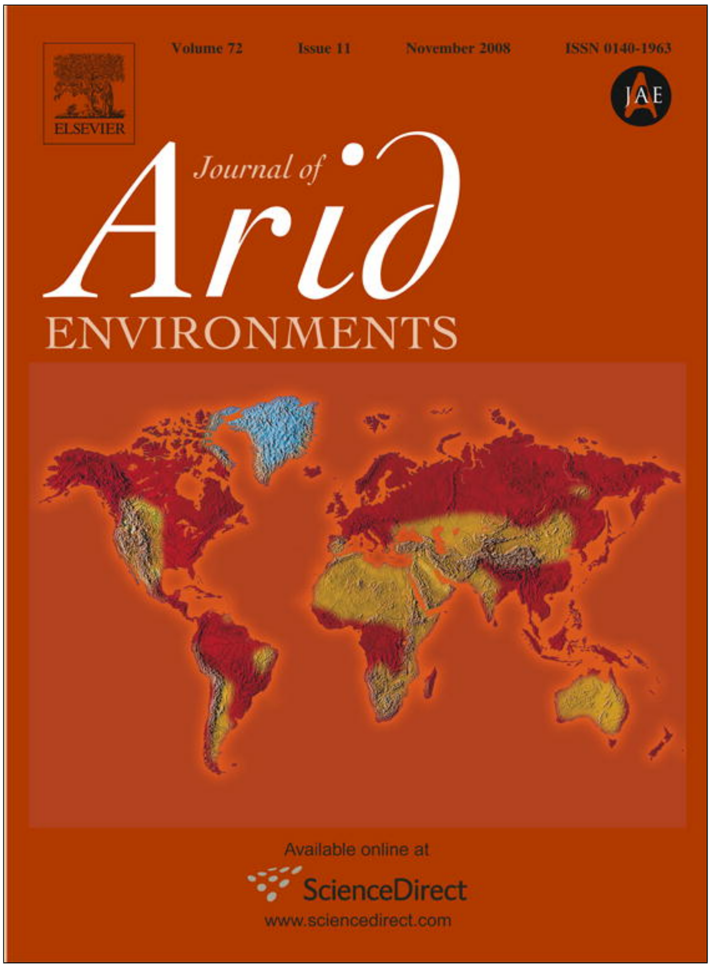
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White-tailed deer distribution in response to patch burning on rangeland

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A B S T R A C T

Management of rangelands has changed substantially over the past few decades; today there is greater emphasis on wildlife management and increased interest in using natural disturbances such as fire to manage rangeland plant and animal communities. To determine the effect of prescribed fires on the distribution of white-tailed deer (*Odocoileus virginianus*), we used Global Positioning System (GPS) collars to monitor the movements of bucks and does during four, month-long, trials before and during the year after implementation of three late summer burns. Deer were expected to increase their use of burned areas to take advantage of fresh plant growth after the disturbance. However, the only increased use of burns occurred 1–2 months after treatment. The presence of cattle did not limit deer use of burns. Low use of burned areas was attributed to drought conditions, which limited vegetation regrowth. Other than a brief flush of fresh grass in autumn, no changes in plant cover could be ascribed to the burns. Thus, in semi-arid areas, use of prescribed burns to reduce brush cover and increase forb production for deer may not be successful, at least in the short-term, if lack of rainfall limits regrowth of vegetation.

1. Introduction

Many semi-arid rangelands have evolved under a regime of natural fires, but a combination of cattle grazing, fire suppression, and climatic change has reduced the frequency of fire and resulted in encroachment of shrubs on former savanna grasslands (Archer, 1989; Archer et al., 1988; Frost and Robertson, 1987; Mayeux et al., 1991; Scifres and Hamilton, 1993; Trollope, 1978; Wright and Bailey, 1982). Increased woody cover often results in lowered productivity of the herbaceous layer, with concomitant decreases in animal productivity (Hamilton et al., 2004). Rangeland improvement practices, such as mechanical brush removal and use of prescribed fire, reduce the over-storey of shrubs to allow more sunlight and precipitation to reach the ground and stimulate production of herbaceous vegetation. The regrowth of herbaceous vegetation and palatable shrubs is often high in protein and low in fiber, providing improved nutrition for herbivores (Everitt, 1983).

