Influence of prescribed fire on lesser prairie-chicken habitat in shinnery oak communities in western Oklahoma

Chad S. Boyd and Terrence G. Bidwell

Abstract Little is known of the effects of fire on lesser prairie-chicken (*Tympanuchus pallidicinctus*) habitat in shinnery oak (*Quercus havardii*) communities. Our objective was to determine the influence of seasonal prescribed fire, at 1 and 2 years post-treatment, on the quality of nesting habitat, foraging and brooding habitat, and thermal and escape cover. In each of 3 study sites in western Oklahoma, 12 60 × 30-m plots were seasonally burned, annually burned, or left unburned, and an array of habitat variables were measured at 1 and 2 years post-fire. During both periods, canopy coverage of shrubs decreased ($P \leq 0.01$) with fall and spring fire. Nesting grass cover decreased ($P=0.007$) with fall and spring burning at 1 year post-fire. Visual obstruction in May and January decreased ($P \leq 0.001$) with burning in all seasons. Burning in all seasons increased warm- (≥100% increase, $P<0.001$) and cool- (≥200% increase, $P=0.026$) season forb coverage in year 1 and grasshopper density ($P \leq 0.100$) in both years. Shinnery oak mast, leaf bud, and catkin production failed at 1 year post-fire. At 2 years post-fire, cool-season forb cover increased ($P=0.014$) with fall and spring burning and winter (January) forb frequency increased ($P=0.047$) 190% with burning in all seasons. Prescribed fire appears to be an effective tool to increase abundance of growing-season forbs and sedges, winter forbs, and grasshoppers associated with quality foraging and brooding habitat. Nesting habitat and thermal and escape cover are impacted negatively by fire, particularly spring fire, due to a reduction in overhead and horizontal cover and reduced abundance of important nesting grasses. Our data suggest a 2- to 3-year recovery period for nesting habitat following burning. Negative impacts of fire on nesting habitat and thermal and escape cover can be reduced by burning in seasons other than spring, decreasing burn size, and interspersing burned and unburned areas.

Key words brooding habitat, insect abundance, lesser prairie-chicken, nesting cover, shinnery oak

The lesser prairie-chicken (*Tympanuchus pallidicinctus*) was historically abundant throughout much of the southern Great Plains region, but populations have declined by perhaps 90% in the twentieth century (Crawford 1980, Taylor and Guthery 1980*a*). Loss of habitat to cultivation (Crawford and Bolen 1976*a*), overgrazing by domestic livestock (Lee 1950), and brush control programs (Jackson and DeArment 1963) are thought to have reduced chicken populations.

Across most of its present range, the lesser prairie-chicken is associated strongly with shinnery oak (*Quercus havardii*) communities (Peterson and Boyd 1998). Historical accounts suggest that shinnery oak communities were structurally dominated by tallgrasses (e.g., *Andropogon*, *Panicum*, *Sorghastrum*), with shinnery oak perhaps 50 cm in height (Marcy 1853, Osborne 1942). Today, shinnery oak may constitute 80% of total canopy coverage (Dhillion et al. 1994) and, in western Oklahoma, may

Authors' address: Department of Plant and Soil Sciences, Oklahoma State University, Stillwater, OK 74078, USA. Present address for Boyd: Eastern Oregon Agricultural Research Center, Burns Station, HC71, 4.51 Hwy. 205, Burns, OR 97720-9399, USA; e-mail: chad.boyd@ orst.edu.

reach 1 m in height, whereas abundance of tallgrasses has decreased (Peterson and Boyd 1998).

As habitat availability for lesser prairie-chickens decreases, proper management of existing habitat increases in importance. The role of fire in affecting structure and composition of shinnery oak plant communities, and thus lesser prairie-chicken habitat, is relatively unexplored. Our objective in this paper was to determine the influence of seasonal prescribed fire, at 1 and 2 years post-treatment, on the quality of nesting habitat, foraging and brooding habitat, and thermal and escape cover for lesser prairie- chickens in shinnery oak habitat.

Methods

Study sites

We located 3 study sites on the Black Kettle National Grassland in Roger Mills County, Oklahoma (35°32′44″N, 99°43′39″W), and the state-owned Packsaddle Wildlife Management Area in Ellis County, Oklahoma (36°4′22′N, 99°54′5″W). We subjectively chose 3 sites to be representative of shinnery oak communities found on sandy soils within western Oklahoma. All sites were grazed by cattle during the growing season before study initiation, but we excluded cattle in 1995 and during the study. Stocking rates prior to our study varied across sites and time, but annual utilization of above-ground plant production was <30% by weight. This level of utilization is probably conservative as compared to most shinnery oak range in western Oklahoma. Before our study, these sites had not burned on a regular basis and had not burned for at least 10 years.

Unburned western Oklahoma shinnery oak community. Shinnery oak and bunchgrasses dominate the overstory plant canopy. In the absence of disturbance, oak leaf litter may reduce bare ground available for herbaceous seedling germination, inhibiting understory plant diversity and abundance.

