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INFLUENCE OF INVASIVE EASTERN REDCEDAR ON DENSITY OF BREEDING WARBLERS IN CROSS TIMBERS FOREST

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Abstract. Several species of North American wood-warblers with population centers in the eastern U.S. reach the southwestern limit of their breeding range in Oklahoma cross timbers forest. Historically, the cross timbers was dominated by post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*), but increasingly, these patches are influenced by eastern redcedar (*Juniperus virginiana*) encroachment. We investigated the influence of eastern redcedar on breeding density of three focal species of Neotropical migrant warblers: Kentucky Warbler (*Oporornis formosus*), Black-and-white Warbler (*Mniotilta varia*), and Louisiana Waterthrush (*Seiurus motacilla*). From May–June in 2007 and 2008, we surveyed seven cross timbers forest patches in Payne County, Oklahoma. The 25 study plots within these patches represented a gradient of condition from low to high prevalence of redcedar. We used repeated samples of a modified spot-mapping approach for focal species, and fixed-radius point counts to reflect the larger breeding bird assemblage. Songbird species richness, diversity, and Partners in Flight conservation value were not affected by cedar encroachment. Among focal warblers, breeding density of Kentucky Warbler was negatively correlated with the abundance of eastern redcedar.

Key Words: Black-and-white Warbler, cross timbers forest, Eastern Redcedar, eastern songbirds, invasive species, *Juniperus virginiana*, Kentucky Warbler, Louisiana Waterthrush.

LA INFLUENCIA DEL ARBOL CONÍFERO *JUNIPERUS VIRGINIANA* EN LAS REINITAS (PARULIDAE) NIDIFICANTES DE LOS CRUZ DE MADERA DE BOSQUES

Resumen. Varias especies de chipes (Parulidae) que nidifican en Norteamérica y que tienen poblaciones centradas en el este de Estados Unidos alcanzan el límite suroccidental de su zona de distribución veraniega en los cruz de madera de bosques del estado de Oklahoma. Antiguamente, la zona del cruz de madera de bosques era dominada por las especies de roble *Quercus stellata* y *Q. marilandica*. Sin embargo, *J. virginiana* incrementa cada vez más su rango de distribución en estos bosques. Investigamos la influencia de *J. virginiana* en la densidad de nidificación de tres especies de chipes migrantes neotropicales: *Oporornis formosus*, *Mniotilta varia* y *Seiurus motacilla*. Durantes los meses de mayo y junio del 2007 y 2008, examinamos viente y cinco puntas en siete areas en la zona de cruz de madera de bosques en el ayuntamiento de Payne en Oklahoma. Las áreas representan una zona de transición de baja a alta presencia de *J. virginiana* en el subdosel en zonas cubiertas de roble. Utilizamos ejemplos repetidos del territorio de la cartografía para las especies objetivas y conteos de punto con radio fijo para hacer una representación completa de la comunidad de aves nidificantes. Riqueza de especies, la diversidad, y Compañeros en Vuelo valor de conservación no fueron afectadas por la invasión de cedro. Entre focales currucas, la densidad de cría de O. formosa se correlacionó negativamente con la abundancia *J. virginiana.*

INTRODUCTION

Several species of North American wood-warblers with population centers in the eastern U.S. reach the southwestern limit of their breeding range in Oklahoma cross timbers forest patches (DeGraaf and Rappole 1995, Sauer et al. 2008). Louisiana Waterthrush (*Seiurus motacilla*), Northern Parula (*Parula americana*), Prothonotary Warbler (*Protonaria citrea*), Kentucky Warbler (*Oporornis formosus*), and Black-and-white Warbler (*Mniotilta varia*) are relatively common breeding birds as far west as central Oklahoma (~97°W), with isolated occurrences extending even farther west (Reinking 2004). These warblers contribute

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to an assemblage of eastern forest songbirds that are able to breed successfully in cross timbers forests; other eastern forest songbirds (e.g., Ovenbird [*Seiurus aurocapilla*] and Wood Thrush [*Hylocichla mustelina*]) do not typically breed in cross timbers forest and reach their western distributional limit in the state ~150 km east (Reinking 2004). Cross timbers forests represent a stark contrast to typical breeding habitats in the core range of eastern forest songbirds, where annual precipitation may average 100–150 cm, and a more diverse community of larger canopy trees is supported. In central Oklahoma cross timbers, landscapes receive an average 75–90 cm of annual precipitation, with high interannual variability.