Over the last two decades, rangeland management in South Texas has moved towards greater use of the land for recreational purposes (Kjelland et al., 2007). The annual economic impact of hunting white-tailed deer (*Odocoileus virginianus*) in Texas was assessed at more than US $2 billion (International Association of Fish and Wildlife Agencies, 2002). Deer hunting leases have therefore become a substantial form of additive ranch income, and in some instances,

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the primary revenue source for ranchers (Adams et al., 2000). Interest in producing trophy deer bearing large antlers is intense, and because maximum expression of antler growth is influenced by year-round nutrition of the animal (Harmel et al., 1989), there has been a surge of interest in improving the quality and quantity of deer forages on rangeland. Historically, white-tailed deer did not inhabit open grassy rangeland, but were restricted to creeks and drainages with greater shrub cover (Inglis et al., 1979). While shrub invasion initially increased useable habitat for deer, current shrub cover is often too dense for optimal production of protein-rich forbs which are an essential component of the deer's diet for maximum growth and antler production (Fulbright and Ortega-S, 2006; Wright et al., 2002).

Traditionally, mechanical methods have been the most commonly used techniques for shrub reduction. These are largely effective, but are often expensive (Scifres and Hamilton, 1993). Prescribed fire may be more cost effective and is often used as a maintenance treatment following shrub reduction by mechanical methods (Rogers et al., 2004). Because the rangeland ecosystem evolved under a regime of natural fires, the vegetation is expected to respond favorably to burning (Ruthven et al., 2000), and the use of patch burns is predicted to emulate the way natural forces, such as lightning, would disturb the area to produce a heterogeneous landscape with an interspersion of shrubs for cover and browse with open areas suitable for forb production.

Use of prescribed burns as an initial treatment to improve habitat and forage quality for wildlife has met with mixed results in southern Texas and other shrub-dominated rangelands. Use of fire, wild and prescribed, was reportedly successful in increasing herbaceous production and vegetative diversity at the Kerr Wildlife Management Area on the Edwards Plateau in Central Texas, although this has not been rigorously tested (Armstrong, 2005). In the South Texas Plains, prescribed fire was effective in increasing forb coverage, but not density (Ruthven et al., 2000). However, in the transitional zone between these two ecoregions, the effect on vegetation composition was found to be minimal (Owens et al., 2002).

Rapid increases in the value of white-tailed deer on rangeland has also lead to new management practices such as supplemental feeding programs and containment of deer within high fences. These practices may permit deer densities to exceed the natural carrying capacity of the land. Even with high rates of supplemental feeding, deer will continue to browse on natural vegetation (Cooper et al., 2006; Doenier et al., 1997) and may over-utilize available browse and damage the habitat (Anderson and Katz, 1993; deCalesta, 1994; Pellerin et al., 2006; Rossell et al., 2005; Russell et al., 2001). In any rangeland improvement project, it is important to consider the impact that resident herbivores will have on regrowth of the vegetation (Hobbs, 1996). Animals are frequently attracted to feed on the new regrowth vegetation emerging after shrub removal or fire (Hobbs and Spowart, 1984; Wallace and Crosthwaite, 2005; Wisley, 1996). The success of rangeland restoration could be limited by an overabundance of deer if they concentrate their feeding activities on treated areas enough to influence vegetative recovery and the restoration process.

This study investigates the distribution of white-tailed deer before and after implementation of patch-scale disturbance by prescribed burns. We hypothesized that the post-burn distribution of deer would change if deer were attracted to feed on the new regrowth vegetation following the prescribed burns. Distribution was estimated using deer fitted with Global Positioning System (GPS) collars to limit human disturbances to the deer and provide a greater amount of more accurate data than traditional radio-telemetry.

