RESPONSE OF NONGAME BIRD POPULATIONS TO HERBICIDES IN THE CROSS TIMBERS OF OKLAHOMA

By

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Bachelor of Science in Fisheries and Wildlife

University of Missouri

Columbia, Missouri

1987

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1989

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HERBICIDES IN THE CROSS TIMBERS

OF OKLAHOMA

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ACKNOWLEDGMENTS

I express my appreciation to my major professor, David M. Leslie, Jr., for his advice and support. I would also like to thank my advisory committee, Drs. Robert L. Lochmiller and David M. Engle for their suggestions in preparation of this manuscript.

I thank Beverly Stark for her long hours in the field. I would also like to thank R. B. Soper, S. T. McMurray, K. Dyer, W. J. Stancill, S. Haggard, J. Jenks, J. Boggs, S. Merrifield, and U. Abdullah for their assistance in the field. I also thank Dr. Elmer J. Finck for his review of the preliminary results.

This study was funded by the Oklahoma Department of Wildlife Conservation and the Oklahoma Cooperative Fish and Wildlife Research Unit.

Final and greatest appreciation is due to my husband, Kenny, and my parents, Jacque and David Sutter, for their unwavering love, encouragement, and support.

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CHAPTER I

INTRODUCTION

This thesis is composed of 2 manuscripts written in formats suitable for submission to selected scientific journals. Each manuscript is complete without supporting materials. The order of arrangement for each manuscript is text, literature cited, tables, and figures. Chapter II, "Fall and winter bird communities on herbicide-treated Cross Timbers in Oklahoma," is written in the format of the Condor. Chapter III, "Effects of herbicide-induced vegetation changes on breeding birds in the Cross Timbers ecosystem of Oklahoma," is written in the format of the Journal of Wildlife Management.

CHAPTER II

FALL AND WINTER BIRD COMMUNITIES ON HERBICIDE-TREATED CROSS TIMBERS IN OKLAHOMA

Abstract.--Fall and winter songbird and woodpecker populations were censused on 5- and 6-year post-herbicide treated sites from October 1987 through February 1989 on the Cross Timbers Experimental Range in central Oklahoma. We censused 2 replications of tebuthiuron-treated, triclopyr-treated, and untreated sites with a modification of the point-count method. Thirty-six species were documented during the entire census period. Overall, 16 species were observed only on herbicide-treated sites and 2 species were observed only on control sites. During fall and winter, greater numbers of birds and more species were found on sites treated with herbicides than on untreated sites. Tebuthiuron and triclopyr sites supported similar numbers of species during both seasons; however, tebuthiuron sites had greater bird species diversity. Herbicide-treated sites provided maximum species diversity and richness, but untreated areas were needed to maintain interior woodland species.

Herbicides play a significant role in vegetation management for cattle grazing rangelands (Best 1972) and timber industries (Morrison and Meslow 1983). Most studies of wildlife responses to herbicides have occurred in areas where herbicides were used to control brush (Best 1972, Beaver 1976, Gruver and Guthery 1986) and to enhance conifer production on clearcuts (McComb and Rumsey 1983, Morrison and Meslow

1984b, Warren et al. 1984, Santillo et al. 1989) by suppressing deciduous growth (Savidge 1978, Warren et al. 1984, de Waal Malefyt 1987). Few studies have examined responses of songbird communities where herbicides were used in conjunction with seasonal cattle grazing.

Songbird/herbicide studies have been conducted in the northeastern and western United States, but little research has been done on herbicide/wildlife relationships in the south-central United States. Most studies have examined effects of 2,4,5-T (e.g., Beaver 1976, Morrison and Meslow 1983, Warren et al. 1984, Gruver and Guthery 1986), 2,4-D (e.g., Morrison and Meslow 1983, Warren et al. 1984), picloram (e.g., McComb and Rumsey 1983), and glyphosate (e.g., Morrison and Meslow 1984a, Santillo et al. 1989) on songbird densities and diversities, but few have involved tebuthiuron or triclopyr, commonly used on rangelands.

The Cross Timbers consists of 3-4 million ha of post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) forests in the south-central United States. This ecosystem can be greatly altered with herbicides to enhance livestock grazing. Few songbird community studies have been conducted in the Cross Timbers ecosystem. This area is ecologically important, especially in Oklahoma, because it is the ecotone between eastern deciduous forests and western prairies. The Cross Timbers Experimental Range, which was established by the Oklahoma Agricultural Experimental Station, offered a unique opportunity to examine songbird use of rangelands treated with tebuthiuron and triclopyr and to compare these sites to untreated controls.

Knowledge of seasonal abundances of songbirds is important to understanding relationships between avian species and vegetation complexity (Meslow 1978, Anderson and Ohmart 1980) and to determine how habitat alterations affect bird species diversity (Willson 1974). Therefore, our objectives were to (1) document fall migrant and winter resident populations of songbirds and woodpeckers in the Cross Timbers and (2) examine effects of herbicide-induced habitat alterations on songbird and woodpecker use of the Cross Timbers. We hypothesized that (1) herbicides applied to the Cross Timbers do not affect songbird and woodpecker community structure (e.g., species diversity) and (2) tebuthiuron and triclopyr do not differ in their influence on songbirds and woodpeckers.

STUDY AREA AND METHODS

Our study was conducted on the Cross Timbers Experimental Range of the Oklahoma Agricultural Experiment Station (Engle et al. 1987). The area was located in Payne County, Oklahoma, and consisted of 20 32.4-ha pastures in sections 2, 3, 10, and 11 T18N, R1E representing 4 replications of 5 experimental treatments (Fig.1). We used 3 treatments in our study: (1) tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N +N′-dimethylurea) (Elanco Product Co., Division of Eli Lilly and Co., Indianapolis, Ind. 46285) applied aerially at 2.2 kg/ha in March 1983; (2) triclopyr ([3,5,6-tricloro-2-pyridinyl)oxy] acetic acid) (Dow Chemical Co., Midland, Mich. 48674) applied aerially at 2.2 kg/ha in June 1983; and (3) a control (no herbicide).

The 2 herbicides were applied to reduce overstory dominance of hardwoods, primarily post oak and blackjack oak in order to enhance production of cattle forage. Both herbicides were effective, but tebuthiuron had better total tree kill (Stritzke et al. 1987). Five- to 6-years post-treatment, both herbicides resulted in large numbers of standing snags and brushy understories; however, triclopyr sites allowed more brush growth in the understory and greater woody canopy cover. These pastures were grazed by yearling cattle from mid-March through mid-August 1987, mid-April through September 1988, and mid-March through September 1989; stocking rates were set to result in moderate use of forage (Engle et al. 1989).

One 10.8-ha grid was placed in each of 6 randomly chosen pastures (i.e., 2 tebuthiuron, 2 triclopyr, and 2 control) to maximize homogeneity among grids. A variation of the point-count method was used to determine fall and winter bird population abundances (Robbins 1978). Migrants were defined as those species that passed through our study area within a brief period of time (i.e., species that were observed for a few consecutive days, then not observed again during the remainder of the census period). We recognize that within a species, individuals are migratory (e.g., Northern Cardinal [Cardinalis cardinalis]), but we did not collect data to determine abundance and occurrence of species with this migratory behavior.

On each grid, 6 points were randomly chosen and visited. Grids were visited in the morning, beginning at sunrise and ending by 10:00, and in the afternoon, beginning 2-4 hours before sunset (Robbins 1972, Shields 1977). Although studies have shown increased bird observability during morning visits (e.g., Robbins 1972, Shields 1977), we conducted evening visits to maximize observations relative to man-power constraints. While some species may have decreased observability during evening counts, we assumed that changes in observability were equal on all treatments and thus did not bias comparisons of treatments. Morning and evening visits were combined for each grid before analysis.

Each of the 6 points were visited for 10 minutes with a 1-minute waiting period before recording observations (Verner 1988, Avery and van Riper III 1989). After the waiting period, all Passeriformes and Piciformes observed or heard were recorded; individuals flying over were not counted. The American Crow (*Corvus brachyrhynchos*) was recorded but was not used in data analysis because it was difficult to determine if this species was actually using the grid during point-counts. One to 2 grids were censused per visit and total time/visit was 1.5-2 hours. Starting points were varied to reduce temporal variation. Censuses were not conducted during periods of precipitation, dense fog (Robbins 1981), or winds $\geq$20 mph. Grids were censused from late September to mid-February, 1987-88 and 1988-89.

Chi-square analyses were used to evaluate treatment differences in fall and winter populations. Significance was set at $P < 0.05$. Shannon diversity was calculated for each treatment for each season (Hair 1980, Brower and Zar 1984).

RESULTS

During the entire census period from 8 October 1987 to 10 February 1989, 36 species and >8,200 individuals were documented. Species abundance was evaluated temporally for both years. Numbers of individuals of some species declined during October and early November (e.g., Northern Flicker [Colaptes auratus], Yellow-rumped Warbler [Dendroica coronata], Northern Cardinal) and stabilized during the latter half of November. Numbers of other species (e.g., Tufted Titmouse [Parus bicolor], American Robin [Turdus migratorius]) increased through fall and began to stabilize during the end of November. Additional species (e.g., Cedar Waxwing [Bombycilla cedrorum], Purple Finch [Carpodacus purpureus]) arrived during late November or early December, and their numbers increased through December and January. Still other species (e.g., Ruby-crowned Kinglet [Regulus calendula], Song Sparrow [Melospiza melodia]) were observed only a few times and were not observed after the end of November. Because of these general trends, we separated data into fall (8 October-30 November 1987; 19 September-30 November 1988) and winter (1 December 1987-5 February 1988; 1 December 1988-10 February 1989) census periods. After early February, spring migrants (e.g., Ruby-crowned Kinglet) were observed, and some species began to exhibit signs of territoriality, such as singing (e.g., Bewick's Wren [Thryomanes bewickii], Northern Cardinal). Nest-box data collected within 8 km of the study site indicated that nesting by the Carolina Wren (Thryothorus ludovicianus) began as early as 12 March (R. B. Soper, pers. commun.).

Fall Population.--We conducted 43 visits in this study; 28 visits during 1987 and 15 visits during 1988. Discrepancies in number of visits were due to weather and time constraints. A total of 34 species was observed throughout the fall migrant survey: 17 species on control sites, 26 species on tebuthiuron-treated sites, and 25 species on triclopyr-treated sites (Table 1). Throughout both fall surveys 17 species were observed only on herbicide sites and 2 species were observed only on control sites (Table 1).

Thirty-one species and >3,000 individuals were observed during the 1987 survey: 17 species on the control sites; 23 species on the tebuthiuron sites; and 24 species on the triclopyr sites. The average Shannon diversity among the 3 treatments was 3.33. The most abundant species on the control site was the Blue Jay (Cyanocitta cristata). The American Robin was the most abundant species on tebuthiuron and triclopyr sites. Fourteen species were observed only on herbicide-treated sites. The White-breasted Nuthatch (Sitta carolinensis) and the Hermit Thrush (Catharus guttatus) were observed only on control sites (Table 1).

Twenty species and >1,000 individuals were observed during the 1988 survey. Eleven species were observed on control sites, 19 species on tebuthiuron sites, and 16 species on triclopyr sites. The average Shannon diversity among the 3 treatments was 2.81. The Blue Jay was the most abundant species on the control and triclopyr sites. The American Robin was the most abundant species on tebuthiuron sites. Nine species were observed only on herbicide-treated sites. No species were observed strictly on control sites (Table 1).

