FIRE, BROWSING, AND DEER DENSITY IN THE MIXED-GRASS PRAIRIE

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CHAPTER I

COMBINING DEER BROWSE AND CAMERA SURVEY METHODS FOR MANAGEMENT APPLICATIONS

ABSTRACT Wildlife managers need new, more reliable tools to monitor and manage high density white-tailed deer (*Odocoileus virginianus*) populations. The most reliable method for monitoring high density populations relative to carrying capacity is through browse indices. In 2008–2009, I estimated deer density and relation to carrying capacity at 2 sites in different Oklahoma habitat types: McBride Pasture in the mixed-grass prairie and the Cross Timbers Experimental Range (CTER) in the cross timbers. To estimate density (ha/deer) and population demographics, I conducted infrared-triggered camera surveys. To estimate relative deer density (to carrying capacity), I conducted browse surveys using the stem-count index. For McBride Pasture, I estimated 1 deer/4.3 ha, which browse surveys indicated was at or exceeding carrying capacity of the habitat. For CTER, I estimated 1 deer/5.4 ha, which browse surveys indicated was within carrying capacity of the habitat. Camera surveys provided insight into population demographics (i.e., sex ratios, reproductive rate) and supported browse survey indications. By combining data from the results of both methods (i.e., buck and doe population estimates, sex ratios, recruitment, percent use of browse palatability classes), I developed a unique

application for developing specific harvest strategies to reach population management objectives. Using Lay's utilization index, I estimated the McBride deer herd needed a 46% reduction in population size to exert moderate levels of browse utilization and be within carrying capacity of the habitat. I estimated a necessary harvest of 88 deer from the initial population of 190. To obtain the desired buck:doe ratio of 1:1.5, 17 bucks and 71 does needed to be harvested, leaving 41 bucks and 62 does in the adult population of 103 deer.

INTRODUCTION

With high density white-tailed deer (*Odocoileus virginianus*) populations becoming prevalent, managers need new tools to monitor and manage them (McShea 1997, Warren 1997). Several methods for estimating deer density (e.g. spotlight surveys and road counts) show low accuracy in surveying populations with high densities; therefore, researchers have suggested the use of browsing indices to monitor high density populations in relation to carrying capacity (Morellet et al. 2001). The relationship between habitat productivity and population density is the cornerstone of management. Therefore, knowledge of deer density on a site is of little value without knowledge of the density the habitat can support. Carrying capacities of habitats vary geographically and fluctuate annually. Highly productive habitats can support as many as 1 deer/6 ha, while habitats with low productivity support 1 deer/51 ha; average carrying capacity for white-tailed deer in Oklahoma is 1 deer/14 ha (Masters et al. 2009).

Monitoring intensity of browse utilization is the most useful method for estimating density relative to carrying capacity (Fulbright and Ortega-S. 2006). Trends in herd condition (e.g. antler characteristics, body mass and condition, fawn crops) also should be monitored as additional indices of population status relative to carrying capacity (Fulbright and Ortega-S. 2006, Keyser et al. 2006).

Infrared-triggered camera (ITC) surveys are an increasingly popular survey method that provides more accurate estimates of population size and density, as well as valuable insight to herd sex and age composition (Jacobson et al. 1997, Gee 2000, Roberts et al. 2006, Watts et al. 2008). The coupling of browse use measurements with ITC population data provides the potential for a unique population management application used to develop specific management (harvest) plans according to estimates of relative density, population size, sex ratio, reproductive rate, and overall deer population management objectives.

My objectives were to 1) determine the deer densities and relative (K) densities of the sites through browse and camera surveys in the mixed-grass prairie and cross timbers (blackjack-post oak), 2) assess whether population data from camera surveys support relative deer density estimates, and 3) assess the feasibility of using browse utilization measurements and population data to formulate a harvest strategy.

STUDY AREAS

I collected winter browse use and ITC data from 2 sites in Oklahoma. The Woods County site (McBride pasture) was in northwest Oklahoma 19 km southeast of Waynoka. The site was adjacent to the Cimmaron River and consisted of 809 ha of mixed-grass prairie and stabilized sand dune habitat type (Duck and Fletcher 1943). Average annual temperature of the site was 15° C with average maximum and minimum temperatures of

22.2° C and 7.2° C, respectively (Oklahoma Climatological Survey 2009). Long-term (30-yr) average precipitation was 71 cm/year. The year prior to the study, 2007, received above-average precipitation of 81 cm, while 2008, the year of the study, received 66 cm (Oklahoma Mesonet 2009). Dominant soil types were Tivoli and Jester fine and loamy fine sands with 1–30% slopes. The woody upland vegetation was dominated by southern hackberry (*Celtis laevigata*), chittamwood (*Bumelia lanuginosa*), eastern red cedar (*Juniperus virginianus*), skunkbush sumac (*Rhus aromatica*), buckbrush (*Symphoricarpos orbiculatus*), and sandplum (*Prunus angustifolia*). Bottomland areas found throughout the site were dominated by buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), and cottonwood (*Populus deltoides*).

In February 2008, the northern 243 ha of McBride Pasture burned in a wildfire; previously the site was unburned for ≥5 years. The site received minimal hunting pressure, with 5–8 deer taken annually. In July 2008, the southern 486 ha was lightly stocked (≤ 12 ha/AU) with cattle, but was previously ungrazed for ≥3 years. In spring 2009 the cattle were rotated onto the northern 324 ha of the site.

The Payne County site in north-central Oklahoma was about 11 km southwest of Stillwater at the Cross Timbers Experimental Range (CTER) and consisted of 737 ha of tallgrass prairie and post oak-blackjack oak habitat type (Duck and Fletcher 1943). Average annual temperature was 15° C with average maximum and minimum temperatures of 21.6° C and 8.6° C, respectively (Oklahoma Climatological Survey 2009). Long-term average annual precipitation was 93 cm, while 2008, the year prior to data collection, received 96 cm (Oklahoma Mesonet 2009). Dominant soils included Harrah-Pulaski and Stephenville-Darnell complexes with slopes ranging from 0–8%

(Web Soil Survey 2009). Dominant woody species included several species of oak (*Quercus* spp.), hackberry, roughleaf dogwood (*Cornus drummondii*), skunkbush sumac, smooth sumac (*Rhus glabra*), buckbrush, and sandplum.

CTER was divided into 32.4-ha burn units with a burn frequency split into thirds; 1/3 burned every 2 years, 1/3 burned every 3 years, and 1/3 burned every 5 years with each unit receiving dormant and growing season burns. Currently, no deer are taken annually from the site.

METHODS

Browse Use

To assess the relative deer density of the sites (below, at, or exceeding carrying capacity), I measured browse use using the stem-count index method. This method does not measure the amount of browse consumed, but rather provides an index of the percentage of browsed stem tips (Rutledge et al. 2008). I conducted surveys in late winter, when the relationship between browse use and density is strongest (Lay 1967, Fulbright et al. 2007, Rutledge et al. 2008). I sampled McBride Pasture in 2008–2009 and at CTER in 2009. I surveyed randomly selected woody browse species within 5-m radius circular plots (McBride 2008 n = 36, 2009 n = 32; CTER 2009 n = 37). For each browse species present within a plot, I counted the number of browsed tips (use) out of 100 twig tips of the species to calculate the percent use of each species in each plot, and ultimately the mean use for each browse species. Species present in ≥20% of plots were then categorized into first, second or third choice palatability classes (Lay 1967, Rutledge et al. 2008), as defined for Oklahoma by Masters et al. (E-979; Table 1.1). The mean species' use in each palatability class were averaged to calculate the mean use per class. The palatability class means were compared to the utilization index developed by Lay (1967; Table 1.2) to determine if deer density was below, at, or exceeding carrying capacity. Use of second choice species is most strongly correlated with deer density (DeYoung et al. 2007), and therefore was used as the most reliable indicator of deer stocking intensity of a site.

Infrared-triggered Camera Survey

To estimate the deer density (ha/deer) of McBride Pasture, in late September to mid October 2009 I conducted 2 consecutive ITC surveys. The site was divided into 20 41-ha blocks (slightly larger than suggested by Jacobson et al. [1997]). For each survey, ten baited camera stations were placed near high traffic areas (e.g. trails, watering holes) at the density of one/41 ha. Bait stations consisted of a Moultrie Game Spy ™ (4 mp) ITC and a Moultrie camera solar panel placed on hand-crafted camera stands (Adam Gourley, Oklahoma State University Research Range) at 1-m height with bait 4 m in the foreground. Shelled corn was costly and likely to attract cattle and other non-target species to camera stations (Adam Gourley, personal communication); therefore, milo was placed as bait every 3–4 days beginning 10 days prior to the survey and continuing throughout the 2-week survey (Jacobson et al. 1997, Koerth et al. 1997, Koerth and Kroll 2000).

Cameras were set to take 3 photographs/trigger to provide adequate views for identifying individual bucks. Each deer present in a set of photographs (3 photographs/trigger) was only recorded only once per photograph set. For example, photo 1: 1 doe, 1 buck; photo 2: 1 doe, 1 fawn; photo 3: 2 does, 1 buck; deer occurrences recorded for this set of photographs would have been 2 does, 1 fawn, and 1 or 2 bucks depending upon whether photos 1 and 3 photographed the same buck or 2 different bucks. Camera trigger delay intervals were set to delay re-triggering for 1 min after taking a set of photographs. Camera trigger sensitivity was set at factory default settings.

