nearest Westvaco road. Nests were grouped into bins, the first interval being the closest nests to road within the bin. In cases where divisions were unequal, remainder nests were placed into the bin furthest from a road.

Distance (m)	# nests	# failures	Mayfield	SE	% Success
<u>Bins of 5</u>					
0-38	26	11	0.9748	0.0075	0.4774
39-66	26	14	0.9661	0.0089	0.3678
66-97	26	11	0.9738	0.0078	0.4632
98-178	26	16	0.9585	0.0101	0.2930
194-645	28	14	0.9656	0.0090	0.3624
<u>Bins of 4</u>					
0-46	33	14	0.9752	0.0065	0.4830
46-75	33	16	0.9688	0.0077	0.3990
78-164	33	19	0.9610	0.0088	0.3157
164-645	33	17	0.9658	0.0081	0.3648
<u>Bins of 3</u>					
0-54	44	20	0.9713	0.0063	0.4299
55-115	44	21	0.9712	0.0062	0.4279
121-645	44	25	0.9608	0.0077	0.3137
<u>Bins of 2</u>					
0-75	66	30	0.9722	0.0050	0.4411
78-645	66	36	0.9635	0.0060	0.3397

Table 15. Acadian Flycatcher nesting success by distance to edge and road combined, 1997-2000. Distance to edge and road were summed and then ranked. Nests are from both corridors and patches combined (n = 132). Distance is to nearest Westvaco edge and road summed. Nests were grouped into bins, the first interval being the closest nests to edge and road summed within the bin. In cases where divisions were unequal, remainder nests were placed into the furthest bin.

Distance (m)	# nests	# failures	Mayfield	SE	% Success
<u>Bins of 5</u>					
10-97	26	8	0.9687	0.0067	0.3978
98-111	26	5	0.9759	0.0053	0.4934
112-168	26	9	0.9601	0.0073	0.3070 ^a
170-299	26	5	0.9685	0.0058	0.3953
299-788	28	5	0.9667	0.0049	0.3741
<u>Bins of 4</u>					
10-102	33	9	0.9719	0.0055	0.4380
102-125	33	7	0.9694	0.0050	0.4058
132-251	33	10	0.9666	0.0061	0.3738
256-788	33	6	0.9637	0.0048	0.3427
<u>Bins of 3</u>					
10-106	44	11	0.9722	0.0048	0.4420
106-198	44	11	0.9666	0.0045	0.3734
200-788	44	10	0.9652	0.0047	0.3575
<u>Bins of 2</u>					
10-125	66	16	0.9707	0.0037	0.4218
132-788	66	16	0.9652	0.0039	0.3581

^a - Significantly different from 98-111 interval (p <.05)

Table 16. Hooded Warbler nesting success by distance to edge, 1997-2000. Nests from both corridors and patches combined (n = 37). Distance is to edge aged 0-5 years. Nests were grouped into bins, the first interval being the closest nests to edge within the bin. In cases where divisions were unequal, remainder nests were placed into the bin furthest from the edge.

<u>Distance (m)</u>	<u># nests</u>	<u># failures</u>	<u>Mayfield</u>	<u>SE</u>	<u>% Success</u>	<u># Cowbird</u>	<u>% Cowbird</u>
<u>Bins of 4</u>							
2-20	9	5	0.9130	0.0372	0.1480	3	0.3333
27-45	9	3	0.9769	0.0132	0.6124	3	0.3333
53-99	9	5	0.9541	0.0200	0.3730	3	0.3333
104-313	10	2	0.9697	0.0211	0.5240	1	0.1000
<u>Bins of 3</u>							
2-28	12	6	0.9245	0.0296	0.1925	4	0.3333
30-68	12	5	0.9701	0.0131	0.5292	3	0.2500
84-313	13	4	0.9654	0.0170	0.4770	3	0.2308
<u>Bins of 2</u>							
2-45	18	8	0.9573	0.0148	0.4002	6	0.3333
45-313	19	7	0.9600	0.0148	0.4243	4	0.2105

Table 17. Hooded Warbler nesting success by distance to road, 1997-2000. Nests from both corridors and patches combined (n = 37). Distance is to nearest Westvaco road. Nests were grouped into bins, the first bin being the closest nests to a road. In cases where divisions were unequal, remainder nests were placed into the bin furthest from the edge.

