EFFECTS OF A TORNADO ON BIRDS IN A CROSS TIMBERS COMMUNITY

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Abstract—Tornados can influence forests by increasing openness of canopies and decreasing the frequency of large trees. These changes may indirectly influence the avian community; therefore, we monitored birds in a Cross Timbers community that had recently experienced an F3 tornado. We surveyed the avian community 6 times during summer of 2 years. We performed surveys along three transects in the impacted site, a nearby non-impacted site, and a grassland. Species richness and composition were significantly different among habitats, but these differences were not related primarily to damage by the tornado. A partial canonical-correspondence analysis suggested that differences among habitats were due to species segregating between habitats with trees (impacted and non-impacted forests) and those without trees (grassland). It appeared that the avian community did not respond strongly to impact of the tornado. We suggest that avian communities in relatively open and patchy forests, such as the Cross Timbers, will not respond as strongly to localized disturbance from wind as will communities in more mesic, closed-canopy forests. Open woodlands lack adequate habitat for species that occupy interiors of forests; these species are expected to segregate the strongest between impacted and non-impacted sites.

Resumen—Los tornados pueden modificar bosques aumentando la abertura del dosel y disminuyendo la frecuencia de árboles grandes. Estos cambios puedan influir indirectamente la comunidad de aves; en consecuencia, monitoreamos las aves en un bosque Cross Timbers donde recientemente había pasado un tornado de intensidad F3. Muestreamos la comunidad de aves 6 veces durante los veranos de 2 años. Realizamos las muestras a lo largo de tres transectos en el sitio impactado, en un sitio cercano no-impactado y en la pradera. El número de especies y la composición fueron significativamente diferentes entre hábitats, sin embargo, estas diferencias no estuvieron principalmente relacionadas al daño ocasionado por el tornado. Un análisis parcial de correspondencia canónica sugirió que las diferencias entre hábitats fueron debidas a segregación de especies entre los hábitats con árboles (bosques impactados y no-impactados) y los sin árboles (la pradera). Pareció que la comunidad de aves no respondió fuertemente al impacto del tornado. Proponemos que las comunidades de aves en un bosque relativamente abierto y con parches, como el Cross Timbers, no responderán tan fuertemente a los disturbios localizados del viento como las comunidades de aves en un bosque más húmedo y con un dosel cerrado. A los bosques abiertos les falta el hábitat adecuado para las especies del interior del bosque; se espera que estas especies segreguen más intensamente entre sitios impactados y no impactados.

Tornados are an iconic symbol of the North American Great Plains; however, their influence on communities of animals rarely has been studied. We know of only two studies relating damage by tornados to populations of birds (McClure, 1945; Prather and Smith, 2003). Lack of information on influence of tornados may be due in part to their unpredictable and localized occurrence (Peterson, 2000). It is estimated that in the United States tornados impact 450,000 ha each year (Dale et al., 2001), and tornados and other catastrophic wind storms affect structure and composition of plant communities in forested areas, particularly in the Midwest (Glitzenstein and Harcombe, 1988; Arévalo et al., 2000; Shirakura et al., 2006). Tornados increase coarse woody debris and the number of snags, and they kill larger trees (Glitzenstein and Harcombe, 1988; Peterson, 2000).

On 5 August 2003, a F3 (254–332 km h^{-1}) tornado hit a 14.48-ha stand of Cross Timbers on the western edge of The Nature Conservancy's Tallgrass Prairie Preserve, Osage County, Oklahoma. The Cross Timbers is an oak forest dominated by post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*). The tornado was responsible for a 20% rate of mortality and a 14% decrease in basal area (m^2 ha^{-1}) in the impacted stand, which changed the forest from being blackjack-dominated to post oak-dominated (Shirakura et al., 2006). The tornado killed larger trees; thus, increasing openness of canopy, woody debris, and distance between patches of forest.

We examined response of the avian community to the forest that was impacted by the tornado by comparing species composition and richness within the impacted site with composition in a nearby grassland and non-impacted forest. We sampled three transects in 2004 and 2005, one in each habitat (impacted forest, non-impacted forest, and grassland) that were either within or near the area damaged by the tornado (Fig. 1). We collected data for 5 min using variable circular-plot point counts (Ralph, 1993). Surveys were conducted during 0600–0900 h, 3 times/year (late May, mid-June, and early July), and all surveys at the same site were ≥2 weeks apart. We sampled four points in each transect 3 times/year. Each point that was sampled within a single transect was 200 m apart.