To maintain a camera density of one/41 ha, 2 survey periods (northern 405 ha, southern 405 ha) were conducted consecutively to census the McBride Pasture. I analyzed data collected from a 2-week camera survey conducted in similar fashion on 405 ha of the CTER site. The CTER data were collected from early to mid January 2009 at a camera density of 1/45 ha the first week, but 1/50 ha the second week due to camera malfunction. At the end of each survey period, photos from camera memory cards were downloaded to a computer for photo analysis.

Photo analysis

Following the photo analysis methods outlined in Jacobson et al. (1997), I analyzed the survey photographs by identifying individual branch-antlered bucks by antler, body, and pelage characteristics to determine the total number of branch-antlered bucks present. As spike-antlered bucks were not easily distinguishable, I used the total number of branch-antlered bucks in combination with the ratio of spike-antlered:branch-antlered buck photograph occurrences to estimate the total number of bucks in the population; i.e.,

$P_s = N_{sa}/N_{ba}$, where

P_s = ratio of spike-antlered:branch-antlered bucks,

N_{sa} = total number of spike-antlered deer occurrences in photographs,

N_{ba} = total number of branch-antlered deer occurrences in photographs,

and

$E_b = BP_s + B$, where

E_b = estimated total buck population,

B = number of individually identified branch-antlered bucks

To estimate the total doe population, I used the estimated total number of bucks (E_b) in combination with the ratio of buck:doe photograph occurrences, i.e.,

$P_d = N_d/N_b$, where

P_d = ratio of does:bucks,

N_d = total number of antlerless adult deer occurrences in photographs,

N_b = total number of antlered adult deer occurrences in photographs, and

$E_d = E_bP_d$, where

E_d = estimated total doe population.

To estimate the total fawn population, I used the estimated total number of does (E_d) in combination with the ratio of fawn:doe photograph occurrences, i.e.,

$P_f = N_f/N_d$, where

P_f = ratio fawns:does,

N_f = total number of fawn occurrences in photographs, and

$E_f = E_dP_f$, where

E_f = estimated total fawn population.

I estimated the total population size (E_p) of the survey area by summing the total estimates of bucks (E_b), does (E_d), and fawns (E_f).

$$E_p = E_b + E_d + E_f$$

Population Management Plan

The optimum relative deer density at the site corresponds with moderate stocking intensity levels of Lay's (1967) use index. Therefore, according to the use index, optimum stocking intensity (deer density) of the site should have 30% use of second choice class browse. Ultimately, I assumed the percent change in browse use corresponded to the percent change needed in population size. To determine the needed reduction in population size for McBride Pasture, I calculated the needed percent change in browse use, i.e.,

$$C = 100(U_{2c} - U_{d2c})/U_{2c}$$, where

C = needed percent change in percent use

U_{2c} = percent use of second choice species

U_{d2c} = desired percent use of second choice species

Inclusion of ITC survey data was necessary to determine the sex and number of deer to harvest. The actual number of deer to be harvested was calculated by applying the needed percent change to the estimated total population size, i.e.

$$H = CE_p$$, where

H = number of deer to harvest

By subtracting the number of deer to harvest from the anticipated total population estimate (total population estimate – harvest), I determined the desired population size. By applying a desired sex ratio to the desired population size, I determined the number of bucks and does to remain in the population, i.e.,

$D_p = E_p - H$, where

D_p = desired population size

And, $D_b = D_p D_{br}$

$D_d = D_p D_{dr}$, where

D_b = number of bucks to remain in population

D_d = number of does to remain in population

D_{br} = desired proportion of bucks in population

D_{dr} = desired proportion of does in population

I calculated the number of bucks and does to harvest from the population to reach the desired population size and sex ratio by subtracting the number of each sex to remain in the population from the anticipated population of each sex (plus expected recruitment [E_f], assuming a 1:1 birth class sex ratio), while accounting for the number of deer harvested between the survey period and the next hunting season (I assumed 8, the upper range of the number of deer normally taken annually), i.e.,

$H_b = E_b + 0.5E_f - D_b - H_{pb} =$, and

$H_d = E_d + 0.5\ E_f - D_d - H_{pd} =$, where

H_b = number of bucks to harvest

H_d = number of does to harvest

H_{pb} = number of bucks harvested post-survey

H_{pd} = number of does harvested post-survey

In this scenario, I used ITC population data from fall 2008 to calculate a harvest strategy for fall 2009, in which case I subtracted the number of bucks and does harvested after the ITC survey (in fall-winter 2008) and prior to the subsequent harvest year to ensure they were counted towards the total number of bucks and does to be harvested.

RESULTS

Browse Utilization

At the McBride Pasture site, browse species present in ≥20% of plots included hackberries (southern and netleaf [*C. reticulata*]), American elm (*Ulmus americana*), sandplum, skunkbush sumac, black willow, eastern cottonwood, chittamwood, buttonbush, buckbrush, redbud (*Cercis canadensis*), and eastern red cedar. The percent use of all browse classes corresponded with heavy stocking intensity (Lay 1967) for both 2008 and 2009 (Table 1.3). Use of second choice browse exceeded index standards of heavy stocking intensity (>40%) both years, and increased from 44% to 56% from 2008 to 2009. Third choice browse species also exceeded heavy stocking intensity standards (10%) by 20-21%.

At CTER, browse species present in ≥ 20% of plots included hackberries, roughleaf dogwood, redbud, sandplum, sumacs (skunkbush, flame-leaf [*Rhus copallinum*], and smooth [*R. glabra*]), chittamwood, black hickory (*Carya texana*), eastern red cedar, oaks (blackjack [*Quercus marilandica*], post [*Q. stellata*], chinkapin

[*Q. muehlenbergii*]), and buckbrush. The use of all browse classes corresponded with moderate stocking intensity (Table 1.3). Use of second choice browse was similar to index standards for moderate stocking intensity.

Infrared- triggered Camera Survey

The north survey of McBride Pasture (partially burned 405 ha) had 14 identifiable branch-antlered bucks and yielded a total population estimate of 197 deer. There was an estimated buck:doe ratio of 1:7.85, an estimated doe:fawn ratio of 1:0.3, and an estimated density of nearly 20 deer per 41 ha (100 ac; Table 1.4). The south (unburned 405 ha) survey had 24 identifiable branch-antlered bucks and a total population estimate of 61 deer. In the south survey there was an estimated buck:doe ratio of 1:1.12, an estimated doe:fawn ratio of 1:0.27, and an estimated density of 6.13 deer per 41 ha (Table 1.4). The north survey estimated over 3 times as many deer as the south survey. To estimate the deer population for the entire site, I combined the north and south surveys and found 38 identifiable branch-antlered bucks; no bucks from the north survey were photographed in the south survey, and no bucks from the south survey were photographed in the north survey. The total population estimate for the entire 809 ha was 190 deer, with an estimated buck:doe ratio of 1:2.86, an estimated doe:fawn ratio of 1:0.29, and a density estimate of 9.7 deer per 41 ha, or 1 deer per 4.3 ha (Table 1.4). The CTER survey had 24 identifiable branch-antlered bucks and yielded a total population estimate of 75 deer, an estimated buck:doe ratio of 1:1.1, an estimated doe:fawn ratio of 1:0.88, and a density estimate of 7.6 deer per 41 ha, or 1 deer per 5.4 ha (Table 1.4).

Population Prescription

Using the population and browse use data from McBride camera and browse survey results, I calculated a needed 46% reduction of the deer population at McBride Pasture to achieve a desirable population size and reduce browse use levels from 56% to a moderate level of 30% use. The annual recruitment for 2009 was 34 fawns; presumably 17 female and 17 male. I estimated the fall 2009 total population size including recruitment to be 190 deer. To reach the desired population size and moderate levels of browse use, I estimated a total of 88 deer need to be harvested. To reach a desirable population size (according to utilization indices) and buck:doe ratio of 1:1.5, 17 bucks and 71 does need to be harvested, which would leave 41 bucks and 62 does remaining in a population of 103 deer at a density of 1 deer/8 ha. No population prescription was calculated for the CTER herd, as it was estimated to be within carrying capacity of the habitat and had desirable sex and age ratios.

DISCUSSION

The McBride camera survey estimated over 3 times as many deer in the northern 405 ha than in the southern 405 ha. I hypothesized this was due to a wildfire that burned the northern ~240 ha in February 2008. Deer tend to concentrate in recently burned areas (Klinger et al. 1989, Holechek et al. 2001). Does have been shown to select burned areas in spring, summer, and fall, while bucks tend to select burned areas only during summer (Leslie et al. 1996). The results for the north and south camera surveys of McBride Pasture in fall 2009 were similar to Leslie et al.'s (1996) findings that does appeared to select the burned area during fall, while the bucks selected against the burned area during fall. Therefore, I combined the 2 surveys to provide more realistic population estimates for McBride Pasture.

