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Source: Natural Areas Journal, 34(1):8-23.
Published By: Natural Areas Association
DOI: http://dx.doi.org/10.3375/043.034.0103
URL: http://www.bioone.org/doi/full/10.3375/043.034.0103

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RESEARCH ARTICLE

Vegetative and Bird Community Response to Management in a Mountain Longleaf Pine Forest

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Natural Areas Journal 34:8–23

ABSTRACT: Over the last century, logging, land conversion, and fire suppression have reduced longleaf pine (*Pinus palustris* Mill.) ecosystems to a small fraction of their original range. Fire suppression, in particular, has facilitated encroachment by non-fire-tolerant trees and heavy litter buildup, leading to shifts in the native plant and animal community. In 2001, efforts were initiated to re-establish parts of Berry College's (Floyd County, GA) fire-suppressed mountain longleaf pine forest using combinations of prescribed fire, clear-cutting, planting, and herbicide application. We designed this study to determine the effects of management practices thus far on vegetation structure and the bird community. In 2009, vegetation structure data were collected in longleaf pine stands comprising three management classes ranging from low- to high-intensity management. Bird surveys were conducted from summer 2009 to spring 2010, and avifaunal community structure was related to vegetative characteristics within each stand. Unmanaged stands were strongly associated with common omnivorous, ground-foraging, and canopy-nesting birds of mixed woodlands. Intermediately managed stands contained mostly birds of mixed diet and aerial- and bark-feeding cavity nesters. Heavily managed stands were strongly associated with insect-, vertebrate-, seed-, and fruit-eating ground and shrub nesters, with several sightings of the near-threatened Bachman's sparrow (*Peucaea aestivalis* Lichtenstein). Intensity of management was positively correlated with canopy openness, understory development, and low litter levels. These vegetative differences helped explain the bird community makeup. We provide baseline data for assessing the impacts of management of mountain longleaf pine and similarly fire-suppressed forests on avian abundance and species richness.

Index terms: bird community, management, *Pinus palustris*, prescribed fire, Southeast U.S., vegetative cover

INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) once covered between 24 (Outcalt and Sheffield 1996) and 38 (Frost 1993) million hectares (ha) from east Texas to south-central Florida, to southern Virginia and inland as far as northwestern Georgia and northeastern Alabama, functioning as the dominant tree throughout much of this region (Harper 1928; Landers et al. 1995). The range has since dwindled to less than 2% of its original area due to fire suppression, land conversion, logging, and tapping of trees for turpentine and other resin products (Landers et al. 1995; Outcalt and Sheffield 1996). Mountain longleaf pine forests occupied a relatively small part of the historic range and were confined to higher elevations of the northwestern part of the range (Varner 1999; Varner et al. 2003). Means (1996) reported that less than 4000 ha of mountain longleaf pine forest remained in 1995 (~0.01% of the original longleaf range). Due to its occurrence within relatively developed agricultural and fire-suppressed landscapes, in comparison with the better understood longleaf pine forests of the southeastern coastal plain and Gulf Coast, mountain longleaf pine habitat loss may be even more dramatic than that seen in coastal systems (Varner 1999; Brockway et al. 2005).

Frequent, low-intensity fire is particularly important in this ecosystem because the trees are relatively poor dispersers, and bare soil and high light intensity facilitate germination and early survival (Platt et al. 1988; Landers et al. 1995). Many plant species in these habitats display fire-dependent life histories and require open conditions (Platt et al. 1988; Means 1996). Fire benefits such species by minimizing competition with non-fire-tolerant species, facilitating seed germination, and maintaining high light and low litter levels.

The longleaf pine ecosystem is highly speciose (Peet and Allard 1993). It includes many species that are almost exclusively associated with longleaf pine, such as red-cockaded woodpeckers (*Picoides borealis* Vieillot) and Bachman's sparrows (*Peucaea aestivalis* Lichtenstein), the former being vulnerable or endangered (Engstrom and Conner 2006) and the latter near threatened and undergoing rapid decline (Sauer et al. 2011). Estimates of historic fire intervals in these areas range from one to three years (Frost 1998) to three to ten years (Christensen 1988), though most remaining natural stands have been fire-suppressed for periods ranging up to several decades, and as a result, show dramatic shifts in their biotas (cf., Engstrom et al. 1984; Varner and Kush 2004).

The loss of these forests has prompted many landowners and organizations to begin managing existing longleaf pine stands, or to begin establishing new ones. By employing methods that open the canopy, reduce hardwood cover, and diminish litter levels, land managers have the potential to restore the native plant and animal community. Management typically consists of prescribed fire, herbicide injection of competing trees, and direct removal of timber (stand thinning or clear cutting) followed by planting. Generally, these have proven effective in reestablishing longleaf pine as the dominant tree (e.g., Kush et al. 2004). Effects of management on the associated flora and fauna, however, are not well studied in mountain longleaf pine forests.

The effect that restoration has on the bird community is of particular interest because bird populations can be quite sensitive to environmental conditions (Maurer 1993) and management-induced changes to vegetation structure are known to impact avian habitat suitability (Webb et al. 1977; Thompson et al. 1992; Tappe et al. 2004). Stand thinning, regardless of technique, can create a mosaic of habitat types that tends to increase overall bird species richness (Greenberg et al. 2007). Reduction in tree cover can also help create appropriate habitats for early-successional birds (Thompson et al. 1995). Long-term hardwood encroachment, on the other hand, can lead to increased forest density and uniformity, and has caused reduction of many of the open habitats needed to support characteristic bird species (Greenberg et al. 2007). Of the 110 – 120 bird species commonly found in longleaf pine stands, 26 are of special concern (Engstrom and Conner 2006). Despite this, studies on the effects of management on both vegetation structure and the bird community in old growth longleaf pine ecosystems are limited and practically absent in mountain longleaf pine habitats. We had two goals: (1) to describe the breeding and non-breeding bird communities within a northwestern Georgia mountain longleaf pine forest, and (2) to quantify changes in vegetative structure produced in the early stages of a management program, and determine if these changes were associated with differences in bird community structure.

STUDY AREA

Study stands were in the Berry College Longleaf Pine Management Area (BCLPMA; lat. 34.34481, long. -85.20717) on Lavender Mountain, Floyd County, Georgia, an area of ~140 ha containing ~120 ha of relict longleaf pine stands (Cipollini 2005). The BCLPMA is centrally located within a Georgia Department of Natural Resources Wildlife Management area on the largely wooded ~10,500-ha Berry College campus. This large campus is adjacent to other large protected forest areas (in particular, Rocky Mountain Recreational Area and Chattahootchee National Forest, both to the north of campus). Old growth longleaf pines in the BCLPMA range from about 75 to 250 years old, and fires have been suppressed since the college was founded in 1902. Prior to restoration efforts, relict longleaf pine stands were subjected to hardwood encroachment, and excessive litter and woody fuel buildup (Cipollini et al. 2005; Huber et al. 2006). Shortleaf pines (*Pinus echinata* Mill.) once shared dominance with longleaf pines in areas of greatest longleaf pine density, although loblolly pine (*Pinus taeda* L.), Virginia pine (*Pinus virginiana* Mill.), and most of the hardwoods had apparently invaded during the period of fire suppression. Starting in 2001, a series of management activities were initiated in this area as part of a long-term project to restore the longleaf pine ecosystem (Table 1).

