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# A BIRD COMMUNITY ON THE EDGE: HABITAT USE OF FOREST SONGBIRDS IN EASTERN OKLAHOMA

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*Abstract***.** Several species of forest songbirds reach a western limit of their respective distributions in eastern Oklahoma. The relative influence of various habitat variables on patterns of occurrence in this region may differ from those same influences in the core of species' ranges. We examined the influence of 16 habitat variables on the occurrence and density of a suite of forest songbirds. We sampled breeding birds with four, fixed-radius point counts along 1-km transects at 75 forested sites in eastern Oklahoma in 2006. Forest cover at fine scales varied by numerous structural characteristics (e.g., canopy cover) as well as species composition (e.g., pines vs. hardwoods). We performed both Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) ordinations using 16 environmental variables and 37 bird species to examine bird habitat relationships. Forward Selection in CCA indicated that the most important environmental variables affecting bird habitat relationships were the amount of forest cover in the surrounding landscape matrix, and at a local scale, canopy height and elevation.

*Key Words:* forest songbirds, Oklahoma, Ouachitas, Ozarks, canonical correspondence analysis, distribution.

## UNA COMUNIDAD DE AVES EN EL MARGEN: EL USO DEL HÁBITAT DE AVES CANTORAS EN BOSQUE ORIENTAL DE OKLAHOMA

*Resumen.* Varias especies de paserinos selváticos norteamericanos alcanzan el límite occidental de sus respectivas distribuciones en el este de Oklahoma. La influencia relativa de varios variables de hábitat en los matices de incidencia de especies en esta región podría ser distinta de la misma influencia en el núcleo del alcance de las especies. Examinamos la influencia de 16 variables de hábitat en la incidencia y la densidad de una gama de paserinos selváticos. En el 2006, mostreamos las aves nidificantes con cuatro conteos de punto fijados a lo largo de transectos de un kilómetro en 75 sitios aforestados en el este de Oklahoma. La cobertura de bosque en pequeña escala variaba en numerosas características estructurales (por ejemplo, la cobertura de bosque) así como la composición de especies (por ejemplo, los pinos y la madera dura). Ejecutamos análisis de correspondencia (DCA & CCA) utilizando 16 variables ambientales y 37 especies de aves para examinar las relaciones entre las aves y sus hábitats. La selección adelantada en el CCA indicó que los variables ambientales más importantes que influencian las relaciones entre las aves y sus hábitats eran el porcentaje de cobertura de bosque, la altura del dósel y la estatura de los árboles.

## INTRODUCTION

Partners in Flight's (PIF) strategic planning for avian conservation has focused on developing objective criteria for ranking priority species and developing ecoregion-specific management prescriptions (Bonney et al. 1999, Beissinger et al. 2000, Carter et al. 2000). Many species of forest birds in eastern North America occur predominantly in large forest tracts (e.g., Galli et al. 1976, Robbins et al. 1989, Freemark et al. 1995). Rich et al. (2004) identified an "Eastern Avifaunal Biome" in which 17 of 44 Species of Continental Importance were dependent on mature deciduous forest. They called for "comprehensive forest planning on all public lands" to maintain these species (Rich et al. 2004). Broad conservation objectives for species at regional and continental scales, however, can be difficult to translate to the finer scale where land

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use decisions are typically made, (e.g., municipal and regional planning offices).

Management prescriptions for forest birds have been provided by Whitcomb et al. (1981), Lynch and Whigham (1984), Robbins et al. (1989), and Freemark and Collins (1992). Due to variability across the area over which forest birds breed in the eastern United States, however, it is difficult to generalize across entire species distributions, and untenable to assume that a relationship determined in one ecoregion can be assumed to apply to another.

In some studies (e.g., Rodewald and Yahner 2000, Hagan and Meehan 2002, Lee et al. 2002), variability in stand-level characteristics, weather conditions, or food availability exerted a greater influence on forest bird populations than did forest cover in the local landscape. In other studies (e.g., Hall 1984, Holmes and Sherry 1988, Rotenberry et al. 1995, Nagy and Holmes 2005), broad scale forest area, isolation, or pattern was important to maintaining quality habitat for forest birds.