2. Materials and methods

2.1. Study area

This study was conducted on the Harris Ranch, located 35 km west of Uvalde, Texas (Uvalde County). The 6764 ha ranch (29°15′0.02″N, 100°5′54.01″W) was situated at the interface of two ecoregions, the Edwards Plateau to the north and the South Texas Plains to the south. Much of the ranch consisted of gently undulating caliche ridges covered by shallow calcareous soils, with areas of deeper clay loam soils in the flatter areas and drainages. Within the ranch, the study was conducted in a 1214 ha pasture north of the river, cattle were limited to this area but deer could cross the cattle fence into a further 877 ha. Thus, deer had access to a 2091 ha area from which their dispersal was limited by high fencing on three sides and a natural bluff formation along the southern border. The West Nueces River runs through the study area but never flowed during the study so was not a barrier to animal movements (Fig. 1). The major ecological sites in the study area are loamy bottomland (27.5%), clay loam (22.2%), stony ridge (18.8%), and shallow ridge (17.5%) (Stevens and Richmond, 1970). The loamy bottomland and clay loam sites are the most productive sites. Loamy bottomland sites supported trees such as live oak (*Quercus virginiana*) and sugar hackberry (*Celtis laevigata*), and thickets of pink mimosa (*Mimosa borealis*). Clay loam rangeland is identified by scattered trees of honey mesquite (*Prosopis glandulosa*) and mixed shrubs including whitebrush (*Aloysia gratissima*). The most abundant grasses on these sites are common curly-mesquite (*Hilaria belangeri*), buffalo grass (*Buchloe dactyloides*), lovegrass tridens (*Tridens eragrostoides*) and Texas wintergrass (*Stipa leucotricha*). Forb cover was diverse and varied with rainfall pattern and abundance, but western ragweed (*Ambrosia psilostachya*), violet ruellia (*Ruellia nudiflora*) and false ragweed (*Parthenium hysterophorus*) were common.

The upland areas have thin soils and lower herbaceous production, and are either shallow ridge or stony ridge ecological sites. The shallow ridge ecological sites are characterized by mixed-shrub communities, consisting primarily of guajillo (*Acacia berlandieri*) and cenízo (*Leucophyllum frutescens*). Stony ridge sites are dominated by spiny shrubs such as blackbrush (*Acacia rigidula*), guajillo, and pricklypear cactus (*Opuntia lindheimeri*). Grass cover is sparse but included

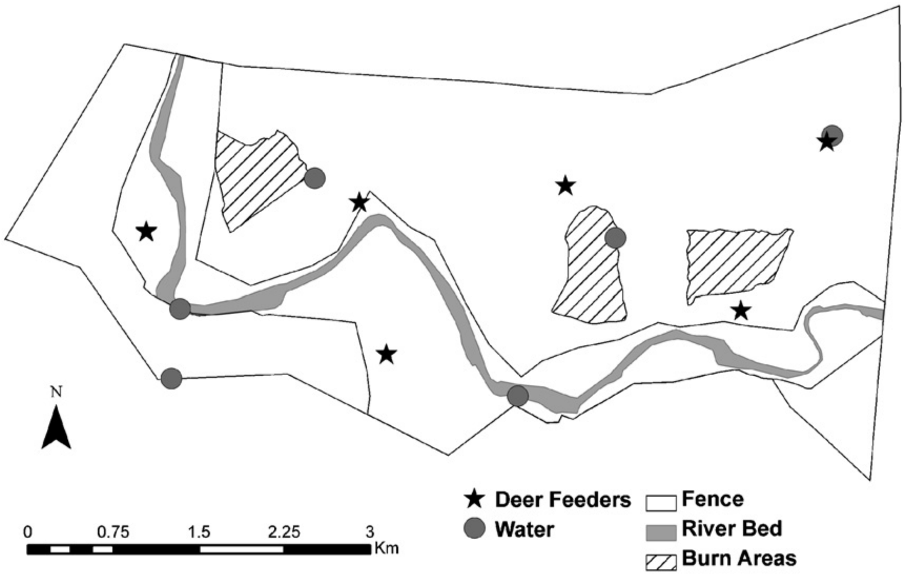

Fig. 1. Map of the study area showing placement of treatment areas, water and deer feeders. The river was dry throughout the project and water was only available at the two locations indicated and at four pumped sites. Cattle were restricted to the northern pasture by a barbed wire fence that did not impede deer movement. All deer were caught in the cattle pasture.

Wright's threeawn (*Aristida purpurea*), red grama (*Bouteloua trifida*) and Hall's panicum (*Panicum hallii*). Forb cover varied with rainfall, but during this study the most abundant forbs were western ragweed (*A. psilostachya*), one-seeded croton (*Croton monoanthogynous*) and noseburn (*Tragia ramosa*) (Rose Cooper, unpublished data).