Distance (m)	# nests	# failures	Mayfield	SE	% Success	# Cowbird	% Cowbird
<u>Bins of 4</u>							
2-30	9	5	0.9471	0.0230	0.3193	5	0.5556
40-106	9	2	0.9753	0.0172	0.5915	2	0.2222
132-181	9	3	0.9672	0.0186	0.4966	1	0.1111
201-668	10	5	0.9476	0.0228	0.3233	2	0.2000
<u>Bins of 3</u>							
2-42	12	5	0.9567	0.0189	0.3948	5	0.4167
45-164	12	5	0.9614	0.0169	0.4374	3	0.2500
166-668	13	5	0.9574	0.0186	0.4012	2	0.1538
<u>Bins of 2</u>							
2-106	18	7	0.9601	0.0148	0.4254	7	0.3889
132-668	19	8	0.9572	0.0148	0.3992	3	0.1579

Table 18. Hooded Warbler nesting success by distance to edge and road combined, 1997-2000. Distance to edge and road were summed and then ranked. Nests are from both corridors and patches combined (n = 37). Distance is to nearest Westvaco edge and road summed. Nests were grouped into bins, the first interval being the closest nests to edge and road summed within the bin. In cases where divisions were unequal, remainder nests were placed into the furthest bin.

Distance (m)	# nests	# failures	Mayfield	SE	% Success	# Cowbird	% Cowbird
<u>Bins of 4</u>							
4-60	9	5	0.9471	0.0230	0.3193	5	0.5556
62-181	9	2	0.9765	0.0164	0.6065	1	0.1111
184-352	9	3	0.9647	0.0200	0.4702	2	0.2222
362-760	10	5	0.9490	0.0222	0.3330	2	0.2000
<u>Bins of 3</u>							
4-90	12	6	0.9506	0.0197	0.3452	6	0.5000
93-282	12	4	0.9652	0.0171	0.4755	2	0.1667
302-760	13	5	0.9603	0.0174	0.4273	2	0.1538
<u>Bins of 2</u>							
4-181	18	7	0.9610	0.0144	0.4337	6	0.3333
184-760	19	8	0.9563	0.0151	0.3911	4	0.2105

Table 19. Northern Cardinal nesting success by distance to edge, 1997-2000. Nests from both corridors and patches combined (n = 52). Distance is to edge aged 0-5 years. Nests were grouped into bins, the first interval being the closest nests to edge within the bin. In cases where divisions were unequal, remainder nests were placed into the bin furthest from the edge.

Distance (m)	# nests	# failures	Mayfield	SE	% Success	# Cowbird	% Cowbird
<u>Bins of 4</u>							
0-10	13	10	0.9177	0.0249	0.1511	0	0.0000
11-26	13	6	0.9590	0.0164	0.3985	1	0.0769
27-54	13	9	0.9362	0.0206	0.2343	0	0.0000
54-206	13	5	0.9688	0.0137	0.4984	1	0.0769
<u>Bins of 3</u>							
0-15	17	12	0.9326	0.0188	0.2153	1	0.0588
17-41	17	10	0.9468	0.0164	0.3004	0	0.0000
44-206	18	8	0.9607	0.0136	0.4138	1	0.0556
<u>Bins of 2</u>							
0-26	26	16	0.9403	0.0145	0.2581	1	0.0385
27-206	26	14	0.9536	0.0121	0.3513	1	0.0385

Table 20. Northern Cardinal nesting success by distance to road, 1997-2000. Nests from both corridors and patches combined (n = 52). Distance is to nearest Westvaco road. Nests were grouped into bins, the first interval being the closest nests to a road within the bin. In cases where divisions were unequal, remainder nests were placed into the bin furthest from the edge.

Distance (m)	# nests	# failures	Mayfield	SE	% Success	# Cowbird	% Cowbird
<u>Bins of 4</u>							
3-14	13	11	0.9151	0.0245	0.1419	0	0.0000
15-55	13	6	0.9609	0.0156	0.4159	0	0.0000
57-157	13	4	0.9761	0.0118	0.5876	1	0.0769
171-515	13	9	0.9244	0.0242	0.1773	1	0.0769
<u>Bins of 3</u>							
3-23	17	12	0.9306	0.0193	0.2057	0	0.0000
21-94	17	8	0.9654	0.0120	0.4605	1	0.0588
104-515	18	10	0.9396	0.0185	0.2538	1	0.0556
<u>Bins of 2</u>							
3-55	26	17	0.9399	0.0141	0.2559	0	0.0000
57-515	26	13	0.9546	0.0123	0.3600	2	0.0769

Table 21. Northern Cardinal nesting success by distance to edge and road combined, 1997-2000. Distance to edge and road were summed and then ranked. Nests are from both corridors and patches combined (n = 52). Distance is to nearest Westvaco edge and road summed. Nests were grouped into bins, the first interval being the closest nests to edge and road summed within the bin. In cases where divisions were unequal, remainder nests were placed into the furthest bin.