O'Connell et al. (2000) described qualitative changes in forest bird communities related to forest extent in the local matrix, and Rodewald (2002, 2003) and Hagan and Meehan (2002) stressed the importance of considering the influence of the disturbance matrix type (e.g., agricultural or silvicultural) in non-forested landscapes. Even within a species, it is difficult to apply general management guidelines everywhere it occurs. For example, Trine (1998) surmised that Wood Thrush (*Hylocichla mustelina*) might need forested tracts >2500 ha to support "source" populations in the Midwest, but Hoover et al. (1995) demonstrated high rates of nest success over a wide range of forested tract sizes (approximately 127 to >10 000 ha) in Pennsylvania.

Approximately 30 forest birds from the eastern United States reach a western range limit in Oklahoma. These include the PIF priorities Ovenbird, Kentucky Warbler, Hooded Warbler, Worm-eating Warbler, Acadian Flycatcher, and Cerulean Warbler (Reinking 2004, Rich et al. 2004). (Table 2 lists scientific names for most species mentioned in the text.) Some of these species are confined to the easternmost counties while others (e.g., Black-and-White Warbler, Northern Parula, and Louisiana Waterthrush [*Seiurus motacilla*]) breed at least 400 km farther west (Reinking 2004).

There are no widely published studies that specifically focus on habitat relationships of forest songbirds on the western edge of the eastern deciduous forest in North America. The ability of these species to occur in fragmented forests on the periphery of their breeding ranges illustrates that their patterns of habitat use can be quite different from that evidenced closer to the core of their ranges. It is important to understand these relationships in the broad zone where eastern forests transition to western grasslands. Effective management for forest songbirds in this ecotone can be augmented by a better understanding of the influence of broad- and fine-scale habitat attributes in Oklahoma ecoregions.

We studied the influence of 16 environmental variables on the distribution and abundance of forest songbirds in eastern Oklahoma. Our main objective was to describe specific elements of vegetation structure and composition that provide suitable conditions for multiple forest-breeding songbirds. We tested the hypothesis that a forested matrix in the local landscape explains the greatest amount of variability in the abundance of multiple forest-breeding songbirds at the western edge of the eastern deciduous forest.

## METHODS

### Study Area

We studied forest songbirds in the Ouachita Mountains and Ozark Highlands of eastern Oklahoma, with study sites in Latimer, Leflore, Pushmataha, McCurtain, Delaware, Cherokee, Washington, and Adair counties (Fig. 1). The Ouachita Mountains occupy approximately 54 000 km$^2$, including portions of 26 Arkansas and 10 Oklahoma counties (Rafferty and Catau 1991). The range is characterized by an east to west orientation, with multiple ridges extending approximately 362 km east to west and 160 km north and south.

The Ouachita region remains one of the largest and most contiguously forested areas in the eastern United States. More than 3200 km$^2$ in this region are managed for mature or old-growth type forests (Chipley et al. 2003). Habitats in this area consist of upland shortleaf (*Pinus echinata*) and loblolly pine (*P. taeda*), mixed pine-hardwood, and oak (*Quercus*)-hickory (*Carya*) forests. Bottomland forests are characterized by oak-gum (*Nyssa*)-cypress (*Taxodium*) or elm (*Ulmus*)-ash (*Fraxinus*)-cottonwood (*Populus*) forests (Chipley et al. 2003). The unusual orientation of the ridges results in markedly different communities on either side of the ridgeline (typically mesic on north faces and xeric on south faces).

The Ozark Highlands occupy a wide region (approximately 21 000 km$^2$) in southern Missouri, Arkansas and northeastern Oklahoma. This region consists of low mountains that are dominated by oak-hickory forests

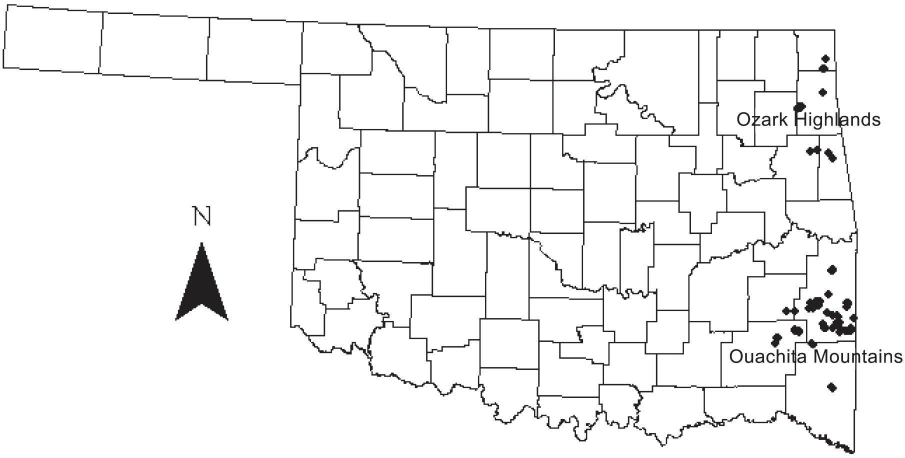


FIGURE 1. Map of the study area in Eastern Oklahoma. Sites are represented by 1-km circular buffers around each site.