Western Oklahoma shinnery oak research plot in August of 1997, 4 months after spring (April) prescribed fire. Perennial rhizomatous grasses predominate in the overstory plant community and forb abundance has increased. Shrub abundance is temporarily reduced, but increases rapidly in the post-fire environment.

Soils were fine sands (Nobscott-Brownfield Association), with no limiting layers in the top 150 cm (United States Department of Agriculture 1982). Shinnery oak, a deciduous, clonal species, is the dominant shrub, with lesser amounts of sand sagebrush (*Artemisia filifolia*) and Oklahoma plum (*Prunus gracilis*). Dominant grasses and forbs include little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), sand bluestem (*Andropogon hallii*), sand lovegrass (*Eragrostis trichodes*), sideoats grama (*Bouteloua curtipendula*), western ragweed (*Ambrosia psilostachya*), erect dayflower (*Commelina erecta*), and primrose (*Calylophus berlandieri*). Average annual precipitation is 65.6 cm; growing-season (March-August) precipitation averages 40.6 cm (United States Department of Agriculture 1982).

Experimental design

We divided each of the 3 study sites into 12 60- × 30-m plots, which we arranged in a 2 × 6 matrix and separated by 7-m firebreaks. We randomly selected 2 plots at each site to be unburned (n=6). We randomly assigned the remaining plots to be burned in fall (September-October, n = 3), winter (January-February, n=6), or spring (April-May, n=6). We replicated this treatment design in the 1996-1997 and 1997-1998 burning seasons. We burned 1 spring and winter burn plot at each site in both burning seasons (annually burned). It was not possible to annually burn in the fall due to a lack of dry fuel at the time of burning. We did not burn, in successive years, one plot slated to be annually burned in spring due to a lack of fuel. We estimated plant canopy coverage by species, at 30 points/plot, in May, June, and August of 1996 (pretreatment) and for 2 years post-fire (1997-1998).

We collected data for all remaining variables (winter forb and grass frequency; oak mast, leaf bud, and catkin density; visual obstruction; and grasshopper density) from a sub-set of plots that included the fall burn (1996) and 1 randomly chosen unburned, winter-burn (1997) and spring-burn (1997) plot at each site ($n=3$ for each treatment). We did not collect pre-treatment data for these variables; response data were collected at 1 (1997) and 2 (1998) years post-fire. We sampled winter forb and grass frequency in January at 30 points/plot (1 and 2 years post-fire). We sampled mast density at 10 points/plot in August (1 and 2 years post-fire), and leaf bud (immature leaves) and catkin densities at 10 points/plot in April (1 and 2 years post-fire). We estimated visual obstruction at 25 points/plot in May (1 and 2 years post fire) and January (1 year post-fire). Grasshopper density was sampled at 16 points/plot in June, July, and August (1 and 2 years post-fire).

We burned all plots using a strip-headfiring technique (Wright and Bailey 1982). We ignited the downwind and flank sides of the plots and allowed the fire to burn about 5 m into the plot. We then ignited a series of headfires about 10-m upwind from the backfire. We conducted all burns with relative humidity >20%, air temperature <29°C, and a surface wind speed of <16 km/hr.

Table 1. Plant genera used in analyisis of prescribed fire effects on lesser prairie chicken foraging and brooding habitat in western Oklahoma.

Category	Genus[a]	Category of use: Foliage	Category of use: Seeds
Warm-season forbs			
	Cassia	X	X
	Commeliana	X	
	Croton	X	X
	Eriogonum	X	
	Euphorbia	X	X
	Evovulus	X	
	Helianthus	X	
	Heterotheca	X	
	Hymenoxys	X	
	Krameria	X	
	Oenothera	X	
	Penstemon	X	
Cool-season forbs			
	Dimorphocarpa	X	X
	Linum	X	X
	Lithospermum	X	X
Warm-season grasses			
	Paspalum	X	
	Sporobolus	X	
	Leptoloma	X	
Sedges			
	Cyperus	X	X
Shrubs			
	Quercus	X	X
	Artemisia	X	

[a] Compiled from Crawford and Bolen 1976*b*, Davis et al. 1980, Doerr and Guthery 1983, and Riley et al. 1993.

Forage and grasshopper abundance

Because of fire ignition pattern, we excluded the outer 5 m of plots from vegetation sampling to eliminate differential effects of variable fire behavior near plot edges. We estimated percentage of bare ground and canopy coverage of each plant species influencing a 20 × 50-cm quadrat (Daubenmire 1959). We followed the nomenclature of the Great Plains Flora Association (1986) except for little bluestem (*Schizachyrium scoparium*). We combined species data into vegetation classes: shrubs, warm-season forbs, cool-season forbs, grasses, and sedges that have been reported as preferred lesser prairie-chicken forage items in shinnery oak habitat (Table 1). We calculated average canopy coverage values for vegetation classes for each season by averaging canopy coverage values across sampling periods by plot, vegetation class, and year (West and Reese 1996). We estimated percentage frequency of occurrence of winter forbs and grasses by recording presence or absence of living forbs and grasses in a 20 × 50-cm quadrat.