The climate of the region is semi-arid. Mean annual high and low temperatures are 27.5 and 13.5 °C, respectively. Mean annual precipitation is approximately 620 mm with peak rainfall occurring in June and September; however, annual rainfall patterns were erratic. During this study, annual rainfall in the study area was 788 mm in 2004 and 456 mm in 2005. After completion of the three burns in September 2005, 86 mm of rain was received in October, after which drought conditions prevailed with only 247 mm of rainfall measured in 2006.

Animal densities at the time of the study were one cow–calf unit/35 ha and the deer population was estimated to be about one deer/10 ha. Deer had access to water at six sites within the study area and year-round supplementary feed (soybeans) at six free-choice feeders.

The original plan was to implement three replicate burns covering 10% of the cattle pasture (6% of the study area) each year for 10 years to create a mosaic of treated patches of differing ages. Summer burns were selected because they were predicted to be more effective in suppressing woody plants and enhancing forb production than cool season burns, which tend to favor grasses which are not greatly used by deer (Hansmire et al., 1988; Ruthven et al., 2005). However, treatment was limited to three replicate burns conducted in late September 2005 because abundant rainfall rendered the vegetation too moist to carry a fire in 2004, and drought conditions in 2006 resulted in enactment of a statewide ban on burning. Each burn site was 40 ha in extent and was situated predominantly on clay loam ecological sites. These higher productivity areas were judged most likely to have adequate fine fuels to carry the fire and to have the potential to show most response to treatment. On all replicates, the fire did not carry well due to sparse herbaceous cover and low flammability of the shrub species. A team of six people followed the fire line restarting the fire as necessary. The result was a fairly complete burn of the herbaceous layer in between the shrubs but many of the shrubs were merely scorched. The three burns were conducted on 3 consecutive days.

2.2. Methods

The spatial distribution of deer was monitored over the course of 1 year during four trials each lasting 30 days. Trial times were 23 July–21 August 2005 (pre-burn), 5 November–4 December 2005 (autumn), 8 March–6 April 2006 (spring), and 7 July–5 August 2006 (summer). Six different adult white-tailed deer were used in each trial, thus during the year the behavior of 24 deer was sampled during the study, i.e., 20% of the deer population in the cattle pasture or 11% of the study area. One buck and one doe were captured by helicopter net-gun in each of the east, central and west sections of the 1214 ha cattle pasture. Each deer was fitted with a Lotek GPS 3300S collar with drop-off latch (Lotek Wireless, Inc., Newmarket, Ont., Canada), and an ear-tag to ensure that these individuals were not recaptured in subsequent trials. Locations collected from the GPS collars were accurate to within 5 m after post-processing differential correction using the Texas Department of Transportation base station in Del Rio 70 km west of the ranch. The collars also contained activity sensors that logged dual-axis motion sensors which enabled identification of peak times of activity when deer are likely to be feeding (Coulombe et al., 2006).

In each trial, collars were programmed to collect one location per hour for 30 days, and within this period there was a 12-day period when sampling frequency was increased to every 5 min. During these 12-day periods, location data were simultaneously available from nine cows carrying GPS collars (Lotek GPS 3300LR) also programmed at 5 min intervals, but cattle collars were not available for use over the full 30-day trials. The cattle were randomly selected from the resident herd of 35 adult crossbred Angus cows in the study area. The reason for the dual scheduling on the deer collars was to maximize information while working within the restraints set by limited battery life of the GPS collars (4000 locations per battery), and to limit statistical problems of spatial autocorrelation of animal locations recorded at frequent intervals. Collection schedules for GPS collar data influence statistical validity of the results. A collection schedule of under 1 h results in under estimation of kernel home range size, but much animal movement and interaction information is lost when data collection schedules are over 1 h (H.L. Perotto, personal communication). Thus, different collection schedules are needed for different objectives. The mean 95% annual kernel home range of white-tailed deer on this ranch was previously calculated to about 700 ha (Cooper et al., 2006), thus a 1-h interval between successive locations should provide adequate time for the deer to move to any location within their annual range. This avoids problems of autocorrelation of sample points when examining animal distributions (Frair et al., 2004). However, a more frequent data collection schedule was required for examination of animal movements, feeding areas and interactions. ArcVIEW 3.2 and 9.1 (ESRI Redlands, CA) were used to calculate the 95% kernel range and 50% core areas used by each deer and to plot these areas relative to the burns. Differences in sizes of monthly range and core areas of bucks and does were assessed by *t*-tests. Due to known annual home range dimensions, it was presumed that there would be at least one burned area with the annual home range of each deer which they would selectively use if the burned areas provided better resources than the untreated areas (Johnson, 1980). To determine whether deer were selectively distributed in burned areas, the number and proportion of 1-hourly position fixes for each deer that fell within the burned areas were calculated and compared by Chi-squared (χ^2) to the proportion expected if the deer used burned areas in proportion to their availability (i.e., 6% of relocation fixes of deer and 10% of cattle would fall within the burned areas). Differences were accepted at $\alpha < 0.05$, with selection for burned areas being when observed value was larger than the expected and selection against burns when the observed value was smaller than the expected. Proportional use of burns was reported as mean percentage with standard deviation. SAS^{TM} PROC CATMOD (Categorical Data Modeling) was used to examine differences between the responses of bucks and does to the burns at different times after the burns.