(Brye et al. 2004), and it supports some of the most extensive forests in central North America (Chipley et al. 2003). The western edge of the Ozark Mountains extends into northeastern Oklahoma where, relative to the Ouachitas to the south, a more even distribution of oak-hickory forest predominates.

### Bird Surveys

We opportunistically selected and surveyed 75 forest sites in the Ozark and Ouachita regions of eastern Oklahoma in 2006. We selected sites to represent gradients of forest cover, elevation, slope, and tree species composition, e.g., amount of overstory pine. We sampled each site once from May to June 2006. Each site consisted of 4 plots spaced 250 m apart along a 1-km transect.

Two observers independently surveyed for breeding songbirds at plots using 6-min, 100-m, fixed-radius point counts. These counts took place from local sunrise to approximately 10:30 CDT (Hutto et al. 1986, Ralph et al. 1995). During point counts, we counted all singing males within 100 m of plot center and noted the time of first detection for each individual as within the first, middle, or final 2 min of the 6-min count. Recording data on singing males in discrete time bands allowed us to apply *post-hoc* removal models to the data (Farnsworth et al. 2002, online supplement) to calculate an observer-specific probability of detection for each species. We then divided the raw number of each species detected on a count by the observer specific detection probability to derive a detection-adjusted estimate of abundance that would permit direct comparison among species and observers. We calculated breeding density at a site by dividing the detection-adjusted abundance by the total area sampled per site (13 ha).

### Environmental Variable Surveys

We considered environmental variables at three scales and quantified vegetation structure modeled on Martin et al. (1997). The plot scale included variables most closely associated with the point from which we conducted a count. We established three vegetation sampling plots 15 m from each point count center at 0, 120, and 240 azimuth degrees. Each sampling plot was a circle of 5 m radius within which we ocularly estimated percent ground cover of grasses, forbs, and dead leaves. We quantified percent shrub cover (leaves associated with woody stems < 10 cm dbh) in these plots as low (<2 m) and high (≥2 m). We used a standardized graphical template to assist all ocular estimates of percent cover.

For trees ≥ 10 cm dbh, we used an angle gauge to estimate basal area from each vegetation plot, and counted the stems of all species included in the basal area calculation. We ocularly estimated percent canopy closure over the vegetation plots and estimated canopy height with a clinometer. We also used the clinometer to estimate percent slope from each point count center and recorded elevation using a Global Positioning System (GPS) receiver.

For analysis, we summarized percent ground and shrub cover, basal area, tree species composition, and canopy height as plot level variables across the 300 point count locations surveyed.

For site scale variables, we averaged percent canopy closure over all plots along a transect ($n$ = 12) as well as elevation, slope, and aspect recorded at each point count center ($n$ = 4).

To characterize the broad scale landscape matrix surrounding sites, we used a GPS to obtain geographic coordinates for the midpoint of each transect. From the midpoint coordinates, we created a 1-km buffer (314 ha around the midpoint) in ArcMap version 9.2 to examine land cover around each site. We overlaid buffers on a land-cover layer developed for the Oklahoma Gap Analysis Project (Fisher and Gregory 2001). We used Hawth's tools in ArcMap to calculate percent land-cover of forest, agricultural, and urban categories.

### Data and Statistical Analysis

We used CANOCO (ter Braak and Smilauer 1988) to explore relationships among breeding bird densities and habitat variables with detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA). DCA can be used for examining species data in relation to known habitat gradients or as an exploratory tool to reveal potential gradients (Kirk and Hobson 2001). We used DCA for graphical exploratory data analysis. CCA is a multivariate ordination technique for comparing species abundance data with multiple environmental factors (ter Braak 1986). In addition to the graphical representation of data spread in a biplot (MacFaden and Capen 2002), a CCA reveals the relative contribution of each explanatory variable to the variance in the response variable. We selected CCA because it is robust to analysis with multiple correlated variables (Palmer 1993). From an initial examination of the correlation matrix of environmental variables, we eliminated from analysis several that were redundant with other variables, but were left with multicollinearity among 16 environmental variables we used for the CCA. Of the 16 variables (Table 1) 11 were continuous and 5 (tree species composition in plots) were nominal. We eliminated bird species from the analyses if we had fewer than 10 observations among the 300 point counts. We relaxed this criterion only for the Cerulean Warbler because of its status as a priority species for conservation. We ultimately included detection-adjusted abundance data for 37 species in the DCA and CCA.