We defined a stand as an area with a uniform management history since 2001 centered within former or existing areas of high longleaf pine density. This study encompassed 15 such stands. Although selected stands did not have absolutely identical management histories (Table 1), they were grouped according to overall intensity of management that reduced tree canopy, particularly hardwood canopy. Five stands (1.5 – 6.9 ha) had been heavily managed (H), having been logged to mitigate infestations of mature loblolly pines and shortleaf pines with southern pine beetle (*Dendroctonus frontalis* Zimmerman). Residual longleaf pines and most large hardwoods were also removed at the time of logging. Following logging, H stands were subjected to foliar and injection applications of herbicides to residual hardwoods, were planted with longleaf pine seedlings, and were burned several times. Five stands (3.9 – 8.4 ha) were mature, formerly fire-suppressed longleaf pine stands that were similar to H stands prior to management, containing a mixture of mature pines and encroaching hardwoods. These stands were intermediately managed (I); most hardwoods had been injected with herbicides and the stands had been burned several times. Five otherwise similar stands (3.6 – 5.7 ha) were completely unmanaged (U). Stands were embedded within a matrix of infrequently burned mature mixed pine and hardwood forest, so H and I stands constituted "islands" within a matrix whose forest composition and structure was similar to U stands. An attempt was made to select stands so that area, slope position, aspect, and other characteristics of the stands did not confound differences in management history. Stands were between 200 m and 400 m in elevation on south and southwest facing slopes of 1% – 45% grade. The rocky, acidic, well-drained soils were dominated by fine sandy-, stony fine sandy-, and gravelly silt-loams (WSS 2011).

METHODS

Vegetation and Litter Data Collection

In spring and summer 2009, from 41 to 47 points were randomly located in each of the 15 stands. From each point the number of pines, hardwoods, and dead trees > 5 m in height were counted using the Bitterlich (1948) variable plot method, using a 1-m-long angle gauge with a 1.4-cm-wide sight. To estimate basal area (BA; m^2/ha) of trees in the area surrounding each point, counts of trees appearing wider than the sight were divided by two (Barbour et al. 1999). Within a 1-m^2 quadrat established at each point, the percent cover of each of the following variables was visually estimated: (1) woody plants 1 – 5 m tall; (2) woody plants < 1 m tall; (3) grasses, herbaceous plants, and litter. Litter depth was taken at the center point and litter volume (L/m^2) was calculated as a product of cover and depth.

Table 1. Land management practices applied in heavily managed (H) and intermediately managed (I) stands in the BCLPMA since 2001, including the total number of times each practice was implemented followed by year of most recent occurrence.

Stand	Area (ha)[a]	Clear Cut[b]	Selective Cut[c]	Prescribed Fire	Hack & Squirt Herbicide[d]	Foliar & Basal Herbicide[e]
H1	4.2	1 (2002)		1 (2005)	2 (2008)	2 (2008)
H2	6.9	1 (2002)[f]	1 (2002)[f]	2 (2009)	2 (2009)	1 (2007)
H3	3.2	1 (2002)		2 (2006)	4 (2009)	3 (2008)
H4	5.2	1 (2002)[f]	1 (2002)[f]	5 (2009)	4 (2009)	3 (2008)
H5	1.5	1 (2005)		3 (2006)	4 (2009)	3 (2008)
I1	7.1			3 (2007)	4 (2009)	
I2	7.1			2 (2007)	4 (2009)	
I3	8.4			2 (2007)	4 (2009)	
I4	5		1 (2000)[f]	2 (2010)	4 (2009)	
I5	3.9			2 (2010)	3 (2009)	

[a] Area of managed habitat.

[b] Commercial timber harvest of all trees > 30 cm in diameter.

[c] All pines removed and all hardwoods < 30 cm in diameter at breast height removed.

[d] Arsenal injected into approximately 50% of living hardwoods.

[e] Arsenal foliar spray, Garlon 3A foliar spray, and Garlon 4 basal spray, primarily targeted at encroaching hardwoods and *Rubus* spp.

[f] Management practice implemented in roughly half of stand.

Bird Surveys

Because point-count methods can be affected by differences in detectability among different bird species in different habitats, we employed the fixed-radius plot technique proposed by Hutto et al. (1986), which is in turn related to the transect-strip method of Emlen (1977). This technique samples from a fixed-area plot that is presumably small enough to allow detection of all cue-producing birds, provided that enough time is spent at each plot to account for all birds present.

To carry out bird surveys, four fixed-radius plots were established near the center of each stand. Based upon data reported by Petit et al. (1995) and Wolf et al. (1995) for birds in heavily forested landscapes, we selected a plot radius of 50 m (the center of each plot being 100 m from adjacent plots) and an observation period of 15 min. These parameters should have allowed detection of all cue-producing birds regardless of habitat, and the general approach is similar to the fixed-area plot approaches used by other researchers comparing bird community structure in relationship to management activities and vegetation structure (e.g., Thiollay 1997; Koenen and Koenen 2000; Sekercioglu 2002). As with all survey methods, silent, motionless, and uneasily flushed birds are likely to be underrepresented using this method regardless of habitat. From August 2009 through May 2010, 18 bird surveys (half within three hours of dawn, and half within three hours of dusk) were conducted in each stand by solitary, trained individuals, with an attempt made to evenly distribute repeat surveys across the survey period. For each survey, data were summed across the four plots to give one species by abundance data set per survey. Bird species were assigned to guilds (Cornell Lab of Ornithology 2011) based on primary diet (I = insects; V = vertebrates; S = seeds; F = fruits; or O = omnivorous), foraging strategy (A = aerial; B = bark; F = foliage; or G = ground), and nesting strategy (CN = canopy; CVB = cavity, bank, or building; SN = shrub; or GN = ground).

Data Analysis

Vegetation data among plots within stands could not be transformed to conform to standard assumptions of parametric analysis, so we compared vegetative variables among the 15 stands using non-parametric Kruskal-Wallis tests (Analytical Software©, Statistix 9, Tallahassee, FL), followed by multiple pairwise comparisons of means (N = 41 – 47 samples per stand; alpha = 0.05). Avian abundance and species richness data were square-root-transformed to normalize them and were analyzed using repeated-measures analysis-of-variance (IBM ©, SPSS Statistics 20, Chicago, IL) to test for differences among the 15 stands (N = 18 surveys per stand). For these and subsequent analysis using bird census data, we did not separate out residents, migrants, and seasonal breeders for analysis. Although migrants and seasonal breeders are expected to have lower overall abundances due to less time spent in the area, our data analysis focused on differences among stands and management classes, and not on direct comparisons of absolute species abundance or on seasonal variation of species compositions. This approach was meant to yield baseline data for the BCLPMA and to facilitate more detailed analyses in the future. To assist interpretations, in Appendix A we list the presumed residency status (Y = year round resident and breeder, SB = summer resident and breeder, M = migratory non-breeder, and W = winter non-breeder) of all observed species.

Variation among the 15 stands was further evaluated using principal component analysis of the means of the vegetative variables (PCA; Unrotated Covariance Matrix; Analytical Software©, Statistix 9, Tallahassee, FL). Principal component loadings were used to determine the association of each vegetative variable with the PCA axes. To map bird community structure onto the PCA, we used canonical correlation analysis (CCA; MANOVA procedure; IBM ©, SPSS Statistics 20, Chicago, IL) in which PC scores for the first two principal components for each stand were used as independent variables. The total number of birds observed in each guild in each stand served as the dependent variables in the CCA analyses (run once for each of the three guild types). Due to relatively low numbers of vertebrate (V) and fruit (F) eaters, for these and subsequent analysis, we combined insect (I) and vertebrate (V) eaters into one category (IV) and combined seed (S) and fruit (F) eaters into one category (SF). Vegetative and bird community data were approximately normally distributed at the stand level, based upon acceptable skewness and kurtosis values (Analytical Software©, Statistix 9, Tallahassee, FL). A second CCA used the raw vegetative variables as the independent variables and the totals in each guild as the dependent variables, allowing the relationship among vegetative structure and guild use to be determined more directly for each guild type. Together, these analyses described the relationship of vegetative variables with broad-level bird community structure at the stand level, but did not directly compare stands that had been grouped a priori by management class and lumped species together. To address this, we used chi-square analysis to compare use of each management class by birds of each guild type and to compare records for each species among the three management classes (for bird species with ≥ 50 total observations). For both guild-level and species-level analyses, the null hypothesis was one of equal use of the three management classes. To satisfy requirements for chi-square analysis, ground and shrub nesting guilds were combined into one group (GN/SN) for the guild-level analyses.