The browse and camera surveys indicated the deer population at McBride Pasture exceeded carrying capacity of the habitat at a density of 1 deer/4.3 ha. However, CTER was within carrying capacity of the habitat at a density of 1 deer per 5.4 ha. The results of the camera surveys supported the results of the browse surveys for both sites. Optimum fawn production of a deer herd is 0.75 – 1.25 fawns per doe (Gee et al. 1994), however the deer population on McBride pasture had low fawn production, which has been found to be characteristic of overabundant populations (Gee et al. 1994, Fulbright and Ortega-S. 2006). Though deer densities were similar between the 2 sites, the results indicate that CTER was the more productive habitat and had a higher carrying capacity than did McBride Pasture. I hypothesized this was due to the higher amount (+23 cm) of annual precipitation that CTER typically receives in comparison to McBride pasture.

Additionally, though food is typically the limiting factor for deer in the Cross Timbers (Gee et al. 1994), the fire frequency of CTER promotes accessibility, diversity, and abundance of desirable deer foods, temporarily improves nutritional quality and palatability of browse and forage, and opens the forest canopy to promote growth of important understory plants that are moderately tolerant to shade intolerant (Gee at al. 1994).

Palatability classifications of browse species are fundamental to using the stem-count index to estimate relative deer density. However, several discrepancies exist among published sources of palatability classifications of browse species. In this study, I relied upon Oklahoma browse classifications by Masters et al. (E-979). However, in cross referencing other publications (i.e. Gee et al. 1994, Tyrl et al. 2002, TPWD 2007) I found several variations in the palatability classification (i.e. first, second, or third choice) of individual species and species complexes. Variation in palatability classifications can lead to variable browse survey results and ultimately different relative density estimates depending upon which reference is used for classifying species according to palatability.

Also, there has been variation in the methods of classifying species; some sources classify browse species complexes, while others classify individual species of those complexes into different palatability classes. The Masters et al. (E-979) palatability classifications have several species classified in species complexes rather than individual species; for example, hackberries and elms are first choice foods; plums, sumacs, and willows are second choice foods; and hickories, pecans, and oaks are third choice foods. However, Texas Parks and Wildlife Department's palatability classifications have sugar hackberry (*C. laevigata*) listed as a first choice food and netleaf hackberry (*C. reticulata*) listed as second choice; blackjack, post, and chinkapin oaks are listed as second choice foods, while live oak is listed as third choice.

There was fluctuation of the use of individual browse species between my 2 sampling seasons at McBride Pasture, which is typical from year to year in correspondence with annual habitat productivity (Fulbright and Ortega-S. 2006). Mean use of palatability classes was higher in 2009 than in 2008. This could be due to the stocking of cattle on the site in summer 2008 or to increased deer browsing pressure as a response to reduction in available vegetation due to below average precipitation. Use of third choice species beyond 10% is a strong indication that the population has reached or exceeded carrying capacity (Lay 1967). I witnessed no browsing on eastern red cedars in 2008; however in 2009 I found utilization of cedar as a source of browse. Eastern red cedars are considered an emergency food for white-tailed deer (Tyrl et al. 2002); the utilization of cedar on McBride is another indication of deer overabundance. Other visual indicators of overabundance were hedging of hackberries and chittamwoods along with distinct browse lines, particularly noticeable on redbuds.

Browse utilization is directly related to the size of the deer population (Fulbright and Ortega-S. 2006). The use of browse use measurements and camera survey population data to develop a population management plan (harvest strategy) relies on a number of assumptions. First, I assumed that preferences of browse species were correctly classified for the habitat surveyed. Second, the harvest strategy calculations assumed a 100% survival rate of the population, which ultimately yields a generous harvest recommendation. However, studies evaluating the accuracy of camera surveys suggest the use of baited camera stations leads to a bias in capture rate of bucks over does (Jacobson et al. 1997, Watts et al. 2008), thus underestimating the buck:doe ratio, yielding a low doe estimate, and ultimately a minimum population estimate. The underestimation of does in the population should presumably reduce the effect of possible overestimation in the harvest recommendations.

The use of ITC surveys also requires a number of assumptions regarding precision of the method: all individual branch-antlered bucks present in the surveys were correctly identified; all photographed deer were correctly classified according to age or sex; and estimates of sex and age ratios were reasonably accurate estimates of the population. The latter 2 assumptions can be met by ensuring appropriate survey timing. Koerth and Kroll

(2000) found no single month to provide the most accurate estimates of both age and sex ratios, and suggest a multi-stage survey may provide the best estimates for each. However, the use of fall surveys is necessary to estimate productivity of the herd prior to hunting season and to accurately distinguish between fawns and adults, and between does and bucks. Months with relatively small coefficients of variation for estimates of age ratios and sex ratios are September and October, respectively (Koerth and Kroll 2000). The use of spotlight surveys to estimate sex ratios has been suggested (Jim Shaw, Oklahoma State University, personal communication). However, bucks have been found to be underrepresented in spotlight surveys, and are also subjective to accessibility and visibility of terrain (McCullough 1982).

Another assumption of the method is a 1:1 recruitment ratio; I assumed there were equal numbers of bucks and does being recruited annually into the adult population. However, estimates of the buck and doe populations from annual follow up camera surveys (accounting for reported harvests) can provide needed insight into the sex ratios of annual recruitment classes. Annual adjustment should be made to the harvest strategy according to recruitment, trends in browse utilization and sex ratios, and overall management objectives.

Management Implications

The results imply that these relatively new survey methods (ITC and stem-count index) not only provide reliable population estimates and data complimentary to the other, but are also more beneficial to managers than other traditional methods. The use of these methods rather than traditional survey methods provides managers with the advantage of an additional management application for improving population management (harvest) decisions according to specific objectives. A major implication of the study was the need for improvement of palatability classifications of browse species. The lack of precision in palatability classifications can reduce reliability of the stem-count index estimates and lead to incorrect management decisions.

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Table 1.1. Palatability classifications of Oklahoma woody browse species sampled at McBride Pasture, Woods County, and CTER, Payne County, Oklahoma, USA. Adapted from Masters, Bidwell, and Shaw (E-979).

First Choice		Second Choice		Third Choice	
Scientific name	Common name	Scientific name	Common name	Scientific name	Common name
Celtis spp.	Hackberries	*Cercis canadensis*	Redbud	*Bumelia lanuginosa*	Chittamwood
Cornus drummondii	Roughleaf dogwood	*Maclura pomifera* [a]	Osage Orange [a]	*Carya* spp.	Pecans & Hickories
Smilax spp.[a]	Greenbriar [a]	*Populus deltoides*	Eastern Cottonwood	*Cephalanthus occidentalis*	Buttonbush
Ulmus spp.	Elms	*Prunus* spp.	Plums	*Juniperus virginiana*	Eastern Red Cedar
Vitis spp. [a]	Grapes [a]	*Rhus* spp.	Sumacs	*Quercus* spp.	Oaks
		Salix spp.	Willows	*Symphoricarpos orbiculatus* [a]	Buckbrush [a]

[a] Indicates species were sampled, but present in <20% of plots and therefore not included in browse utilization analyses.

Table 1.2. Browse utilization (percent use) index by palatability class for stocking intensity (deer density) relative to carrying capacity. Adapted from Lay (1967).

	Deer Stocking Intensity		
Palatability Class	Light	Moderate	Heavy
Browse:			
First choice	35	55	60
Second choice	10	30	40
Third choice	1	5	15
Grasses	0	trace	trace
Pine	0	0	3

Table 1.3. Deer use (% browsed stem tips) of woody browse for McBride Pasture, Woods County, in late winter 2008–2009 and Cross Timbers Experimental Range, Payne County, Oklahoma, in late winter 2009.

Palatability class (choice)	Browse use (%) at Deer Stocking Intensity			Observed browse use (%) McBride		Observed browse use (%) Cross Timbers
	Light	Moderate	Heavy	2008	2009	2009
First	35	55	60	56	61	52
Second	10	30	40	44	56	31
Third	1	5	15	36	48	8

Table 1.4. Infrared-triggered camera survey data from white-tailed deer populations on McBride Pasture, Woods County, collected in fall 2008; and Cross Timbers Experimental Range, Payne County, Oklahoma, collected in winter 2008–2009. The McBride combined survey represents 809 ha, while all others represent 405 ha.