We were interested in the overall importance of each of the environmental variables in explaining bird species habitat relationships. To determine the relative importance of the variables, we used forward step-wise selection during the CCA in CANOCO. This process tested individual effects of each of the environmental variables (marginal effects) and the effect that each variable had in addition to the variables that have already been selected (conditional effects) (Leps and Smilauer 2003). To assess deviation from a randomly generated distribution, we applied Monte Carlo estimation (499 permutations) to the forward selection procedure (Leps and Smilauer 2003).

TABLE 1. Environmental variables included in Canonical Correspondence Analysis. Variables are arranged by the scale of measurement or summation: plot (average over three, 5-m plots per sampling location), site (average over four points per 1000-m transect), and landscape (condition within 314-ha area centered on the midpoint of the transect).

| Variable (scale) | Abbreviation |
|---|---|
| percent forest cover (landscape) | per Fc |
| average percent canopy cover (site) | Av Pr CC |
| elevation (site) | elev |
| percent slope (site) | slope |
| basal area (plot) | BASAR |
| canopy height (plot) | Canht |
| percent leaf ground cover (plot) | perleco |
| percent grass cover (plot) | pergrco |
| percent herbaceous ground cover (plot) | perheco |
| percent shrubs < 2 m (plot) | pr lunco |
| percent shrubs ≥ 2 m (plot) | hunco |
| cross timbers oak forest (plot) | cross |
| hickory forest (plot) | hick |
| oak-hickory forest (plot) | oakhick |
| other hardwood forest (plot) | other |
| pine forest (plot) | pine |

## RESULTS

### Overview

Sampled sites exhibited a range of forested condition from mature oak-hickory forests on north facing slopes in the Ozark Highlands and Ouachita Mountains to bottomland hardwood-cypress forests in extreme southeastern Oklahoma to short rotation pine plantation forestry in McCurtain, Pushmataha, and LeFlore counties. Some sites included forest edges with other land uses (e.g., pasture, residential development) represented. Elevation ranged from 135 m at Beaver's Bend State Park in McCurtain County to 716 m on Lynn Mountain in LeFlore County. Forest cover in landscape buffers ranged 18–100%, although most sites had >75% cover. In sampled plots, canopy cover ranged 14–75% and the range of canopy height was 5–22 m.

We encountered 74 species during point counts at 75 sites in 2006. The five most abundant species detected in the study area were

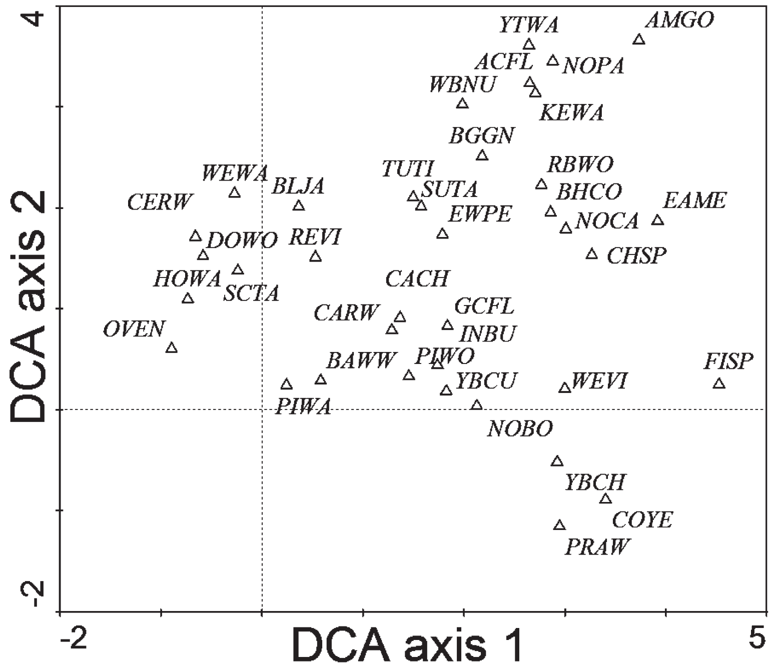


FIGURE 2. Detrended Correspondence Analysis biplot of bird species abundance data. Axis 1 sorts along a gradient of forest cover; Axis 2 is generally associated with moisture. Table 2 lists species names for alpha codes.