We estimated abundance of oak acorns and leaf buds by counting them on shinnery oak plants rooted within 0.5-m^2 quadrats. We counted mast and leaf buds directly; we estimated catkin abundance by counting the number of catkins associated with the first 5 leaf buds encountered in each quadrat (50 buds/plot). We multiplied the average number of catkins/leaf bud by bud density for the plot to obtain an estimate of catkin density. We estimated grasshopper density by counting number of grasshoppers flushed from 1-m^2 quadrats. We arranged quadrats systematically within plots in a 2 × 8 grid, and quadrat boundaries were marked with pin flags 2 days prior to counts.

Habitat structure

We grouped canopy cover of all shrub species and grass genera important as nesting habitat (perennial tallgrasses) as vegetation classes. We estimated visual obstruction using a density board (Nudds 1977) as modified by Guthery et al. (1981) for use in shinnery oak communities. The density board measured 120 × 6.8 cm and was marked in alternating black and white 10-cm strata. We estimated percentage visual obstruction every other meter on both sides of a 50-m transect through the center of the long axis of each plot. We made estimates from a height of 1 m and a distance of 7 m and averaged scores of each strata.

Statistical analysis

We evaluated treatment effects on canopy coverage as a randomized block design with 3 blocks (sites) using analysis of covariance (SAS Institute 1988). We used pre-treatment scores for vegetation classes as a covariate and season of burn, or annual fire, as the main effect. We evaluated season of burn using separate models for 1 and 2 years post-fire. We combined data across years (1997-1998) for the 1-year post-fire model, and only used data from 1998 in the 2 years post-fire and annual fire models because data from annually burned plots and plots 2 years since fire were not available in 1997 (i.e., 1997 was the first year of treatment response data collection). Models contained terms for the main effect, site, year (where applicable), and all possible interactions. When we found significant model and treatment variable effects, we used multiple comparisons (LSD, $\alpha = 0.10$) to detect differences between treatment means. Model and treatment effects were considered significant at $P \leq 0.10$.

We evaluated effects of season of burn on counts for catkins, acorns, leaf buds, grasshoppers, and forb and grass frequency as a randomized block design with 3 blocks (sites) using analysis of variance (SAS Institute 1988). We evaluated these variables using separate models for 1 and 2 years post-fire. Models contained terms for the main effect (season of burn) and site. We did not include interaction terms in the model due to a lack of degrees of freedom (i.e., small number of plots). We compared treatment means as described above (LSD). We determined effects of season of burn on visual obstruction using multivariate repeated measures analysis of variance (Stroup and Stubbendieck 1983, SAS Institute 1988). For this analysis, we set values for strata 1 through 12 as dependent variables and season of burn as the main effect. We treated strata 1 through 12 as a repeated measure in this model, such that we were testing for treatment differences in the response curve of visual obstruction across the 12 strata. We determined the significance of season of burn using the P-value associated with the strata × treatment interaction.

Results

Forage and grasshopper abundance

Season of burn altered preferred shrub ($P < 0.001$), warm-season forb ($P < 0.001$), cool-season forb ($P = 0.026$), and sedge coverage ($P = 0.015$) at 1 year post-fire, but did not influence coverage of preferred grasses ($P = 0.1845$, Table 2). Preferred shrub coverage decreased with fall (18% decrease), winter (19% decrease), or spring (57% decrease) burning. Preferred warm-season forb coverage doubled with winter burning and more than tripled with fall or spring burning, whereas cool-season forb coverage increased 1,200% with fall burning and at least 200% with winter or spring burning. Preferred sedge coverage increased at least 600% with burning in all seasons and was greatest with spring burning.

At 2 years post-fire, season of burn altered coverage of preferred shrubs ($P < 0.001$), cool-season forbs ($P = 0.014$), and sedges ($P = 0.001$), but did not affect preferred warm-season forbs ($P = 0.156$) or grass ($P = 0.147$) coverage (Table 2). Coverage of preferred shrubs was higher with fall (8% higher) or winter (7% higher) burning and lower with spring burning (13% lower). Coverage of preferred cool season forbs increased with burning in all seasons by at least 100% and was highest for fall burns. Coverage of preferred sedges increased with spring burning (1,900%); preferred sedges were not recorded in fall- or winter-burned plots at 2 years post-fire. Annual burning did not influence coverage of preferred shrubs ($P = 0.980$), warm-season forbs ($P = 0.458$), cool-season forbs ($P = 0.223$), grasses ($P = 0.954$), or sedges ($P = 0.175$, Table 2).

Catkin, leaf bud, and mast production was eliminated at 1 year post-fire (Table 3). At 2 years post-fire, catkin density was unaffected by fall or winter burning ($P = 0.088$) but was virtually eliminated in spring-burned plots. Leaf bud ($P = 0.385$) and mast ($P = 0.422$) density were not affected by season of burn at 2 years post-fire. Forb and grass frequency data for winter and spring burns were not available in 1997 because these plots had not yet been

Table 2. Canopy coverage (%) of shrubs, bare ground, and lesser prairie chicken forage and nesting plants for shinnery oak communities in western Oklahoma, 1 and 2 years post-fire (1997–1998).