Historically, cross timbers habitat existed as a north–south band at the zone of transition between broad-leaf deciduous forest and tallgrass and mixed-grass prairies in the Southern Plains. A drought- and fire-maintained mosaic of cross timbers forest and tallgrass prairie was the historically dominant habitat in central Oklahoma (Rice and Penfound 1959). Cross timbers forest is characterized by a low (<18 m), continuous canopy of post (*Quercus stellata*) and blackjack oak (*Q. marilandica*), with eastern redcedar (*Juniperus virginiana*), pecan (*Carya illinoensis*), hackberry (*Celtis occidentalis*), and cottonwood (*Populus deltoides*) occasionally dominant in the canopy, especially in riparian areas. The understory may be relatively open, including regenerating canopy tree species, or it may be densely vegetated with dominants such as buckbrush (*Symphoricarpos orbiculatas*), briars (*Smilax* spp.), and poison ivy (*Toxicodendron radicans*). Understory condition is strongly influenced by the frequency and intensity of fire. Generations of fire suppression have led to a profusion of eastern redcedar in central Oklahoma rangeland and in cross timbers forest patches (Briggs et al. 2005, Clark et al. 2005).

Eastern redcedar can exert multiple ecological influences on forest patches in which it becomes invasive. The dense foliage extending to the ground physically prevents vegetative growth beneath the trees, potentially limiting regeneration of canopy oaks. Shading from redcedar also inhibits understory growth, thus decreasing the amount of fuel (e.g., grasses, forbs) that can accumulate beneath stands. Leaf-litter from this species also significantly increases the pH of surface soil beneath the trees effectively limiting vegetative growth immediately beneath the tree (Bekele et al. 2005). These factors greatlly reduce the chances of ignition in low intensity fires. As more red cedars within a stand survive periodic low intensity fires, the species becomes increasingly dominant in the canopy (DeSantis, pers. comm.), and the effectiveness of burning as a means of control is rapidly limited as tree height increases (Engle and Kulbeth 1992).

The ecology of eastern forest songbirds breeding in cross timbers forest has received little study (e.g., Schulz et al. 1992), despite the fact that at least 4 million ha of these forests remain. At least 9 of 30 species considered regional priorities for the Oaks and Prairies Bird Conservation Region of Partners in Flight (Panjabi et al. 2005) are widely distributed in cross timbers forest patches in central Oklahoma. The relative importance of these patches for these species could change due to increased fragmentation from exurban development, climatic changes (e.g., prolonged drought) that influence primary productivity, and structural and compositional changes resulting from the proliferation of invasive species, especially eastern redcedar.

To begin to understand the ecological relationships of breeding songbirds in cross timbers forest, we surveyed 25 study plots in 7 cross timbers forest patches during the spring of 2007 and 2008. We used a combination of spot mapping and point counts to obtain species assemblage data and calculate breeding density of three focal warblers: Kentucky Warbler, Black-and-white Warbler, and Louisiana Waterthrush. Our specific objectives were to 1) characterize the breeding songbird community in cross timbers forest patches, and 2) determine if the breeding density of the focal warblers is influenced by redcedar invasion.

METHODS

We surveyed cross timbers songbirds in seven forest patches ~15 km west of Stillwater in Payne County, Oklahoma (36°05'N, 97°12'W). We established three or four survey plots within each of the patches, resulting in 25 bird sampling plots. Plots were centered at least 100 m from the nearest forest edge, and arranged spatially so that plot centers within each patch were separated from each other by at least 250 m. The plots represented a gradient of eastern redcedar canopy cover from 0 to nearly 100%. We recorded UTM coordinates for plot centers in the field using a hand held GPS (Garmin Geko 201, Garmin International, Olathe, KS, USA). We used optical rangefinders to judge distances from the plot center in the field. We mapped survey plots in a GIS (ArcMap 9, ESRI, Redlands, CA, USA) using a National Agriculture Imagery Program (NAIP) 2003 photograph (USDA 2003) as the base map.