Our analysis of the bird community examined all birds that use the BCLPMA, including spring and fall migrants, summer breeders, winter residents, and year-long residents. This was primarily to prevent an overly sparse data set and was also a consequence of our decision to not organize surveys strictly by season. Our species list (Appendix A) provides comprehensive baseline data for birds of mountain longleaf pine habitats in northwestern Georgia, and includes residency status of each species. Our analyses regarding the effects of management were conservative because habitat selection often tends to be looser for non-breeding birds (cf., Hutto 1985 for an analysis of factors used by birds in habitat selection).

RESULTS

Vegetation Structure Analysis

Pairwise comparisons following Kruskal-Wallis tests revealed significant differences among the 15 stands for all vegetative variables except woody plants 1 – 5 m tall (Figure 1; Kruskal-Wallis test statistics all > 50, P values all < 0.001). In general, there was greater grass and herbaceous plant cover, and lower litter volume and basal area of hardwoods and pines > 5 m tall as management intensity increased (H vs I vs U stands). Compared to I stands, H stands contained lower basal area of hardwoods and pines > 5 m tall (about 70% and 80% lower, respectively), over 6 times greater grass cover, nearly twice the herbaceous plant cover, and about 30% lower litter volume. Compared to U stands, I stands had lower hardwood and pine basal area (about 50% and 25% lower, respectively), about 50% lower litter volume, nearly four times the grass cover, and over four times the herbaceous plant cover. I stands also had greater basal area of dead trees > 5 m tall in comparison with both H and U stands (about 3.5 times greater, respectively). While stands differed significantly in woody plants < 1 m tall, variation was not obviously related to management history.

Bird Community and Guild Analysis

A total of 5278 individuals (unknowns excluded) and 96 species were observed (See Appendix A for details, scientific names, and authorities). Repeated-measures ANOVA showed significant differences among the stands with both avian abundance ($F_{14, 238} = 5.31$; $P < 0.001$) and species richness ($F_{14, 238} = 5.61$; $P < 0.001$) per survey generally higher in managed stands (Figure 2).

The first three axes of the PCA ordination explained about 82%, 12%, and 4% of the variation (97.5% cumulatively), so examination of the first two axes alone was sufficient to reveal major patterns in the data (Figure 3). Examination of loadings (Table 2) showed that the first PCA axis (PC1) was positively associated with grass and herbaceous cover and was negatively associated with litter and with hardwoods and pines > 5 m tall. The second PC axis (PC2) was positively associated with herbaceous plant cover, dead trees > 5 m tall, and woody plants < 1 m tall, and was negatively associated with litter, grass cover, and hardwoods > 5 m tall. As seen in Figure 3, PC1 separated H from U and I stands, whereas PC2 separated U from I stands, and separated H stands with or without substantial tree basal area. Based upon CCA (Figure 3, Table 3a), PC1 was positively associated with insect/vertebrate eaters, foliage feeders, shrub nesters, and cavity/bank/building nesters, and was negatively associated with canopy nesters. PC2 was positively associated with ground foragers and canopy nesters. Direct examination of the relationships of vegetative variables to guild use using CCA (Table 3b) showed the following patterns: (1) stands low in hardwoods > 5 m tall or high

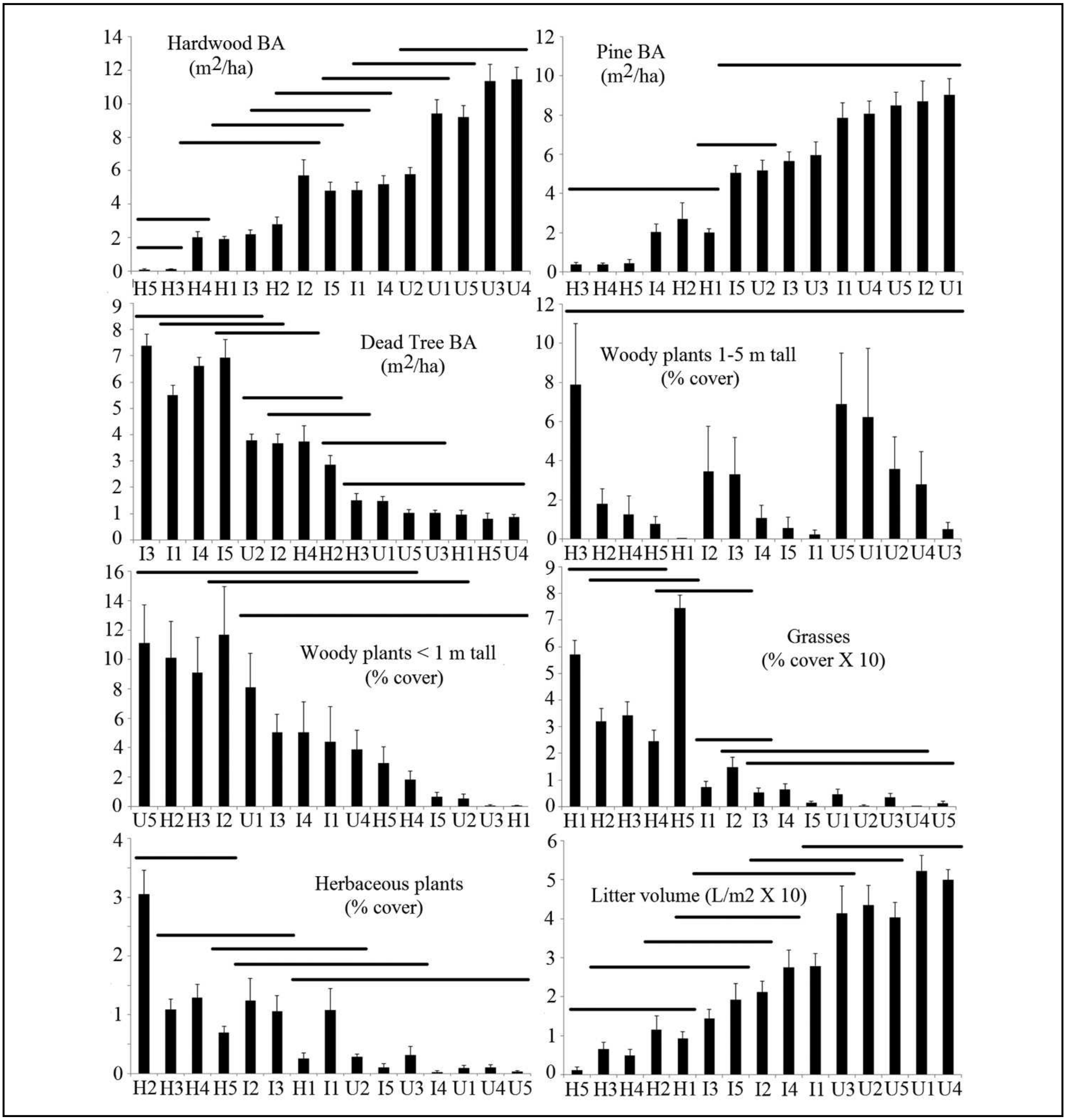

Figure 1. Vegetative structure of stands of various management regimes in the BCLPMA in 2009. Results are means and standard errors for vegetative variables by stand. Horizontal bars denote homogeneous groups (P <= 0.05) based upon pairwise Kruskal-Wallis comparisons of means. Stand designations are H (heavily managed), I (intermediately managed), and U (unmanaged). The horizontal axis of each subfigure is oriented such that most of the heavily managed stands (H) are to the left, and most unmanaged stands (U) are to the right.