Treatment category		Habitat structure variables						Forage plants									
		Shrubs		Nesting grasses		%Bare ground		Preferred[a] shrubs		Preferred warm season forbs		Preferred cool season forbs		Preferred grasses		Preferred sedges	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Season of burn (1 year post-fire)[b]																	
Unburned	12	74.2	3.7 A[c]	63.9	4.9 A	6.4	1.2 A	56.0	4.1 A	0.5	0.1 A	0.03	0.02 A	0.4	0.2	0.03	0.02 A
Fall	6	58.5	6.2 B	45.5	8.1 B	64.1	5.6 B	46.1	6.8 B	2.2	1.0 B	0.40	0.12 B	1.2	0.4	0.31	0.17 B
Winter	12	59.3	2.3 B	56.9	5.2 A	49.4	3.3 C	45.1	3.8 B	1.1	0.5 C	0.13	0.06 C	1.0	0.3	0.23	0.08 B
Spring	12	31.3	2.3 C	47.6	6.6 B	48.8	2.7 C	24.1	2.3 C	1.8	0.4 B	0.09	0.05 AC	1.1	0.5	0.56	0.18 C
Season of burn (2 years post-fire)[d]																	
Unburned	6	74.0	5.9 A	63.8	6.7	5.3	1.4 A	54.9	5.6 A	0.2	0.1	0.01	0.01 A	0.2	0.1	0.004	0.004 A
Fall	3	68.3	9.9 B	63.6	7.1	35.2	6.3 B	59.2	11.9 B	0.5	0.2	0.20	0.10 B	0.7	0.2	0.00	0.00 A
Winter	3	70.7	2.2 AB	68.0	16.6	32.2	5.5 B	58.5	5.5 B	0.6	0.3	0.02	0.02 A	0.8	0.3	0.00	0.00 A
Spring	4	61.5	7.7 C	69.4	11.5	35.5	4.6 B	47.6	3.2 C	0.5	0.1	0.06	0.05 C	0.7	0.2	0.08	0.05 B
Annual fire[e]																	
Single-event fire (1 year post-fire)	15	48.2	4.0	46.9	4.4 A	55.2	3.5	38.1	4.1	1.5	0.5	0.06	0.03	0.5	0.2	0.24	0.07
Annual fire (1 year since last fire)	5	46.1	8.8	68.9	9.5 B	55.9	5.2	37.4	9.5	0.9	0.3	0.07	0.04	0.4	0.1	0.07	0.04

[a] "Preferred" denotes the sum cover of plant genera reported in the literature to be utilized by lesser prairie chickens as a forage plant (foliage or seed, Table 1)."

[b] Data for 1997 and 1998 are combined.

[c] Means within a year and treatment category with no letters or without different letters do not differ significantly (LSD) at alpha = 0.10.

[d] Annually burned plots were not included in this analysis.

[e] Analysis includes only data from the 1998 growing season because data for annual fires and 2 years post-fire were not available in 1997.

burned at the time of sampling (Table 3). Although winter forbs and grasses were not recorded in fall-burn plots in 1997, the means for unburned plots did not differ significantly from 0.0, so no treatment differences were found (Table 3). At 2 years post-fire, frequency of winter forbs varied with season of burn ($P = 0.024$) and increased approximately 3-fold with burning in all seasons. Grass frequency was unaffected by season of burn ($P = 0.109$) at 2 years post-fire.

At 1 year post-fire, grasshopper density was affected by season of burn in June ($P = 0.031$) and July ($P = 0.005$), but not August ($P = 0.140$, Figure 1). Density was highest for fall burns in the June sampling period (105% higher than unburned density) and spring burns in the July sampling period (39% higher than unburned density). At 2 years post-fire, grasshopper density varied by season of burn in the July ($P = 0.063$) and August ($P = 0.027$) sampling periods, but not in June ($P = 0.139$). In July, burning increased grasshopper density by at least 46%, whereas fall- (53% increase) and spring- (109% increase) burn treatments had higher densities than unburned plots for the August sampling period.

Habitat structure

Season of burn affected coverage of shrubs ($P < 0.001$), nesting grasses ($P = 0.007$), and bare ground ($P < 0.001$) at 1 year post-fire (Table 2). Shrub coverage decreased with any burning treatment, but most strongly with spring

Table 3. Shinnery oak leaf bud and catkin density (No./m^2) in April, shinnery oak mast density (No./m2) in August, and forb and grass frequency (0.1-m^2 quadrat) in January for shinnery oak communities in western Oklahoma, 1 and 2 years post-fire (1997–1998).