We sampled birds from the plot centers of the 25 sampling plots using a combination of

100-m, fixed-radius point counts (Toms et al. 2006) and a modified spot-mapping approach (Christman 1984) for the focal warblers. We conducted point counts during early morning hours (0530–0930 CDT) in May and June 2007 and 2008 under dry conditions with relatively light winds. We followed standard songbird sampling procedures for counts of singing males as recommended in Ralph et al. (1995) with some modifications. Point counts lasted seven minutes, and we counted only those singing males judged to be within 100 m of the plot center and using the habitat, excluding flyovers. We surveyed plots six times each in 2007 and 2008, using the mean abundance of each survey as our estimate of abundance for the season. We used counts from a single observer (JRH) to minimize observer biases. We omitted from analysis all species detected on two or fewer surveys, and assumed that species detected on at least three surveys were representing individuals on breeding territories.

To estimate breeding density of Louisiana Waterthrush, Black-and-white Warbler, and Kentucky Warbler, we made six visits (separated by at least seven days) to the plots from April through June (of 2007 and 2008) and applied a modified spot-mapping procedure. From the center point, a single observer (JRH) mapped the relative location of singing males on a schematic map of the plot (Christman et al. 1984). We conducted these counts for seven minutes per sample for a total of 42 minutes of sampling per plot per season. We considered males detected in the same region of the plot on at least three of the six visits to have been territorial. We assumed that the six visits would provide a detection probability of 1.0 for the three focal species so we estimated density within each plot as the number of territories identified divided by the area sampled (3.14 ha for each 100-m radius plot). We expressed density as the number of territories per 10 ha.

To quantify vegetation structure and composition at the plots, we established 10 m radius subplots 15 m from plot center at 0°, 120°, and 240°. In these subplots, we made visual estimates of percent ground cover in leaves, grasses, forbs, rocks, woody debris, and bare soil. We also estimated shrub cover up to 5 m and total tree canopy cover, and identified to species all trees and shrubs within the subplots. We used a clinometer to estimate canopy height and an angle gauge from plot center to estimate stand basal area (Stoddard and Stoddard 1987).

We used Spearman's rank correlation to analyze relationships between mean percent eastern redcedar cover at each site and mean songbird richness, diversity, and summed regional Partners in Flight (PIF) combined scores (Panjabi et al. 2005). We then established three categories (low = 0–5%, intermediate = 5–33%, and high = 33–100%) of eastern redcedar invasion based on the percentage of redcedar cover in the tree canopy of plots. We compared territory density of focal warblers using one-way ANOVA ($\alpha = 0.05$) among these categories. For ANOVAs, we first tested for homogeneity of variance with Levene's test. For *post-hoc* multiple comparisons, we used Tukey's test (Neter et al. 1990). We performed all statistical analysis in SPSS.

RESULTS

We encountered 35 breeding species using cross timbers forest in the study area. Composition of the species assemblages was consistent from patch to patch. Nine of the 10 most common species occupied 63% of the forest patches, while at least eight of the 10 most commonly occurring species were present in 88% of the patches. In addition, the cross timbers forests supported several species of high conservation priority. Of the 15 most commonly occurring species, seven have been categorized by Partners in Flight as being of either regional or continental concern (Table 1). Mean richness (±SD) among sites was 20 ± 2.21 (range: 18–24). Neither richness ($r = -0.704$, $P = 0.088$), diversity ($r = -0.357$, $P = 0.444$), nor summed Partners in Flight combined scores ($r = -0.750$, $P = 0.066$) were correlated with percent cover of eastern redcedar in sample plots.

Frequency of occurrence for focal warblers in patches ($n = 7$) was high. We detected territorial Black-and-white Warbler at 100%, Louisiana Waterthrush at 86%, and Kentucky Warbler at 57% of the study sites. Kentucky Warbler density was higher in plots with low redcedar cover ($F = 7.510$, df = 2 and 27, $P < 0.001$) than in plots with intermediate and high cedar cover (Fig. 1). Breeding densities of Black-and-white Warbler and Louisiana Waterthrush were not associated with percent cover of eastern redcedar ($F = 0.998$, df = 2 and 27, $P < 0.376$, and $F = 1.516$, df = 2 and 27, $P < 0.230$, respectively).