Distance (m)	# nests	# failures	Mayfield	SE	% Success	# Cowbird	% Cowbird
<u>Bins of 4</u>							
10-36	13	10	0.9293	0.0215	0.1994	0	0.0000
41-100	13	5	0.9673	0.0144	0.4814	1	0.0769
102-256	13	7	0.9529	0.0174	0.3457	0	0.0000
263-721	13	8	0.9368	0.0216	0.2376	1	0.0769
<u>Bins of 3</u>							
10-54	17	12	0.9294	0.0196	0.1998	0	0.0000
54-170	17	8	0.9620	0.0132	0.4264	1	0.0588
186-721	18	10	0.9471	0.0163	0.3024	1	0.0556
<u>Bins of 2</u>							
10-100	26	15	0.9491	0.0128	0.3166	1	0.0385
102-721	26	15	0.9455	0.0137	0.2911	1	0.0385

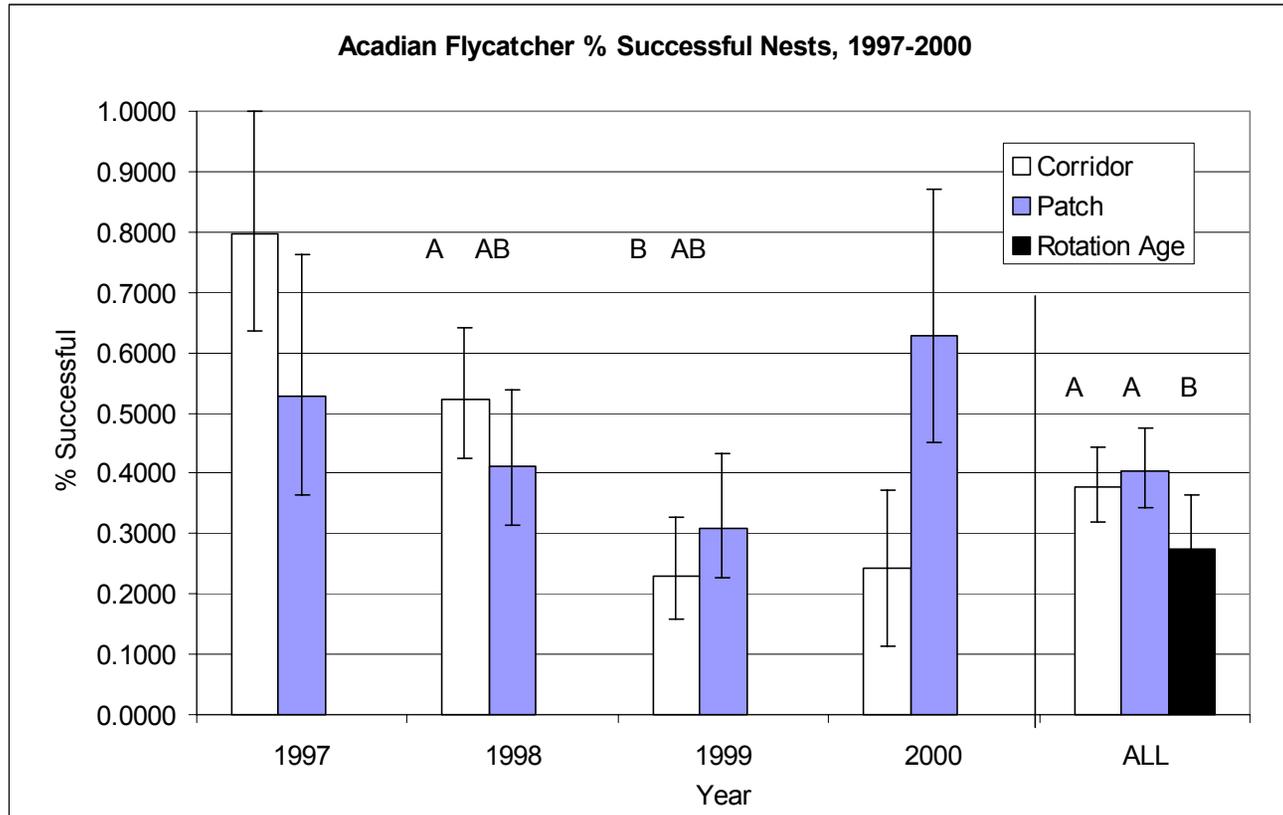


Figure 1. Acadian Flycatcher nest success (%) estimated by the Mayfield method, 1997-2000. Only years with greater than 20 nests are compared (1998, 1999). Different letters denote significant differences ($p < 0.05$). Comparisons across all years (ALL) were computed separately from the between year comparisons.