Treatment category	Leaf buds/m^2			Catkins/m^2		Mast/m^2		% Frequency of occurrence Forbs		Grasses	
	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1 year post-fire											
Season of burn											
Unburned	3	469.2	105.2 A[a]	1,288.2	369.0 A	0.6	0.2 A	4.0	4.0	1.3	1.3
Fall	3	0.0	0.0 B	0.0	0.0 B	0.0	0.0 B	0.0	0.0	0.0	0.0
Winter[b]	3	0.0	0.0 B	0.0	0.0 B	0.0	0.0 B				
Spring[c]	3					0.0	0.0 B				
2 years post-fire											
Season of burn											
Unburned	3	250.7	82.3	517.4	196.0 A	8.0	7.3	16.0	2.3 A	0.0	0.0
Fall	3	281.3	62.1	249.4	94.3 AB	11.5	5.9	46.7	5.8 B	8.0	4.0
Winter	3	208.8	70.8	290.2	155.7 AB	5.8	4.3	48.0	10.1 B	2.7	1.3
Spring	3	186.9	20.4	13.6	13.6 B	0.1	0.1	52.0	6.1 B	4.0	0.0

[a] Means within a year and treatment category with no letters or without different letters do not differ significantly (LSD) at alpha = 0.10.
[b] Frequency data are not presented for winter burns at 1 year post-fire because these plots were not yet burned at the time of sampling.
[c] Catkin, bud, and frequency data are not presented for spring burns at 1 year post-fire because these plots were not yet burned at the time of sampling.

burns (58% decrease). Coverage of nesting grasses decreased with fall (29% decrease) and spring burning (26% decrease), but was unaffected by winter burning. Coverage of bare ground increased by over 600% with burning in all seasons. At 2 years post-fire, coverage of shrubs ($P=0.014$) and bare ground ($P=0.003$) was altered by season of burn, whereas nesting grass abundance was unaffected ($P=0.101$,Table 2). Shrub coverage decreased with fall (8% decrease) and spring (17% decrease) burning and was not affected by winter burning. Cover of bare ground increased by at least 500% with burning in all seasons. Annual burning did not influence shrubs ($P=0.875$) or bare ground ($P=0.954$), but coverage of nesting grasses increased ($P<0.001$) by 47% with annual burning relative to single-event fires (Table 2). Season of burn altered visual obstruction profiles in May of the first ($P<0.001$) and second years ($P<0.001$) post-fire (Figure 2) and January of 1 year post-fire. At a given height, visual obstruction for burned plots was less than that for unburned plots on any sampling date.

Discussion

Nesting habitat

Nesting success of lesser prairie-chickens increases with cover of perennial tallgrasses, whereas standing dead grass is important for overhead cover because nesting takes place prior to or very near the time of initiation of spring grass growth (Copelin 1963, Riley et al. 1992). Haukos and Smith (1989) found that hens selected nest sites with >75% visual obstruction in the first 33 cm and at least 50% overhead cover. Fire, whether wild or prescribed, destroys available nesting cover in the year of burning. Our data indicate that fire, particularly spring burning, also may decrease nesting habitat quality in years subsequent to burning. Shrubs and nesting grasses are important cover components in shinnery oak communities, contributing over 90% of overhead screening cover in our study. We found that cover of these 2 components will be less in burned areas during the first growing season post-fire. By the second growing season post-fire, cover of nesting grasses is similar between burned and unburned areas, but overhead shrub cover may still be affected negatively in fall and spring burns. Most of the decrease in nesting grass cover following fire was due to a reduction in cover of the bunchgrass little bluestem (Boyd 1999), which is less fire-tolerant than other rhizomatous nesting grasses. Using the findings of Haukos and Smith (1989) as a guideline, visual obstruction values in May for unburned plots and for burned plots at 2 years post-fire indicate

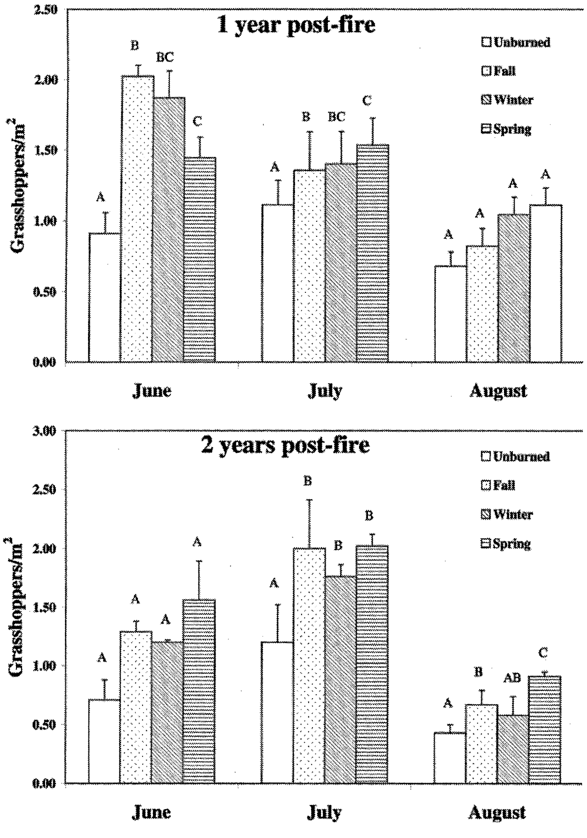

Figure 1. Grasshopper density (individuals/m^2) for unburned and fall-, winter-, and spring-burned shinnery oak communities in western Oklahoma, 1 and 2 years post-fire (1997–1998). Bars within a year and sampling month without a common letter differ significantly (LSD) at $\alpha = 0.10$.