Songbird assemblages were significantly different among the 3 treatments for the 1987 survey ($\underline{X}^2$ = 202.169, $\underline{P}$ <0.001) and the 1988 survey ($\underline{X}^2$ = 96.434, $\underline{P}$ <0.001). Significant differences also were found between the 2 survey years (control, $\underline{X}^2$ = 27.306, $\underline{P}$ < 0.001; tebuthiuron, $\underline{X}^2$ = 36.825, $\underline{P}$ < 0.001; triclopyr, $\underline{X}^2$ = 85.010, $\underline{P}$ < 0.001).

Winter Population.--A total of 60 visits was conducted: 32 visits during 1987-88 and 28 visits during 1988-89. A total of 29 species was observed throughout the winter resident survey: 18 species on control sites; 24 species on tebuthiuron sites; and 26 species on triclopyr sites (Table 2). Of these, 11 species were winter-only residents. Twelve species were observed only on herbicide sites and 2 species were observed only on control sites (Table 2).

Twenty-five species and >2,300 individuals were observed during the 1987-88 survey. Sixteen species were observed on control sites, 23 species on tebuthiuron sites, and 22 species on triclopyr sites. The average Shannon diversity among the 3 treatments was 3.25. The Blue Jay was the most abundant species on control sites. The Carolina Chickadee (*Parus carolinensis*) was the most abundant species on the tebuthiuron sites. The American Robin was the most abundant species on triclopyr sites. Nine species were observed only on herbicide-treated sites. The White-breasted Nuthatch was observed only on control sites (Table 2).

Twenty-two species and >1,800 individuals were observed during the 1988-89 survey: 14 species on control sites; 19 species on tebuthiuron sites; and 20 species on triclopyr sites. The average Shannon diversity among the 3 treatments was 2.79. The Tufted Titmouse and the American Robin were the most abundant species on control sites. The American Robin was the most abundant species on both herbicide-treated sites. Eight species were observed only on herbicide-treated sites. The Hermit Thrush was observed only on control sites (Table 2).

Songbird assemblages were significantly different among the 3 treatments for the 1987-88 survey (X^2 = 425.277, P <0.001) and for the 1988-89 survey (X^2 = 214.605, P <0.001). Differences also were found between the 2 survey years (control, X^2 = 12.188, P < 0.05; tebuthiuron, X^2 = 138.470, P < 0.001; triclopyr, X^2 = 22.855, P < 0.001).

DISCUSSION

Few studies have examined effects of herbicide-induced vegetation changes on songbirds during winter; fall migrant studies conducted under similar conditions are virtually non-existent. Fall and winter studies are important in areas that support large numbers of species year-round (Manuwal and Huff 1987), such as Oklahoma. Herbicides alter habitat by changing vegetation structure (Scifres and Mutz 1978, Morrison and

Meslow 1983, Santillo et al. 1989), which may greatly alter songbird communities (Slagsvold 1977, Savidge 1978, Meslow 1978, Titterington et al. 1979, de Waal Malefyt 1987).

Responses of avian communities to herbicide applications depend on: (1) the type of vegetation affected by the herbicide (Slagsvold 1977, Morrison and Meslow 1984b); (2) amount of herbicide application (Best 1972, Slagsvold 1977, Doerr and Guthery 1983); (3) post-herbicide seral stage (Johnston and Odum 1956, Shugart and James 1973, Slagsvold 1977, Santillo et al. 1989); and (4) time lapsed since application (Schroeder and Sturges 1975, Morrison and Meslow 1984a, Warren et al. 1984). Morrison and Meslow (1983) suggested that other factors such as overwinter mortality, pre-existing vegetation differences between treated and untreated sites, and abiotic factors may affect avian communities regardless of treatment scheme.

Fall Population.--The majority of the changes in bird species composition during the fall surveys was due to the arrival of winter residents (e.g., Cedar Waxwing, Golden-crowned Kinglet [*Regulus satrapa*]). Throughout both survey periods, 2 migrant species were observed using the study area. The Ruby-crowned Kinglet and the Song Sparrow were both observed a few times during the 1987 survey. However, Grzybowski (1986) listed both species as occurring in central Oklahoma throughout fall and winter.

Several other species (Meadowlark [*Sturnella spp.*], Red-winged Blackbird [*Agelaius phoeniceus*], Common Grackle [*Quiscalus quiscula*], Brown-headed Cowbird [Molothrus ater]) were observed on only 1-3 visits during the fall 1987 survey. However, these species have been recorded in central Oklahoma year-round (Grzybowski 1986) and were frequently observed on areas adjacent to the study site. The Eastern Phoebe (Sayornis phoebe) also was observed only during the fall survey; however, this flycatcher is a late-leaving summer resident (Grzybowski 1986), not a fall migrant. During the 1987 survey, the Hermit Thrush was thought to be a fall migrant; however, it was observed several times during the winter census of 1988-89, which was likely due to milder weather conditions during the second year (Appendix A).

Fall songbird assemblages differed between the 2 surveys. Total number of individuals, numbers of species, and average species diversity were greater during the 1987 survey, which was due in part to the decrease in visits in fall 1988. Nevertheless, some differences between years were expected. Robbins (1972, 1978) reported that differences of -15% to +30% per species between years were normal and did not necessarily indicate population changes. The weather in 1988 was warmer than in 1987 (Appendix A), which could have delayed species arrival (e.g., Cedar Waxwing). Another possibility is a decrease in food availability due to drought conditions in 1988. It should be noted that Meadowlarks, Red-winged Blackbirds, Common Grackles, and Brown-headed Cowbirds were not observed on the study site during 1988 but were seen on adjacent areas during the study period; their absence accounted for some of the differences between the 2 survey years.

Winter Population.--Songbird assemblages were different between the 2 surveys. Fewer species (22 vs. 25), fewer individuals (1,833 vs. 2,302), and a lower average species diversity (1.94 vs. 2.25) were observed during the 1988-89 survey as compared to the 1987-88 survey, which was likely due to differences in weather between the 2 years. Rotenberry et al. (1979) stated that winter populations were influenced by weather conditions because food resources were less stable during that time. The influence of weather on bird communities was reflected in our data for 1988-89 by higher counts of those species whose northern-most winter range is Oklahoma. One example is the Hermit Thrush; no thrushes were observed during the 1987-88 survey, but several individuals were recorded during the 1988-89 survey (Table 2). This seems to correspond to differences in weather between the 2 survey periods (Appendix A).

Response to Herbicides.--Both herbicides were applied in the spring and early summer of 1983. Complete leaf fall did not occur until the fall of 1983 (D. M. Engle, pers. commun.). Leaves of oak species in the Cross Timbers ecosystem are typically shed from November through early March (Johnson and Risser 1974). Thus, during the subsequent fall and winter, bird species richness and abundance on herbicide-treatments was probably quite similar to that of control sites. Some studies have shown that bird species density did not change during the first year post-treatment (Best 1972, Schroeder and Sturges 1975).

By the fall/winter of 1984, many trees were partially to totally leafless and grass/forb production had dramatically increased on herbicide-treated sites (Engle et al. 1989). Bird species richness and abundance during the fall/winter of 1984 was probably higher on herbicide sites due to increased food availability. Most studies have found a decline in breeding bird density or abundance 2 years post-application (Schroeder and Sturges 1975, Slagsvold 1977). Slagsvold (1977) suggested that declines in food caused the decline in bird abundance on treated sites. In our study, available food, apparently in the form of seeds, increased 2 years post-treatment.

By the fall/winter of 1985, the majority of small branches had fallen from herbicide-treated brush species. Grass/forb production was greater than in 1984 (Engle et al. 1989) and songbird richness and abundance was likely similar to that of 1984. Slagsvold (1977) found lower numbers of territories on treated plots 3-years post-spray. Again, food availability was cited as a major factor (Slagsvold 1977).

By 1986, only wind-protected snags had any remaining branches and some smaller snags had fallen over; grass production had increased, but forb production was lower than in 1985, although it was still greater than that on the control sites. By 1986, some brush species had resprouted and canopy cover had begun to increase, especially on triclopyr sites (Stritzke et al. 1988). During 1986, species richness and abundance was probably slightly lower than in 1985 and similar to our results for 1987. McComb and Rumsey (1983) found greater numbers of species and individuals on treated sites, but no differences in species diversity for winter bird populations on 4-year post-picloram treated sites in the Central Appalachians.

By the fall/winter of 1987, many small snags had fallen and grass/forb production had declined on herbicide-treated sites, although production was still greater than on control sites (Engle et al. 1989). During all surveys, we observed more species on herbicide-treated sites compared to controls, which was likely due to changes in food availability and habitat structure. Food available to songbirds was likely increased by a 20-fold increase in grass and forb production on the herbicide treatments (Engle et al. 1989), which we assume increased seed production on herbicide-treated sites relative to control sites. Snags also may be an important winter food source, especially for woodpeckers (Brawn et al. 1982).

Both herbicide treatments increased snag and slash availability and thereby increased foraging substrate, as well as the number of cavities, brush piles, etc. that provide protection for migrating and overwintering birds (Manuwal and Huff 1987). Gruver and Guthery (1986) stated that dead mesquite (*Prosopis glandulosa*) stems that remained standing after herbicide treatment were used for cover, protection, and foraging.

Herbicide-treated sites also had more edge habitat than control sites due to brush resprouting, small patches of tree species, and stands of eastern redcedar (*Juniperus virginiana*) within open prairie and the forests. Increase in edge habitat could have partially increased number of species on herbicide sites. Gruver and Guthery (1986) found that the Northern Mockingbird (Mimus polyglottos), a typical edge species, was more abundant on treated sites 12-13 years post-treatment. McComb and Rumsey (1983) found an increase in bird density on treated sites and felt that this was mainly due to an increase in the number of individuals of edge species.

Management Implications.--Application of herbicides such as tebuthiuron and triclopyr can increase availability of forage for cattle relative to non-treated sites. However, tebuthiuron is more effective in brush reduction than triclopyr in the Cross Timbers habitat (Stritzke et al. 1987). Five- and 6-years post-treatment tebuthiuron sites provide greater bird species diversity than triclopyr and non-treated sites. The Brown Thrasher (Toxostoma rufum) was the only species that occurred solely on triclopyr-treated sites; however, edge habitat created in the transition area of treatment to non-treatment sites should provide adequate habitat for this species. The manager should be aware that application of either herbicide will result in the disappearance of some interior woodland species (e.g., White-breasted Nuthatch, Hermit Thrush) and other species will decline in abundance (e.g., Tufted Titmouse). Application of tebuthiuron on some areas in combination with nearby non-treated areas should provide maximum species diversity and richness 5- and 6-years post-treatment.

LITERATURE CITED

Anderson, B. W., and R. D. Ohmart. 1980. Designing and developing a predictive model and testing a revegetated riparian community for southwestern birds. Pages 434-450 in R. M. DeGraaf, tech. coord. Proc. workshop management of western forests and grasslands for non-game birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Avery, M. L., and C. van Riper III. 1989. Seasonal changes in bird communities of the chaparral and blue-oak woodlands in central California. Condor 91:288-295.

Beaver, D. L. 1976. Avian populations in herbicide treated brush fields. Auk 93:543-553.