Red-eyed Vireo (416), Indigo Bunting (208), Tufted Titmouse (154), Pine Warbler (133), and Carolina Chickadee (111).

### Detrended Correspondence Analysis

The DCA indicated two important gradients of species abundance (Fig. 2). Axis 1 sorted species according to reliance on forest cover, with forest species such as Scarlet Tanager, Ovenbird, and Cerulean Warbler on the left grading to grassland and shrubland species such as Eastern Meadowlark and Field Sparrow on the right. Axis 2 was not readily interpretable but may have been driven by moisture, (e.g., soil moisture and relative humidity) The cluster of Yellow-throated Warbler, Acadian Flycatcher, and Kentucky Warbler (obligate–facultative riparian forest species) in the top panel of the biplot contrasts with Prairie Warbler, Common Yellowthroat, and Yellow-breasted Chat (species associated with regenerating clearcuts) in the bottom panel.

### Canonical Correspondence Analysis

CCA indicated that 38% of the variance in species abundance was explained by 15 environmental variables. Nine of those variables, representing a mix of site- and plot-scale vegetation structure, produced significant conditional effects (Table 3). Site-scale average percent forest cover explained a greater proportion of the variance in forest bird abundance (8%) than any other variable.

The CCA biplot (Fig. 3) like the DCA illustrated primary axes related to gradients of forest cover and moisture. Species such as Ovenbird, Hooded Warbler, Cerulean Warbler, and Scarlet Tanager tended to co-occur and were associated positively with elevation and forest cover. In contrast, Yellow-breasted Chat, Prairie Warbler, and Common Yellowthroat were positively associated with grass and herbaceous cover. The cluster of Kentucky Warbler, Acadian Flycatcher, Yellow-throated Warbler, and Northern Parula was associated with bottomland hardwood forests, which tended to exhibit high plot-scale canopy cover and the highest canopy heights (> 20 m) of any sites surveyed.

## DISCUSSION

In agreement with Holmes and Sherry (1998), O'Connell et al. (2000), and Nagy and Holmes (2005), we found that a broad scale forested matrix was the primary determinant in explaining the distribution and abundance of

TABLE 2. List of 37 species included in the Canonical Correspondence Analysis in descending order from most to least abundant.

| Species | Scientific name | Alpha code |
|---|---|---|
| Red-eyed Vireo | *Vireo olivaceus* | REVI |
| Indigo Bunting | *Passerina cyanea* | INBU |
| Tufted Titmouse | *Baeolophys bicolor* | TUTI |
| Pine Warbler | *Dendroica pinus* | PIWA |
| Carolina Chickadee | *Poecile atricapilla* | CACH |
| Ovenbird | *Seiurus aurocapillus* | OVEN |
| Summer Tanager | *Piranga rubra* | SUTA |
| Black-and-White Warbler | *Mniotilta varia* | BAWW |
| Carolina Wren | *Thryothorus ludovicianus* | CARW |
| Northern Cardinal | *Cardinalis cardinalis* | NOCA |
| Blue-gray Gnatcatcher | *Polioptilla caerulea* | BGGN |
| Yellow-breasted Chat | *Icteria virens* | YBCH |
| Northern Parula | *Parula americana* | NOPA |
| Scarlet Tanager | *Piranga olivacea* | SCTA |
| Eastern Wood-Pewee | *Contopus virens* | EWPE |
| White-eyed Vireo | *Vireo griseus* | WEVI |
| Kentucky Warbler | *Oporornis formosus* | KEWA |
| Acadian Flycatcher | *Empidonax virescens* | ACFL |
| White-breasted Nuthatch | *Sitta carolinensis* | WBNU |
| Prairie Warbler | *Dendroica discolor* | PRWA |
| Red-bellied Woodpecker | *Melanerpes carolinus* | RBWO |
| Yellow-billed Cuckoo | *Coccyzus americanus* | YBCU |
| Common Yellowthroat | *Geothlypis trichas* | COYE |
| Hooded Warbler | *Wilsonia citrina* | HOWA |
| Field Sparrow | *Spizella pusilla* | FISP |
| Brown-headed Cowbird | *Molothrus ater* | BHCO |
| Northern Bobwhite | *Colinus virginianus* | NOBO |
| Yellow-throated Warbler | *Dendroica dominica* | YTWA |
| American Goldfinch | *Carduelis tristis* | AMGO |
| Great Crested Flycatcher | *Myiarchus crinitus* | GCFL |
| Blue Jay | *Cyanocitta cristata* | BLJA |
| Pileated Woodpecker | *Dryocopus pileatus* | PIWO |
| Downy Woodpecker | *Picoides pubescens* | DOWO |
| Chipping Sparrow | *Spizella passerina* | CHSP |
| Eastern Meadowlark | *Sturnella magna* | EAME |
| Worm-eating Warbler | *Helmitheros vermivora* | WEWA |
| Cerulean Warbler | *Dendroica cerulea* | CERW |