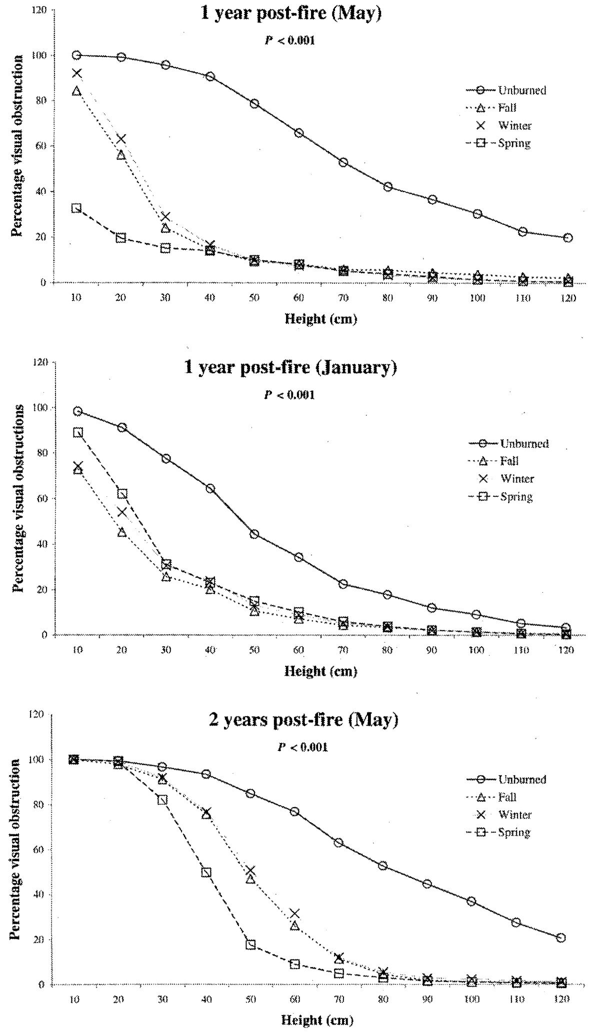

Figure 2. January and May visual obstruction values for unburned and fall-, winter-, and spring-burned shinnery oak communities in western Oklahoma, 1 and 2 years post-fire (1997–1998). *P* values reflect differences between treatment height × visual obstruction response curves.

adequate cover for nesting purposes, whereas values for burned plots at 1 year post-fire suggest that cover is inadequate. Overall, our data suggest at least a 2-year window of recovery for nesting habitat following a single-event fire.

Our data also indicate that annual burning may increase (47%) cover of nesting grasses relative to single-event fires. However, we found that annual prescribed fire will not be possible in years when production of fine fuels is limited by environmental factors or grazing. Our annual burns were conducted following a wetter than normal growing season, in ungrazed plots, with fine fuel loading ranging from 0.35 to 0.90 kg/m^2. Fire ignition with lesser fine fuel loading will be difficult.

Foraging and brooding habitat

In shinnery oak habitat, the diet of lesser prairie-chickens varies strongly by season. In spring, diets are dominated by vegetative material, mainly forbs, and shinnery oak catkins and leaf buds (Davis et al. 1980, Doerr and Guthery 1983). Summer diets consist of roughly equal amounts of vegetative material (mainly forbs) and insects, but shinnery oak acorns also may be consumed. Insect consumption is largely grasshoppers (Davis et al. 1980, Doerr and Guthery 1983). In fall, insect and forb consumption continues, but oak acorns and seeds from herbaceous plants may become important dietary items (Crawford and Bolen 1976*b*, Doerr and Guthery 1983, Riley et al. 1993). Oak acorns and seeds from herbaceous plants dominate winter diets; vegetative material may comprise 25–30% of the winter diet (Doerr and Guthery 1983, Riley et al. 1993). Brooding habitat is characterized by a high forb availability and abundant bare ground (Jones 1963, Riley et al. 1992). Insects, particularly grasshoppers, are important food items for chicks and juveniles (Davis et al. 1980).

Most indicators of foraging and brooding habitat quality in this study responded positively to fire treatment or were unaffected. Increased warm-season forb abundance associated with fire treatment should improve spring and summer foraging and brooding habitat at 1 year post-fire, whereas increased abundance of cool-season forbs may improve spring foraging and brooding habitat at 1 and 2 years post-fire. A lack of warm-season forb response at 2 years post-fire suggests that frequent fire may be necessary to sustain increases in warm-season forb abundance. Growing-season foraging and brooding habitat also should benefit from elevated grasshopper production following fire; this increase was sustained through year 2 post-fire. Increased bare ground associated with burning improves access to seeds and insects at ground level. The ground surface in unburned plots in our study was almost completely covered in oak leaf litter. Increased forb and sedge abundance with burning should promote seed availability in fall and winter 1 and 2 years post-fire. Winter foraging habitat also will benefit from increased abundance of green forbs with burning in any season.

Spring foraging habitat will be affected negatively by the loss of shinnery oak catkin and leaf bud production at 1 year post-fire. Catkins and leaf buds may represent a valuable food source during the mid-spring period, given that availability of other food sources may be limited (Peterson and Boyd 1998). Loss of the oak mast crop may reduce food availability during fall and winter, but the net impact of a lost mast crop is questionable, given that significant mast production occurs in only about 3 out of 10 years (Pettit 1986).