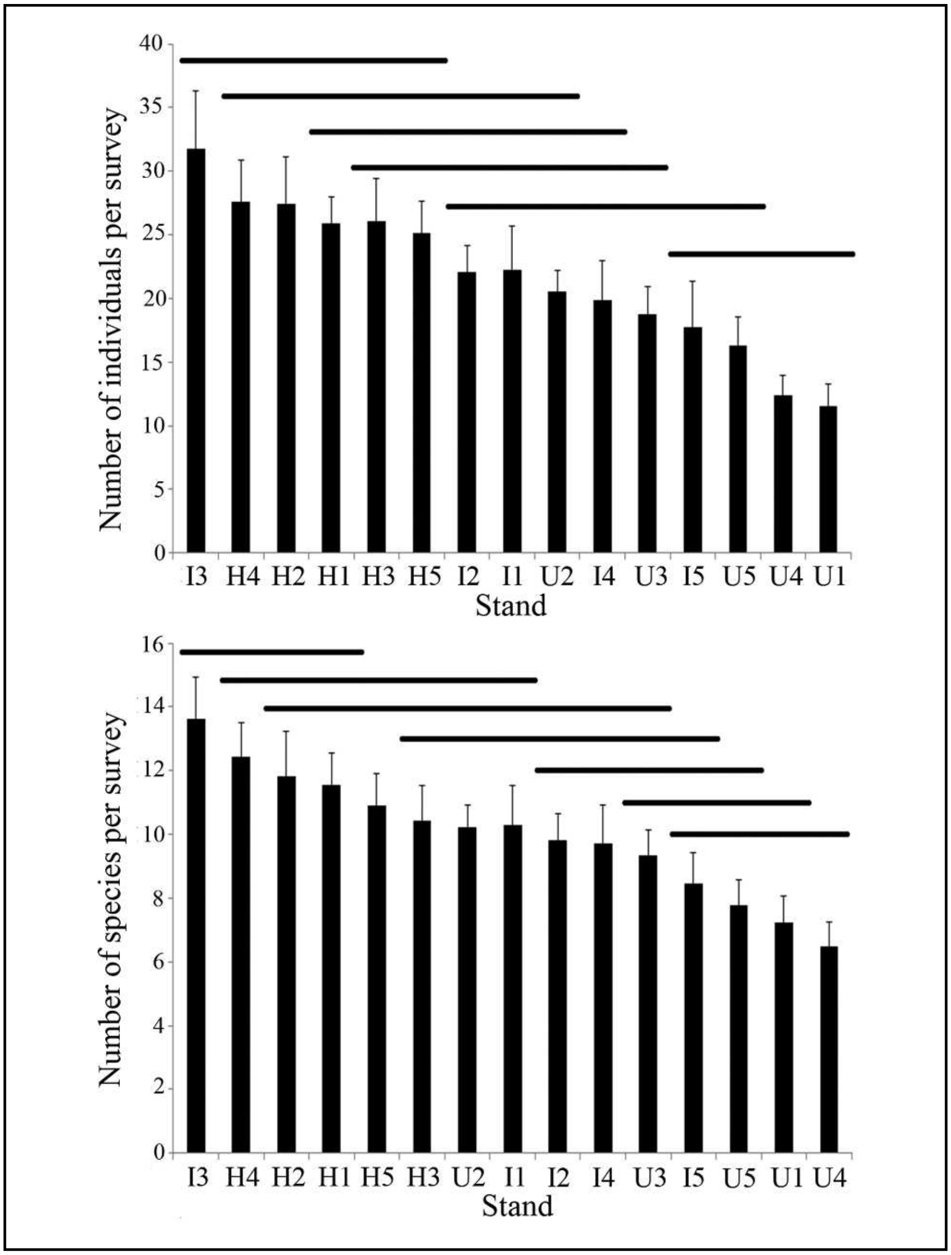

Figure 2. Bird abundances and species richness of stands of various management regimes in the BCLP-MA 2009 to 2010. Results are means and standard errors for numbers of birds and numbers of bird species recorded per survey by stand. Horizontal bars denote homogeneous groups (P <= 0.05) based upon least-square-means tests following repeated-measure ANOVA. Stand designations are H (heavily managed), I (intermediately managed), and U (unmanaged). The horizontal axis of each subfigure is oriented such that most of the heavily managed stands (H) are to the left, and most unmanaged stands (U) are to the right.

in herbaceous plant cover were positively associated with insect/vertebrate eaters and foliage feeders; (2) stands high in woody plants 1 – 5 m tall were positively associated with aerial feeders and negatively associated with bark feeders; (3) stands low in litter were positively associated with foliage feeders; and (4) stands high in grass cover were positively associated with cavity/bank/building nesters and shrub nesters, and negatively associated with canopy nesters.

Results of chi-square analyses for the three guild types (Figure 4), show the following patterns for designated management classes relative to the other classes in each group: (1) dietary guilds: higher than expected numbers of insect/vertebrate and seed/fruit feeders were recorded in H stands, and lower than expected insect/vertebrate feeders and omnivores were recorded in U stands ($X^2 = 260.5$; $P \leq 0.001$); (2) foraging guilds: higher than expected numbers of foliage and ground feeders were recorded in H stands, higher than expected numbers of bark feeders in I stands, and lower than expected numbers of all foraging guilds in U stands ($X^2 = 326.7$; $P \leq 0.001$); and (3) nesting guilds: higher than expected numbers of ground/shrub nesters were recorded in H and I stands, and lower than expected numbers of all nesting guilds in U stands ($X^2 = 523.8$; $P \leq 0.001$). Thus, differences in bird community structure were related to differences among the stands in vegetative characteristics associated with differing management practices.

Considering species with at least 50 total records (Appendix A) and using chi-square analysis (detailed results not shown), there were nine species with significantly higher abundance in H stands, relative to other stand types (American goldfinch, blue-gray gnatcatcher, golden-crowned kinglet, indigo bunting, northern cardinal, prairie warbler, red-headed woodpecker, red-bellied woodpecker, and tufted titmouse). This list is dominated by various finches, warblers, and woodpeckers commonly found in open thickets and reflects species most likely to respond to intensive management, particularly the reduction of tree cover and the production of standing dead trees. Five additional species had significantly higher abundances in both H and I stands, relative to U stands (Carolina chickadee, Carolina wren, downy woodpecker, eastern bluebird, and summer tanager); again, species expected to respond positively to canopy openness. Four species had significantly higher abundances in I stands, relative to other stand types (American crow, hairy woodpecker, pine warbler, and white-breasted nuthatch). Intermediately managed stands were those where large living pines and standing dead trees were common. Two species had significantly higher abundances in I and U stands, relative to H stands (blue jay and red-eyed vireo), and only one species had higher abundance in U stands, relative to other stand types (pileated woodpecker).

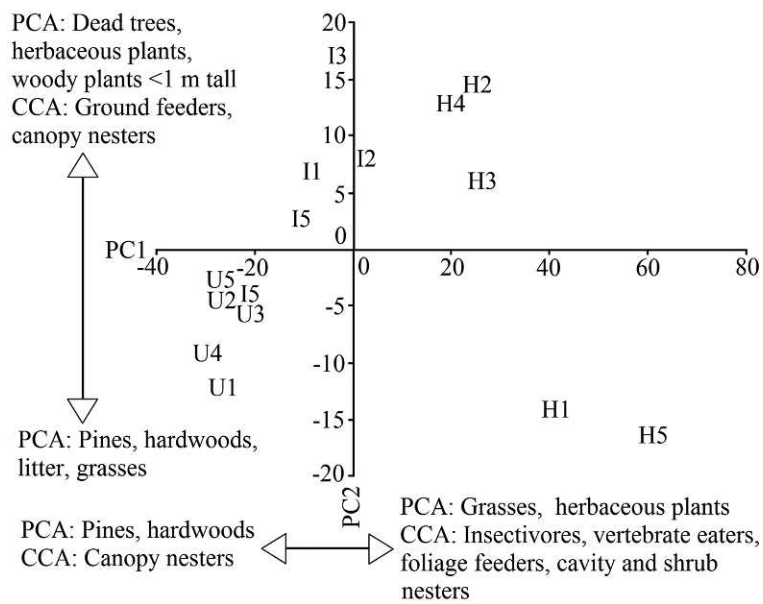

Figure 3. Principal components analysis (PCA) plot showing BCLPMA stands ordinated by differences in vegetative structure (2009) on the first two principal components axes. Mapped upon this figure are variables loading strongly on each PC axes (labelled PCA; see Table 2) and bird guilds relating significantly to each axis based upon canonical correlation analysis (labelled CCA; see Table 3a).