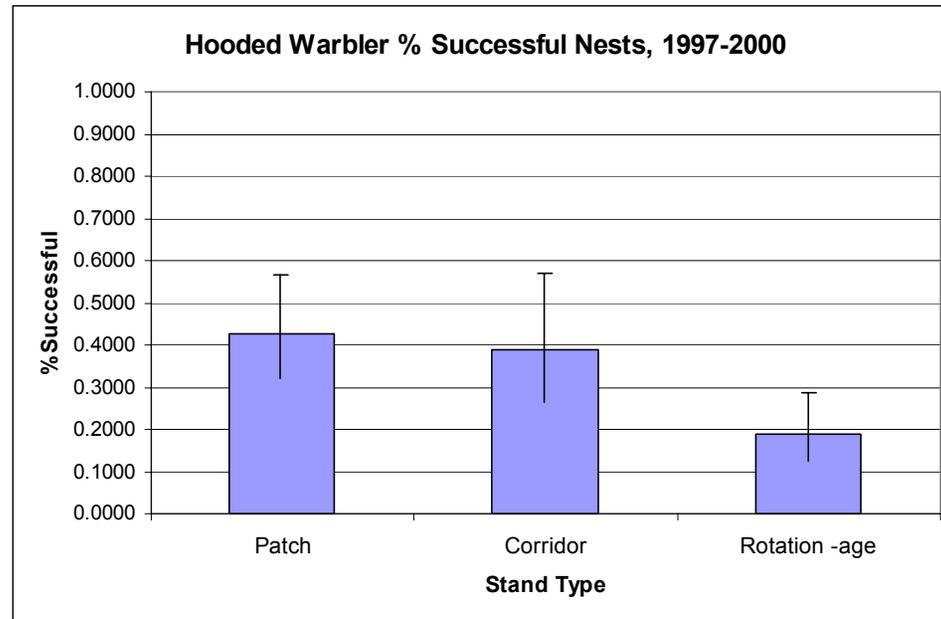


Figure 2. Hooded Warbler nest success (%) estimated by the Mayfield method, 1997-2000. No significant differences were found in all comparisons.

OVERALL SUMMARY

Avian Diversity and Abundance

Avian species diversity and assemblage composition were very similar between post-rotation-age corridors and patches (Chapter 2). Corridors had a species richness of 44 whereas patches had a species richness of 38.

Differences in diversity were from rare, often edge-associated species. Of the 11 species unique to corridors, none occurred in relative abundance of greater than 1.3%, and 8 of the 11 were edge-associated species (Chapter 2, Table 3). Of the 5 species unique to patches, none occurred in relative abundance of greater than 0.4% and 3 were forest-associated species (Chapter 2, Table 3).

Spearman's rank correlation coefficient on the ranked relative abundance of species within patches and corridors showed that the assemblages were highly correlated in their composition ($r = 0.7877$, $p < 0.0001$).

In individual species comparisons, 2 species were more abundant within corridors and 1 was more abundant within patches. The Blue-gray Gnatcatcher and Brown-headed Cowbird were significantly more abundant in corridors relative to patches, whereas the Red-eyed Vireo was more abundant in patches relative to corridors (Chapter 2, Table 5). When patch points were divided into 2 distance categories (patch-edge points and patch-interior points), most of the significant differences were from edge-associated species being more abundant in edge points. However, in these comparisons the Red-eyed Vireo was the only species to show consistent significant higher abundance in more forest-interior

like conditions. Across a gradient of edge-like conditions from corridors to patch-edge to patch-interior, the Red-eyed Vireo increased in abundance (0.213, 0.364, and 0.508, respectively). Thus within the landscape, only the Red-eyed Vireo was found to be sensitive to edges.

Avian Nest Survival

Avian nest survival for the Acadian Flycatcher, Hooded Warbler, and Northern Cardinal were not significantly different between post-rotation-age corridors and patches (Chapter 3). In comparisons with other published studies, nest survival within both patches and corridors were similar or greater (Chapter 3). However, The Acadian Flycatcher had significantly greater nest survival within both corridors and patches relative to rotation-age stands ($p < 0.05$), the Hooded Warbler had marginally higher nest survival within both corridors and patches ($p = 0.10-0.05$) relative to rotation-age patches, and the Northern Cardinal had higher but not significant nest survival within both patches and corridors relative to rotation-age stands.

Analysis of nest survival based on a nest's distance to edge (with loblolly aged 0-5), road, and edge+road found no consistent significant differences for the Acadian Flycatcher, Hooded Warbler, and Northern Cardinal. However, a possible trend of lower nest survival within 30m of an edge was apparent for the Hooded Warbler (Chapter 3, Table 16) and Northern Cardinal (Chapter 3, Table 19). Sample sizes were too low to confirm this trend.

The Hooded Warbler was the most parasitized by the Brown-headed Cowbird (10 of 37 nests, 27%). Nine were within patches and 1 within a corridor. This result was in contrast to avian abundance analysis (Chapter 3, Table 5) that showed Cowbirds to be significantly more abundant within corridors relative to patches. However, parasitized nests were not significantly different from non-parasitized nests based on distance to edge ($p = 0.7100$), distance to road ($p = 0.2111$), or distance to edge+road ($p = 0.2492$). These results indicate that within the landscape, Cowbirds were not deterred by forest interior conditions. Both corridors and patches were surrounded by loblolly pine stands aged 0-5 years and often adjacent to roads. The largest patch in this study was 32 hectares; the small stand sizes coupled with roads and edges with loblolly 0-5 years may have facilitated Cowbird host searching.

General Discussion

My study represents an analysis of the initial impacts of corridors. Most corridors were created after 1995, and as a result both post-rotation-age corridors and patches used in this study were adjacent to loblolly pine stands aged 0-5 years. However, post-rotation-age corridors and patches were connected within the landscape (Appendix-Maps 1 and 2). In this current landscape configuration, corridors and patches were found to be similar in avian diversity, abundance and nest survival.