TABLE 3. Conditional effects from Monte Carlo estimation of forward selection in Canonical Correspondence Analysis (CCA). The CCA explained 38% of total variance in abundance of 37 bird species.

| Variable | Order in model | Eigenvalue | *F* | *P* | Explained variance (%) |
|---|---|---|---|---|---|
| Forest cover (%) | 2 | 0.17 | 6.39 | 0.002 | 8.00 |
| Canopy height (m) | 11 | 0.11 | 4.37 | 0.002 | 5.00 |
| Elevation (m) | 5 | 0.10 | 4.17 | 0.002 | 5.00 |
| Pine overstory (%) | 6 | 0.08 | 3.31 | 0.002 | 4.00 |
| Herbaceous (%) | 13 | 0.07 | 3.20 | 0.002 | 3.00 |
| Basal area ($m^2$ $plot^{-1}$) | 15 | 0.04 | 1.88 | 0.004 | 2.00 |
| Canopy cover (%) | 1 | 0.04 | 1.67 | 0.014 | 2.00 |
| Leaf litter cover (%) | 14 | 0.04 | 1.74 | 0.018 | 2.00 |
| Shrub cover (<2 m) % | 3 | 0.03 | 1.55 | 0.042 | 1.00 |
| Cross | 7 | 0.03 | 1.45 | 0.094 | 1.00 |
| Shrub cover (≥2 m) % | 4 | 0.03 | 1.06 | 0.382 | 1.00 |
| Mean slope (%) | 10 | 0.02 | 0.99 | 0.498 | 1.00 |
| Oak-hickory (%) | 8 | 0.02 | 0.88 | 0.608 | 1.00 |
| Grass cover (%) | 12 | 0.02 | 0.84 | 0.694 | 1.00 |
| Hickory overstory (%) | 9 | 0.01 | 0.59 | 0.95 | 0.05 |

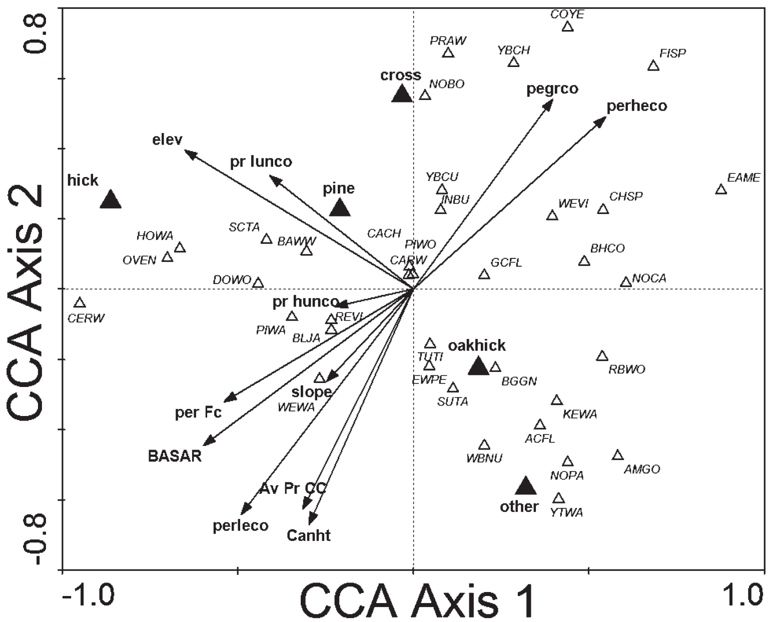


FIGURE 3. Canonical Correspondence Analysis biplot of ordination between bird species abundance and 16 environmental variables. Environmental variable codes are provided in Table 1 and bird species codes in Table 2.

forest songbirds. The amount of forest cover in a 314-ha buffer around the midpoint of sample sites accounted for 8% of the total variance in songbird abundance.