We used all visual and audible observations within 100 m of a monitoring point to characterize avian communities in each habitat. First, we tested for spatial and temporal autocorrelation in abundance, richness, and species composition by calculating distance matrices (Bray–Curtis distance for species and Euclidian distance for all other matrices) and then by performing Mantel tests with 3,000 constrained permutations of the explanatory distance matrix (Legendre and Legendre, 1998). To test for spatial autocorrelation within habitats, we constrained the permutation of the geographicdistance matrix to occur only within a single habitat, and to test for temporal autocorrelation, we constrained permutations of the temporal-distance matrix to occur only at the observed sampling site. We found that spatial dependence for abundance (Pearson's correlation coefficient: $r = 0.01$, $P = 0.80$), richness ($r = -0.02$, $P = 0.93$), and species composition ($r = 0.08$, $P = 0.55$) was negligible and nonsignificant. Although temporal autocorrelation also was negligible for abundance ($r < 0.01$, $P = 0.16$) and richness ($r = -0.01$, $P = 0.84$), there was significant positive temporal autocorrelation in species composition ($r = 0.06$, $P < 0.01$). Therefore, we proceeded through subsequent analysis assuming that our samples were spatially, but not temporally, independent. We calculated total abundance and species richness for each sample, and then we tested for significant differences among habitats after factoring out year as a covariable. We used the same procedure to test if abundance of individual species was related to habitat. Only species that represented >3.3% of total abundance were included in this analysis due to limitations of statistical power. We examined response of composition of communities to the tornado with a partial canonical-correspondence analysis (pCCA) on the species-by-site abundance matrix. We used 499 permutations to test the influence of habitat on species composition after factoring out the influence of year and month as covariables (Legendre and Legendre, 1998). We constrained permutations to only occur within a given year. The analysis identified variation in composition that could be explained by habitat after first removing variation in composition associated with a linear combination of dummy variables for year and month. A total of 15 tests of significance are reported herein, and to minimize Type I error we judged significance of all tests at the Bonferroni-corrected alpha level of 0.003. The pCCA was performed with CANOCO version 4.5 (Plant Research International, Wageningen, The Netherlands); the Mantel tests were conducted with the Vegan package in R version 2.8.0 (R Developmental Core Team, Vienna, Austria).

We observed a total of 37 species; 9 species were common to all habitats, 7 species were unique to non-impacted forest, 3 were unique to grassland, and only 2 were unique to impacted forest. There was no significant difference in abundance among habitats, but there was a significant effect of habitat on richness (Table 1). The non-impacted forest had the greatest richness followed by impacted forest and grassland. The significance of habitat as an explanatory variable for richness was due primarily to low richness in the grassland relative to impacted and non-impacted forests.

The pCCA indicated that habitat explained a significant amount (ca. 10%) of the inertia in species composition ($F = 4.995$, $P = 0.002$). In the pCCA biplot, each habitat is displayed at its centroid (Fig. 2). Grassland and forests are differentiated along the first axis of the pCCA biplot (eigenvalue = 0.55). The second axis separated species that had varying degrees of selection for impacted or non-impacted forests and only had an eigenvalue of 0.10. The strength of the first axis relative to the second (i.e., the larger eigenvalue) and the large degree of proximity of forested sites along this first axis indicate that species primarily differentiated between sites with some wooded cover (both impacted and non-impacted sites) and those without wooded cover (grassland sites). An additional analysis in which samples from the grassland were excluded from the pCCA did not result in significant differences in species composition between the impacted and non-impacted forests.

Placement of species in ordination space indicates to what degree a species behaved like a habitat generalist or specialist within our study site with respect to the three habitats we recognized (Fig. 2). Species that are closer to the center of the ordination space represent habitat generalists, such as northern bobwhites (*Colinus virginianus*), and those species closer to vertices behaved more like habitat specialists, such as grasshopper sparrows (*Ammodramus savannarum*) and eastern meadowlarks (*Sturnella magna*). Some species with the greatest range of abundance exhibited significant differences in abundance among habitats (Table 1). The dickcissel (*Spiza americana*), which comprised 20% of observations in the study, had its highest abundance in grassland. The grasshopper sparrow also was significantly more commonly detected in grassland. The field sparrow (*Spizella pusilla*) was significantly more abundant in impacted forest, and the blue-gray gnatcatcher (*Polioptila caerulea*) had almost equal abundance in both types of forests, but was not detected in the grassland.