Population variable	McBride north survey	McBride south survey	McBride combined	Cross Timbers
Branch-antlered bucks	14	24	38	24
Branched:Spike ratio	1:0.26	1:0.01	1:0.07	1:0.00
Total Buck Estimate	18	24	41	24
Buck:Doe ratio	1:7.85	1:1.18	1:2.86	1:1.13
Total Doe Estimate	138	29	116	27
Doe:Fawn ratio	1:0.3	1:0.27	1:0.29	1:0.88
Total Fawn Estimate	41	8	34	24
Total Population Estimate	197	61	190	75
Density (ha/deer)	2.10	6.70	4.30	5.40

CHAPTER II

EFFECTS OF FIRE AND BROWSING ON NORTHERN BOBWHITE FOOD RESOURCES

ABSTRACT White-tailed deer (*Odocoileus virginianus)* are keystone herbivores that exert direct and indirect effects on several species of birds, invertebrates, plants, and mammals. I studied how fire and deer browsing affected growth and reproduction of 4 northern bobwhite (*Colinus virginianus*) food plants (*Panicum oligosanthes, Commelina erecta, Chenopodium album, Ambrosia psilostachya*) on burned and unburned site in mixed-grass prairie in northwest Oklahoma. To quantify the effects of fire and browsing, I measured mean stem length and biomass, percentage of browsed and reproductive stems/plot, and sexual reproductive effort (percent biomass allocated to reproductive structures) of each species at peak flower from within each of 8 burned and 8 unburned sets of exclosures, as well as the browsed vegetation surrounding each set. Exclosure sets consisted of 2 types of adjacent exclosures: one to exclude deer herbivory, and the other to exclude both deer and rabbit herbivory. Samples were compared among both exclosure types and browsed vegetation. Browsing ranged from 0–100 % of stems per plot, and was similar between both exclosure types for all species. Sexual reproductive effort was 1.3–5.6× higher for plants in burned treatments, while browsing did not reduce sexual reproductive effort for any species. Herbivory was attributed to deer browsing rather

than rabbits or the combination of both species. The deer population did not reduce food resources for bobwhites through browsing. However, fire increased plant seed production.

INTRODUCTION

As North America's most popular game animal, the white-tailed deer (*Odocoileus virginianus*) hunting industry generates nearly $14 billion (USD) in annual revenue (Conover 1997). Conversely, deer are also responsible for an estimated >$2 billion (USD) in damages to vehicles, agriculture and timber industries, and metropolitan households (Conover 1997). The deer population in the U.S. experienced rapid growth during the 20th century following the eradication of large predators (e.g. wolves [*Canis lupus*] and cougars [*Puma concolor*]) and the implementation of harvest regulations (Leopold et al. 1947, McCabe and McCabe 1997). With reduced predation, habitats increasingly experienced deer populations reaching or exceeding carrying capacity (McCullough 1997, Cote et al. 2004). The substantial influences deer browsing can exert upon ecosystems has led to an increase in research focusing on the implications of deer overabundance (Fagerstone and Clay 1997, Healy et al. 1997, McShea et al. 1997, Augustine and DeCalesta 2003, Cote et al. 2004).

Sustained browsing pressure has been shown to modify habitats by altering the vegetative structure and nutrient cycling of an ecosystem (Rooney and Waller 2003). Deer cause several direct and indirect effects upon species of multiple trophic levels and are therefore considered keystone herbivores (McShea and Rappole 1992, Waller and Alverson 1997, Rooney 2001, Rooney and Waller 2003, Greenwald et al. 2008). As keystone herbivores, deer exert cascading effects onto many species of birds, invertebrates, and other mammals (DeCalesta 1994, McShea 2000, McShea and Rappole 2000, Stewart 2001, Allombert 2005).

Several studies have been conducted on sensitive, threatened, or endangered herbaceous species (Miller and Bratton 1992), with many focusing on native understory forbs as indicators of deer overabundance and browsing intensity (Anderson 1994, Augustine and DeCalesta 2003). Most browsing studies have been conducted in forested regions in the north-central and northeastern United States. In fragmented forests of southeastern Minnesota, high deer densities (2.9–4 ha/deer) resulted in a 50% reduction in *Trillium* spp. reproduction, whereas deer exclusion for two growing seasons resulted in larger plants with increased flowering rates (Augustine and Frelich 1998). In the forests of northern Wisconsin, browsing by low deer densities (25 ha/deer) prevented regeneration of common woody species [Canada yew (*Taxus canadensis*), eastern hemlock (*Tsuga canadensis*), and white cedar (*Thuja occidentalis*)], as well as elimination of several herbaceous species (Alverson et al. 1988, Rooney 2001, Rooney and Waller 2003). Changes in stem morphology and reduced plant growth caused by deer browsing have been well documented throughout the north-central and the northeastern U.S. (Russell et al. 2001). While virtually all habitat types experience deer overabundance, ecosystem and population-level effects in many regions with large deer populations are relatively unstudied (Russell et al. 2001).

Deer diets predominantly consist of woody browse, but deer can exhibit dietary shifts to consume ≤90% forbs and grasses in seasons of availability (Miller and Bratton 1992). Forbs and grasses are important seed producers for northern bobwhites (*Colinus* *virginianus*). Seeds comprise more than half of the winter bobwhite diets and ≤80% of the summer diet when deer browsing of forbs is highest (Lyons and Ginnett L-5196). Studies conducted on 100 forb species in the tallgrass prairie have shown that high densities of deer (2.4–3.3 ha/deer) reduce plant reproductive success, abundance, diversity, distribution, and survival and result in extensive removal of flowering stems causing a shift towards less desirable species (Anderson et al. 2001, Anderson et al. 2005, Gubanyi 2008). Though bobwhite population declines have been widely attributed to habitat loss (Guthery 2000, Brennan 2007), it is possible that the reduction of vital food resources (seeds) is a contributing factor to local population decline.

My main objective was to assess effects of fire and browsing on aboveground growth and reproduction of grass and forb species which are important seed producers for northern bobwhites. To address this objective, I selected 1 grass and 3 forb species that were considered common forage for white-tailed deer, important seed producers for bobwhite quail, and abundant enough in the study site to obtain adequate sample sizes. Specifically, I sought to assess the following: what percentage of stems/m^2 were browsed for each species; was browsing attributable to deer, rabbits, or both; how did browsing affect growth and reproduction of each species; and how did burning affect growth and reproduction of each species.

STUDY AREA

The study was conducted April through September 2008 in northwest Oklahoma, about 19 km southeast of Waynoka, located near the Cimarron River in southern Woods County (Figure 2.1; 36°28’14”N, 98°41’37” W). The site, McBride Pasture, of a larger, private ranch, consisted of 8.1 km^2 of mixed grass prairie and stabilized sand dune type vegetation (Figure 2.2; Duck and Fletcher 1943). The pasture was primarily used for oil and gas production, but was also managed for bobwhites.

Dominant soil types included Tivoli and Jester fine sands and loamy fine sands with slopes ranging from 1–30% (Web Soil Survey 2009). The long-term average annual temperature was 15° C with average maximum and minimum temperatures of 22.2° C and 7.2° C, respectively. Long-term average precipitation was 71 cm annually with approximately 50 cm received during the 199-day growing season. In 2007, the year prior to the study, the site received above-average annual precipitation of 81 cm. However, in 2008 there was a rainfall deficit of 5 cm for the spring and summer of the study period (Oklahoma Climatological Survey 2009). Dominant vegetation included little bluestem (*Schizachyrium scoparium*), sand bluestem (*Andropogon gerardii hallii*), western ragweed (*Ambrosia psilostachya*), Texas croton (*Croton texensis*), sunflower (*Helianthus* spp.), fragrant sumac (*Rhus aromatica*), sandplum (*Prunus angustifolia*), eastern red cedar (*Juniperus virginianus*), chittamwood (*Bumelia lanuginosa*), hackberry (*Celtis laevigata*), buckbrush (*Symphoricarpos orbiculatus*), and soapberry (*Sapindus drummondii*). Bottomland areas were found throughout the site, in which the dominant species were buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), and cottonwood (*Populus deltoides*).

In February 2008, the northern 243 ha were burned in a wildfire, while the remaining area was left unburned. The site was previously ungrazed for ≥3 years prior to July 2008, at which time it was lightly stocked with cattle (≤ 12 ha/AU) on the southern

(486 ha) region of the site. In spring 2009 the cattle were rotated onto the northern 324 ha of the site. Deer harvest on the pasture was 5–8 deer annually.

METHODS

Grass and forb species

Species selected for the study were Scribner's panicum (*Panicum oligosanthes*; Poaceae), erect dayflower (*Commelina erecta*; Commelinaceae), lambsquarters (*Chenopodium album*; Chenopodiaceae), and western ragweed (*Ambrosia psilostachya*; Asteraceae [Nomenclature from USDA Plants Database (2009)]). Species' wildlife significance was determined from *Field Guide to Oklahoma Plants* (Tyrl et al. 2002). Scribner's panicum (hereafter; panicum), is a native, cool season (C_3), perennial grass that exhibits two growth forms and flowering periods; the spring form exhibits longer, unbranched culms and flowers from April to June, while the summer-autumn form exhibits shorter, branched culms and flowers when moisture is readily available. Winter basal rosettes of panicum are important winter forage for deer, which form in the fall and persist through spring. Commonly encountered across the body of Oklahoma and moist sites of the panhandle, panicum occurs in loam and clay-loam soils, is characteristic of mid to late seral stages (Tyrl et al. 2002).

Erect dayflower (hereafter; dayflower), is a perennial forb with initially erect stems, which become decumbent with maturity. Dayflower is common in sandy and clay soils and is found in nearly all habitats (Ajilvsgi 1984).

Lambsquarters is an annual forb, which, though introduced from Eurasia, has naturalized across North America. Lambsquarters has erect, branched stems, flowers from May to September, and is a prolific seed producer; one plant may produce up to 75,000 seeds. Common to recently disturbed soils, lambsquarters is characteristic of early seral stages (Tyrl et al. 2002).