The lack of edge effects within the landscape may be attributed to several factors. First, although both patches and corridors were surrounded by young

edges, they were connected. In regards to avian abundance, if avian species use corridors for movements, the connected nature of the patches and corridors within the landscape may serve to equalize avian abundance. In a study examining the frequency of bird movements in riparian buffer strips between forest reserves in a mixed wood boreal forest, Machtans et al (1996) found that riparian buffer strips enhanced juvenile bird movements and that adult bird species maintained territories within the strips. Schmiegelow et al. (1997) studied bird responses to experimentally fragmented 1, 10, 40 and 100-hectare forest patches in boreal mixed-wood forest connected with 100-meter-wide riparian buffer strips. Corridors were cited as mitigating declines in comparison with isolated fragments. A study involving the Bachman's Sparrow () found that isolated patches were less likely to be colonized than were non-isolated patches (Dunning et al. 1995). Thus, within my landscape, the connected nature of the corridor/patch system may serve to equalize corridor and patch avian abundance, assuming birds use corridors for movement. Research on the movement function of corridors is needed within my study site to confirm this.

Second, results from this study were consistent with published studies from forested landscapes (Hanski et al. 1996, Huhta et al. 1998, Tweksbury et al. 1998). These studies failed to find negative edge effects within forested landscapes. Initial fragmentation and edge effects studies were primarily done within forests surrounded by an agricultural matrix (i.e. Donovan et al. 1995, Robinson et al. 1995). In a study on Acadian Flycatchers within a large

bottomland hardwood reserve surrounded by an agricultural matrix, Wilson and Cooper (1998b) found Cowbird parasitism rates of 21%. In contrast, within my study area, no Acadian Flycatcher nest has been found parasitized since nest monitoring began in 1997. The dynamic nature of forested landscapes (harvesting and regrowth), lack of a permanent agricultural matrix, and the predominance of forest cover may serve to mitigate edge effects relative to agricultural landscapes.

Third, the stand sizes for both corridors (9.4 -30.0 ha) and patches (16.1-38.0 ha) were similar. Many previous studies were conducted across many patch size scales (Robinson et al. 1995, Roberts and Norment 1999, Rosenberg et al. 1999, Villard et al. 1999). The power of this study may have been too low to detect significant differences at the stand-level scale. Because corridors and patches were vegetatively similar, similar in age, and similar in stand size, the power required to detect significant differences may not have been achieved in this study. However, the lack of significant edge effects may indicate that corridors and patches in general were relatively similar.

Fourth, the edges adjacent to patches and corridors were highly disturbed. Stands adjacent to corridors and patches were harvested, allowed to go fallow 1-3 years, then plowed, bedded and planted. These planted stands then may undergo herbicide treatment 1-5 years after planting. The highly disturbed nature of the adjacent stands to corridors and patches may not have provided favorable foraging sites for nest predators or Cowbirds. No Cowbirds have been observed

foraging within these young stands (personal observation). This disturbed habitat may have also disrupted population dynamics of nest predators. In 2000, infrared cameras were used to monitor a subset nests. Of the 4 predation events observed, 3 were snakes and 1 was a Crow. The distribution of and abundance of snakes within the study area are unknown. It is possible that the disturbed stands adjacent to corridors and patches may have resulted in lower densities of snakes within corridors and patches. This may explain why rotation-age stands had consistently lower nest success relative to post-rotation-age patches and corridors. Rotation-age stands typically occurred in large blocks of stands that have had relatively little local disturbance. If local disturbance effects nest predator density negatively, rotation-age stands may have had greater densities of nest predators. If nest predators search randomly in space and time (Wilson and Cooper 1998a), greater density may translate into greater observed nest predation. More research on nest predator identity, distribution, and abundance is needed to confirm or refute this.

Management Recommendations

Post-rotation-age corridors and patches were found to be similar in avian diversity, abundance, and nest productivity. In the current landscape configuration, avian species appear to use corridors as breeding habitat similar to patches within the landscape. However, one species, the Red-eyed Vireo, was found to be more abundant in patches relative to corridors, and sensitive to edges in general. The Brown-headed Cowbird was found to be more abundant

in corridors relative to patches. However, nest data found greater parasitism rates in patches relative to corridors and no relationship of parasitism to distance to edge or road for the Hooded Warbler.

Thus, in its current configuration, patches and corridors function similarly as breeding habitat for landbirds. However, the patches used within this study were scheduled for harvest after the study completion. In many cases the corridors adjacent to these patches are to be extended via harvesting. Thus the future landscape will consist of longer corridors and fewer patches embedded within the corridor system. The effects of removal of patches and the lengthening of corridors are unclear. The future landscape structure will contain more forest edge structure through the loss of patches.