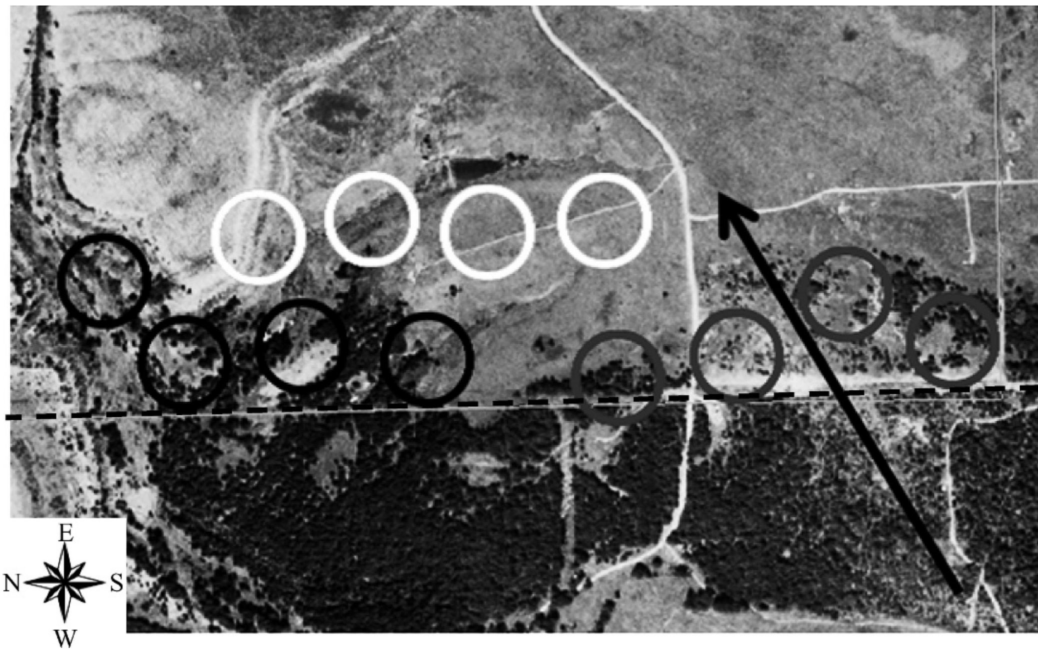

FIG. 1—The study site in Osage County, Oklahoma, after damage by a tornado. Direction and path of the tornado is marked by the black arrow. Each point sampled in assessment of the avifauna is a circle with a radius of 100 m (drawn to scale) and each habitat is represented by a shaded circle: black is non-impacted forest, gray is impacted forest, and white is grassland. The black dotted line is the western boundary of the Tallgrass Prairie Preserve.

TABLE 1—Two community indices ± *SE* and average abundance ± *SE* of birds within each habitat in order of abundance. These values are based on observations recorded within 100 m of the observation point.

Index/Species	Grouping[b]	Forest		Grassland	$F_{2,69}$	*P*-value[a]
		Impacted	Non-impacted			
Index						
Abundance		6.92 ± 0.98	6.50 ± 0.57	6.38 ± 0.42	0.17	0.844
Species richness		4.50 ± 0.38	4.92 ± 0.38	3.04 ± 0.19	9.18	<0.001
Species						
Dickcissel	Grassland	0.50 ± 0.17	0.71 ± 0.22	2.75 ± 0.32	16.08	<0.001
Field sparrow	Edge	1.96 ± 0.34	1.41 ± 0.24	0.46 ± 0.17	13.17	<0.001
Blue-gray gnatcatcher	Woodland	0.67 ± 0.15	0.83 ± 0.16	0.00	18.57	<0.001
Grasshopper sparrow	Grassland	0.04 ± 0.04	0.00	1.13 ± 0.22	10.97	0.001
Brown-headed cowbird	Edge	0.71 ± 0.38	0.25 ± 0.11	0.17 ± 0.08	1.31	0.291
American crow	Urban	0.21 ± 0.14	0.67 ± 0.23	0.04 ± 0.04	3.72	0.041
Painted bunting	Edge	0.33 ± 0.13	0.50 ± 0.12	0.00	5.30	0.014
Northern cardinal	Urban	0.50 ± 0.13	0.25 ± 0.11	0.04 ± 0.04	6.46	0.007
Northern bobwhite	Edge	0.17 ± 0.08	0.33 ± 0.21	0.17 ± 0.08	0.50	0.612
Carolina chickadee	Woodland	0.25 ± 0.12	0.38 ± 0.19	0.04 ± 0.04	1.58	0.229
Eastern meadowlark	Grassland	0.00	0.08 ± 0.06	0.58 ± 0.18	7.17	0.004

[a] Significance should be judged at the Bonferroni-corrected alpha level of 0.0033.
[b] Habitat groupings based on Peterjohn and Sauer (1993).