Best, L. B. 1972. First-year effects of sagebrush control on two sparrows. J. Wildl. Manage. 36:534-544.

Brawn, J. D., W. H. Elder, and K. E. Evans. 1982. Winter foraging by cavity-nesting birds in an oak-hickory forest. Wildl. Soc. Bull. 10:271-275.

Brower, J. E., and J. H. Zar. 1984. Field and laboratory methods for general ecology. Second ed. Wm. C. Brown Publ., Dubuque, Iowa. 226pp.

de Waal Malefyt, J. J. 1987. Effects of herbicide spraying on breeding songbird habitat along electric transmission rights-of-way. Unpubl. ms., New York Dep. Public Serv., Albany, N.Y.

Doerr, T. B., and F. S. Guthery. 1983. Effects of tebuthiuron on lesser prairie-chicken habitat and foods. J. Wildl. Manage.

47:1138-1142.

Engle, D. M., J. F. Stritzke, and F. T. McCollum. 1987. Brush management on the Cross Timbers Experimental Range: II. Herbaceous plant responses. Okla. Agr. Exp. Stn. MP-119:103-109.

_____, _____, and _____. 1989. Vegetation manipulation in the Cross Timbers: response to herbicides and burning. Unpubl. ms., Okla. Agr. Exp. Stn., Okla. State Univ., Stillwater.

Gruver, B. J., and F. S. Guthery. 1986. Effects of brush control and game-bird management on nongame birds. J. Range Manage. 39:251-253.

Grzybowski, J. A. 1986. Date guide to the occurrences of birds in Oklahoma. Okla. Ornithol. Soc., Norman, Okla. 32pp.

Hair, J. D. 1980. Measurement of ecological diversity. Pages 269-275 in S. D. Schemnitz, ed. Wildlife management techniques manual. Fourth ed. The Wildlife Society, Washington, D. C.

Johnson, F. L., and P. G. Risser. 1974. Biomass, annual net primary production, and dynamics of six mineral elements in a post oak-blackjack oak forest. Ecology 55:1246-1258.

Johnston, D. W., and E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the piedmont of Georgia. Ecology 37:50-62.

Manuwal, D. A., and M. H. Huff. 1987. Spring and winter bird populations in a Douglas-fir forest sere. J. Wildl. Manage. 51:586-595.

McComb, W. C., and R. L. Rumsey. 1983. Bird density and habitat use in forest openings created by herbicides and clearcutting in the Central Appalachians. Brimleyana 9:83-95.

Meslow, E. C. 1978. The relationship of birds to habitat structure-plant communities and successional stages. Pages 12-18 in R. M. DeGraaf, tech. coord. Proc. workshop nongame bird habitat management in coniferous forests of the western U.S. U.S. For. Serv. Gen. Tech. Rep. PNW-64.

Morrison, M. L., and E. C. Meslow. 1983. Impacts of forest herbicides on wildlife: toxicity and habitat alteration. Trans. North Am. Wildl. and Nat. Resour. Conf. 48:175-185.

_____, and _____. 1984a. Effects of the herbicide glyphosate on bird community structure, western Oregon. For. Sci. 30:95-106.

_____, and _____. 1984b. Response of avian communities to herbicide-induced vegetation changes. J. Wildl. Manage. 48:14-22.

Robbins, C. S. 1972. An appraisal of the winter bird-population study technique. Am. Birds 26:688-692.

_____. 1978. Census techniques for forest birds. Pages 142-163 in R. M. DeGraaf, tech. coord. Proc. workshop management of southern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. SE-14.

_____. 1981. Bird activity levels related to weather. Avian Biol. 6:301-310.

Rotenberry, J. T., R. E. Fitzner, and W. H. Rickard. 1979. Seasonal variation in avian community structure: differences in mechanisms regulating diversity. Auk 96:499-505.

Santillo, D. J., P. W. Brown, and D. M. Leslie, Jr. 1989. Response of songbirds to glyphosate-induced habitat changes on clearcuts. J. Wildl. Manage. 53:64-71.

Savidge, J. A. 1978. Wildlife in a herbicide-treated Jeffrey Pine plantation in eastern California. J. For. 76:476-478.

Schroeder, M. H., and D. L. Sturges. 1975. The effect on the Brewer's sparrow of spraying big sagebrush. J. Range Manage. 28:294-297.

Scifres, C. J., and J. L. Mutz. 1978. Herbaceous vegetation changes following applications of tebuthiuron for brush control. J. Range Manage. 31:375-378.

Shields, W. M. 1977. The effect of time of day on avian census results. Auk 94:380-383.

Shugart, H. H. Jr., and D. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62-77.

Slagsvold, T. 1977. Bird populations after clearcut of deciduous scrub. Biol. Conserv. 12:229-244.

Stritzke, J. F., D. M. Engle, and F. T. McCollum. 1987. Brush management on the Cross Timbers Experimental Range: I. Brush problems and responses to herbicides. Okla. Agr. Exp. Sta. MP-119:99-102.

_____, _____, and _____. 1988. Brush management in the Cross Timbers: I. Brush problems and responses to herbicides. Annual Meeting Soc. Range Manage., Corpus Christi, Tex.

Titterington, R. W., H. S. Crawford, and B. N. Burgason. 1979. Songbird responses to commercial clear-cutting in Maine spruce-fir forests. J. Wildl. Manage. 43:602-609.

Verner, J. 1988. Optimizing the duration of point counts for monitoring trends in bird populations. U.S. For. Serv. Res. Note PSW-395.

Warren, R. C., G. A. Hurst, and T. L. Darden, Jr. 1984. Relative abundance of cavity nesting birds on pine plantations site prepared by herbicides. Pages 197-205 in W. C. McComb, ed. Proc. workshop management of nongame species and ecological communities. Dep. For., Univ. Kent., Lexington.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

Table 1. Bird species (normalized[1]) observed during fall population surveys on herbicide-treated and untreated Cross Timbers in Oklahoma, 1987 and 1988. (Numbers in parentheses are percentage of total).

	Fall 1987						Fall 1988					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
Species	n	%	n	%	n	%	n	%	n	%	n	%
Major Species												
Northern Flicker	3.9	(6.4)	19.2	(12.0)	7.5	(7.0)	4.2	(13.6)	21.4	(16.5)	12.8	(19.1)
Red-bellied Woodpecker	7.4	(12.1)	7.8	(4.9)	5.1	(4.8)	0.7	(2.3)	1.8	(1.4)	1.5	(2.2)
Blue Jay	18.9	(30.9)	24.2	(15.2)	21.1	(19.8)	12.8	(41.4)	21.8	(16.8)	24.3	(36.2)
Carolina Chickadee	8.4	(13.7)	23.9	(15.0)	19.0	(17.8)	4.2	(13.6)	14.8	(11.4)	7.0	(10.4)
Tufted Titmouse	9.1	(14.9)	6.0	(3.8)	9.3	(8.7)	3.7	(12.0)	4.8	(3.7)	1.3	(1.9)
American Robin	5.6	(9.2)	30.1	(18.9)	26.4	(24.7)	3.0	(9.7)	36.0	(27.7)	11.3	(16.8)
Eastern Bluebird	0		9.0	(5.6)	1.4	(1.3)	0		9.8	(7.6)	0.5	(0.8)
Cedar Waxwing	0		20.2	(12.7)	0		0		0		0	
Total Major Species	53.3	(87.2)	140.4	(88.1)	89.8	(84.1)	28.6	(92.6)	110.4	(85.01)	58.7	(87.4)

Table 1. Continued.

	Fall 1987						Fall 1988					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
Species	n	%	n	%	n	%	n	%	n	%	n	%
Minor Species												
Pileated Woodpecker	0.1	(0.2)	0.4	(0.3)	0.1	(0.1)	0.2	(0.7)	0.4	(0.3)	1.0	(1.5)
Red-headed Woodpecker	0		0		0		0		2.6	(2.0)	0	
Downy/Hairy Woodpecker	3.0	(4.9)	5.1	(3.2)	3.6	(3.4)	0.7	(2.3)	2.8	(2.2)	2.0	(3.0)
Eastern Phoebe	0		0		0		0		0.4	(0.3)	0	
White-breasted Nuthatch	0.2	(0.3)	0		0		0		0		0	
Bewick's Wren	0		0		0		0		0.4	(0.3)	0.5	(0.8)
Carolina Wren	0		0.3	(0.2)	0.2	(0.2)	0		0		0	
Northern Mockingbird	0		1.2	(0.8)	0.6	(0.6)	0		0		0	
Brown Thrasher	0		0		0.1	(0.1)	0		0		0	
Hermit Thrush	0.4	(0.7)	0		0		0		0		0	

Table 1. Continued.

Species	Fall 1987						Fall 1988					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
	n	%	n	%	n	%	n	%	n	%	n	%
Golden-crowned Kinglet	2.2	(3.6)	0		0.7	(0.7)	0		0		0	
Ruby-crowned Kinglet	0.2	(0.3)	0.1	(0.1)	0.2	(0.2)	0		0		0	
Yellow-rumped Warbler	0.2	(0.3)	1.1	(0.7)	1.2	(1.1)	0		5.6	(4.3)	1.5	(2.2)
Meadowlark spp.	0		0		0.8	(0.8)	0		0		0	
Red-winged Blackbird	0		0		0.5	(0.5)	0		0		0	
Common Grackle	0		0		0.2	(0.2)	0		0		0	
Brown-headed Cowbird	0		0		0.1	(0.1)	0		0		0	
Northern Cardinal	0.2	(0.3)	2.3	(1.4)	2.0	(1.9)	0.2	(0.7)	1.0	(0.8)	0.5	(0.8)
American Goldfinch	0		0.1	(0.1)	0		0		0.2	(0.2)	0	
Rufous-sided Towhee	0		0.6	(0.4)	3.1	(2.9)	0		0		0.3	(0.5)
Dark-eyed Junco	1.0	(1.6)	4.2	(2.6)	3.4	(3.2)	1.2	(3.9)	4.0	(3.1)	2.3	(3.4)

Table 1. Continued.

	Fall 1987						Fall 1988					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
Species	n	%	n	%	n	%	n	%	n	%	n	%
American Tree Sparrow	0		0.5	(0.3)	0		0		0		0	
Field Sparrow	0		0.3	(0.2)	0		0		1.0	(0.8)	0	
White-throated Sparrow	0.4	(0.7)	2.6	(1.6)	0.1	(0.1)	0		1.0	(0.8)	0.3	(0.5)
Song Sparrow	0		0.4	(0.3)	0		0		0		0	
Total Minor Species	7.9	(12.9)	19.2	(12.2)	16.9	(16.1)	2.3	(7.6)	19.4	(15.1)	8.4	(12.7)
Overall Total	61.2		159.6		106.7		30.9		129.8		67.1	
Total Visits	9		9		10		6		5		4	
Number Species	17		23		24		11		19		16	
Shannon Diversity	3.15		3.51		3.33		2.37		3.26		2.81	

[1] Normalized = total no. birds observed/total no. visits

Table 2. Bird species (normalized[1]) observed during winter population surveys on herbicide-treated and untreated Cross Timbers in Oklahoma, 1987-1989. (Numbers in parentheses are percentage of total).