DISCUSSION

Research over the past decade has provided ample evidence to suggest that eastern redcedar can degrade native grasslands and alter grassland songbird communities (Coppedge et al. 2001, Barth 2002, Fuhlendorf et al. 2002, Chapman et al. 2004a, Briggs et al. 2005). However, little has been done to attempt to quantify this species' influence on forest bird

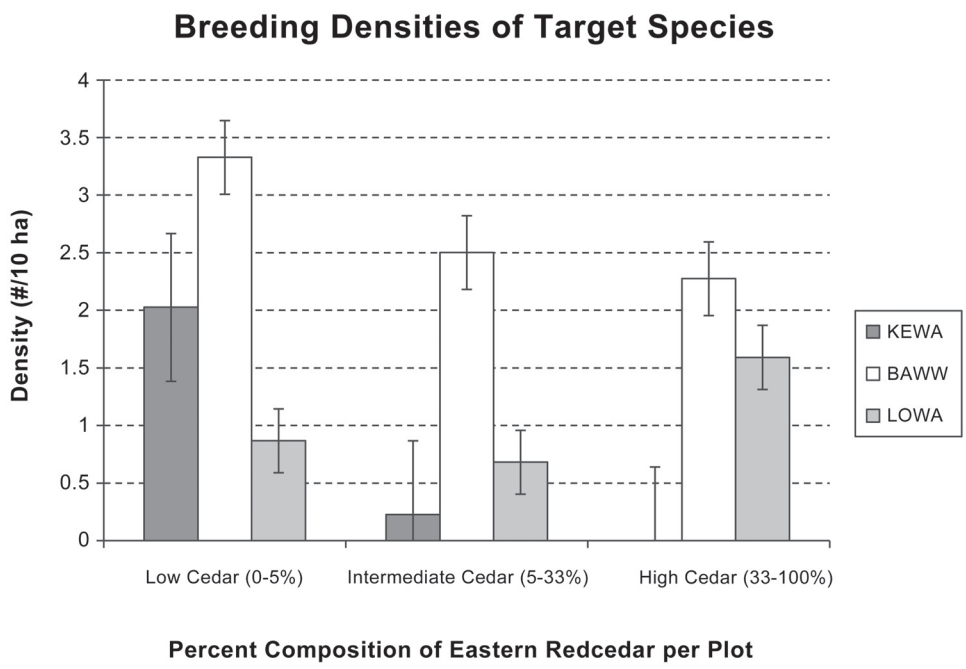

FIGURE 1. Mean breeding densities (±SE) of Kentucky Warbler, Black-and-white Warbler, and Louisiana Waterthrush in cross timbers forest study plots with low, intermediate, and high eastern redcedar (ERC) cover.

TABLE 1. Partners in Flight species assessment scores by species for the Oaks and Prairies (Region 21). Species are listed in descending order of mean relative abundance as encountered on our study plots.

Species	Rel. Ab. per Plot	RCS-b*	CC**	RC***
Northern Cardinal	1.04	10	-	-
Blue-gray Gnatcatcher	0.96	10	-	-
Tufted Titmouse	0.86	13	-	-
Carolina Chickadee	0.72	16	-	-
Black-and-white Warbler	0.53	11	-	-
Indigo Bunting	0.43	9	-	-
Field Sparrow	0.42	16	-	Y
Red-bellied Woodpecker	0.32	13	-	-
Carolina Wren	0.28	13	-	-
Yellow-billed Cuckoo	0.25	15	-	Y
Summer Tanager	0.25	15	-	Y
Blue Jay	0.25	10	-	-
Great Crested Flycatcher	0.23	15	-	Y
Painted Bunting	0.22	20	Y	Y
Kentucky Warbler	0.20	14	Y	-
Louisiana Waterthrush	0.20	15	-	Y
Red-eyed Vireo	0.19	9	-	-
Brown-headed Cowbird	0.15	12	-	-
White-eyed Vireo	0.14	11	-	-
Downy Woodpecker	0.12	11	-	-
Prothonotary Warbler	0.09	14	Y	-
Northern Parula	0.07	11	-	-
Mourning Dove	0.04	12	-	-
Hairy Woodpecker	0.04	10	-	-
Brown Thrasher	0.03	10	-	-

*RCS-b: Regional Combined Score for the breeding season (sum of scores for Breeding Distribution, Population Size, regional Population Trend, breeding Relative Density, and regional Threats to Breeding).
**CC: Continental Concern species (Y = yes, blank = no).
***RC: Regional Concern species (Y = yes, blank = no).

communities. It may be that while the spread of eastern redcedar in grasslands (and the obvious conversion from grassland to shrubland communities) has been well studied (e.g., Barth 2002), the encroachment of redcedar into the midstory of forest patches has only recently attracted significant research attention. For example, we know of just one, ongoing study that quantifies the change in basal area of redcedar in cross timbers forest during the 20th century period of encroachment (DeSantis, pers comm.).