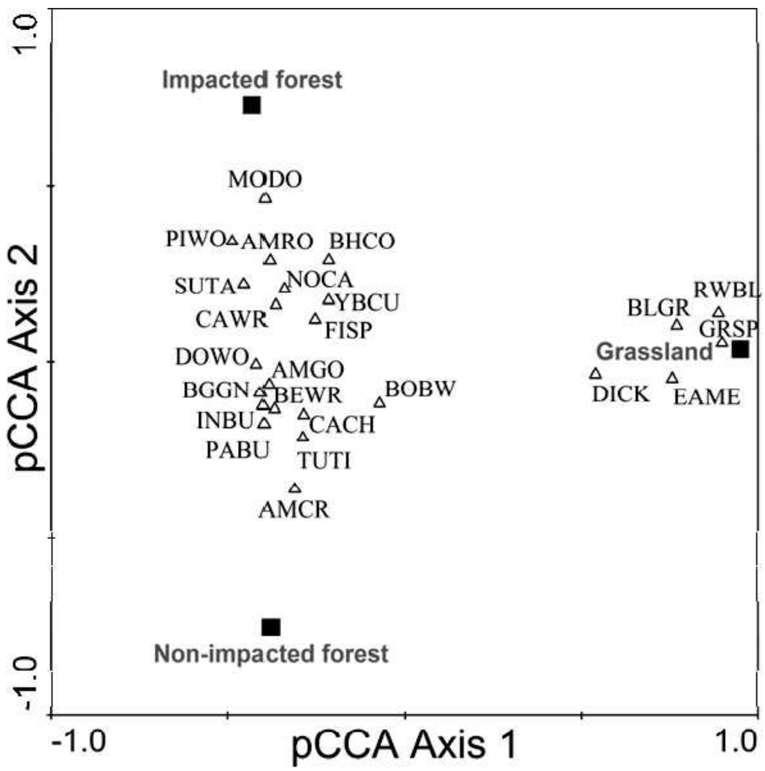

FIG. 2—Biplot for partial canonical-correspondence analysis (pCCA), the first axis had an eigenvalue of 0.546 and the second axis had an eigenvalue of 0.098. The sum of these eigenvalues was significantly different from 499 constrained permutations of the species-by-site abundance matrix ($F = 3.951$, $P = 0.002$). The 24 most abundant species are plotted: AMCR, American crow; AMGO, American goldfinch; AMRO, American robin; BEWR, Bewick's wren; BGGN, blue-gray gnatcatcher; BHCO, brown-headed cowbird; BLGR, blue grosbeak; BOBW, northern bobwhite; CACH, Carolina chickadee; CAWR, Carolina wren; DICK, dickcissel; DOWO, downy woodpecker; EAME, eastern meadowlark; FISP, field sparrow; GRSP, grasshopper sparrow; INBU, indigo bunting; MODO, mourning dove; NOCA, northern cardinal; PABU, painted bunting; PIWO, pileated woodpecker; SUTA, summer tanager; TUTI, tufted titmouse; RWBL, red-winged blackbird; YBCU, yellow-billed cuckoo.

Although we observed significant effects of habitat on species composition and richness, these differences were not due primarily to effects of damage by the tornado. The importance of habitat as a significant predictor of species composition and richness was due predominately to birds segregating between areas with trees and areas without trees.

In the area impacted by the tornado, habitat for forest-edge species such as field sparrows and brown-headed cowbirds (*Molothrus ater*) was enhanced; however, impacted forest still supported species dependent on dense forested habitats such as yellow-billed cuckoos (*Coccyzus americanus*) and Carolina chickadees (*Parus carolinensis*). Prather and Smith (2003) noticed a similar effect on the avian community in forests of Arkansas where forest-interior species such as Acadian flycatchers (*Empidonax virescens*) and red-eyed vireos (*Vireo olivaceus*) were still present after a tornado. However, unlike the Ozark community, our Cross Timbers community did not exhibit strong segregation between impacted and non-impacted patches. Similarity in species composition in the two forested sites may be attributed to the fact that the non-impacted forest we sampled had a rather open and patchy canopy (Fig. 1), which provided relatively poor breeding habitats for forest-interior species. The patchy nature of our non-impacted forest is characteristic of many Cross Timbers forests (Bruner, 1931; Rice and Penfound, 1959), and it seems reasonable to expect that local damage from wind in the Cross Timbers should not have as strong of an influence on species composition when compared with more mesic forests. Other studies relating birds and disturbance of forests have documented that even relatively small gaps can sustain unique assemblages of birds (Greenberg and Lanham, 2001); however, these results may not be relevant to ecoregions in which forests maintain a relatively open and patchy structure.