Thermal and escape cover

Thermal and escape cover refer to areas with horizontally and vertically dense vegetation that offer concealment (mainly for broods) and protection from temperature extremes. Lesser prairie-chicken broods use shinnery oak, little bluestem, and sand bluestem as thermal cover in summer, and height of vegetation used by broods is correlated positively with ambient temperature (Donaldson 1969). Broods in Oklahoma use taller oak mottes to escape midday summer temperature extremes (Copelin 1963), whereas areas of dense grass or evergreen shrubs are used for winter cover (Taylor and Guthery 1980*b*). Our data indicate that fire, particularly fall and spring burns, may impair thermal and escape cover for at least 2 years post-fire. Loss of shrub cover associated with fire may decrease availability of horizontal and overhead cover in summer, whereas decreased abundance of dominant grasses in burned areas may decrease horizontal and overhead cover in summer and winter. Additionally, areas burned in winter or fall lack winter cover in the year of burning. We found that winter (January) horizontal cover (i.e., visual obstruction) is decreased in burned plots for at least 1 year post-fire.

Summary and management implications

Effect of fire on lesser prairie-chicken habitat in shinnery oak communities varies by season of burn and habitat parameter. Fire can be used to increase forb and grasshopper abundance associated with quality foraging and brooding sites and can greatly increase abundance of vegetative foods during winter. Bare ground increases with fire, improving access to seeds and insects. Our field observations indicate that plowing fire breaks (necessary in this fuel type due to the potential for intense fire behavior) often results in continuous forb cover, which may serve as high-quality foraging and brooding habitat. Offsetting these improvements, mast, leaf bud, and catkin production failed the year following fire, and nesting habitat quality was negatively influenced, particularly by spring burning, for

A spring (April) prescribed fire moving through a previously unburned research plot with an overstory of shinnery oak. This fuel type is capable of generating intense fire behavior. Conservative fire prescriptions and plowed fire breaks give fire managers an increased measure of control and help ensure the safety of burn crews.

2 years following fire. Spring burning can dramatically decrease canopy coverage of shrubs, which reduces availability of thermal and escape cover. Burning in seasons other than spring, decreasing burn size, or plowing fire breaks around oak mottes prior to burning should minimize fire impact on thermal and escape cover. Shinnery oak communities are resilient to effects of fire, implying rapid recovery of habitat parameters harmed by fire and frequent fire treatment to maintain benefits.

At larger scales, consideration of burn size and interspersion of burned and unburned patches may minimize negative effects of fire on habitat elements across the landscape. Because the effects of fire are variable with increasing time post-fire, managers should consider age of existing burns when developing burn plans for management areas. Interspersion of patches with different time-since-fire intervals will increase between-habitat diversity and decrease size of areas where some habitat elements (e.g., nesting habitat) may be impacted negatively.

On a regional basis, fire effects on shinnery oak habitat may differ from our findings. Our study sites were in the most mesic portion of the shinnery oak range and receive approximately twice the annual precipitation of more arid shinnery oak communities in southeastern New Mexico (Peterson and Boyd 1998). In drier areas the magnitude and character of plant-community response to fire has the potential to vary strongly with precipitation. The herbaceous component of shinnery oak communities dominated by shortgrasses may be harmed by fire. These grasses are not as well adapted to fire disturbance as the mid- and tallgrass species in our study (Wright and Bailey 1982). Further research is needed to quantify the long-term effects of fire on habitat dynamics in shinnery oak communities and to determine the appropriate size and interspersion of burned areas necessary to optimize habitat quality for lesser prairie- chickens.

Acknowledgments. We wish to thank the United States Forest Service for financial support of this research, personnel of the Black Kettle National Grassland for help with prescribed burning activities, and the numerous students and personnel in the Department of Plant and Soil Sciences, Oklahoma State University, for their help in collecting field data and conducting prescribed burns.

Literature cited

BOYD, C. S. 1999. The effects of burning season and frequency on the vegetative character and insect abundance of sand shinnery oak range in western Oklahoma. Dissertation, Oklahoma State University, Stillwater, USA.

COPELIN, F.F. 1963. The lesser prairie chicken in Oklahoma. Oklahoma Wildlife Conservation Department, Technical Bulletin 6, Oklahoma City, USA.

CRAWFORD, J. A., AND E. G. BOLEN. 1976*a*. Effects of land use on lesser prairie chickens in Texas. Journal of Wildlife Management 40:96-104.

CRAWFORD, J. A., AND E. G. BOLEN. 1976*b*. Fall diet of lesser prairie chickens in west Texas. Condor 78:142-144.

CRAWFORD, J. A. 1980. Status, problems, and research needs of the lesser prairie chicken. Pages 1-7 *in* Proceedings of the prairie grouse symposium. Oklahoma State University, 17-18 September 1980, Stillwater, USA.