In terms of influence on forest birds, invasive species studies have focused instead on exotic, invasive species such as *Lonicera maackii* and *Rosa multiflora* (e.g., Borgmann and Rodewald 2004). In some studies (Schmidt and Whelan 1999, Borgmann and Rodewald 2004), birds nesting in exotic shrubs experienced lower reproductive success than those that nested in native shrubs. Leston and Rodewald (2006), however, found that nest success of Northern Cardinal (*Cardinalis cardinalis*) was similar between urban (where exotic shrubs were the preferred nest substrate) and rural sites. Schmidt et al. (2005) found that Veeries (*Catharus fuscescens*) nesting in *Berberis thunbergii* experienced lower rates of nest predation than those that opted to nest on the ground. These studies indicate no clear pattern of a consistent positive or negative influence of exotic shrubs on nesting songbirds.

In terms of nesting density of the three focal warblers in this study, our results were variable as well. Kentucky Warbler density declined with increasing redcedar encroachment, with no plots containing high levels of encroachment supporting territorial males. Black-and-white Warbler also exhibited its lowest density in plots heavily invaded by redcedar, but at approximately 2 males/10 ha this species was still well represented in plots with abundant cedar. In contrast, density of Louisiana Waterthrush was positively correlated with redcedar encroachment.

Breeding Bird Survey data for Black-and-white Warbler show no significant trend either rangewide (+0.1% per year) or in Oklahoma (+0.3% per year) between 1966 and 2000. The breeding distribution of this species in central Oklahoma and throughout the cross timbers is ill-defined. The Black-and-white Warbler was indicated only as a "probable" breeding resident in Payne County in Oklahoma's Breeding Bird Atlas (Reinking 2004). Area searches of our 7 sites in 2007 produced 35 territorial males, and point count data suggest that Black-and-white Warbler is the fifth most commonly occurring songbird in these forest patches (Table 1). We also observed several (20+) cases of successful breeding over the two field seasons (all sightings were of either one or two successfully fledged young) both in forest patches with minimal cedar component as well as forest patches dominated by eastern redcedar, suggesting that despite lower breeding densities in patches with moderate to high cedar component, cedar encroachment did not significantly impact the breeding success of this species.

The density of breeding Kentucky Warblers in the study area was negatively associated with eastern redcedar invasion. We found an average breeding density of 2.1 males/10 ha at sites with low percent cover of eastern redcedar, and an overall density of 0.6 males/10 ha in cross timbers forest throughout the study site. Across its range Kentucky Warbler densities within large forest patches averaged 2.2 males/10 ha as compared to 1.4 males/10 ha in smaller forest fragments (Gibbs and Faaborg 1990).

Louisiana Waterthrush breeding density estimates from southern Illinois, New York, and Connecticut were 2.5 pairs/km, 2.8 pairs/km, and 1.0 pair/km of stream respectively (Eaton 1958, Craig 1981, Robinson 1990). We surveyed an estimated 5.4 km of stream with a mean of 0.2 km surveyed per plot. Across all plots we had a breeding density of 1.3 singing males/km of stream. Our density estimate is comparable to other density data from sites nearer the center (IL) and the northeastern limits (NY, CT) of the species' range, suggesting that the cross timbers forests may provide quality habitat for this species. Our data suggest that waterthrush distribution and abundance may be positively correlated with eastern redcedar, but this is likely an artifact of the abundance of redcedar along riparian zones in the cross timbers.

Preliminary research has provided evidence that both Kentucky Warbler and Black-and-white Warbler densities may have been reduced by redcedar encroachment. We also conclude based on this limited research that cedar is not detrimentally affecting breeding densities of Louisiana Waterthrush. We recommend that future investigations of breeding warblers in cross timbers forests examine additional aspects of breeding biology related to eastern redcedar encroachment. While this study has illustrated some patterns in the density of breeding males, we lack basic information on survivorship, nest success, and recruitment for multiple forest songbirds near the western edge of their respective ranges. This information will become increasingly important in providing a more complete picture of the use and condition of all forest habitat used by forest songbirds.

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