	Winter 1987-88						Winter 1988-89					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
Species	n	%	n	%	n	%	n	%	n	%	n	%
Major Species												
Northern Flicker	1.0	(1.8)	3.0	(3.7)	2.0	(2.5)	0.9	(4.2)	7.7	(7.1)	2.3	(3.5)
Red-bellied Woodpecker	2.5	(4.6)	5.3	(6.5)	1.7	(2.1)	0.2	(0.9)	3.3	(3.0)	1.4	(2.1)
Blue Jay	12.5	(23.0)	9.0	(11.1)	7.5	(9.3)	4.2	(19.6)	25.3	(23.4)	5.7	(8.6)
Carolina Chickadee	8.5	(15.6)	18.0	(22.2)	10.3	(12.7)	3.8	(17.8)	12.7	(11.7)	9.9	(14.9)
Tufted Titmouse	9.5	(17.4)	3.8	(4.7)	6.5	(8.0)	5.2	(24.3)	4.2	(3.9)	3.4	(5.1)
American Robin	12.5	(22.9)	10.6	(13.1)	35.3	(43.5)	5.2	(24.3)	33.1	(30.6)	31.0	(46.6)
Eastern Bluebird	0		4.3	(5.3)	0.5	(0.6)	0		8.7	(8.0)	2.0	(3.0)
Cedar Waxwing	1.7	(3.1)	15.3	(18.9)	6.0	(7.4)	0		3.4	(3.1)	0.6	(0.9)
Yellow-rumped Warbler	0.4	(0.7)	2.6	(3.2)	1.5	(1.9)	0.1	(0.5)	4.3	(4.0)	4.0	(6.0)
Total Major Species	48.6	(89.1)	71.9	(88.7)	71.3	(88.0)	19.6	(91.6)	102.7	(94.8)	60.3	(90.7)

Table 2. Continued.

	Winter 1987-88						Winter 1988-89					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
Species	n	%	n	%	n	%	n	%	n	%	n	%
Minor Species												
Pileated Woodpecker	0.3	(0.6)	0.8	(1.0)	0.2	(0.3)	0.6	(2.8)	0.6	(0.6)	0.6	(0.9)
Red-headed Woodpecker	0		0.2	(0.3)	0		0		0		0	
Downy/Hairy Woodpecker	1.5	(2.8)	2.4	(3.0)	1.3	(1.6)	0.7	(3.3)	0.9	(0.8)	0.5	(0.8)
White-breasted Nuthatch	0.8	(1.5)	0		0		0		0		0	
Brown Creeper	0		0		0		0.1	(0.5)	0.1	(0.1)	0.1	(0.2)
Bewick's Wren	0		0.1	(0.1)	0		0		0.6	(0.6)	2.1	(3.2)
Carolina Wren	0		0		0		0		0		0.2	(0.3)
Northern Mockingbird	0		0.2	(0.3)	0.2	(0.3)	0		0.1	(0.1)	0	
Brown Thrasher	0		0		0		0		0		0.1	(0.2)
Hermit Thrush	0		0		0		0.1	(0.5)	0		0	

Table 2. Continued.

	Winter 1987-88						Winter 1988-89					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
Species	n	%	n	%	n	%	n	%	n	%	n	%
Golden-crowned Kinglet	1.5	(2.8)	0.4	(0.5)	0.9	(1.1)	0		0		0	
Northern Cardinal	0.6	(1.1)	0.9	(1.1)	2.7	(3.3)	0.2	(0.9)	1.9	(1.8)	2.0	(3.0)
American Goldfinch	0		0.1	(0.1)	0.3	(0.4)	0		0		0	
Purple Finch	0		0.5	(0.6)	1.9	(2.3)	0		0		0	
Rufous-sided Towhee	0.5	(0.9)	0.5	(0.6)	0.4	(0.5)	0		0		0	
Dark-eyed Junco	0.7	(1.3)	2.2	(2.7)	1.1	(1.4)	0.1	(0.5)	0.9	(0.8)	0.2	(0.3)
American Tree Sparrow	0		0		0.1	(0.1)	0		0		0	
Field Sparrow	0		0.3	(0.4)	0.3	(0.4)	0		0.2	(0.2)	0.4	(0.6)
White-throated Sparrow	0		0.5	(0.6)	0.4	(0.5)	0		0.2	(0.2)	0.1	(0.2)
Total Minor Species	5.9	(11.0)	9.1	(11.3)	9.8	(12.2)	1.8	(8.5)	5.5	(5.2)	6.3	(9.7)
Overall Total	54.5		81.0		81.1		21.4		108.2		66.6	

Table 2. Continued.

	Winter 1987-88						Winter 1988-89					
	Control		Tebuthiuron		Triclopyr		Control		Tebuthiuron		Triclopyr	
Species	n	%	n	%	n	%	n	%	n	%	n	%
Total Visits	11		11		10		9		9		10	
Number Species	16		23		22		14		19		20	
Shannon Diversity	3.16		3.51		3.07		2.67		2.97		2.74	

[1] Normalized = total no. birds observed/total no. visits

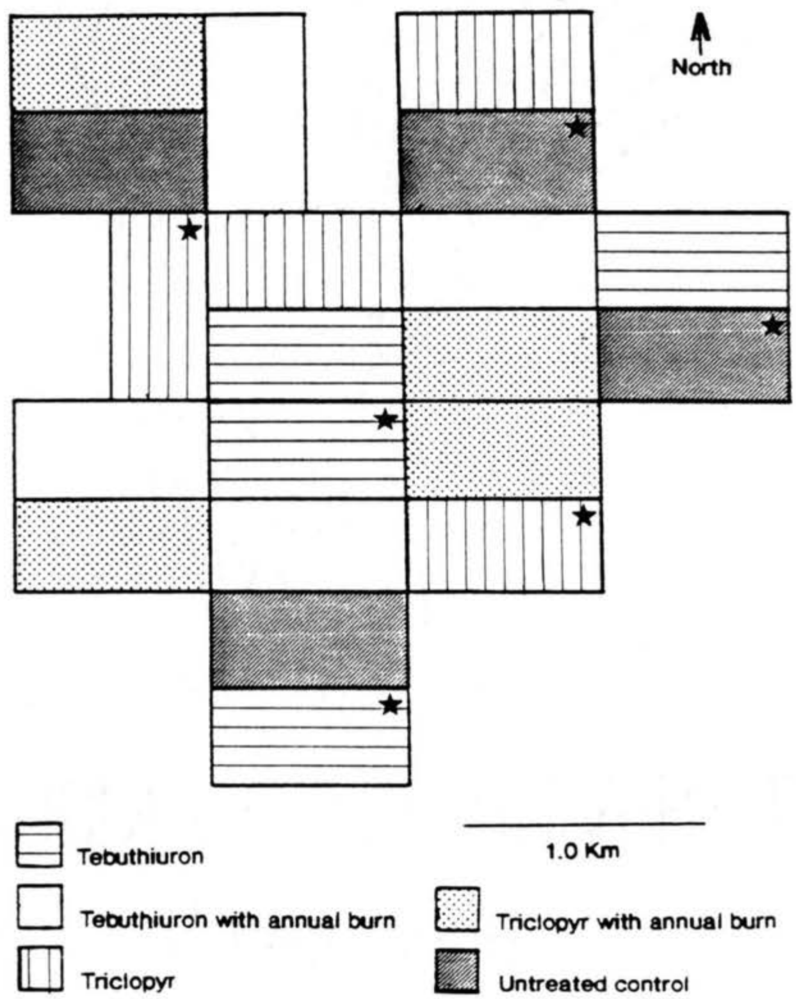

Fig. 1. Treatment scheme for the Cross Timbers Experimental Range, Payne County, Oklahoma (star denotes pastures used in our study).

CHAPTER III

EFFECTS OF HERBICIDE-INDUCED VEGETATION CHANGES ON BREEDING BIRDS IN THE CROSS TIMBERS ECOSYSTEM OF OKLAHOMA

Abstract.--Breeding nongame birds were censused on 5- and 6-year post herbicide-treated and untreated sites. The 2 herbicides used were tebuthiuron and triclopyr. Eleven vegetation parameters were measured on each site. A total of 20 breeding bird species was observed. Breeding birds were divided into 7 guilds based on foraging strategy. Spearman rank correlations were calculated for guilds and individual species. Five of the 7 guilds and several individual species were correlated with habitat parameters. No treatment effects were observed for total bird density, but species composition differed among treatments. Some vegetation parameters were significantly different between treated and untreated sites. We concluded that changes in habitat structure, amount of edge, and possibly food availability resulted in differences in species composition on each treatment, although treatments supported similar total density and diversity of breeding birds.

Herbicides play an important role in both forest (Morrison and Meslow 1983) and range management (Best 1972). Herbicides are used to control brush (Best 1972, Beaver 1976, Gruver and Guthery 1986), improve grazing habitat for cattle (Engle et al. 1989), and prevent growth of unwanted tree species during conifer production (McComb and Rumsey 1983, Morrison and Meslow 1984b, Warren et al. 1984, Santillo et al. 1989). Songbird/herbicide studies have been conducted in the northeastern, western, and southeastern United States. Few studies have been conducted in the south-central United States. Some studies have examined effects of herbicides such as 2,4-D (e.g., Morrison and Meslow 1983, Warren et al. 1984), 2,4,5-T (e.g. Beaver 1976, Morrison and Meslow 1983, Warren et al. 1984, Gruver and Guthery 1986), glyphosate (e.g., Morrison and Meslow 1984a, Santillo et al. 1989), and picloram (McComb and Rumsey 1983), but few studies have examined effects of tebuthiuron and triclopyr on songbirds concurrent with cattle grazing.

The Cross Timbers consists of 3-4 million ha of post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) forests in the south-central United States. This ecosystem can be greatly altered with herbicides to enhance livestock grazing (McCollum et al. 1988). Few avian community studies have been conducted in the Cross Timbers ecosystem. The Cross Timbers are ecologically important, especially in Oklahoma, because it is the ecotone between eastern deciduous forests and western prairies. The Cross Timbers Experimental Range, which was established by the Oklahoma Agricultural Experimental Station, offered a unique opportunity to examine songbird and woodpecker use of sites treated with tebuthiuron and triclopyr and to compare these sites to untreated mature forest.

Vegetation complexity and diversity are directly related to bird species diversity (MacArthur and MacArthur 1961). Knowledge of seasonal abundance of birds is an important component in understanding relationships between bird species and vegetation complexity (Meslow 1978, Anderson and Ohmart 1980) and in determining how habitat alterations affect bird species diversity (Willson 1974). Therefore, our objectives were to (1) document breeding populations of songbirds and woodpeckers in the Cross Timbers and (2) examine effects of herbicide-induced habitat alterations on songbird and woodpecker use of the Cross Timbers. We hypothesized that (1) herbicides applied to the Cross Timbers do not affect songbird and woodpecker community structure (e.g., species density and/or diversity); (2) tebuthiuron and triclopyr do not differ in their influence on songbirds and woodpeckers; and (3) there is no difference in snag and slash densities on control and herbicide-treated areas.

STUDY AREA AND METHODS

Our study was conducted on the Cross Timbers Experimental Range of the Oklahoma Agricultural Experiment Station (Engle et al. 1987). This area was located in Payne County, Oklahoma, and consisted of 20 32.4-ha pastures in sections 2, 3, 10, and 11 T18N, R1E (Fig. 1), representing 4 replications of 5 experimental treatments. The 3 treatments included in our study were: (1) tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N+N'-dimethylurea) (Elanco Product Co., Division of Eli Lilly and Co., Indianapolis, Ind. 46285) applied aerially at 2.2 kg active ingredient/ha in March 1983; (2) triclopyr ([3,5,6-tricloro-2-

pyridinyl)oxy]acetic acid) (Dow Chemical Co., Midland, Mich. 48674) applied aerially at 2.2 kg triclopyr acetic acid/ha in March 1983; and (3) a control (no herbicide, no burning).