A conservative management strategy would be to maintain "nodes" of patches within the current corridor system. These patches should be of similar age and structure to corridors. Point count analysis across ages 15-28 (Chapter 1, Table 5) found 10 species to be increasing with stand age. Five were midstory or overstory nesting species (Acadian Flycatcher, Blue-gray Gnatcatcher, Pine Warbler, Red-eyed Vireo, and Summer Tanager) and 4 were cavity nesting species (Carolina Chickadee, Eastern Tufted Titmouse, Great-crested Flycatcher, and Red-bellied Woodpecker). Connecting corridors with rotation-age or younger stands may result in a habitat discontinuity for these species. In addition, nest survival analysis found lower nest survival within rotation-age stands (Chapter 3).

Because the rotation-age across the landscape is 20 years, maintenance of the post-rotation-age corridor/patch system for 40-60 years will likely benefit these 10 species through time. If maintenance of patches as "nodes" is not possible due to economic constraints, a positive management strategy may be to connect corridors to mature hardwood stands instead of rotation-age or younger stands. Five of the ten species were bottomland-hardwood-associated species (Acadian Flycatcher, Blue-gray Gnatcatcher, Red-eyed Vireo, Great-crested Flycatcher and Kentucky Warbler). Connecting corridors to hardwood stands may be less of a habitat contrast for these species than connecting corridors to rotation-age or younger stands. Hardwood stands also are on longer rotations (60-100 years), thus a corridor/patch system incorporating hardwood patches would persist relatively longer within the landscape.

Future Research Needs

If maintenance of a patch/corridor configuration as in this study is not possible, research should be conducted within corridors at a future date for 2 reasons. First, the effects of removal of patches and lengthening of corridors are unknown. Removal of patches will increase edges within the landscape and may affect avian movements, abundance, or nest productivity. Second, the landscape is dynamic, and stands adjacent to corridors will grow rapidly through time, possibly changing the edge effects with corridors. The edge contrast will be lessened through time, and it is unclear how this will effect avian abundance and nest survival within corridors adjacent to younger, but more forest-like stands.

Results from rotation-age nest survival analysis indicate that nest survival may actually decrease if increased forest cover adjacent to corridors increases nest predator density.

Second, future research should focus on nest predator identity, distribution and abundance. Personal observations and infrared camera monitoring indicate that snakes may play a large role within the landscape. Knowledge of snake (or other nest predators) distribution and abundance would facilitate inference into causal factors of differential nest survival between rotation-age and post-rotation-age stands.

Finally, this study assessed corridors as breeding habitat for landbirds. Analysis of the movement function of corridors would determine if avian species were preferentially using corridors for dispersal within the landscape. If this is the case, corridors may facilitate the location of suitable habitat patches for avian species. Results from a movement study would help in inferences as to why avian diversity and abundance were similar between corridors and patches.