Western ragweed (hereafter; ragweed) is a perennial forb with erect stems, and rhizome-like woody roots, which often form extensive clones. Ragweed flowers from late July to October, though achenes may remain on dead plants throughout the winter. Ragweed is found throughout the mixed-grass prairie and present in all seral stages (Tyrl et al. 2002).

To quantify browsing effects on plant growth and reproduction, I constructed 16 sets of herbivore exclosures to eliminate browsing upon target plant species. Each set of exclosures consisted of two types: a deer exclosure, to exclude deer, but allow rabbit herbivory; and an adjacent deer-rabbit exclosure to exclude both deer and rabbit herbivory. I constructed the deer exclosures by making a square pen using t-posts and weld-wire cattle panels (5 m × 1.22 m). I constructed the deer-rabbit exclosures in the same fashion, but with the addition of 0.61-m-tall wire poultry netting (2.54-cm mesh) around the perimeter base of the panels. I erected 8 exclosure sets within the burned area and 8 within the unburned area. Where forbs were greatest in abundance, I strategically placed the exclosures to contain similar abundances within and around each exclosure. The experimental design allowed for comparisons between unbrowsed plants within exclosures and browsed plants surrounding the exclosures, and between burned and unburned sites, as well as effects of burning and browsing interactions. The exclosure types also allowed for assessing if observed browsing was attributable to deer, rabbits, or both.

Target grass and forb species were sampled at each species' peak flower: June for panicum and dayflower, August for lambsquarters, and September for ragweed. Within each exclosure and surrounding browsed area, I clipped at ground level ≤20 established stems or tillers within each of ≤5 1-m^2 plots (Table 2.1). I measured individual stem heights (mm), reproductive status (reproductive or vegetative), and browsing status (browsed or unbrowsed), then separated reproductive structures from vegetative structures and oven-dried both at 60°C for 48–72 hours before quantifying the vegetative biomass and reproductive biomass to the nearest 0.01 g. I measured plant growth as the mean stem length and mean stem biomass per plot. Sexual reproductive effort (SRE), or the amount of biomass allocated to reproductive structures, was calculated as reproductive biomass/total vegetative biomass. I also calculated the percentage of browsed and reproductive stems per plot.

Data Analysis

I assessed differences among burning and browsing treatments for percent of browsed stems, mean stem length, mean stem biomass, percent of reproductive stems, and SRE for each species using two-way multivariate analysis of variance (MANOVA; SPSS 16.0 2007, Chicago, Illinois, USA). Given unequal sample sizes, I used Pillai's Trace multivariate statistic ($\alpha = 0.05$) to determine significance of interaction and main effects of burning and browsing. To reduce the chance of a Type I error, I used the Bonferroni adjustment ($P = 0.05/5$ dependent variables) and calculated an adjusted alpha level of $P = 0.01$ for test effects on individual dependent (growth and reproductive) variables. Effect size (eta squared: η^2), or the proportion of the variance in the dependent variable that can be explained by the independent variable, follows Cohen's (1988) criteria: 0.01 = small effect, 0.06 = moderate effect, 0.14 = large effect. To determine differences among the 6 burning × browsing treatments I used one-way ANOVA with least significant difference (LSD) post hoc tests (SPSS 16. 0 2007). Additionally, Pearson's correlation coefficients (*r*) were used to assess linear relationships of growth and reproductive variables.

RESULTS

Scribner's panicum

Panicum experienced little browsing compared to the other species (0.5–1.9% of tillers/m^2) with no evidence of browsing in 3 of the 6 treatments (burned, browsed; burned and unburned deer-rabbit [Figure 2.3A]). Burned vegetation had greater stem length than unburned vegetation, but when stems were burned and browsed (< 2% stems/m^2) stem length was 26% less than unburned, browsed vegetation (Figure 2.3B). Burning reduced stem biomass by 33% ($P = 0.039$; $\eta^2 = 0.270$; Figure 2.3C). Burning increased the percent of reproductive stems/m^2 and SRE ($P = 0.007$, $\eta^2 = 0.420$); limited (<2% stems/m^2) browsing on burned vegetation further increased both the percent of reproductive stems/m^2 and SRE (Figures 2.3D; 2.3E, respectively).

Erect dayflower

The percent of browsed stems/m^2 ranged from 0–22% of and was 20× greater in the browsed vegetation at burned sites than browsed vegetation at unburned sites (Figure 2.4A). Mean stem length of burned, unbrowsed (within exclosures) vegetation was an average of 20% greater than unburned/unbrowsed vegetation ($P = 0.050$, $\eta^2 = 0.157$). However, the increased percentage of browsed stems (20% stems/m^2) on burned, browsed vegetation led to a 20% reduction in stem length relative to stems within browsed exclosures (Figure 2.4B). Mean stem biomass of burned, unbrowsed (within exclosures) vegetation was an average of 20% greater than unburned, unbrowsed vegetation. Limited browsing (3%/m^2) of unburned dayflower stems increased mean stem biomass by 18%. However, burned dayflower stems experiencing increased levels of browsing had a 23% reduction in stem length (Figure 2.4C). For both burned and unburned vegetation, the decrease of the percent of reproductive stems/m^2 coincided with the percent of browsed stems/m^2 (Figure 2.4D). SRE of burned, unbrowsed dayflower was an average of 12% greater than unburned, unbrowsed, but burned/browsed stems had 66% greater SRE than did unburned, browsed stems (Figure 2.4E) and exhibited a positive relationship ($r = 0.635$; $P < 0.001$) with the percentage of browsed stems/m^2.

Lambsquarters

The percent of browsed lambsquarters stems/m^2 ranged from 2.4–100% and was an average of 9× greater at unburned sites than burned sites ($P = 0.001$, $\eta^2 = 0.567$; Figure 2.5A). For both burned and unburned sites, mean stem length in browsed vegetation was consistently 33% shorter than stems within exclosures ($P = 0.038$, $\eta^2 = 0.374$; Figure 2.5B). Mean stem biomass was an average of 248% greater at burned sites; trends were parallel to changes in mean stem length (Figure 2.5C). The percent of reproductive stems/m^2 was 36% greater in burned, unbrowsed (within exclosures) vegetation than within unburned exclosures, which had 38–45% stems browsed/m^2

($P < 0.001$, $\eta^2 = 0.624$; Figure 2.5D). SRE of lambsquarters was reduced by browsing only at burned sites, but was consistently 4.9–5.6× greater at burned sites than unburned sites ($P = 0.007$, $\eta^2 = 0.415$; Figure 2.5E).

Western ragweed

The percent of browsed ragweed stems/m^2 ranged from 3.4–15% with 12–15% of stems browsed within burned exclosures. Browsing outside exclosures was similar between burned and unburned sites (Figure 2.6A). Mean stem length at unburned sites was reduced by browsing, however burning increased stem length an average of 16% ($P = 0.008$, $\eta^2 = 0.244$); when burned, browsing did not reduce stem length (Figure 2.6B). Burning increased mean stem biomass by an average of 45% ($P = 0.006$, $\eta^2 = 0.255$; Figure 2.6C). The percent of reproductive stems/m^2 at unburned sites was reduced by browsing. However, burning slightly increased the percent of reproductive stems/m^2 by 11%; when burned, browsing did not reduce the percent of reproductive stems/m^2 (Figure 2.6D). SRE was increased 34% by browsing, 40% by burning, and 52% when both burned and browsed (Figure 2.6E)

DISCUSSION

My results indicated that dormant season burns in the mixed-grass prairie can stimulate both growth and reproduction of important food resources for northern bobwhites. In addition, my results indicated that deer browsing does not reduce reproduction of the selected grass and forb species, at least when the habitat is managed with fire. Though I tended to see increased browsing at burned sites, stem length and biomass were greater at burned sites relative to unburned sites, indicating fire stimulated forb growth. Fire increased biomass of all species but panicum. I hypothesized this was caused by the dual growth forms of panicum; winter basal rosettes persist from winter through spring when growth of the summer-autumn form begins from existent biomass. The dormant season fire removed all aboveground biomass of panicum rosettes, which in the unburned sites remained actively growing throughout the study period. Fire also increased the percent of reproductive stems/m^2 and SRE of all species, including panicum.

Removal of accumulated litter by fire may stimulate growth and development of herbaceous vegetation (Benson 2001). Removal of the detritus layer has been shown to increase soil temperatures during the growing season by 10° C by increasing the light reaching soil surface (Adams and Anderson 1978, Deregibus et al. 1985). Fire also recycles nutrients and stimulates germination of forb species (Landers and Mueller 1992).

Browsing reduced length and biomass for dayflower and lambsquarter. Though it reduced the percentage of reproductive stems/m^2, browsing stimulated the SRE of dayflower stems that were reproductive. The results indicated dayflower responds positively to increases in disturbance (burning and browsing). Little is known about the effects of browsing or grazing on dayflower even though it is considered one of the highest ranked forbs for deer selectivity (Soltero-Gardea et al. 1994). A study assessing the effects of fire and grazing on forbs in the western south Texas plains have shown fire increases density of dayflower (Ruthven et al. 2002).