The 2 herbicides were applied to reduce overstory dominance of hardwoods, primarily post oak and blackjack oak. Both herbicides were effective, but tebuthiuron had better total tree kill than triclopyr (Stritzke et al. 1987). Five- to 6-years post-treatment, both herbicides resulted in large numbers of standing snags and brushy understories; however, more brush growth in the understory and greater foliar cover was present on triclopyr treatments. These pastures were grazed by yearling cattle from mid-April through September 1988 and mid-March through September 1989; stocking rates were set to result in moderate use of forage (Engle et al. 1989).

One 10.8-ha grid was placed in each of 9 pastures (i.e., 3 control, 3 tebuthiuron, and 3 triclopyr) to maximize homogeneity of grids. Each grid contained 30 stations 60 m apart with intermediary flags every 30 m for accuracy during spot-mapping.

All vegetation measurements were made in 0.04-ha circular plots (i.e., 11.3-m radius) using the grid station as the center of each plot (Noon 1980). During 1988, foliage height diversity was estimated twice at 10 randomly chosen stations on each of the 9 grids: (1) when birds first began to establish territories in March and early April (Lewis 1987) and (2) in May and June when nesting began and some species were beginning to hatch (Balda 1975). Foliage height diversity was estimated using a density board (Noon 1980), which was divided into 4 height intervals that corresponded to low ground (0-0.3 m), high ground (0.3-1.0 m), low shrub (1.0-2.0 m), and high shrub (2.0-3.0 m) (Noon 1980). Readings were made 11.3-m from each grid station in the 4 cardinal directions (Noon 1980), and the number of squares in each height interval >50% obscured by foliage was recorded.

Density of snags and slash were estimated in summer 1988 at all stations with the point-quarter method (Smith 1980) by measuring the distance to the closest snag ($\geq$8 cm in diameter) and the closest slash ($\geq$1.5 m long, $\geq$8 cm in diameter) in each quarter of each 0.04-ha plot (Noon 1980). Density equaled mean area/ha, where mean area = (total distance/number of distances)^2 (Smith 1980). Snag basal area was estimated using the formula given by Smith (1980). Slash volume was estimated using a formula for the volume of a tapering cylinder (R. B. Renken, pers. commun.). Herbaceous and shrub cover were visually estimated at each station in summer 1988. Foliar cover (above shoulder height) was measured in summer 1989 at all stations using a forest densiometer (Lemmon 1957).

Grids were censused using the spot-mapping method (Kendeigh 1944, Int. Breeding Bird Census Comm. 1970). During each visit species were recorded on detailed maps of each grid. Although the Pileated Woodpecker (Dryocopus pileatus) was frequently observed, accurate densities could not be established because its average territory size (53-160-ha) (Renken and Wiggers 1989) was larger than our grid size.

The American Crow (Corvus brachyrhynchos) and the Brown-headed Cowbird (Molothrus ater) also were observed on our study site, however we felt that the crow could not be accurately censused due to its large territory size and the Brown-headed Cowbird was observed only in association with cattle using the grids. Grids were visited in the mornings and evenings, alternating starting points to reduce temporal variation. Total visit time/grid was approximately 3 hours. All visits were made under favorable weather conditions (i.e., no precipitation or fog; wind $\leq$20 mph).

Daily community maps were transferred to individual species maps for each grid. Densities (i.e., number of territorial males/10.8-ha) were estimated for each species for each grid following guidelines established by the International Breeding Bird Census Committee (1970). Breeding birds were placed into 7 guilds based on foraging behavior: (1) foliage/bark-gleaning omnivores (Carolina Chickadee [Parus carolinensis], Tufted Titmouse [Parus bicolor]); (2) upper-level foliage-gleaning insectivores (Yellow-billed Cuckoo [Coccyzus americanus], Summer Tanager [Piranga rubra]); (3) lower-level foliage-gleaning insectivores (Bewick's Wren [Thryomanes bewickii], Blue-gray Gnatcatcher [Polioptila caerulea]); (4) ground-gleaning omnivores (Northern Cardinal [Cardinalis cardinalis], Indigo Bunting [Passerina cyanea], Painted Bunting [P. ciris], Field Sparrow [Spizella pusilla]); (5) bark-gleaning insectivores (Red-bellied Woodpecker [Melanerpes carolinus], Red-headed Woodpecker [M. erythrocephalus], Downy Woodpecker

[Picoides pubescens], Hairy Woodpecker [P. villosus], Black-and-white Warbler [Mniotilta varia]); (6) ground-gleaning insectivores (Louisiana Waterthrush [Seiurus motacilla]); and (7) insectivorous air-salliers (Great Crested Flycatcher [Myiarchus crinitus], Eastern Phoebe [Sayornis phoebe], Eastern Bluebird [Sialia sialis]). The Blue Jay (Cyanocitta cristata) was not included in a foraging guild because it is a generalist species that would not fit into any of the above guilds (Robbins et al. 1983).

The Shannon diversity index ($H' = - \sum p_i \log_2 p_i$) was used to determine bird species diversity for each grid (Tramer 1969, Hair 1980, Brower and Zar 1984). The Shannon diversity index was used for several reasons: (1) it is the best measure of diversity when populations are randomly sampled, (2) it is simple to calculate and is frequently used in avian diversity studies, and (3) it is independent of sample size because it assumes that all species in the community are contained in the random sample (Hair 1980:273-274). Foliage height diversity also was determined for each grid using this method.

Kruskal-Wallis H-tests were used to determine differences in territorial male density among the 3 treatments. Chi-square approximations are given in place of H (SAS Inst., Inc. 1988). Wilcoxon 2 sample tests were used to compare bird densities between treated and control sites and between the 2 herbicide treatments. Z-values are given in place of U (SAS Inst., Inc. 1988). Because of small sample sizes (n = 3/treatment), the 2 years of breeding bird data were combined before analysis. Spearman rank correlations were calculated to examine relationships between habitat variables and individual species of birds, total bird density, and foraging guilds. Kruskal-Wallis $\underline{H}$-tests were used to determine differences in vegetation measurements among the 3 treatments. Wilcoxon 2 sample tests were used to determine differences in vegetation between treated and untreated sites and between the 2 treated sites. Minimum significance level was set at $\underline{P} < 0.05$.

RESULTS

Vegetation.--Foliage obscurity was similar in both lower height strata (0-0.3 m and 0.4-1.0 m) for both time periods, although obscurity was slightly less for 0.4-1.0 m (Table 1). Percent obscurity in the upper 2 height strata (1.1-2.0 m and 2.1-3.0 m) for both time periods was similar for both control and triclopyr sites but was slightly less for tebuthiuron sites (Table 1). Foliage height diversity remained the same or increased from the first to the second measurement, except on pasture 20 where it decreased slightly on the second measurement (Table 1). Foliage height diversity was similar on control and triclopyr sites, but it was slightly less on the tebuthiuron sites during both measurements (Table 1).

Snags/ha, snag basal area, and slash/ha were greater on herbicide sites than on controls (Table 1); however, no significant differences among treatments occurred using the Kruskal-Wallis test for treatment effects. Slash volume/ha was variable (Table 1), and no differences were found among the 3 treatments. However, when all herbicide-treated sites (i.e., both tebuthiuron and triclopyr; $\underline{n}$ = 6) were contrasted to control sites ($\underline{n}$ = 3) with the Wilcoxon 2 sample test, snags/ha ($\underline{P}$ = 0.028), snag basal area ($\underline{P}$ = 0.028), and slash/ha ($\underline{P}$ = 0.028) differed significantly between treatments.

Foliar cover was greater on control than herbicide sites, but no significant differences were found among treatments using the Kruskal-Wallis test. When all herbicide sites ($\underline{n}$ = 6) were compared to control sites ($\underline{n}$ = 3) using the Wilcoxon 2 sample test, foliar cover was significantly ($\underline{P}$ = 0.028) less on herbicide treatments. Herbaceous cover tended to be greater on herbicide treatments than controls and was significantly different ($\underline{P}$ = 0.05) using the Kruskal-Wallis test for treatment effects. Shrub cover was variable and did not differ among the 3 treatments.

Breeding Birds.--Grids were visited 8 times from 16 March through 15 August, 1988 and 6 times from 23 March to 26 August, 1989. Discrepancies in numbers of visits were due to weather constraints. Twenty territorial species were observed during the entire breeding bird survey. Overall, 16 species were observed on both control and tebuthiuron sites, and 15 species were observed on triclopyr sites (Table 2). The Northern Cardinal and the Blue-gray Gnatcatcher were the 2 most abundant species during both years on all treatments. The Bewick's Wren and Indigo Bunting were observed only on herbicide-treated sites (Table 2). The Red-headed Woodpecker and the Eastern Bluebird were observed only on tebuthiuron sites. The Eastern Phoebe and the Louisiana Waterthrush were observed only on control sites (Table 2).

Nineteen species were observed during the 1988 survey. Species richness was greatest on control sites ($\underline{n}$ = 15), slightly less on tebuthiuron sites ($\underline{n}$ = 14), and least on triclopyr sites ($\underline{n}$ = 10). The Bewick's Wren, Eastern Bluebird, and Indigo Bunting were observed only on herbicide-treated sites. The Red-headed Woodpecker was observed only on tebuthiuron sites. The Yellow-billed Cuckoo, Black-and-white Warbler, Louisiana Waterthrush, Summer Tanager, and Painted Bunting were observed only on control sites. Species diversity was greatest on control sites and least on the triclopyr sites (Table 2).

Twenty species were observed during the 1989 survey. Species richness was greatest on triclopyr sites ($\underline{n}$ = 15) and lower on tebuthiuron ($\underline{n}$ = 13) and control ($\underline{n}$ = 12) sites. The Bewick's Wren, Indigo Bunting, and Painted Bunting were observed only on herbicide-treated sites. The Red-headed Woodpecker, Eastern Bluebird, and Summer Tanager were observed only on tebuthiuron sites. The Downy/Hairy Woodpecker was observed only on triclopyr sites. The Eastern Phoebe and Louisiana Waterthrush were observed only on control sites. Species diversity was highest on triclopyr sites and lowest on tebuthiuron sites, although overall differences were small.

Total density of territorial males was not significantly different among the 3 treatments ($\underline{X}^2$ = 0.38, $\underline{P}$ = 0.827). Densities of Tufted Titmouse ($\underline{X}^2$ = 11.44, $\underline{P}$ = 0.003), Bewick's Wren ($\underline{X}^2$ = 11.16, $\underline{P}$ = 0.004), Eastern Bluebird ($\underline{X}^2$ = 6.75, $\underline{P}$ = 0.034), Black-and-white Warbler ($\underline{X}^2$ = 7.15, $\underline{P}$ = 0.028), Louisiana Waterthrush ($\underline{X}^2$ = 17.00, $\underline{P}$ = 0.0002), and Indigo Bunting ($\underline{X}^2$ = 7.32, $\underline{P}$ = 0.026) were significantly different among the 3 treatments. No other species showed significant differences in density among treatments.