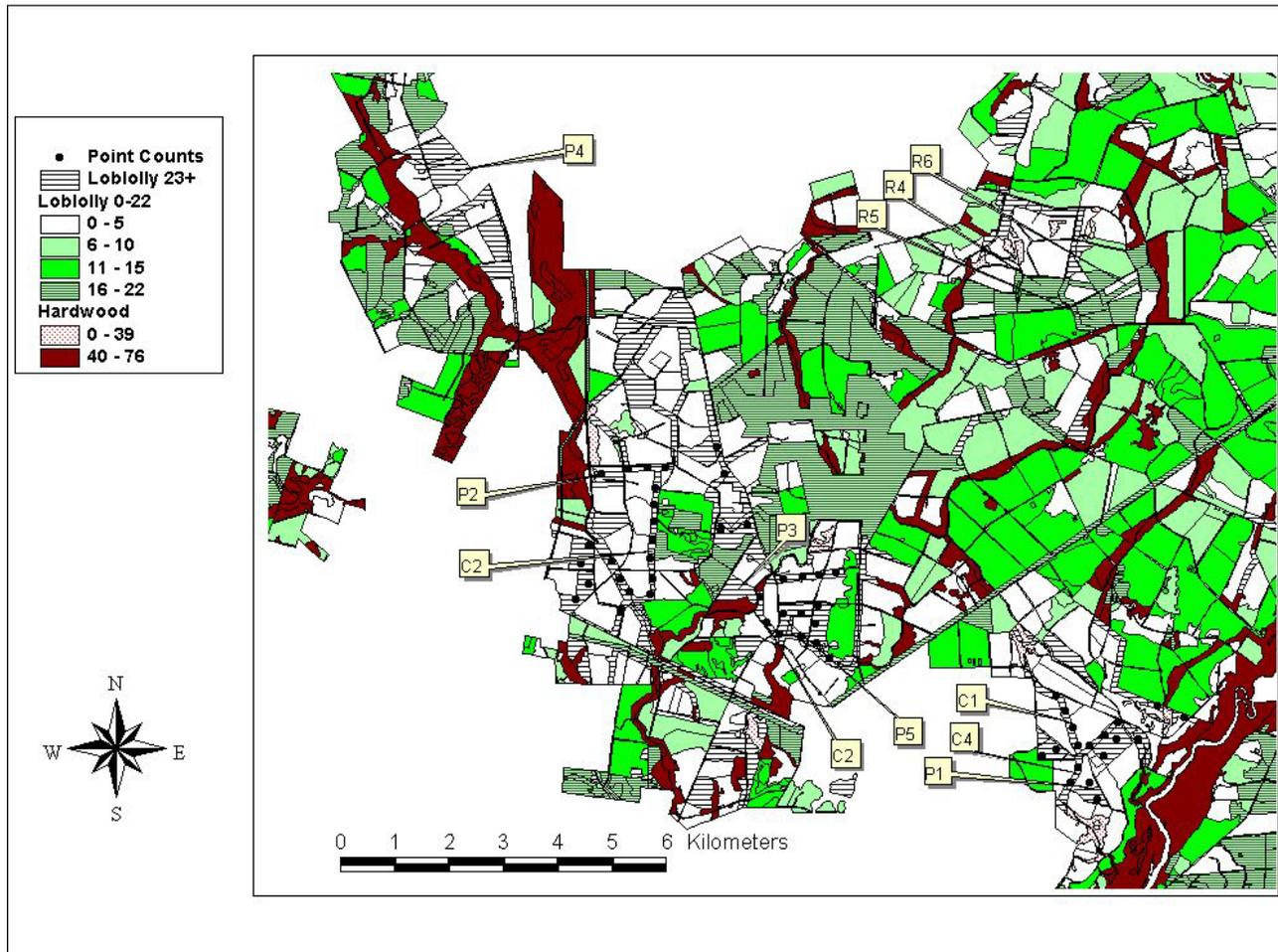
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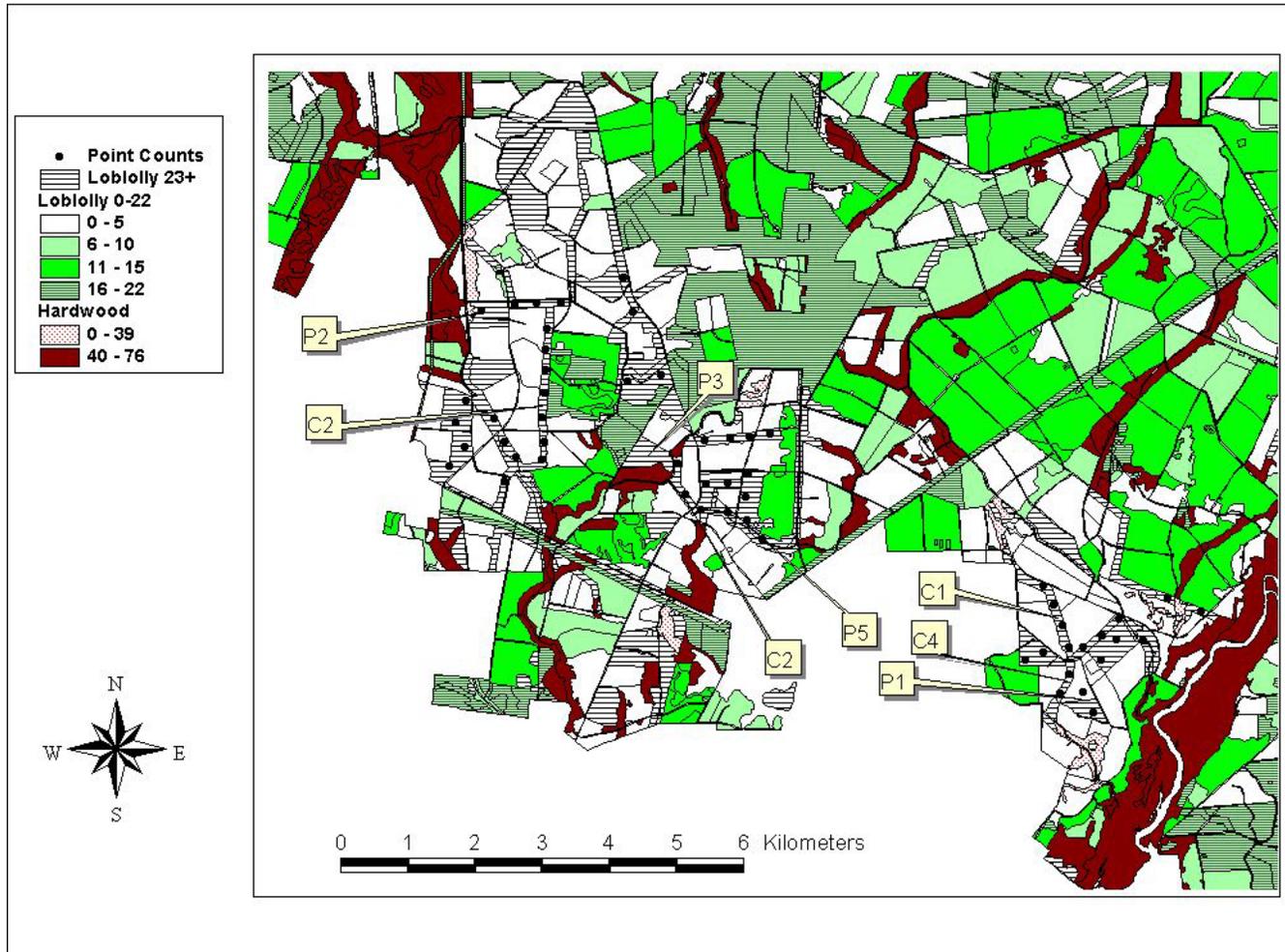
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Appendix -Table 1. Avian species codes (American Ornithologists Union codes), common names, and scientific names.