Lambsquarters was the only species that experienced a reduction in SRE due to browsing; however, lambsquarters could only be located in 1 plot in the unburned, browsed vegetation. I hypothesized the lack of available unburned stems for sampling outside exclosures was due to the heavy browsing on lambsquarters I observed in the months prior to sampling. However, the results indicated that SRE and biomass were increased by intermediate disturbances (burning or browsing) but the increased disturbance of burning × browsing reduced SRE and biomass of lambsquarters. Though browsing did not stimulate growth or reproductive effort, deer have been shown to be the dominant herbivore responsible for seed dispersal of lambsquarters, and therefore indirectly promote the species population (Eycott et al. 2007). Lambsquarters and ragweed were sampled 2–3 months after the study site was lightly stocked with cattle; however, cattle were restricted to the southern unburned area of McBride Pasture. During sampling periods for lambsquarters and ragweed, cattle were only sighted in the far southern portions of the ranch where no exclosures were located. Cattle were not sighted in the vicinity of exclosures until October after all sampled had been conducted. Therefore, browsing observed on lambsquarters and ragweed outside exclosures was attributed to deer browsing rather than cattle grazing.

Fire increased all growth and reproduction measures of ragweed. Though browsing did not stimulate growth of ragweed, it did stimulated reproduction measures. Ragweed experienced the greatest increases in growth and reproduction when exposed to both burning and browsing, indicating ragweed responds positively to increases in disturbance, which is ecologically characteristic of ragweed (Tyrl et al. 2002). Collins (1987) reported that ragweed abundance and cover had positive relationships with both burning and grazing, but no relationship with the interaction of burning × grazing. Flaws in exclosure design led to some occurrence of browsing within exclosures and essentially nullified certain “unbrowsed” treatments causing difficulty in estimating true effects of browsing.

I was unable to assess the effects of browsing on panicum due to the low percentage of browsed stems/m^2. Researchers have observed white-tailed deer in Oklahoma consume winter basal rosettes of panicum rather than summer growth (Russell Stevens, Noble Foundation, personal communication). Panicum dominates the summer diet (31–34%) of cottontail rabbits (*Sylvilagus floridanus*) in upland hardwood forests and tallgrass prairies in Oklahoma (Peitz et al. 1997). The low levels of browsing on this species may be a possible indicator of a low population density of cottontails at this site.

Hickman and Hartnett (2002) found that moderate to high levels (15–75% of stems browsed/m^2) of grazing reduced growth and reproduction of forbs in the tallgrass prairie (fringeleaf ruellia [*Ruellia humilis*], leadplant [*Amorpha canescens*], and heath aster [*Aster ericoides*]), and did not stimulate plant growth or reproduction for any of the species. Prairie vegetation response to fire and herbivory varies considerably among species (Collins and Barber 1985, Collins 1987). Studies in the tallgrass prairie found perennial grasses have no clear relationship with season of fire, grazing intensity, or climatic variation, while forbs had a relationship with all variables (Coppedge et al. 1998). Though fire influences grazing patterns, studies focusing on fire and native ungulates in the mixed-grass prairie are sparse, particularly relative to research in the tallgrass prairie. Research conducted in the tallgrass prairie has mainly focused on effects of seasonal fires and fire × grazing interactions of cattle or bison (Coppedge et al. 2008). Of the few studies focusing on deer browsing, variables measured typically include forb abundance, distribution, diversity, and reproductive success rather than seed production (Anderson et al. 2001; 2005). A study on bobwhite foods' seed production found burning did not increase seed production of dayflower, panicum, or ragweed (Peoples et al. 1994). Aside from the Peoples et al. (1994) study, literature pertaining to seed production of bobwhite foods is lacking. A larger scale, high-fenced (>2.4 m) exclosure monitored over a long-term (>5 years) study period would provide more reliable estimates of deer browsing effects on food resources of northern bobwhites.

Management Implications

The major implications of this study relate to plant response to fire and grazing (browsing) practices as related to food production for northern bobwhites. These results can assist managers in selecting superior plant species for wildlife plantings in habitats managed with fire or with overabundant deer populations. These species' reproductive responses to fire and grazing practices could also be paired with species' nutritional information (true metabolizable energy) to further improve decisions about plant species selection.

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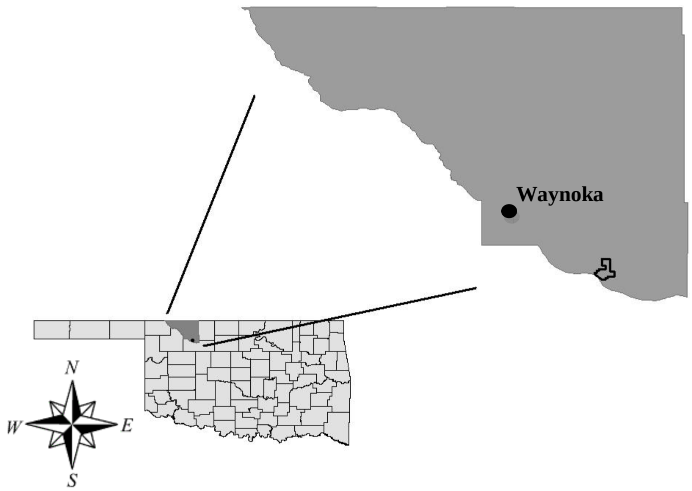

Figure 2.1. The study site, McBride Pasture, (inset) was located on the Cimmaron River in southern Woods County, about 19 km southeast of Waynoka, Oklahoma.

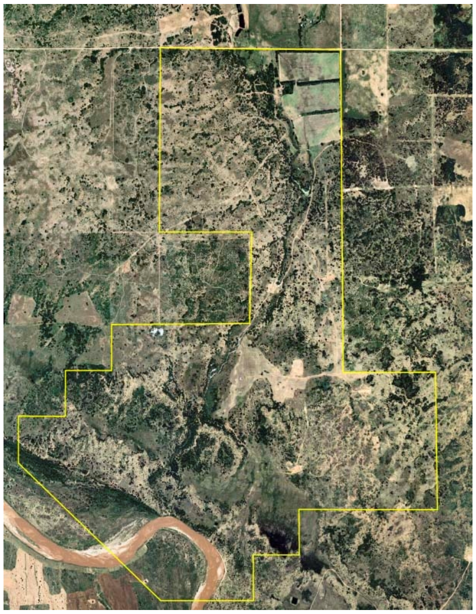

Figure 2.2. Aerial view of the study site, McBride Pasture, in the mixed-grass prairie in southern Woods County, Oklahoma, along the Cimmaron River. About 19 km southeast of Waynoka, Oklahoma.

Table 2.1. Number of sites each species was present, number of plots (1 m^2) sampled, and number of stems or tillers sampled for target grass and forb species within burned and unburned portions at McBride Pasture in southern Woods County, Oklahoma, in June–September 2008.

	Burned			Unburned		
Species	**Sites**	**Plots**	**Stems or tillers**	**Sites**	**Plots**	**Stems or tillers**
Scribner's panicum	**2**	**21**	**303**	**5**	**72**	**1,235**
Erect dayflower	**5**	**57**	**724**	**5**	**63**	**649**
Lambsquarters	**6**	**81**	**1,111**	**1**	**9**	**26**
Western ragweed	**6**	**53**	**941**	**7**	**67**	**1,266**