Variability in the distribution and abundance of breeding forest birds was well explained by the suite of multi-scale environmental variables we included in exploratory data analysis with DCA and CCA. Forward selection in CCA indicated that a 15-variable model explained 38% of the total variation in abundance among 37 bird species. In addition to percent forest cover in the local landscape, the model included five other variables with Eigenvalues that were significant at a < 0.01: canopy height (plot), elevation (site), percent overstory pine (plot), percent herbaceous cover (plot), and tree basal area (plot). Eigenvalues significant at a < 0.05 included average percent canopy cover (site), percent leaf litter (plot), and the percent cover of shrubs < 2 m in height (plot). These results make it difficult to interpret a firm conclusion to a test of the hypothesis that landscape matrix is the primary driver of variability of abundance of forest breeding birds at the western edge of the eastern deciduous forest. Among individual variables, landscape forest matrix explained the greatest amount of variability at 8%, but the subsequent 8 variables in the model (a mix of plot- and site-level characteristics) accounted for the next 24 percent. General forest cover is important, but an understanding of forest bird distribution and abundance is incomplete without information on elevation, tree species composition, tree stature, and understory cover.

Partners in Flight has developed a Bird Conservation Plan for the Ozark/Ouachitas with a list of species presented as being conservation priorities for this region (Fitzgerald and Pashley 2000). Our study provides additional information about bird habitat relationships that has management implications for a number of these priority species within the Oklahoma portions of their respective ranges.

For example, several species, including the high priority Cerulean Warbler, responded strongly to a gradient of elevation. Our study revealed that at the southwestern edge of the species' distribution, Cerulean Warbler is associated with dense forest stands at the highest elevations. If blocks of high-elevation forests in the Ozark/Ouachita region that have maximum size and canopy of overstory trees remain intact, conservation of the Cerulean Warbler will be enhanced. Additional priority species that could benefit from management that promotes mature forests at high elevation include Ovenbird and Worm-eating Warbler.

High elevation forests in eastern Oklahoma provide a relatively cooler and wetter microclimate than prevailing conditions for the region, supporting a mesic deciduous forest more typical of areas farther east and north. Some global warming scenarios forecast that Oklahoma will be generally warmer and drier in the future (American Bird Conservancy 2006). This could mean an end to the conditions suitable for the growth of high-elevation, mesic forests in Oklahoma and a likely range contraction for priority species that depend on these forests at the southwestern edge of their breeding range.

In addition to high elevation forests, our results indicate that bottomland forests also provide habitat for priority species in Oklahoma. Kentucky Warbler and Acadian Flycatcher were positively associated with canopy height and percent canopy cover, but were negatively associated with elevation. These species also sorted strongly toward the wetter end of the moisture gradient, suggesting their reliance on mature, bottomland forest. Again, drier conditions forecast for the future could lead to range contractions, and management should strive to promote large blocks of mature bottomland forest.

Conservation priority species that are not dependent on mature forests were also represented in the data. Prairie Warbler, Field Sparrow, and Northern Bobwhite responded well to high grass and herbaceous cover and consequently lower forest cover, canopy cover, and canopy height. Dramatic changes in future condition for the region could lead to management opportunities for these species.

A challenge for managers will be to continually monitor changing populations of birds in the region so that a general management plan pursued will be well suited to prevailing condition. For now, a diverse assemblage of breeding songbirds that typify the Eastern Avifaunal Biome (Rich et al. 2004) are well represented among the low mountains and ridges of eastern Oklahoma. These species are predictable in time and space, occur at densities similar to elsewhere in their ranges, and appear to be successfully reproducing on the edge of the eastern deciduous forest. Studies of reproductive success of multiple species would enhance our understanding of avian community ecology in forested ecosystems. As populations of eastern forest birds at their southwestern limit could be among the first to be affected by rapid climate change, such studies should pay particular attention to the interannual variation in demographic parameters that could be related to variability in temperature and precipitation.

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