AOU CODE	Common Name	Species Name
ACFL	Acadian Flycatcher	<i>Empidonax virescens</i>
AMCR	American Crow	<i>Corvus brachyrhynchos</i>
BAAW	Black-and-white Warbler	<i>Mniotilta varia</i>
BACS	Bachman's Sparrow	<i>Aimophila aestivalis</i>
BGGN	Blue-gray Gnatcatcher	<i>Polioptila caerulea</i>
BHCO	Brown-headed Cowbird	<i>Molothrus ater</i>
BHNU	Brown-headed Nuthatch	<i>Sitta pusilla</i>
BLGR	Blue Grosbeak	<i>Guiraca caerulea</i>
BLJA	Blue Jay	<i>Cyanocitta cristata</i>
CACH	Carolina Chickadee	<i>Poecile carolinensis</i>
CARW	Carolina Wren	<i>Thryothorus ludovicianus</i>
COGR	Common Grackle	<i>Quiscalus quiscula</i>
COYE	Common Yellowthroat	<i>Geothlypis trichas</i>
DOWO	Downy Woodpecker	<i>Picoides pubescens</i>
EABL	Eastern Bluebird	<i>Sialia sialis</i>
EATO	Eastern Towhee	<i>Pipilo erythrophthalmus</i>
EAWP	Eastern Wood-Pewee	<i>Contopus virens</i>
ETTI	Eastern Tufted Titmouse	<i>Baeolophus bicolor</i>
FICR	Fish Crow	<i>Corvus ossifragus</i>
GCFL	Great Crested Flycatcher	<i>Myiarchus crinitus</i>
GRCA	Gray Catbird	<i>Dumetella carolinensis</i>
HAWO	Hairy Woodpecker	<i>Picoides villosus</i>
HOWA	Hooded Warbler	<i>Wilsonia citrina</i>
INBU	Indigo Bunting	<i>Passerina cyanea</i>
KEWA	Kentucky Warbler	<i>Oporornis formosus</i>
LBHE	Little Blue Heron	<i>Egretta caerulea</i>
MODO	Mourning Dove	<i>Zenaida macroura</i>
NOBO	Northern Bobwhite	<i>Colinus virginianus</i>
NOCA	Northern Cardinal	<i>Cardinalis cardinalis</i>
NOPA	Northern Parula	<i>Parula americana</i>
OROR	Orchard Oriole	<i>Icterus spurius</i>
OVEN	Ovenbird	<i>Seiurus aurocapillus</i>
PIWA	Pine Warbler	<i>Dendroica pinus</i>
PIWO	Pileated Woodpecker	<i>Dryocopus pileatus</i>
PRAW	Prairie Warbler	<i>Dendroica discolor</i>
RBWO	Red-bellied Woodpecker	<i>Melanerpes carolinus</i>
REVI	Red-eyed Vireo	<i>Vireo olivaceus</i>
RHWO	Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>
RTHU	Ruby-throated Hummingbird	<i>Archilochus colubris</i>
SUTA	Summer Tanager	<i>Piranga rubra</i>
WBNU	White-breasted Nuthatch	<i>Sitta carolinensis</i>
WEVI	White-eyed Vireo	<i>Vireo griseus</i>
WEWA	Worm-eating Warbler	<i>Helmitheros vermivorus</i>
WITU	Wild Turkey	<i>Meleagris gallopavo</i>
WOTH	Wood Thrush	<i>Hylocichla mustelina</i>
YBCH	Yellow-breasted Chat	<i>Icteria virens</i>
YBCU	Yellow-billed Cuckoo	<i>Coccyzus americanus</i>
YTVI	Yellow-throated Vireo	<i>Vireo flavifrons</i>
YTWA	Yellow-throated Warbler	<i>Dendroica dominica</i>



Appendix - Map 1 - Nest searching stands, Edisto District. Stand codes are as from Table 1, Chapter 1 (C = corridors, P = patches, R = rotation-age).



Appendix - Map 2 - Point count plots within post-rotation-age patches and corridors, Edisto District, 1996-1999.