DAVIS, C. A., T. Z. RILEY, R. A. SMITH, AND M. D. WISDOM. 1980. Spring-summer foods of the lesser prairie chicken in New Mexico. Pages 75-80 *in* Proceedings of the prairie grouse symposium. Oklahoma State University, 17-18 September 1980, Stillwater, USA.

DAUBENMIRE, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

DHILLION, S. S., M. A. MCGINLEY, C. F. FRIESE, AND J. C. ZAK. 1994. Construction of sand shinnery oak communities of the Llanno Estacado: Animal disturbances, plant community structure, and restoration. Restoration Ecology 2:51-60.

DOERR, T. B., AND F. S. GUTHERY. 1983. Food selection by lesser prairie chickens in northwest Texas. Southwestern Naturalist 28:381-383.

DONALDSON, D. D. 1969. Effect on lesser prairie chickens of brush control in western Oklahoma. Dissertation, Oklahoma State University, Stillwater, USA.

GREAT PLAINS FLORA ASSOCIATION. 1986. Flora of the Great Plains. University Press of Kansas, Lawrence, USA.

GUTHERY, F. S., T. B. DOERR, AND M. A. TAYLOR. 1981. Use of a profile board in sand shinnery oak communities. Journal of Range Management 34:157-158.

HAUKOS, D. A., AND L. M. SMITH. 1989. Lesser prairie-chicken nest site selection and vegetation characteristics in tebuthiuron-treated and untreated sand shinnery oak in Texas. Great Basin Naturalist 49:624-626.

JACKSON, A. S., AND R. DEARMENT. 1963. The lesser prairie chicken in the Texas Panhandle. Journal of Wildlife Management 27: 733-737.

JONES, R. E. 1963. Identification and analysis of lesser and greater prairie chicken habitat. Journal of Wildlife Management 27: 757-778.

LEE, L. 1950. Kill analysis for the lesser prairie chicken in New Mexico, 1949. Journal of Wildlife Management 14:475-477.

MARCY, R. B. 1853. Explorations of the Red River of Louisiana in the year 1852. 32nd Congress, 2nd Session, Senate Executive Document 54, Public Document 666.

NUDDS, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113-117.

OSBORNE, B. 1942. Prairie dogs in shinnery (oak scrub) savannah. Ecology 23: 110-115.

PETERSON, R. S., AND C. S. BOYD. 1998. Ecology and management of sand shinnery communities: A literature review. United States Forest Service, General Technical Report 16, Fort Collins, Colorado, USA.

PETTIT, R. D. 1986. Sand shinnery oak: control and management. Texas Tech University, Range and Wildlife Management Department, Management Note 8, Lubbock, USA.

RILEY, T. Z., C. A. DAVIS, M. ORITIZ, AND M.J. WISDOM. 1992. Vegetative characteristic of successful and unsuccessful nests of lesser prairie chickens. Journal of Wildlife Management 56: 383-387.

RILEY, T. Z., C. A. DAVIS, AND R. A. SMITH. 1993. Autumn-winter foods of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) (Galliformes: Tetraonidae). Great Basin Naturalist 53: 186-189.

SAS INSTITUTE, INC. 1988. SAS procedures guide, release 6.03. SAS Institute, Cary, North Carolina, USA.

STROUP, W. W., AND J. STUBBENDIECK. 1983. Multivariate statistical methods to determine changes in botanical composition. Journal of Range Management 36: 208-212.

TAYLOR, M. A., AND F. S. GUTHERY. 1980*a*. Status, ecology and management of the lesser prairie chicken. United States Forest Service, General Technical Report 77, Fort Collins, Colorado, USA.

TAYLOR, M. A., AND F. S. GUTHERY. 1980*b*. Fall-winter movements, ranges and habitat use of lesser prairie chickens. Journal of Wildlife Management 44: 521-524.

UNITED STATES DEPARTMENT OF AGRICULTURE. 1982. Soil survey: Roger Mills County Oklahoma. United States Government Printing Office, Washington, D.C., USA.

WEST, N. E., AND G. A. REESE. 1996. Comparison of some methods for collecting and analyzing data on aboveground net production and diversity of herbaceous vegetation in a northern Utah subalpine context. Vegetatio 96: 145-163.

WRIGHT, H. A. AND A. W. BAILEY. 1982. Fire ecology: United States and southern Canada. John Wiley and Sons, New York, USA.

Chad S. Boyd **(photo)** is a rangeland scientist with Agricultural Research Service, stationed at the Eastern Oregon Agricultural Research Center in Burns, Oregon. He holds a Ph.D. in rangeland ecology and management from Oklahoma State University. His research interests center around the disturbance ecology of plant communities and the ramifications of plant community change to wildlife habitat quality. His current research focuses on the impacts of livestock grazing on riparian plant communities and developing and improving photographic monitoring technologies for evaluating riparian and upland plant abundance. ***Terrence G. (Terry) Bidwell*** is a professor and state extension specialist in rangeland ecology and management at Oklahoma State University. He holds a Ph.D. in rangeland ecology and management from Oklahoma State University. His academic and research interests include fire ecology, successional dynamics of plant communities, and ecological restoration and conservation of native plant communities.

Associate editor: *Servello*