The Yellow-billed Cuckoo ($\underline{Z}$ = 2.21, $\underline{P}$ = 0.027), Tufted Titmouse ($\underline{Z}$ = 2.75, $\underline{P}$ = 0.006), Bewick's Wren ($\underline{Z}$ = -3.00, $\underline{P}$ = 0.003), Black-and-white Warbler ($\underline{Z}$ = 2.20, $\underline{P}$ = 0.028), Louisiana Waterthrush ($\underline{Z}$ = 3.22, $\underline{P}$ = 0.001), and Indigo Bunting ($\underline{Z}$ = -2.65, $\underline{P}$ = 0.008) had significantly different densities between control and tebuthiuron plots. The Red-bellied Woodpecker ($\underline{Z}$ = 2.24, $\underline{P}$ = 0.025), Tufted Titmouse ($\underline{Z}$ = 2.51, $\underline{P}$ = 0.012), Bewick's Wren ($\underline{Z}$ = -2.59, $\underline{P}$ = 0.01), Louisiana Waterthrush ($\underline{Z}$ = 3.22, $\underline{P}$ = 0.001), and Field Sparrow ($\underline{Z}$ = -2.03, $\underline{P}$ = 0.043) had significantly different densities between control and triclopyr sites. No significant differences in bird densities were found between the 2 herbicide treatments.

Foliage/bark-gleaning omnivores and ground-gleaning insectivores were correlated positively with foliage height diversity and foliar cover. They were negatively correlated with herbaceous cover, snags, and slash. Lower level foliage-gleaning insectivores and ground-gleaning omnivores were correlated positively with herbaceous cover and negatively correlated with foliage height diversity and foliar cover. Bark-gleaning insectivores were not correlated with many habitat variables, but correlations were found with foliar and herbaceous cover

(Table 3). The upper level foliage-gleaning insectivores and the insectivorous air-salliers were not significantly correlated with any habitat variables.

The Blue-gray Gnatcatcher, Bewick's Wren, and Field Sparrow were correlated positively with herbaceous cover and negatively correlated with foliage height diversity and foliar cover (Table 3). Tufted Titmouse densities were correlated positively with foliage height diversity and total foliage density; densities were correlated negatively with herbaceous cover, snags, snag basal area, and slash. The Northern Cardinal was the most abundant species but did not show significant correlation with any habitat variables. The Carolina Chickadee was also an abundant species but was only significantly correlated with foliar cover ($r_s = 1.00$). Total bird density was not significantly correlated with any habitat variables.

DISCUSSION

Changes in food availability or type (Slagsvold 1977), amount of edge habitat (McComb and Rumsey 1983), foraging behavior (Morrison and Meslow 1983), and nesting cover (Best 1972, Titterington et al. 1979, Morrison and Meslow 1984b) can alter bird species diversity and density in any community type. Other factors can influence songbird use of herbicide-treated areas including habitat type (Slagsvold 1977, Morrison and Meslow 1984b) and location, number of years post-treatment (Schroeder and Sturges 1975, Morrison and Meslow 1984a, Warren et al.

1984), over-winter mortality of birds (Morrison and Meslow 1983), and pre-treatment site differences (Morrison and Meslow 1983).

Our control sites were characterized by a slightly more diverse foliage structure, greater foliar cover, less snags and slash, and less herbaceous cover than herbicide-treated sites. Five- to 6-years post-treatment, triclopyr and tebuthiuron sites did not differ significantly in habitat as we measured it, but tebuthiuron sites generally had less brush than triclopyr sites.

Five- and 6-years post-treatment total densities and diversities of birds showed no significant treatment effects on our study site. Osaki (1979) found no treatment effects upon examining brush fields treated 6 to 7 years previously with 2,4,5-T. Savidge (1978) found a 2-fold increase in total number of birds on untreated sites as compared to treated sites when examining brush fields treated 1-2 years previously with 2,4,5-T. She felt that the collapse of brush species on treated sites was responsible for the decline in nesting density. Morrison and Meslow (1984b) found only slight changes in nesting bird densities between treated and untreated sites up to 4-years post-treatment because shrub densities remained approximately the same on all sites. In our study, snags began to fall about 4-years post-treatment D. M. Engle, pers. commun.), but herbicide sites still supported larger numbers of snags than control sites 5- and 6-years post-treatment.

Slagsvold (1977) found that bird numbers were lower on 2,4,5-T treated than untreated areas 5-years post-treatment. He suggested that reduced food availability caused the decrease in density on treated sites. In our study, food (i.e., seeds from grasses and forbs) increased more than 20X on treated sites as compared to untreated sites (D. M. Engle, pers. commun.). Snags and slash can be an important food source (Warren et al. 1984). The increased seed production along with the abundance of snags and slash in our study may have mitigated any detrimental effects caused by herbicides.

Although bird species diversity and total density did not show any treatment effects, species composition differed among the 3 treatments. Herbicide-treated sites supported more edge (e.g., Bewick's Wren) and open habitat species (e.g., Eastern Bluebird) than control sites. Control sites supported more interior-woodland types of species (e.g., Louisiana Waterthrush) than treated sites. Osaki (1979) also found no treatment effects on total abundance of birds 6-7 years post-treatment, but densities of some species differed among treatments. Beaver (1976) found no changes in population size or composition, which he attributed to proximate habitat factors that were not altered for each species. He concluded that the lack of treatment effects was mainly due to the similarity of proximate factors on all treatments, especially foliage profile.

Although some vegetation parameters were similar in our study (e.g., foliage height diversity), overall foliage profile differed between treated and untreated sites. Warren et al. (1984) found that cavity nesting species on pine plantations subjected to clear-cutting, 2,4,5-T, and 2,4-D were most abundant 4-years post-treatment and that numbers were still relatively high after 8 years, due to creation of temporary nesting habitat. This may explain why some species such as the Bewick's Wren and Eastern Bluebird were found only on herbicide-treated sites in our study. Morrison and Meslow (1984b) found that species dependent on deciduous trees decreased in density post-treatment, similar to the Black-and-white Warbler and the Louisiana Waterthrush in our study.

Overall, bird species presence/absence was as expected for the region (Grzybowski 1986) and for the most part, guilds and species were correlated logically with habitat variables, based on our field observations and extant literature (e.g., Kahl et al. 1985). However, the Tufted Titmouse was anomalous; it had significantly higher densities on control sites as compared to herbicide treatments and was positively correlated with characteristics of control sites. Kahl et al. (1985) found that the Tufted Titmouse occurred in a variety of wooded habitats, including grass-shrub savannah, and was secondarily correlated with canopy closure and canopy height. We also found the Tufted Titmouse to be correlated positively with foliar cover, but height was not measured. Other authors found that distance to edge was an important factor in Tufted Titmouse density (Fitch 1958, Anderson 1979). Kahl et al. (1985) reviewed studies of habitat characteristics and found that the Tufted Titmouse did not respond consistently to any particular variable.

McComb and Rumsey (1983) found that Tufted Titmouse numbers were significantly greater on 4-year post-picloram treated plots. They also felt that Tufted Titmouse densities were not predictable after herbicide-induced vegetation changes occurred. Warren et al. (1984) found that the Tufted Titmouse was common on sites treated with 2,4,5-T and 2,4-D. Our results suggested that Tufted Titmouse density may be influenced by additional factors, such as other secondary cavity nesters, proximity of edge, and lack of canopy cover on treated sites.

Management Implications.--Herbicides are important tools for both forest and range management. Tebuthiuron and triclopyr are both used in the south-central United States to improve grazed hardwood forests for increased production of cattle forage. Resulting vegetation, 5- to 6-years post-treatment, on herbicide sites was different from that of untreated sites. Both herbicides increased the amount of snags and slash; however, tebuthiuron created open, grassy sites, and triclopyr created brushy sites with deciduous resprouting. We found that total breeding bird populations 5- and 6-years post-treatment were similar in density and diversity for all treatments. However, the manager should be aware that species composition and evenness differed among treatments. Herbicide-treated sites supported more edge and open habitat species; control sites supported more interior-woodland species. The application of either herbicide depends upon the manager's future goals, especially types of bird species and vegetation desired.

LITERATURE CITED

Anderson, S. H. 1979. Habitat assessment for breeding bird populations. Trans. North Am. Wildl. and Nat. Resour. Conf. 44:431-445.

Anderson, B. W., and R. D. Ohmart. 1980. Designing and developing a predictive model and testing a revegetated riparian community for southwestern birds. Pages 434-450 in R. M. DeGraaf, tech. coord. Proc. workshop management of western forests and grasslands for non-game birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Pages 59-80 in D. R. Smith, tech. coord. Proc. symp. forest and range habitats for nongame birds. U.S. For. Serv. Gen. Tech. Rep. WO-1.

Beaver, D. L. 1976. Avian populations in herbicide treated brush fields. Auk 93:543-553.

Best, L. B. 1972. First-year effects of sagebrush control on two sparrows. J. Wildl. Manage. 36:534-544.

Brower, J. E., and J. H. Zar. 1984. Field and laboratory methods for general ecology. Second ed. Wm. C. Brown Publ., Dubuque, Iowa. 226pp.

Engle, D. M., J. F. Stritzke, and F. T. McCollum. 1987. Brush management on the Cross Timbers Experimental Range: II. Herbaceous plant responses. Okla. Agr. Exp. Stn. MP-119:103-109.

_____, _____, and _____. 1989. Vegetation manipulation in the Cross Timbers: response to herbicides and burning. Unpubl. ms., Okla.

Agr. Exp. Stn., Okla. State Univ., Stillwater.

Fitch, H. S. 1958. Home ranges, territories, and seasonal movement of vertebrates of the National History Reservation. Univ. Kansas, Mus. Nat. Hist. Publ. 11:63-326.

Gruver, B. J., and F. S. Guthery. 1986. Effects of brush control and game-bird management on nongame birds. J. Range Manage. 39:251-253.

Grzybowski, J. A. 1986. Date guide to the occurrences of birds in Oklahoma. Okla. Ornithol. Soc., Norman, Okla. 32pp.

Hair, J. D. 1980. Measurement of ecological diversity. Pages 269-275 in S. D. Schemnitz, ed. Wildlife management techniques manual. Fourth ed. The Wildlife Society, Washington, D.C.

International Bird Census Committee. 1970. Recommendations for an international standard for a mapping method in bird census work. Aud. Field Notes 24:722-726.

Kahl, R. B., T. S. Baskett, J. A. Ellis, and J. N. Burroughs. 1985. Characteristics of summer habitats of selected nongame birds in Missouri. Missouri Agr. Exp. Stn. Res. Bull. 1056. 155pp.

Kendeigh, S. C. 1944. Measurements of bird populations. Ecol. Monogr. 14:67-106.

Lemmon, P. E. 1957. A new instrument for measuring forest overstory density. J. For. 55:667-669.

Lewis, S. 1987. Wildlife quiz. Outdoor Okla. 43:54-55.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.

McCollum, F. T., D. M. Engle, and J. F. Stritzke. 1988. Brush management in the Cross Timbers: III. Carrying capacity and livestock responses. Annu. Meet. Soc. Range Manage., Corpus Christi, Tex.

McComb, W. C., and R. L. Rumsey. 1983. Bird density and habitat use in forest openings created by herbicides and clearcutting in the Central Appalachians. Brimleyana 9:83-95.