Although there was not a strong difference between forests, the grassland habitat contained a unique assemblage of species, which is likely because grassland birds are intolerant of vertical structures (Rosenstock and Van Riper, 2001; Grant et al., 2004). Grassland birds in Oklahoma generally avoid habitat with >25% woody cover (Chapman et al., 2004) and species such as the grasshopper sparrow require large treeless areas (Herkert, 1994).

Our results suggest that the influence of catastrophic disturbance by wind on composition of avian communities in the Cross Timbers may be weak if the forest originally lacks habitat for forest-interior species. Due to the unpredictability of tornados, it is difficult to implement a rigorous experimental design when studying their impacts, but we suggest a few ideas for increasing the strength of future studies of the impact of tornados. Future research should investigate the impact of scale, severity of the disturbance, and the landscape context in which the disturbance occurs on how birds respond to a tornado. Statistical problems associated with a lack of baseline data for the impacted area can be alleviated by sampling for multiple years, at multiple sites, or both within impacted and non-impacted areas (Underwood, 1994). The effect of the increase in coarse woody debris and snags as nesting substrate for birds also is worthy of investigation. Overall, impacts of a tornado on an avian community are likely to be variable; however, their importance may be predictable based on regional characteristics of the avian community.

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Literature Cited

Arévalo, J. R., J. K. DeCoster, S. McAlister, and M. W. Palmer. 2000. Changes in two Minnesota forests during 14 years following catastrophic windthrow. Journal of Vegetation Science 11:833–840.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecological Monographs 1:100–188.

Chapman, R. N., D. M. Engle, R. E. Masters, and D. M. Leslie. 2004. Tree invasion constrains the influence of herbaceous structure in grassland bird habitats. Ecoscience 11:55–63.

Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, D. Simberloff, F. J. Swanson, B. J. Stocks, and B. M. Wotton. 2001. Climate change and forest disturbances. BioScience 51: 723–734.

Glitzenstein, J. S., and P. A. Harcombe. 1988. Effects of the December 1983 tornado on forest vegetation of the Big Thicket, Southeast Texas, USA. Forest Ecology and Management 25:269–290.

Grant, T. A., E. Madden, and G. B. Berkey. 2004. Tree and shrub invasion in northern mixed-grass prairie: implications for breeding grassland birds. Wildlife Society Bulletin 32:807–818.

Greenberg, C. H., and J. D. Lanham. 2001. Breeding bird assemblages of hurricane-created gaps and adjacent closed canopy forest in the southern Appalachians. Forest Ecology and Management 154:251–260.

Herkert, J. R. 1994. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4:461–471.

Legendre, P., and L. Legendre. 1998. Numerical ecology. Elsevier, Boston, Massachusetts.

McClure, H. E. 1945. Effects of a tornado on bird life. Auk 62:414–418.

Peterjohn, B. G., and J. R. Sauer. 1993. North American Breeding Bird Survey annual summary 1990–1991. Bird Populations 1:1–24.

Peterson, C. J. 2000. Catastrophic wind damage to North American forests and the potential impact of climate change. Science of the Total Environment 262:287–311.

Prather, J. W., and K. G. Smith. 2003. Effects of tornado damage on forest bird populations in the Arkansas Ozarks. Southwestern Naturalist 48:292–297.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. United States Department of Agriculture Forest Service, Pacific Southwest Research Station PSW-GTR-144:1–41.

Rice, E. L., and W. T. Penfound. 1959. The upland forests of Oklahoma. Ecology 40:593–608.

Rosenstock, S. S., and C. Van Riper. 2001. Breeding bird responses to juniper woodland expansion. Journal of Range Management 54:226–232.

Shirakura, F., K. Sasaki, J. R. Arevalo, and M. W. Palmer. 2006. Tornado damage of *Quercus stellata* and *Quercus marilandica* in the Cross Timbers, Oklahoma, USA. Journal of Vegetation Science 17: 347–352.

Underwood, A. J. 1994. On beyond BACI—sampling designs that might reliably detect environmental disturbances. Ecological Applications 4:3–15.

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