These latter two groups include species commonly associated with deciduous or mixed hardwood-pine forests that contain large canopy trees. Such species are likely to be reduced by heavy management that diminishes canopy cover, particularly hardwood cover.

Some of the rarer species were only recorded in stands within one management class (Appendix A). Eighteen species were observed solely in H stands (Cooper's hawk, Bachman's sparrow, Swainson's thrush, belted kingfisher, common nighthawk, yellow-throated warbler, palm warbler, willow flycatcher, common yellowthroat, loggerhead shrike, wild turkey, eastern towhee, prothonotary warbler, ovenbird, American redstart, pine siskin, eastern meadowlark, and hooded warbler), three in I stands (house finch, Blackburnian warbler, and American kestrel), and two in U stands (northern bobwhite and golden-winged warbler). Of the species observed only in the H stands, only the most abundant species (eastern towhee) had more than 10 observations (27 total). Species seen uniquely in H stands include two species of concern whose recent declines are associated with the reduction of open grassland type habitats (Bachman's sparrow and loggerhead shrike). Although the relatively longer list of species unique to H stands largely represents occasional species of very low abundance, many are known to be associated with relatively open habitats.

DISCUSSION

Although some vegetative differences existed among stands within the three management classes due both to site and management differences, they differed as expected in vegetative structure. Heavily managed stands had far less tree canopy cover and leaf litter, and far higher levels of grass and herbaceous plant cover than the other two management classes. As expected, I stands had lower tree cover and litter levels, and more grass and herbaceous plant cover than U stands. Because of practices allowing the retention of standing dead trees, I stands tended to contain greater dead tree cover than both H and U stand types. Woody plants ranging from 0 – 5 m tall varied among stands in ways mostly unrelated to management history. In some unmanaged areas, understory woody plants were likely restricted by heavy shading from overstory and subcanopy trees;

Table 2. Principle components eigenvalues based on the covariance matrix, using means of vegetative variables for 15 BCLMA stands in 2009, followed by variable loadings associated with each of the first three axes (sorted by PC1 loading).

PC	Eigenvalue	Variance	Cumulative variance
1	772	82.10%	82.10%
2	111.1	11.80%	93.90%
3	33.8	3.60%	97.50%

	Principal components axis loadings		
Variable	PC1	PC2	PC3
Litter volume	-0.582	-0.6044	-0.4379
Hardwoods > 5 m tall	-0.1202	-0.1221	-0.1191
Pines > 5 m tall	-0.0931	-0.0295	-0.16
Woody plants 1-5 m tall	-0.0269	0.0087	-0.0732
Dead trees > 5 m tall	-0.0116	0.1442	0.1551
Woody plants < 1 m tall	-0.0106	0.1377	-0.3553
Herbaceous plants	0.1306	0.5244	-0.7444
Grasses	0.7875	-0.5515	-0.2423

Table 3. Canonical correlation (CCA) results: a) using scores for stands on PC1 and PC2 as independent variables, and b) using average vegetative variables for each stand as independent variables. In both cases, the numbers of individuals recorded in each guild type in each BCLPMA stand in 2009-2010 were used as dependent variables (dietary guild: IV = insects and/or vertebrates, O = omnivorous, and SF = seeds and/or fruit; foraging guild: A = aerial, B = bark, F = foliage, and G = ground; nesting guild: CN = canopy, CVB = cavity, bank, or building, GN = ground, SN = shrub). Shown are regression coefficients (B) and P-values for significant (P <= 0.05) and marginally significant relationships (P >0.05<=0.10) where the overall F statistic for that relationship was significant (P <= 0.05).

a) CCA using PC scores for each stand as independent variables (see Figure 3):

		B	Guild	P
Dietary guilds				
	PC1	0.265	IV	0.036
Foraging guilds				
	PC1	0.465	F	0.01
	PC2	0.307	G	0.075
Nesting guilds				
	PC1	-0.48	CN	0.043
	PC1	0.711	SN	0.027
	PC1	0.304	CVB	0.011
	PC2	0.313	CN	0.014

b) CCA using average vegetative variables for each stand as independent variables:

	Variable	B	Guild	P
Dietary guilds				
	Hardwoods >5 m tall	-0.027	IV	0.042
	Herbaceous plants	0.12	IV	0.001
	Herbaceous plants	-0.141	O	0.054
	Herbaceous plants	-0.564	SF	0.05
Foraging guilds				
	Hardwoods >5 m tall	-0.061	F	0.002
	Woody plants 1-5 m tall	0.078	A	0.041
	Woody plants 1-5 m tall	-0.127	B	0.002
	Herbaceous plants	0.117	F	0.026
	Litter	-0.269	F	0.003
Nesting guilds				
	Dead trees >5 m tall	0.07	CN	0.009
	Dead trees >5 m tall	-0.093	SN	0.009
	Grasses	-0.558	CN	0.022
	Grasses	0.244	CVB	0.03
	Grasses	0.622	S	0.035

in some managed areas, understory woody plants had likely been reduced by recent burning and herbicide applications.

Even though our study was conducted less than ten years after management practices had begun in relatively small parcels (additional factors making this study conservative), the results showed effects of stand management on both the total number of birds and the number of species encountered. Differences in vegetative structure were related to differences in the general types of birds found using these habitats. Heavily managed stands were more likely to attract relatively specialized insect, vertebrate, seed, or fruit eaters that forage on foliage or on the ground, and nest on the ground or in shrubs. I stands tended to fall between H and U in bird community structure, although I stands were more likely to maintain birds dependent in some way upon standing trees, and were dominated by bark-feeding and cavity-nesting birds. The bird communities of I stands confirm the expectation of Anderson and Shugart (1974) that such habitats (having increased canopy openness and understory development, in addition to the presence of standing living and dead trees) should attract and maintain higher levels of aerial- and bark-feeding, and cavity-nesting species such as woodpeckers. Such groups may be on the decline worldwide due to forest management practices that reduce this habitat type (c.f., Cockle et al. 2011). Of further relevance, Cipollini et al. (2012) found a very high diversity (160 – 170 species) of flowering herbaceous plants and grasses in H stands during the same time frame as our study, whereas understory plant diversity in U stands was represented by only 14 species. Even I stands, with less-intensive management, had nearly an order of magnitude more plant species (120 – 130 species) than U stands. This highly speciose understory ought to promote a consistent seasonal availability of small seeded plants and insects and vertebrates that feed upon these plants. Birds attracted to such foraging and feeding opportunities commonly nest in low-lying vegetative strata (the cavity-nesting eastern bluebird, being an obvious exception). Although many of the species we observed probably did not nest during the time of our observation, it is not surprising that H stands tended to attract ground- and shrub-nesting birds, since non-breeding and breeding-season habitat selection is often at least somewhat related within a species (cf., Igl and Ballard 1999). Tappe et al. (2004) recorded a similar increase in ground and shrub nesters in heavily managed areas of the Ouachita Mountains, Arkansas. Although based upon relatively few observations, our results also suggest that substantial tree canopy reduction and an increase in herbaceous ground cover may be a way of attracting species such as the Bachman's sparrow and the loggerhead shrike, because these species were only recorded in the most