The total daily distribution of deer does not show whether animals are using particular areas for feeding, resting or other activities. The GPS locations collected at 5-min intervals were used to provide accurate, fine-scale information of distribution of deer during the 4 h of maximum activity identified by the motion sensors in the collars. This heightened activity occurred around dawn and dusk when deer were most likely to be feeding (Montgomery, 1963). Again Chi-squared test was used to determine whether or not the deer were selectively distributed in the burned areas during their most active periods.

To compare forage availability for deer in the burned and unburned plots, vegetation was sampled on three paired transects inside and outside the eastern and central burn patches (total six treated and six untreated), in June and July 2005 before the burns and June and July 2006 after the burns. The western treatment plot was randomly selected not to be sampled due to limitations of time and personnel. Transect locations were allocated through use of the Random Sampling Tools Extension in ArcView 3.2. Paired transects were located within 26–135 m of the edge of a treatment and placed within similar habitats. Along these 30 m × 2 m belt transects woody shrub density, shrub cover, and herbaceous ground cover were measured. Shrubs were divided into preferred and non-preferred deer forage categories based on information from Taylor et al. (1997) and local expertise. Shrub density was assessed by counting every individual stem with its own root system within the transect. Shrub cover was measured by the line-intercept method (Bonham, 1989). Mean shrub density and cover for treatment, year, and treatment × year interaction was compared using SAS PROC GLM (General Linear Model).

Herbaceous ground cover was calculated from five, 0.25 m^2 quadrats placed along each transect. The first quadrat was placed randomly between 0 and 5 m, and the remaining four quadrats were placed at 5 m intervals. These quadrats were positioned so that they would not include any large woody shrub stems because grass and forbs were the life forms of focus in these samples. Within each quadrat, percent basal cover of grass, forbs, litter and debris, and bare ground was visually assessed. Differences in categories of herbaceous ground cover on burned versus pre-treatment and untreated areas were assessed using *t*-tests.

3. Results

3.1. Use of burned areas by deer

During the 30-day trials no individual deer used the entire study area. Area use by bucks was substantially greater than that of does ($t_{20} = 4.96$, $P < 0.001$). Mean monthly 95% kernel range used was 234 ± 36 ha (maximum 504 ha) for bucks and 67 ± 11 ha (maximum 124 ha) for does. Core use areas, encompassing 50% of relocations, were approximately 10% of the monthly ranges (bucks 9.86%, does 11.05%), and some deer had more than one core use area.

Categorical analysis of proportion of locations in the burned areas for bucks and does identified significant differences both in the use of burned areas between trials ($\chi^2_3 = 379.13$, $P \leqslant 0.001$) and between genders ($\chi^2_1 = 76.37$, $P \leqslant 0.001$). Therefore, we considered the responses of bucks and does separately.

Deer were not attracted to treatment areas prior to implementation of prescribed burns. The 95% kernel range of two bucks and one doe overlapped the intended burn sites, but intensity of use was low, and none of the 50% core areas of these deer fell within the pre-treatment areas. The proportion of relocations of deer within the pre-treatment areas was less than expected for bucks (1.95 ± 3.13%, $\chi^2_1 = 39.08$, $P \leqslant 0.001$), but these areas were used in proportion to availability by does (5.31 ± 8.47%, $\chi^2_1 = 1.12$, $P = 0.290$).