Meslow, E. C. 1978. The relationship of birds to habitat structure-plant communities and successional stages. Pages 12-18 in R. M. DeGraaf, tech. coord. Proc. workshop nongame bird habitat management in coniferous forests of the western U.S. U.S. For. Serv. Gen. Tech. Rep. PNW-64.

Morrison, M. L., and E. C. Meslow. 1983. Impacts of forest herbicides on wildlife: toxicity and habitat alteration. Trans. North Amer. Wildl. and Nat. Res. Conf. 48:175-185.

_____, and _____. 1984a. Effects of the herbicide glyphosate on bird community structure, western Oregon. For. Sci. 30:95-106.

_____, and _____. 1984b. Response of avian communities to herbicide-induced vegetation changes. J. Wildl. Manage. 48:14-22.

Noon, B. R. 1980. Techniques for sampling avian habitats. Pages 42-52 in D. E. Capen, ed. The use of multivariate statistics in studies of wildlife habitat. U.S. For. Serv. Gen. Tech. Rep. RM-87.

Osaki, S. K. 1979. An assessment of wildlife populations and habitat in herbicide-treated Jeffrey pine plantations. M.S. Thesis, Univ. California, Berkeley. 83pp.

Renken, R. B., and E. P. Wiggers. 1989. Forest characteristics related to pileated woodpecker territory size in Missouri. Condor 91:642-652.

Robbins, C. S., B. Bruun, and H. S. Zim. 1983. A guide to field identification birds of North America. Western Publ. Co., Racine, Wis. 360pp.

Santillo, D. J., P. W. Brown, and D. M. Leslie, Jr. 1989. Response of songbirds to glyphosate-induced habitat changes on clearcuts. J. Wildl. Manage. 53:64-71.

SAS Institute, Inc. 1988. SAS/stat user's guide. SAS Inst., Inc. Cary, N.C. 1028pp.

Savidge, J. A. 1978. Wildlife in a herbicide-treated Jeffrey Pine plantation in eastern California. J. For. 76:476-478.

Schroeder, M. H., and D. L. Sturges. 1975. The effect on the Brewer's Sparrow of spraying big sagebrush. J. Range Manage. 28:294-297.

Slagsvold, T. 1977. Bird populations after clearcut of deciduous scrub. Biol. Conserv. 12:229-244.

Smith, R. L. 1980. Ecology and field biology. Third ed. Harper and Row Publ., New York, N.Y. 835pp.

Stritzke, J. F., D. M. Engle, and F. T. McCollum. 1987. Brush management on the Cross Timbers Experimental Range: I. Brush problems and responses to herbicides. Okla. Agr. Exp. Stn. MP-

119:99-102.

Tramer, E. J. 1969. Bird species diversity: components of Shannon's formula. Ecology 50:927-929.

Titterington, R. W., H. S. Crawford, and B. N. Burgason. 1979. Songbird responses to commercial clear-cutting in Maine spruce-fir forests. J. Wildl. Manage. 43:602-609.

Warren, R. C., G. A. Hurst, and T. L. Darden, Jr. 1984. Relative abundance of cavity nesting birds on pine plantations site prepared by herbicides. Pages 197-205 in W. C. McComb, ed. Proc. workshop management of nongame species and ecological communities. Dep. For., Univ. Kent., Lexington.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

Table 1. Habitat characteristics of herbicide-treated and untreated Cross Timbers in Oklahoma, 1988-1989.

Habitat parameter	Treatment								
	Control			Tebuthiuron			Triclopyr		
	11[a]	14	20	8	9	12	3	13	18
Obscurity by ht stratum (m)									
Mar-Apr									
0-0.3	79.5	91.5	66.5	93.5	83.3	87.7	89.8	84.7	94.2
0.4-1.0	70.5	84.6	54.4	78.4	51.9	69.3	70.9	77.2	74.1
1.1-2.0	68.4	72.3	54.0	56.9	41.6	47.7	67.2	68.7	65.5
2.1-3.0	62.5	69.7	47.3	49.0	31.9	44.1	60.7	63.3	64.3
Total foliage density	280.9	318.1	222.2	277.8	208.7	248.8	288.6	293.9	298.1
Foliage ht diversity	1.99	1.99	1.99	1.95	1.90	1.95	1.99	1.99	1.98
May-Jun									
0-0.3	96.5	97.3	89.7	99.0	92.8	96.8	91.7	87.5	87.0
0.4-1.0	88.5	90.6	78.9	87.6	70.8	82.3	72.6	80.1	68.8
1.1-2.0	87.4	85.4	62.2	86.8	46.9	63.0	67.7	74.2	67.1
2.1-3.0	86.9	88.4	53.7	59.3	44.7	51.1	65.8	69.3	63.9
Total foliage density	359.3	361.7	284.5	314.7	255.2	293.2	297.8	311.1	286.8
Foliage ht diversity	2.01	2.01	1.98	1.98	1.93	1.96	1.99	1.99	1.99
Snags/ha	64	56	58	253	204	199	312	315	123
Snag basal area (m^2/ha)	1.28	1.29	1.16	5.06	5.71	7.56	5.62	11.03	3.81
Slash/ha	195	221	206	1275	366	743	823	594	321

Table 1. Continued.

Habitat parameter	Treatment								
	Control			Tebuthiuron			Triclopyr		
	11[a]	14	20	8	9	12	3	13	18
Slash volume (m^3/ha)	34.08	17.07	12.87	18.21	22.09	79.20	30.10	33.75	20.40
Foliar cover (%)	90.96	84.66	68.56	33.01	22.72	35.14	29.19	44.94	36.84
Herbaceous cover (%)	26.57	27.07	30.33	84.30	93.90	84.30	89.07	58.93	74.83
Shrub cover (%)	34.33	38.13	22.53	25.37	10.00	29.67	26.47	47.80	39.57

[a]Individual pasture numbers of the Cross Timbers Experimental Range.

Table 2. Breeding densities of songbirds and woodpeckers (no. territorial males\10.8 ha) on herbicide-treated and untreated Cross Timbers in Oklahoma, 1988 and 1989.

		Treatments								
		Control			Tebuthiuron			Triclopyr		
Species	Year	11[a]	14	20	8	9	12	3	13	18
Yellow-billed	1988	1.0	0	1.0	0	0	0	0	0	0
Cuckoo	1989	3.0	0	1.0	0	0	0	1.0	1.0	1.0
Red-bellied	1988	1.5	2.0	1.0	2.0	1.0	0	0	0	0
Woodpecker	1989	0	1.0	3.0	0	0	1.0	0	1.0	0
Red-headed	1988	0	0	0	1.0	0	0	0	0	0
Woodpecker	1989	0	0	0	1.0	0	0	0	0	0
Downy/Hairy	1988	1.0	0	0	0.5	0	1.5	0	2.0	0
Woodpecker	1989	0	0	0	0	0	0	0	1.0	1.0
Great Crested	1988	1.5	1.0	0	0	0	1.0	0	0	0
Flycatcher	1989	0	0	2.0	0	0	0	0	1.0	0
Eastern Phoebe	1988	0	0	0	0	0	0	0	0	0
	1989	0	1.0	0	0	0	0	0	0	0
Blue Jay	1988	1.0	3.0	0	0	1.0	0	0	2.0	2.0
	1989	1.0	1.0	0	0	1.0	0	1.0	0	0

Table 2. Continued.

		Treatments								
		Control			Tebuthiuron			Triclopyr		
Species	Year	11[a]	14	20	8	9	12	3	13	18
Carolina Chickadee	1988	4.0	3.0	1.0	2.0	3.0	2.0	2.0	3.0	3.0
	1989	0	1.0	2.0	0	0	1.0	1.0	1.0	0
Tufted Titmouse	1988	7.0	5.5	3.0	1.0	0	2.0	3.0	2.0	1.5
	1989	5.0	6.0	2.0	0	1.0	1.0	1.0	1.0	1.0
Bewick's Wren	1988	0	0	0	2.0	4.0	1.0	1.0	1.0	0
	1989	0	0	0	5.0	3.0	2.0	2.0	3.0	4.0
Eastern Bluebird	1988	0	0	0	0	2.0	3.5	0	0	0
	1989	0	0	0	0	2.0	0	0	0	0
Blue-gray	1988	5.0	2.5	5.0	3.0	5.5	7.0	10.0	5.0	3.0
Gnatcatcher	1989	2.0	4.0	6.0	5.0	8.0	7.0	5.0	5.0	4.0
Black-and-white	1988	0	4.0	2.0	0	0	0	0	0	0
Warbler	1989	0	1.0	1.0	0	0	0	0	1.0	0
Louisiana	1988	1.0	1.0	1.0	0	0	0	0	0	0
Waterthrush	1989	1.0	1.0	1.0	0	0	0	0	0	0

Table 2. Continued.

		Treatments								
		Control			Tebuthiuron			Triclopyr		
Species	Year	11[a]	14	20	8	9	12	3	13	18
Summer Tanager	1988	0	1.0	0	0	0	0	0	0	0
	1989	0	0	0	0	0	1.0	0	0	0
Northern Cardinal	1988	13.5	6.0	2.5	7.5	9.5	5.5	7.0	9.5	9.5
	1989	8.0	5.0	5.0	7.0	7.0	8.0	5.0	5.0	12.0
Indigo Bunting	1988	0	0	0	2.0	1.0	1.0	2.0	0	1.0
	1989	0	0	0	1.0	0	1.0	0	1.0	0
Painted Bunting	1988	0	0	1.0	0	0	0	0	0	0
	1989	0	0	0	0	1.0	0	1.0		1.0
Field Sparrow	1988	0.5	0.5	3.0	4.0	7.5	2.5	4.5	1.5	4.0
	1989	0	0	3.0	2.0	5.0	2.0	3.0	1.0	4.0
Totals	1988	37	29.5	20.5	25	34.5	27	29.5	26	24
	1989	20	21	26	21	28	24	20	22	28
Number of species	1988	12	11	10	11	9	11	7	9	7
	1989	6	9	10	6	8	9	9	13	9

Table 2. Continued.

		Treatments								
		Control			Tebuthiuron			Triclopyr		
Species	Year	11[a]	14	20	8	9	12	3	13	18
Shannon diversity	1988	2.74	3.15	3.07	2.96	2.76	2.99	2.47	2.63	2.45
	1989	2.21	2.73	3.06	2.25	2.60	2.60	2.83	3.19	2.41

[a]Individual pasture numbers of the Cross Timbers Experimental Range.

Table 3. Spearman rank correlations of habitat variables with foliage/bark-gleaning omnivores (F/BGO), lower-level foliage-gleaning insectivores (FGI/L), ground-gleaning omnivores (GGO), bark-gleaning insectivores (BGI), ground-gleaning insectivores (GGI), and 4 bird species on herbicide-treated and untreated Cross Timbers in Oklahoma, 1988 and 1989.