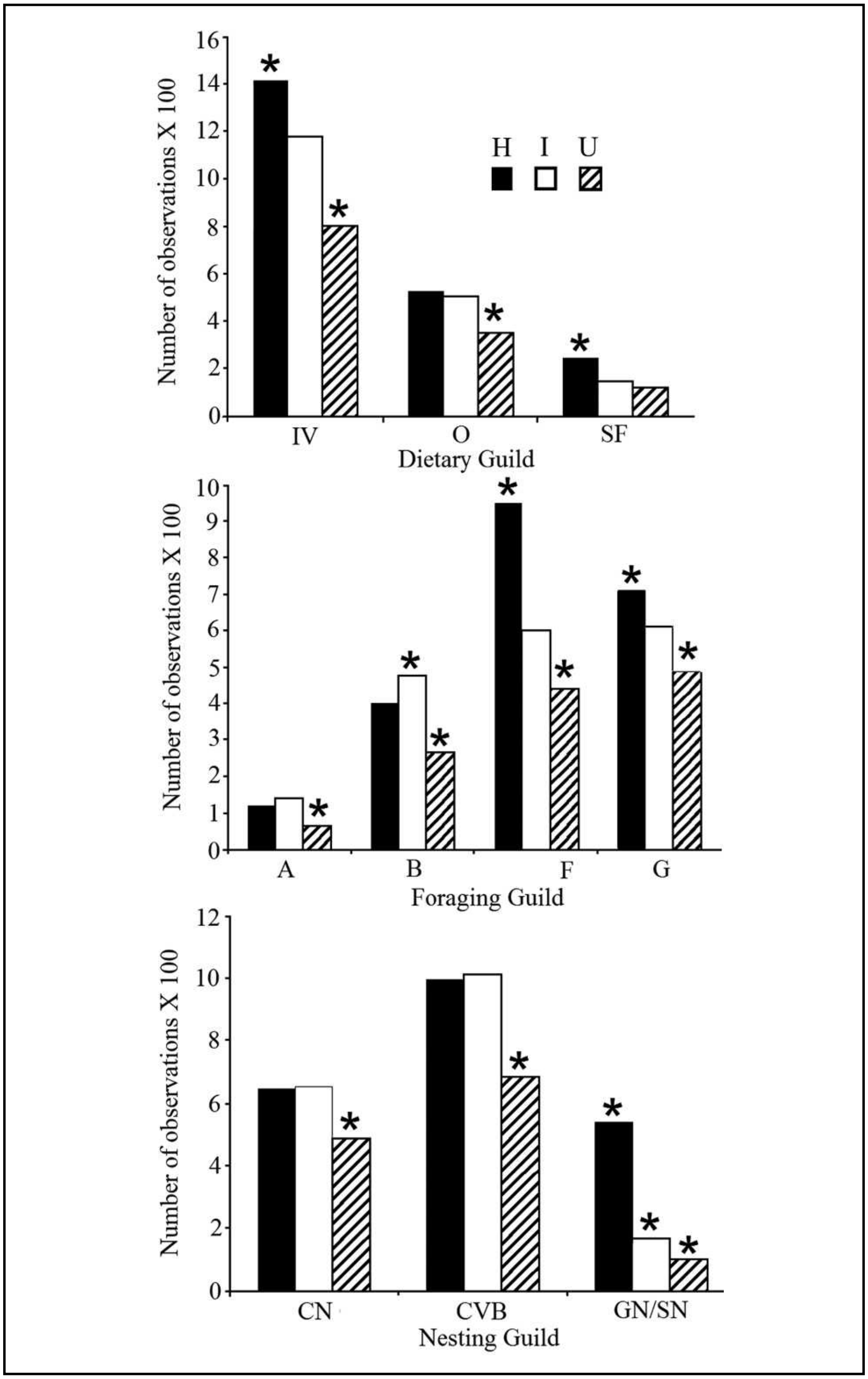

Figure 4. Total number of observations of birds within BCLPMA stands of each management class (H = heavily managed, I = intermediately managed, and U = unmanaged) by guild (dietary guilds: IV = insects and vertebrates, O = omnivorous, and SF = seeds and fruits; foraging guilds: A = aerial, B = bark, F = foliage, and G = ground; nesting guilds: CN = canopy, CVB = cavity/bank/building, and GN/SN = ground and shrub nesters. Asterisks denote values whose associated partial X^2 statistic exceeded the critical X^2 value for the overall effect.

open areas. This conclusion corroborates those of Engstrom et al. (1984) and Tucker et al. (2004).

In contrast, U stands were dominated by a somewhat reduced biota of widely distributed ground-feeding and canopy-nesting omnivores. Fire suppression and lack of active management in these areas was associated with an accumulation of non-fire-tolerant hardwoods, buildup of litter, and loss of herbaceous, grass, and shrub cover (cf., Currie et al. 2006 and Huber et al. 2006 for earlier reports on conditions in unmanaged areas of the BCLPMA). High litter levels may be a predominant driving force in suppressing establishment and maintenance of ground-cover plants in fire-suppressed forests (Hiers et al. 2007). Furthermore, closed canopy conditions likely contributed to the observed lower abundance of birds that have dietary, foraging, or nesting requirements dependent either directly or indirectly on high understory plant cover and diversity.

As with most studies that compare bird community structure among habitats, there is some possibility that patterns reflected inequalities in the detectability of different species. Though our survey methods were designed to minimize this problem, we here examine characteristics of species seen predominantly in the most (H) and least open (U) habitats. There were 26 species with at least 10 more observations in H versus U stands (Appendix A). Eight of these species are small, drab, or secretive, and could have been missed by observers more often in U areas, though the habitat preferences of six of these eight species (yellow-breasted chat, blue-gray gnatcatcher, tree swallow, song sparrow, field sparrow, and brown-headed nuthatch) suggest they were present where expected and absent where not. Two species (ruby-crowned and golden-crowned kinglets), in particular, may have been missed in some of the thicker forests. The remaining 18 species recorded predominantly in H areas are brightly colored, conspicuous, active, and their habitat preferences suggest strong associations with open areas and standing dead trees. There were six species with at least ten more observations in U versus H stands. Two of these species (blue-headed and red-eyed vireo) can be inconspicuous but were observed in habitats matching their documented preferences. The remaining four species (American crow, northern flicker, blue jay, and pileated woodpecker) are large and loud, seen year round, and should be very conspicuous from up to 50 m in all areas. Taken together, these observations do not suggest that species records were influenced heavily by differential detectability.

This is the first study that focused on the birds of mountain longleaf pine habitats in Georgia. The only previous studies describing bird community and vegetative structure relationships in managed mountain longleaf pine systems were conducted within the Talladega National Forest (TNF) in northeastern Alabama. For example, Hill (1998) compared the bird communities of four forest types – hardwood forest, mixed pine and hardwood forest, established longleaf pine, and recently cut and planted longleaf stands – and found significantly higher abundance and species richness in established and recently planted longleaf stands. In another TNF study, Womack and Wilson (2003) found that fire frequency (and thus canopy openness) was positively correlated with avian species richness. Although Shurette et al. (2007) found no significant difference in species richness between managed and unmanaged sites at TNF, they did find a pattern similar to ours in that there were more species found uniquely within managed stands.

Relevant coastal longleaf pine studies include that of Conner et al. (2002) on the effects of management practices directed toward red-cockaded woodpecker maintenance on non-targeted bird species. These authors found a significantly higher species richness and bird abundance in managed areas. Similar effects have been observed in forests undergoing restoration to open up canopies and promote understory development, including studies done in a coastal plain longleaf pine forest in Mississippi (Wood et al. 2004), a shortleaf pine-bluestem community in Arkansas (Masters et al. 2002), and for several target species (Bachman's sparrow, Henslow's sparrow [*Ammodramus henslowii* Audubon], and sedge wren [*Cistothorus platensis* Latham]) in a restored grassland community in southern Mississippi (Brennan et al. 1995; Brooks and Stouffer 2011). Our results, thus, concur with a number of regional studies suggesting overall positive effects of typical management practices (stand thinning, hardwood control, prescribed fire) on understory development, bird abundance and species diversity, and the attraction and maintenance of bird species dependent in some way upon open canopy conditions.