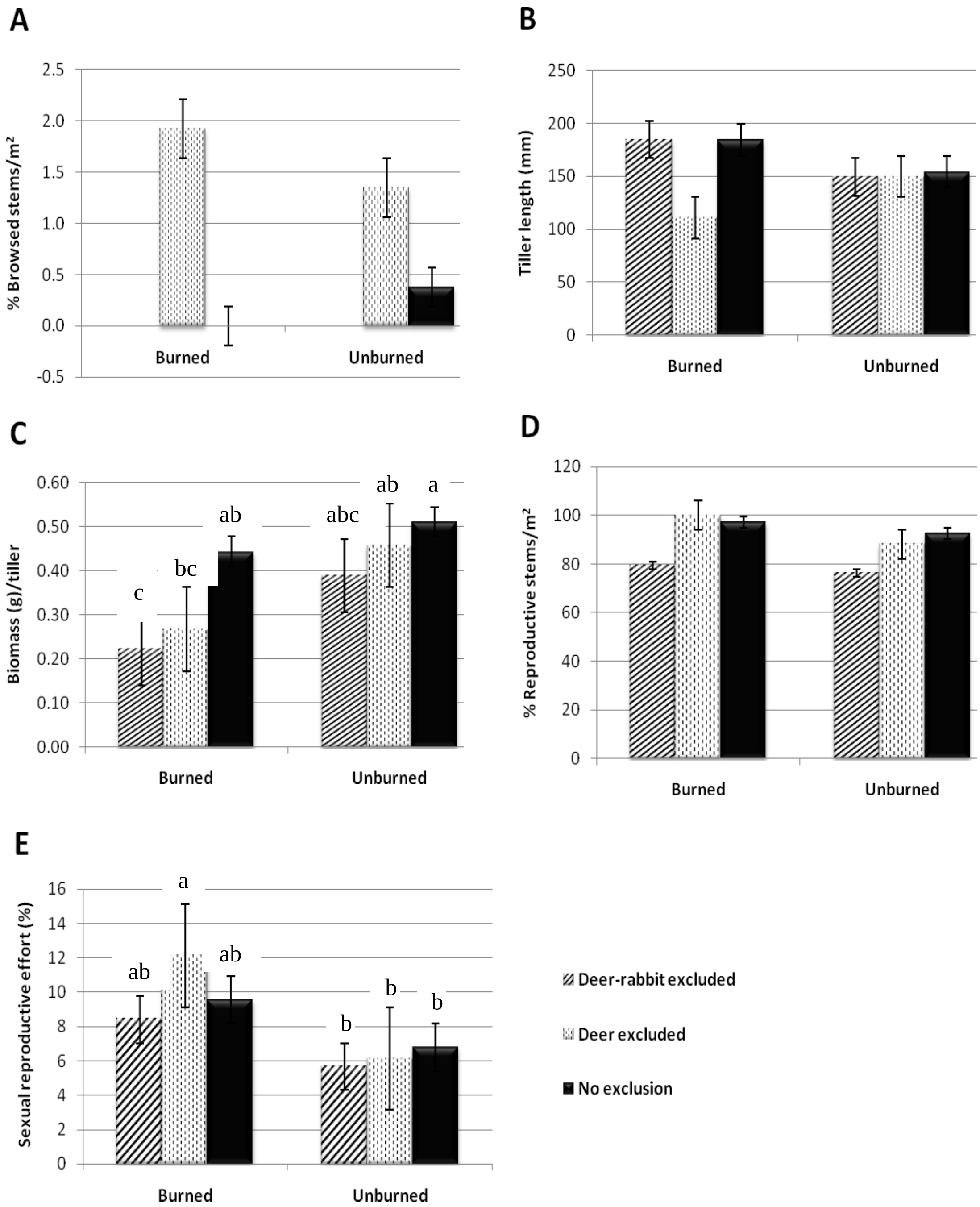

Figure 2.3. Scribner's panicum response (2008 sample means ± SE) to fire and browsing in southern Woods County, Oklahoma mixed-grass prairie. A. Percentage of stems per plot which were browsed. B. Mean length of individual tillers. C. Mean biomass of individual stems per plot. D. Percentage of stems per plot which were reproductive. E. Sexual reproductive effort as percent biomass allocated to reproductive structures. Significantly different ($P < 0.05$) treatments are denoted by different letters.

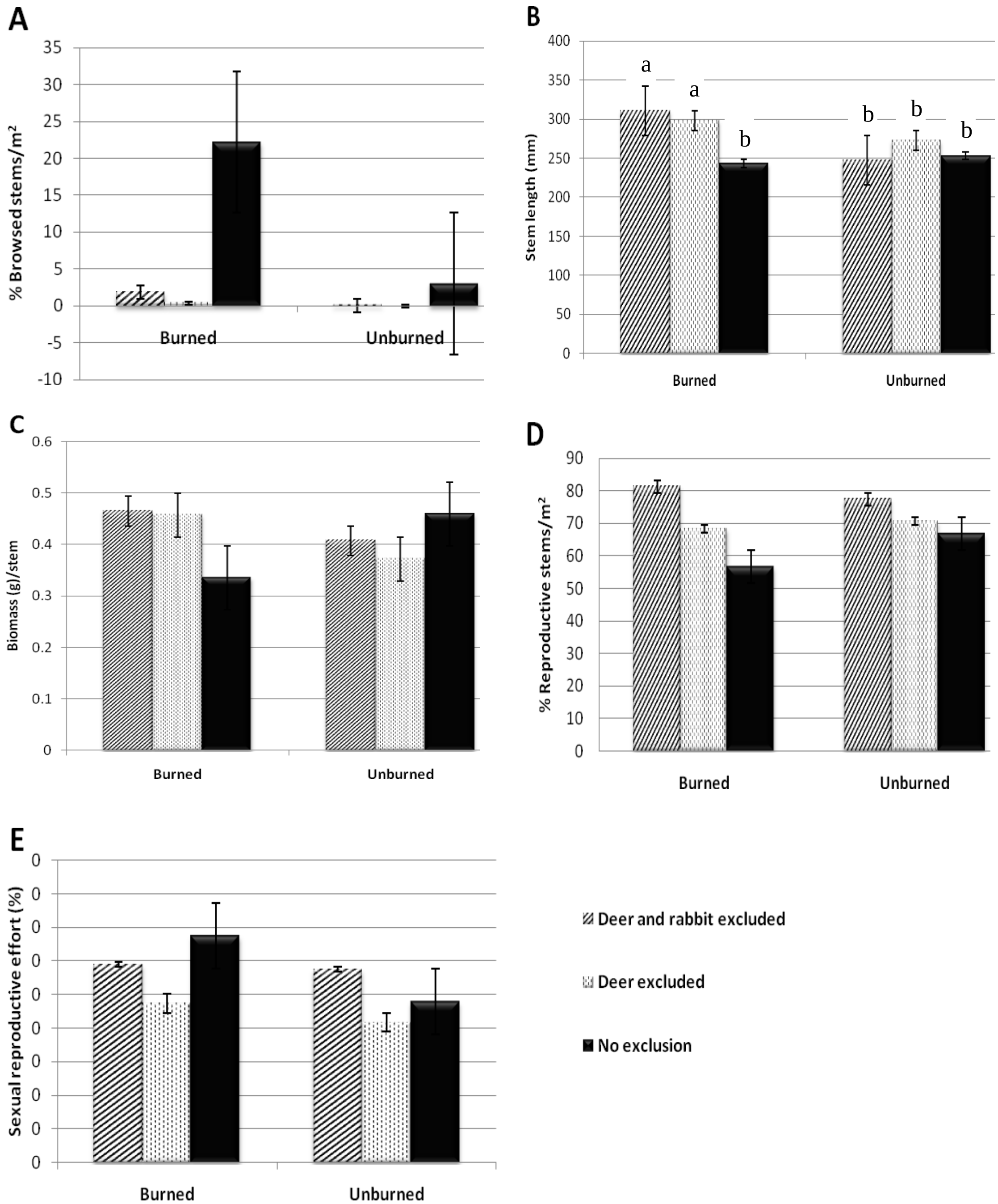

Figure 2.4. Erect dayflower response (2008 sample means ± SE) to fire and browsing in southern Woods County, Oklahoma mixed-grass prairie. A. Percentage of stems per plot which were browsed. B. Mean length of individual stems. C. Mean biomass of individual stems per plot. D. Percentage of stems per plot which were reproductive. E. Sexual reproductive effort as percent biomass allocated to reproductive structures. Significantly different ($P < 0.05$) treatments are denoted by different letters.