	Foraging Guilds					Individual Species			
Habitat variable	F/BGO	FGI/L	GGO	BGI	GGI	Blue-gray Gnatcatcher	Field Sparrow	Tufted Titmouse	Bewick's Wren
Foliage ht diversity[1]	0.43[a]	-0.31[c]	-0.24[b]	0.13	0.60[a]	-0.29	-0.56[b]	0.70[a]	-0.64[a]
Foliage ht diversity[2]	0.41[b]	-0.39[b]	-0.26[b]	0.06	0.52[b]	-0.65[a]	-0.66[a]	0.68[a]	-0.54[b]
Total foliage density[1]	0.24	-0.28	-0.11	0.04	0.09	-0.61[a]	-0.45[c]	0.36	-0.25
Total foliage density[2]	0.29[c]	-0.28[c]	-0.24[b]	0.16	0.37	-0.56[b]	-0.79[a]	0.49[b]	-0.30
Foliar cover	0.45[a]	-0.41[b]	-0.31[a]	0.23[b]	0.82[a]	-0.55[b]	-0.79[a]	0.32	-0.40[c]
Herbaceous cover	-0.44[a]	0.41[b]	0.31[a]	-0.24[b]	-0.83[a]	0.59[b]	0.79[a]	-0.75[a]	0.72[a]
Shrub cover	0.22	-0.23	-0.13	0.06	0.00	-0.49[b]	-0.55[b]	0.31	-0.21
Snags	-0.33[b]	0.32[c]	0.19	-0.13	-0.82[a]	0.36	0.33	-0.60[a]	0.67[a]

Table 3. Continued.

Habitat variable	Foraging Guilds					Individual Species			
	F/BGO	FGI/L	GGO	BGI	GGI	Blue-gray Gnatcatcher	Field Sparrow	Tufted Titmouse	Bewick's Wren
Snag basal area	-0.28	0.33[b]	0.18	-0.10	-0.82[a]	0.45[c]	0.21	-0.55[b]	0.63[a]
Slash	-0.38[b]	0.32[c]	0.24[b]	-0.09	-0.82[a]	0.33	0.36	-0.64[a]	0.67[a]
Slash volume	-0.00	0.11	-0.02	-0.19	-0.37	0.29	-0.18	-0.04	0.17

[a] $\underline{P} < 0.01$.

[b] $\underline{P} < 0.05$.

[c] $\underline{P} < 0.10$.

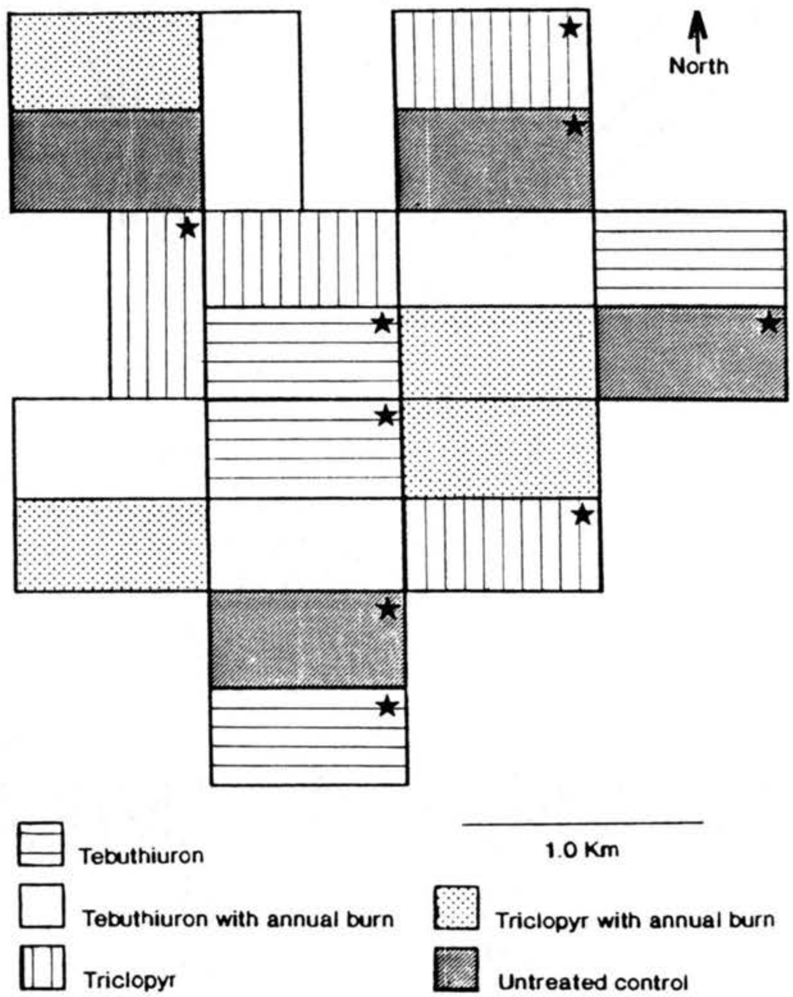

Fig. 1. Treatment scheme for the Cross Timbers Experimental Range, Payne County, Oklahoma (star denotes pastures used in our study).

APPENDIXES

Appendix A. Weather values for six sampling periods on the Cross Timbers of central Oklahoma, 1987-1989.

Sampling Period	$\bar{X}$ high temp. (C)	$\bar{X}$ low temp. (C)	Temp. range (C)	$\bar{X}$ rainfall (cm)
Year 1[a]				
Fall	16.1	-0.6	(-9.4) - 26.1	12.57
Winter	3.3	-10.0	(-25.0) - 15.0	5.16
Summer	30.0	14.4	(-10.6) - 40.6	38.48
Year 2[b]				
Fall	23.3	6.7	(-5.6) - 32.8	17.09
Winter	11.7	-3.9	(-18.3) - 26.1	10.54
Summer	28.9	15.0	(-2.2) - 37.8	65.81

[a]Fall = 8 Oct - 1 Nov 1987; Winter = 1 Dec 1987 - 5 Feb 1988; Summer = 16 Mar - 15 Aug 1988

[b]Fall = 19 Sep - 1 Nov 1988; Winter = 1 Dec 1988 - 10 Feb 1989; Summer = 23 Mar - 26 Aug 1989

Appendix B. Summary of bird species on the Cross Timbers Experimental Range, 1987-1989.

	Season			Treatment		
Species	Fall (F)	Winter (W)	Breeding (B)	Control	Tebuthiuron	Triclopyr
Yellow-billed Cuckoo (*Coccyzus americanus*)			B	B	B	B
Chuck-will's-widow (*Caprimulgus carolinensis*)			B	B		
Whip-poor-will (*C. vociferus*)			B[b]	B		
Ruby-throated Hummingbird (*Archilochus colubris*)			B	B		B[b]
Northern Flicker (*Colaptes auratus*)	F	W		F,W	F,W	F,W
Pileated Woodpecker (*Dryocopus pileatus*)	F	W	B	F,W,B	F,W,B	F,W,B
Red-bellied Woodpecker (*Melanerpes carolinus*)	F	W	B	F,W,B	F,W,B	F,W,B
Red-headed Woodpecker (*M. erythrocephalus*)	F[a]	W[b]	B	B	F,W,B	
Hairy Woodpecker (*Picoides villosus*)	F	W	B	F,W,B	F,W,B	F,W,B
Downy Woodpecker (*P. pubescens*)	F	W	B	F,W,B[b]	F,W,B	F,W,B
Scissor-tailed Flycatcher (*Tyrannus forficatus*)			B[b]			B
Eastern Kingbird (*T. tyrannus*)			B[b]			B
Great Crested Flycatcher (*Myiarchus crinitus*)			B	B	B	B
Eastern Phoebe (*Sayornis phoebe*)	F[a]		B[a]	B	F,B	
Eastern Wood-Pewee (*Contopus virens*)			B	B	B	B[a]
Blue Jay (*Cyanocitta cristata*)	F	W	B	F,W,B	F,W,B	F,W,B
American Crow (*Corvus brachyrhynchos*)	F	W	B	F,W,B	F,W,B	F,W,B
Carolina Chickadee (*Parus carolinensis*)	F	W	B	F,W,B	F,W,B	F,W,B
Tufted Titmouse (*P. bicolor*)	F	W	B	F,W,B	F,W,B	F,W,B
White-breasted Nuthatch (*Sitta carolinensis*)	F[b]	W[b]	B[b]	F,W,B		

Appendix B. Continued.

	Season			Treatment		
Species	Fall (F)	Winter (W)	Breeding (B)	Control	Tebuthiuron	Triclopyr
Brown Creeper (*Certhia americana*)		W[a]	B[b]	W	W	W,B
Bewick's Wren (*Thryomanes bewickii*)	F[a]	W	B	B	F,W,B	F[a],W,B
Carolina Wren (*Thryothorus ludovicianus*)	F[b]	W[a]	B	B[a]	F,B	F,W,B
Northern Mockingbird (*Mimus polyglottos*)	F[b]	W	B	B[a]	F,W,B	F,W[b],B[b]
Brown Thrasher (*Toxostoma rufum*)	F[b]	W[a]	B	B	B[b]	F,W,B[a]
American Robin (*Turdus migratorius*)	F	W		F,W	F,W	F,W
Hermit Thrush (*Catharus guttatus*)	F[b]	W[a]		F,W		
Eastern Bluebird (*Sialia sialis*)	F	W	B	B	F,W,B	F,W,B
Blue-gray Gnatcatcher (*Polioptila caerulea*)			B	B	B	B
Golden-crowned Kinglet (*Regulus satrapa*)	F[b]	W[b]		F,W	W	F,W
Ruby-crowned Kinglet (*R. calendula*)	F[b]			F	F	F
Cedar Waxwing (*Bombycilla cedrorum*)	F[b]	W		W[b]	F,W	W
European Starling (*Sturnus vulgaris*)			B[b]		B	
Black-and-white Warbler (*Mniotilta varia*)			B	B	B[a]	B
Yellow-rumped Warbler (*Dendroica coronata*)	F	W		F[b],W	F,W	F,W
Louisiana Waterthrush (*Seiurus motacilla*)			B	B	B[b]	B
Yellow-breasted Chat (*Icteria virens*)			B[b]		B	
Kentucky Warbler (*Oporornis formosus*)			B	B[b]		B
Meadowlark spp. (*Sturnella spp.*)	F[b]					F
Red-winged Blackbird (*Agelaius phoeniceus*)	F[b]		B[b]	B		F

Appendix B. Continued.

Species	Season			Treatment		
	Fall (F)	Winter (W)	Breeding (B)	Control	Tebuthiuron	Triclopyr
Common Grackle (Quiscalus quiscula)	F[b]					F
Brown-headed Cowbird (Molothrus ater)	F[b]		B	B	B	B,F
Summer Tanager (Piranga rubra)			B	B	B	B[b]
Northern Cardinal (Cardinalis cardinalis)	F	W	B	F,W,B	F,W,B	F,W,B
Indigo Bunting (Passerina cyanea)			B	B	B	B
Painted Bunting (P. ciris)			B	B	B	B
Purple Finch (Carpodacus purpureus)		W[b]			W	W
American Goldfinch (Carduelis tristis)	F	W[b]	B		F,W,B	W,B
Rufous-sided Towhee (Pipilo erythrophthalmus)	F	W[b]	B[a]		B	
Lark Sparrow (Chondestes grammacus)			B	B	B	B[a]
Dark-eyed Junco (Junco hyemalis)	F	W		F,W	F,W	F,W
American Tree Sparrow (Spizella arborea)	F[b]				F	
Field Sparrow (S. pusilla)	F	W	B	B	F,W,B	W,B
White-throated Sparrow (Zonotrichia albicollis)	F	W	B[a]	F[b]	F,W,B	F,W,B
Song Sparrow (Melospiza melodia)	F[b]				F	

[a]Not observed fall 1987 - summer 1988

[b]Not observed fall 1988 - summer 1989

VITA

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