Many publicly and privately protected forests in the southeastern United States and elsewhere are in some stages of fire suppression, which has lead to high tree densities and reduced understory development (Nowacki and Abrams 2008). By demonstrating avifaunal correlations with vegetative changes resulting from commonly practiced management techniques that open the canopy, our results should be informative to land managers interested in restoring fire-suppressed forests. As managed stands within the BCLPMA begin to build canopy, it will likely be necessary to maintain open canopy conditions as a means of maintaining the bird community differences observed in our study. If managed consistently with prescribed fire (as currently planned), we expect the managed stands (H and I) to ultimately converge in overall vegetative and bird community characteristics. Given that these stands lie within a matrix of either commercial plantation (monoculture) pines or fire-suppressed mixed pines and hardwoods, active management will thus be necessary to promote maximum avian diversity within the BCLPMA. Since most of the bird species we studied have wide distributional ranges (i.e., are not restricted in any way to longleaf pine forests), we expect them to respond in similar ways to variation in canopy and understory development in forests in other areas of their ranges.

ACKNOWLEDGMENTS

We thank the Berry College Student Work Office, Council for Student Scholarship Committee, School of Mathematics and Natural Sciences (Dean D. B. Conn), and the National Fish and Wildlife Foundation and Southern Company Longleaf Legacy program for funding. We are further indebted to the Biology Department for providing equipment, and to President S. Briggs, the Educational Land Management program, and the Forestry and Land Management Office (Director W. Yeomans) for allowing us to work in the BCLPMA and for logistical support (especially with prescribed fire). The spring 2009 Forest Ecology class provided considerable help collecting vegetative data, and several anonymous reviewers of an earlier version of this manuscript provided invaluable critiques; our thanks go out to them as well.

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APPENDIX A. BIRD SPECIES DETAILS

Bird species encountered during survey work in the Berry College Longleaf Pine Management Area (BCLPMA), along with number of observations in each management type, dietary, foraging, and nesting guilds designations, and residency status. Table is sorted by number of observations in heavily managed (H), intermediately managed (I), and unmanaged (U) stands, in that order.

			Number of Observations					Guild Designations [a]		
Scientific Name	Authority	Common Name	H	I	U	Total	DIET [b]	FORAGE [c]	NEST [d]	Residency [e]
Thryothorus ludovicianus	Latham, 1790	Carolina wren	209	212	180	601	I	G	CVB	Y
Baeolophus bicolor	Linnaeus, 1766	tufted titmouse	191	134	123	448	O	F	CVB	Y
Regulus satrapa	Lichtenstein, 1823	golden-crowned kinglet	136	35	52	223	I	F	CN	W
Melanerpes carolinus	Linnaeus, 1758	red-bellied woodpecker	134	99	54	287	I	B	CVB	Y
Cardinalis cardinalis	Linnaeus, 1758	northern cardinal	105	26	39	170	S	G	SN	Y
Piranga rubra	Linnaeus, 1758	summer tanager	98	109	37	244	I	F	CN	SB
Poecile carolinensis	Audubon, 1834	Carolina chickadee	97	105	79	281	O	F	CVB	Y
Setophaga discolor	Vieillot, 1809	prairie warbler	87	1	0	88	I	F	SN	SB
Passerina cyanea	Linnaeus, 1766	indigo bunting	84	27	6	117	I	F	SN	SB
Picoides pubescens	Linnaeus, 1766	downy woodpecker	75	76	34	185	I	B	CVB	Y
Zenaida macroura	Linnaeus, 1758	mourning dove	58	62	51	171	S	G	CN	Y
Picoides villosus	Linnaeus, 1766	hairy woodpecker	55	89	42	186	I	B	CVB	Y
Cyanocitta cristata	Linnaeus, 1758	blue jay	55	86	85	226	O	G	CN	Y
Sialia sialis	Linnaeus, 1758	eastern bluebird	54	52	21	127	I	G	CVB	Y
Spinus tristis	Linnaeus, 1758	American goldfinch	51	33	17	101	S	F	SN	Y
Setophaga pinus	Wilson, 1811	pine warbler	45	99	40	184	I	B	CN	Y
Melanerpes erythrocephalus	Linnaeus, 1758	red-headed woodpecker	45	77	9	131	O	A	CVB	Y
Polioptila caerulea	Linnaeus, 1766	blue-gray gnatcatcher	36	15	9	60	I	F	CN	SB
Spizella pusilla	Wilson, 1810	field sparrow	32	3	0	35	O	G	GN	Y
Dryocopus pileatus	Linnaeus, 1758	pileated woodpecker	30	37	60	127	I	B	CVB	Y
Icteria virens	Linnaeus, 1758	yellow-breasted chat	29	2	0	31	I	F	SN	SB
Setophaga virens	Gmelin, 1789	black-throated green warbler	28	19	31	78	I	F	CN	M/SB
Sitta carolinensis	Latham, 1790	white-breasted nuthatch	27	58	26	111	I	B	CVB	Y
Pipilo erythrophthalmus	Linnaeus, 1758	eastern towhee	27	0	0	27	O	G	GN	Y
Melospiza melodia	Wilson, 1810	song sparrow	26	10	3	39	I	G	SN	Y
Corvus brachyrhynchos	Brehm, 1822	American crow	23	78	38	139	O	G	CN	Y
Turdus migratorius	Linnaeus, 1766	American robin	21	4	13	38	I	G	CN	Y
Vireo olivaceus	Linnaeus, 1766	red-eyed vireo	20	41	42	103	I	F	CN	SB

Continued

APPENDIX A. BIRD SPECIES DETAILS

Bird species encountered during survey work in the Berry College Longleaf Pine Management Area (BCLPMA), along with number of observations in each management type, dietary, foraging, and nesting guilds designations, and residency status. Table is sorted by number of observations in heavily managed (H), intermediately managed (I), and unmanaged (U) stands, in that order. (Cont'd.)

			Number of Observations					Guild Designations [a]		
Scientific Name	Authority	Common Name	H	I	U	Total	DIET [b]	FORAGE [c]	NEST [d]	Residency [e]
Tachycineta bicolor	Vieillot, 1808	tree swallow	18	17	8	43	I	A	CVB	M/SB
Regulus calendula	Linnaeus, 1766	ruby-crowned kinglet	18	9	7	34	I	F	CN	W
Molothrus ater	Boddaert, 1783	brown-headed cowbird	18	2	1	21	O	G	CN	Y
Contopus virens	Linnaeus, 1766	eastern wood-pewee	17	21	15	53	I	A	CN	SB
Passerina caerulea	Linnaeus, 1758	blue grosbeak	12	8	2	22	O	G	SN	SB
Sitta pusilla	Latham, 1790	brown-headed nuthatch	12	3	0	15	I	B	CVB	Y
Icterus spurius	Linnaeus, 1766	orchard oriole	11	1	0	12	I	F	CN	SB
Piranga olivacea	Gmelin, 1789	scarlet tanager	10	9	10	29	I	F	CN	SB
Toxostoma rufum	Linnaeus, 1758	brown thrasher	10	4	7	21	O	G	SN	Y
Zonotrichia albicollis	Gmelin, 1789	white-throated sparrow	10	3	2	15	S	G	GN	W
Archilochus colubris	Linnaeus, 1758	ruby-throated hummingbird	10	0	1	11	O	F	CN	SB
Setophaga dominica	Linnaeus, 1766	yellow-throated warbler	10	0	0	10	I	B	CN	SB
Geothlypis formosus	Wilson, 1811	Kentucky warbler	9	2	2	13	I	G	GN	SB
Troglodytes aedon	Vieillot, 1809	house wren	9	0	1	10	I	F	CVB	SB
Passer domesticus	Linnaeus, 1758	house sparrow	8	3	2	13	S	G	CVB	Y
Dumetella carolinensis	Linnaeus, 1766	gray catbird	8	1	2	11	I	G	SN	SB
Colaptes auratus	Linnaeus, 1758	northern flicker	7	12	22	41	I	G	CVB	Y
Empidonax traillii	Audubon, 1828	willow flycatcher	6	0	0	6	I	A	SN	M
Vireo solitarius	Wilson, 1810	blue-headed vireo	5	25	16	46	I	F	CN	M
Setophaga petechia	Linnaeus, 1766	yellow warbler	5	4	0	9	I	F	SN	M/SB
Sitta canadensis	Linnaeus, 1766	red-breasted nuthatch	5	1	2	8	I	B	CVB	W
Helmitheros vermivorum	Gmelin, 1789	worm-eating warbler	4	10	5	19	I	F	GN	SB
Chaetura pelagica	Linnaeus, 1758	chimney swift	4	7	3	14	I	A	CVB	SB
Spizella passerina	Bechstein, 1798	chipping sparrow	4	6	4	14	S	G	SN	SB
Mniotilta varia	Linnaeus, 1766	black-and-white warbler	4	5	1	10	I	B	GN	M/SB
Empidonax minimus	Baird, 1843	least flycatcher	4	1	8	13	I	A	CN	M
Peucaea aestivalis	Lichtenstein, 1823	Bachman's sparrow	4	0	0	4	S	G	GN	Y
Megaceryle alcyon	Linnaeus, 1758	belted kingfisher	4	0	0	4	V	A	CVB	Y