In November, 1–2 months after the burn, deer use of burned areas increased, five of the six deer had some proportion of their 95% kernel distribution within the burned areas. None of the core use areas fell within the burns, however, both bucks and does were relocated within the burns more often than expected (11.52 ± 9.22%, $\chi^2_1 = 71.50$, $P \leqslant 0.001$ and 9.09 ± 8.70%, $\chi^2_1 = 22.35$, $P \leqslant 0.001$, respectively).

Use of burned areas by deer declined in March, two bucks and one doe included burned areas within their 95% kernel distribution, but once again, none of their 50% core areas overlapped the burned areas. Relocation records indicate that bucks used the burns less than expected (4.29 ± 3.78%, $\chi^2_1 = 6.93$, $P = 0.009$), and does used the burned patches in similar proportion to their availability (5.01 ± 7.09%, $\chi^2_1 = 2.33$, $P = 0.127$).

In July, 10 months after the burns, bucks used burned patches as available (6.99 ± 1.38%, $\chi^2_1 = 2.35$, $P = 0.125$). The 95% distribution of one buck encompassed an entire burn patch, and overlapped a small part of two other burned areas, but only a small proportion of his core area fell within a burn. Does were relocated in the burned areas less than expected (1.40 ± 2.19%, $\chi^2_1 = 47.10$, $P \leqslant 0.001$).

3.2. *Deer use of burns at dawn and dusk*

Examination of deer distributions during the 4 h of peak activity around sunrise and sunset, confirmed that deer did not favor the burn areas as feeding sites prior to treatment, nor did they select burned areas after treatment, even in November. Prior to the burns, bucks selected against pre-treatment areas ($\chi^2_2 = 12.45$, $P \leqslant 0.001$) and does used these areas in proportion to availability. In November, this pattern reversed, bucks used the burns in proportion to availability while does were relocated in the burns less than expected ($\chi^2_2 = 7.89$, $P \leqslant 0.01$). In March and July, all deer used the burned areas proportionally less than their availability ($\chi^2_4 = 38.28$, $P \leqslant 0.01$, and $\chi^2_4 = 26.42$, $P \leqslant 0.001$, respectively), thus showing selection against using the burned areas during the dawn and dusk periods.

3.3. *Use of burns by cattle*

Information on cattle use of burned areas was limited to 12 days per trial. Only 2.76 ± 2.67% of cattle relocations fell within the treatment areas prior to burning, indicating avoidance of these areas ($\chi^2_8 = 52.93$, $P < 0.001$). One month after the burns cattle increased use of treated areas to 8.41 ± 3.15%, which was proportional to availability. In March, 18.83 ± 2.52% of cattle relocations were within the burned areas indicating selection for the burns ($\chi^2_7 = 66.77$, $P < 0.001$); however, 92.3% of these records were clustered within the central burn area where a leaky water trough had overflowed into a depression creating a shady, moist, muddy area favored by resting cattle. In July, cattle use of burned areas declined to 3.13 ± 2.83% ($\chi^2_5 = 32.40$, $P < 0.001$). Thus, overall cattle were not attracted to graze in the treated areas.

3.4. *Response of vegetation to prescribed burns*

No significant change in vegetative production could be attributed to the effects of the prescribed burns. Shrub density, as measured by the number of stems produced, was not altered in response to burning ($F_{3,4} = 2.98$, $P = 0.16$).

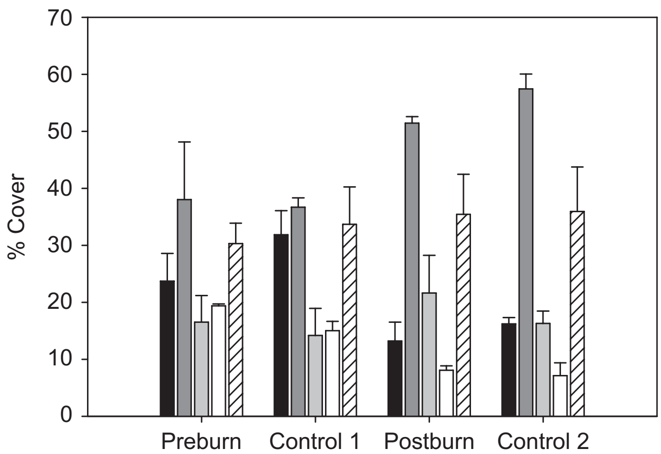

Fig. 2. Mean cover (%) with SE of grass (black), bare ground (dark grey), litter and debris (grey), forbs (white), and shrubs (hatched) in treatment and untreated control plots ($n = 2$) before and after prescribed burning.