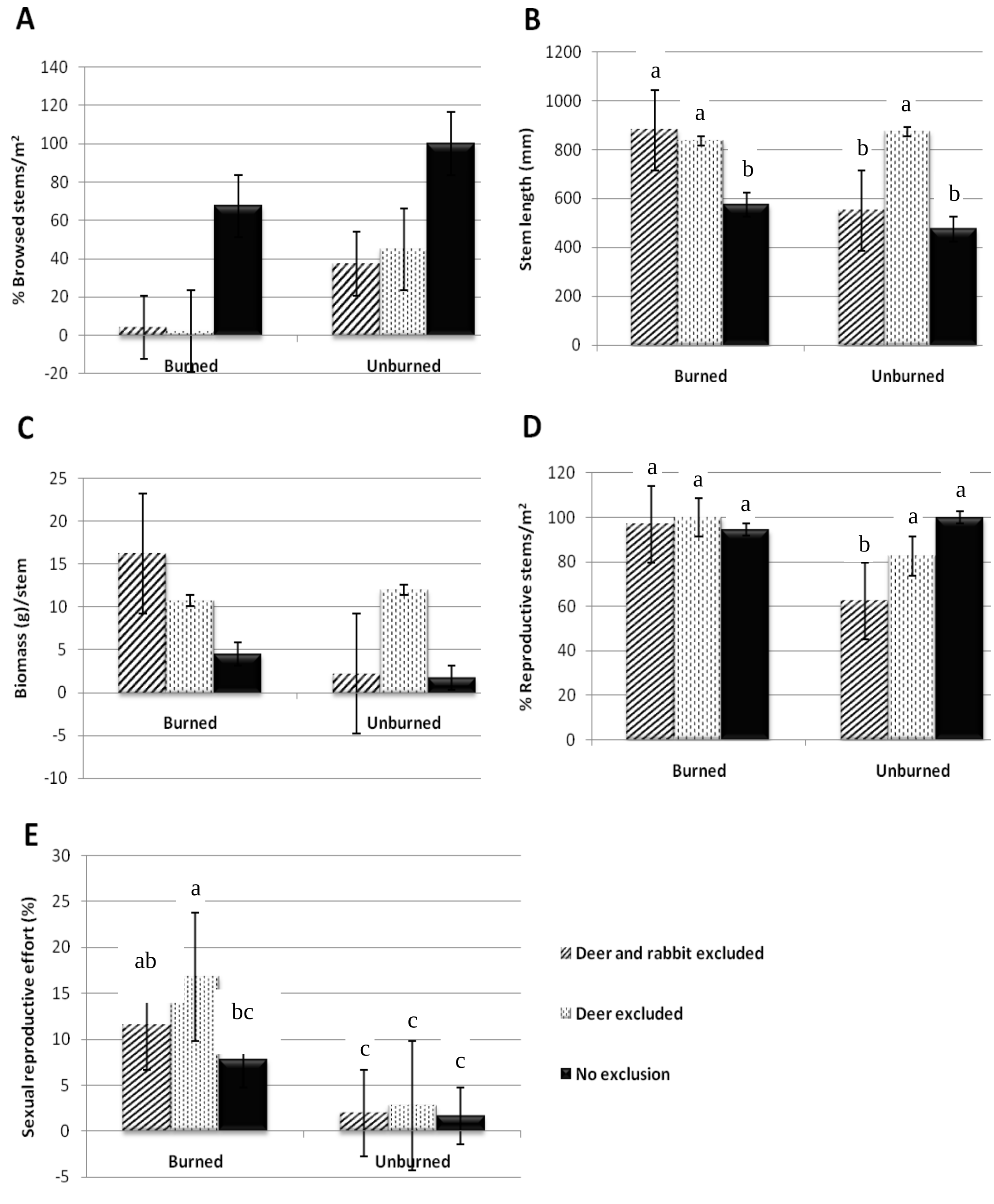

Figure 2.5. Lambsquarters response (2008 sample means ± SE) to fire and browsing in southern Woods County, Oklahoma mixed-grass prairie. A. Percentage of stems per plot which were browsed. B. Mean length of individual stems. C. Mean biomass of individual stems per plot. D. Percentage of stems per plot which were reproductive. E. Sexual reproductive effort as percent biomass allocated to reproductive structures. Significantly different ($P < 0.05$) treatments are enoted by different letters.

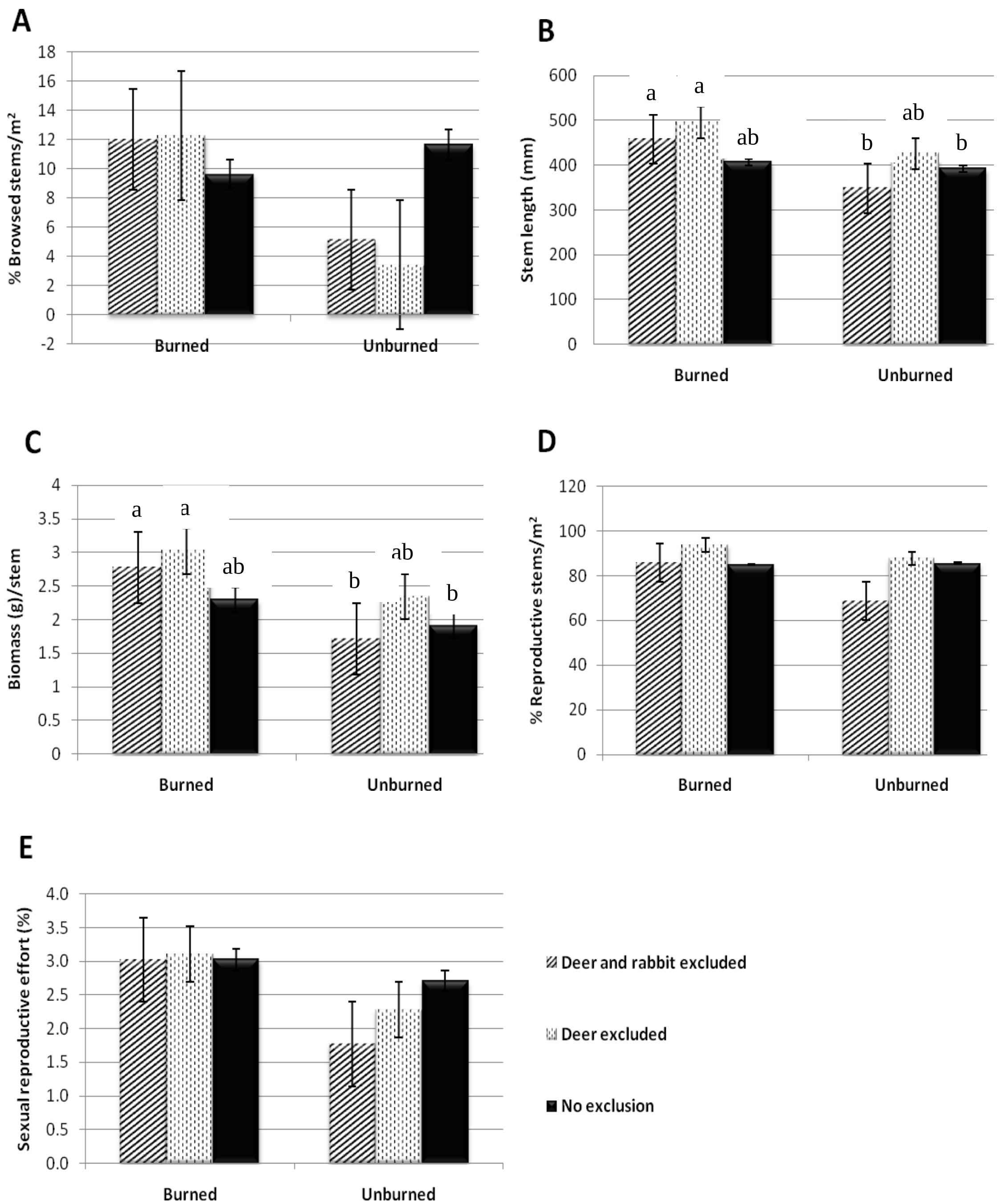

Figure 2.6. Western ragweed response (2008 sample means ± SE) to fire and browsing in southern Woods County, Oklahoma mixed-grass prairie. A. Percentage of stems per plot which were browsed. B. Mean length of individual stems. C. Mean biomass of individual stems per plot. D. Percentage of stems per plot which were reproductive. E. Sexual reproductive effort as percent biomass allocated to reproductive structures. Significantly different ($P < 0.05$) treatments are denoted by different letters.

VITA

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Candidate for the Degree of

Master of Science

Thesis: FIRE, BROWSING, AND DEER DENSITY IN THE MIXED-GRASS PRAIRIE

Major Field: Natural Resource Ecology and Management

Option: Wildlife Ecology and Management

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Education:
I received a Bachelor of Science in Fisheries and Wildlife Biology from Northeastern State University, Tahlequah, Oklahoma, in December 2007. I completed the requirements for the Master of Science in Natural Resource Ecology and Management with an emphasis in Wildlife Ecology and Management at Oklahoma State University, Stillwater, Oklahoma in May, 2010.

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Name: Valerie K. Cook Date of Degree: May, 2010

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: FIRE, BROWSING, AND DEER DENSITY IN THE MIXED-GRASS PRAIRIE

Pages in Study: 54 Candidate for the Degree of Master of Science

Major Field: Natural Resource Ecology and Management

Scope and Method of Study: White-tailed deer are keystone herbivores that have been shown to reduce reproductive success, abundance, diversity, distribution, and survival of plants in the tallgrass prairie. I assessed concerns that deer browsing reduced food resources for northern bobwhites by reducing seed production of important grass and forb species. I also compared results of deer browse and camera survey methods and combined the 2 methods to develop a management (harvest) application. In 2008–2009, I conducted fall and winter infra-red triggered camera surveys to estimate absolute (ha/deer) density and winter browse surveys to estimate relative (above, at, or below carrying capacity) deer density on McBride pasture in Woods County, and the Cross Timbers Experimental Range (CTER) in Payne County, Oklahoma. I quantified effects of fire and browsing on growth and reproduction of one grass and three forb species (Scribner's panicum, erect dayflower, lambsquarters, and western ragweed) at McBride. In June–September 2008, I measured mean stem length and biomass, sexual reproductive effort, and percent of browsed and reproductive stems per 1 m^2 plot from within deer exclosures, deer and rabbit exclosures, and surrounding browsed vegetation in burned and unburned portions of McBride pasture.

Findings and Conclusions: Deer density on McBride was one deer/4.3 ha with a recruitment rate of 0.3 fawns/doe, which browse surveys indicated to be exceeding carrying capacity. Deer density on CTER was one deer/5.4 ha with a recruitment rate of 0.9 fawns/doe, which browse surveys indicated to be within carrying capacity. Camera survey population data supported browse survey findings and indicated CTER was the more productive site of the 2 habitats. I calculated 17 bucks and 71 does needed to be harvested from McBride to achieve a desirable sex ratio and bring the population to within carrying capacity of the site. Herbivory at McBride was attributed to deer rather than rabbits or the combination of both species. Browsing ranged from zero to 100% of stems per plot. Species' growth responses varied considerably, but sexual reproductive effort (seed production) was 1.3 – 5.6 × higher for plants in burned treatments. Though browse surveys indicated deer density on McBride pasture exceeded carrying capacity, browsing did not reduce food resources for bobwhites. However, fire increased plant reproductive effort.

ADVISER'S APPROVAL: Dr. Karen R. Hickman