Continued

APPENDIX A. BIRD SPECIES DETAILS

Bird species encountered during survey work in the Berry College Longleaf Pine Management Area (BCLPMA), along with number of observations in each management type, dietary, foraging, and nesting guilds designations, and residency status. Table is sorted by number of observations in heavily managed (H), intermediately managed (I), and unmanaged (U) stands, in that order. (Cont'd.)

			Number of Observations				Guild Designations [a]			
Scientific Name	Authority	Common Name	H	I	U	Total	DIET [b]	FORAGE [c]	NEST [d]	Residency [e]
Sphyrapicus varius	Linnaeus, 1766	yellow-bellied sapsucker	3	9	1	13	I	B	CVB	W
Buteo lineatus	Gmelin, 1788	red-shouldered hawk	3	3	4	10	V	A	CN	Y
Empidonax virescens	Vieillot, 1818	Acadian flycatcher	3	2	2	7	I	A	CN	SB
Myiarchus crinitus	Linnaeus, 1758	great crested flycatcher	3	0	5	8	I	A	CVB	SB
Chordeiles minor	Forster, 1771	common nighthawk	3	0	0	3	I	A	GN	SB
Geothlypis trichas	Linnaeus, 1766	common yellowthroat	3	0	0	3	I	F	SN	SB
Lanius ludovicianus	Linnaeus, 1766	loggerhead shrike	3	0	0	3	I	A	CN	Y
Junco hyemalis	Linnaeus, 1758	dark-eyed junco	2	10	1	13	S	G	GN	W/Y
Sayornis phoebe	Latham, 1790	eastern phoebe	2	9	8	19	I	A	CVB	Y
Coccyzus americanus	Linnaeus, 1758	yellow-billed cuckoo	2	8	6	16	I	F	CN	SB
Setophaga pensylvanica	Linnaeus, 1766	chestnut-sided warbler	2	5	0	7	I	F	SN	M/SB
Quiscalus quiscula	Linnaeus, 1758	common grackle	2	2	3	7	O	G	CN	Y
Vermivora cyanoptera	Linnaeus, 1766	blue-winged warbler	2	1	1	4	I	F	GN	M/SB
Vireo griseus	Boddaert, 1783	white-eyed vireo	2	0	1	3	I	F	SN	SB
Setophaga ruticilla	Linnaeus, 1758	American redstart	2	0	0	2	I	F	CN	M
Accipiter cooperii	Bonaparte, 1828	Cooper's hawk	2	0	0	2	V	A	CN	Y
Sturnus vulgaris	Linnaeus, 1758	European starling	1	10	0	11	I	G	CVB	Y
Mimus polyglottos	Linnaeus, 1758	northern mockingbird	1	6	1	8	O	G	SN	Y
Buteo jamaicensis	Gmelin, 1788	red-tailed hawk	1	5	3	9	V	A	CN	Y
Certhia americana	Bonaparte, 1838	brown creeper	1	2	4	7	I	B	CN	W
Bombycilla cedrorum	Vieillot, 1808	cedar waxwing	1	2	2	5	S	F	CN	W/Y
Vireo flavifrons	Vieillot, 1808	yellow-throated vireo	1	1	1	3	I	F	CN	SB
Setophaga coronata	Linnaeus, 1766	yellow-rumped warbler	1	1	0	2	I	F	CN	M/W
Megascops asio	Linnaeus, 1758	eastern screech-owl	1	0	1	2	I	A	CVB	Y
Bubo virginianus	Gmelin, 1788	great horned owl	1	0	1	2	V	A	CN	Y
Setophaga palmarum	Gmelin, 1789	palm warbler	1	0	0	1	I	G	G	M
Catharus ustulatus	Nuttall, 1840	Swainson's thrush	1	0	0	1	I	F	SN	M
Seiurus aurocapilla	Linnaeus, 1766	ovenbird	1	0	0	1	I	G	G	M/SB

Continued

APPENDIX A. BIRD SPECIES DETAILS

Bird species encountered during survey work in the Berry College Longleaf Pine Management Area (BCLPMA), along with number of observations in each management type, dietary, foraging, and nesting guilds designations, and residency status. Table is sorted by number of observations in heavily managed (H), intermediately managed (I), and unmanaged (U) stands, in that order. (Cont'd.)

			Number of Observations					Guild Designations [a]		
Scientific Name	Authority	Common Name	H	I	U	Total	DIET [b]	FORAGE [c]	NEST [d]	Residency [e]
Setophaga citrina	Boddaert, 1783	hooded warbler	1	0	0	1	I	F	SN	SB
Protonotaria citrea	Boddaert, 1783	prothonotary warbler	1	0	0	1	I	B	CVB	SB
Spinus pinus	Wilson, 1810	pine siskin	1	0	0	1	S	F	CN	W
Sturnella magna	Linnaeus, 1758	eastern meadowlark	1	0	0	1	I	G	GN	Y
Meleagris gallopavo	Linnaeus, 1758	wild turkey	1	0	0	1	O	G	GN	Y
Hylocichla mustelina	Gmelin, 1789	wood thrush	0	6	6	12	I	G	CN	SB
Setophaga fusca	Muller, 1776	Blackburnian warbler	0	2	0	2	I	F	CN	M
Carpodacus mexicanus	Muller, 1776	house finch	0	2	0	2	S	G	CN	Y
Oreothlypis ruficapilla	Wilson, 1811	Nashville warbler	0	1	2	3	I	F	GN	M
Falco sparverius	Linnaeus, 1758	American kestrel	0	1	0	1	I	G	CVB	Y
Vermivora chrysoptera	Linnaeus, 1766	golden-winged warbler	0	0	1	1	I	F	GN	M/SB
Colinus virginianus	Linnaeus, 1758	northern bobwhite	0	0	1	1	O	G	GN	Y
		Total	2180	1831	1267	5278				

[a] Source: Cornell Lab of Ornithology (2011).

[b] Dietary guild: I = insects, S = seeds or fruits, V = vertebrates, O = omnivorous.

[c] Foraging guild: A = aerial, B = bark, F = foliage, G = ground.

[d] Nesting guild: CN = canopy, CVB = cavity, bank, or building, SN = shrub, GN = ground.

[e] Residency status: Y = year round resident and breeder, SB = summer resident and breeder, M = migratory non-breeding, W = winter non-breeding. Species with multiple designations (e.g., M/SB) are on the borders of ranges in the BCLPMA.