This relationship was the same for shrubs providing browse for deer ($F_{3,4} = 2.39$, $P = 0.21$) and for non-preferred shrubs ($F_{3,4} = 0.91$, $P = 0.51$). Mean density of preferred shrubs (stems/100 m^2) in treatment areas was 22.78 ± 6.88 pre-burn and 31.12 ± 7.99 post-burn. Density of preferred shrubs in the untreated areas was similar to that of treatment areas in both years (23.06 ± 7.67 pre-burn and 35.84 ± 18.31 post-burn). Density of non-preferred shrubs was similar to that of preferred shrubs and showed similar lack of response to the burns. Prescribed burning did not alter shrub cover ($F_{3,4} = 0.33$, $P = 0.804$). In the summer after the burns, herbaceous cover declined and proportion of bare ground increased on both burned and untreated sites (Fig. 2). This indicates that changes in vegetative cover were due to less favorable growing conditions in the second year rather than treatment effect. The greatest changes in the second year were a decrease in forbs on the burned areas ($t_{10} = 10.27$, $P \leqslant 0.001$), and grass cover decreased ($t_{10} = 2.95$, $P = 0.015$), and bare ground increased ($t_{10} = 4.86$, $P \leqslant 0.001$) on the untreated sites. Post-burn litter cover was similar to before the burn due to drought stress induced leaf fall from many of the woody species in 2007.

4. Discussion and conclusion

In semi-arid rangelands, fire is considered to have been a natural, and often beneficial, force which limited shrub expansion into grasslands (Aber and Mellilo, 1991; Schmidly, 2002; Scifres and Hamilton, 1993; Wright and Bailey, 1982). Once woody plants have become established fire rarely reduces shrub density. Fire can, however, reduce vegetative cover, allowing more sunlight and precipitation to reach the ground (Owens et al., 2002). As a result of fire, production of forbs and grasses may be stimulated and many fire adapted woody plants will resprout providing additional food for browsers (Bozzo et al., 1992). Despite the effectiveness of fire in grass-dominated systems to improve forage quality for wild and domestic grazers (Rogers et al., 2004; Vermeire et al., 2004; Wallace and Crosthwaite, 2005), the success of range restoration by prescribed fire in shrub-dominated systems has had varying results. This may be a combination of differences in responses of the vegetation communities, climatic factors affecting vegetative regrowth, and fire frequency and intensity (Owens et al., 2002). On the Edwards Plateau in Central Texas, repeated prescribed burning has been successful in reducing the cover of *Juniperus* species, leading to increased forb production and diversity (Armstrong, 2005). Together with an integrated deer management plan this has reportedly lead to greatly improved body condition and antler size of the local white-tailed deer (Armstrong and Young, 2000). In the more mesic eastern regions of Texas, prescribed burns increased production of many species of wildlife foods (Box and White, 1969; Landers and Mueller, 1992), but in more xeric regions, prescribed burning tends to be less effective (Ruthven et al., 2000). Similarly, Owens et al. (2002) at the interface of the Edwards Plateau and the South Texas Plains and Valone et al. (2002) in New Mexico, found the effect of prescribed fire on vegetation cover and composition to be minimal. In these more arid areas of lower productivity, fuel loads are often insufficient to support the intense fires needed to reduce shrub dominance (Frost and Robertson, 1987; Owens et al., 2002). Following the same pattern, in this study treated areas became a mosaic of burned and unburned areas without large changes in the structure and composition of the woody component of the vegetation.

Prior to implementation of the three 40 ha prescribed burns in late September 2005, the distribution of deer indicated that they had no preference for the treatment areas. Rainfall, a week after the burns, produced a slight flush of fresh grass growth but no measurable long-term response of shrubs or forbs. In the November trial, 1–2 months after the burn, the deer exhibited some selection for the burned areas. New foliage is typically in short supply in autumn and deer may have been attracted to the new growth of grass. Although grass is not typically important in the diet of white-tailed deer, browsers can use new growth grass while it is still young and comparatively low in fiber and lignin and rich in nutrients. Chamrad and Box (1968) found that during the winter–spring period deer in coastal South Texas obtained 22% of their diet from grasses. Food may not have been the factor attracting the deer to the burns. If deer were attracted to the burn to feed we would expect that the proportion of relocations on the burned areas would be highest at dawn and dusk when deer are known to be active and feeding (Montgomery, 1963). This did not happen, rather, deer were less attracted to the burned areas during their active periods than when resting time is included in the analysis. Thus, it is doubtful that increased foraging opportunities were the driving factor in any alteration of deer distribution. Supplemental feed was available for the deer at six sites away from the burns. Analysis of deer use of water and supplemental feeders using the same data set, however, indicates that deer do not linger by these resources; less than 2% of relocations place deer within 100 m of water or feeders (Cooper et al., 2008).

If cattle gathered on the burns their presence could possibly displace deer from prime feeding areas since white-tailed deer tend to avoid concentrations of cattle (Cohen et al., 1989). Cattle, however, showed similar seasonal responses to the treated areas as deer. Prior to treatment, areas to be burned were under-utilized by cattle. In November, cattle spent more time on two of the burns, presumably to feed on the small amount of fresh grass available. As the drought progressed, cattle were no longer attracted to the burn, other than to rest in the muddy depression created in a grove of trees when the water trough leaked in March. When deer and cattle use the same habitats they generally exhibit temporal separation. On the few occasions that the two species come close to each other, deer tend not to move away until cattle are within 50 m (Cooper et al., 2008). Consequently, on large areas of treated land, cattle are unlikely to displace deer and prevent them from feeding.

A decreased attraction over time of burned areas to herbivores was also noted by Wallace and Crosthwaite (2005) for bison grazing in Oklahoma. They attributed this to a decline in the contrast in nutritional quality between regrowth and unburned vegetation. Drought conditions prevailed in South Texas throughout 2006. Herbaceous vegetation therefore had little chance to continue the initial flush of growth seen in autumn 2005. In fact, in the summer of 2006 there was a decrease in grass and forb production and increase in bare ground in both burned and unburned areas. No increase in herbaceous production and resprouting of woody plants was seen in the burned areas compared to the paired untreated areas, thus the prescribed burns failed to produce additional forage for the deer. Due to the lack of vegetative regrowth, we were unable to test the hypothesis that deer may retard range restoration efforts by altering their distribution on the land and concentrating their feeding on the new vegetation.

Management implications of this study are that the use of prescribed burns for the improvement of range forage for livestock and wildlife can be a valuable asset, but only when environmental conditions are suitable. Use of a detailed Integrated Brush Management System (IBMS) is essential to efficient and effective achievement of rangeland restoration goals (Hamilton et al., 2004; Scifres et al., 1983, 1985). In shrub-dominated systems, lack of fine fuels to carry the fire may be a problem. Reducing the stocking of livestock to allow fine fuels to accumulate is advisable but may still provide insufficient fuel to effect an intense burn that will cause changes in woody plant dominance. One way to possibly increase the effectiveness of fire in this ecosystem may be the use of mechanical techniques or herbicide treatment to knock down shrubs to supplement or provide the entire fuel load for a prescribed burn (Ruthven et al., 2005). Once this debris is dry it should provide a better source to fuel the fire.

Another limitation of prescribed burning on semi-arid rangeland is the unpredictable, intermittent rainfall. Lack of sufficient rain after a burn, as in this study, will lead to minimal regrowth of vegetation and thus little advantage to the land manager. Drought conditions may also cause local or state officials to enact a burn ban at a time when prescribed fire would carry effectively. In such situations, however, the risks outweigh any potential benefit, especially if dry conditions persist and little regrowth occurs. In conclusion, the use of prescribed burning as a management tool on semi-arid rangeland may not always be successful or applicable to certain situations due to climatic and social constraints. Prescribed fire should be considered as just one of several range improvement tools used by land managers in an integrated brush management program.

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