SAND PLUM IN OKLAHOMA: SMALL MAMMAL OCCUPANCY AND THE ACUTE EFFECTS OF PRESCRIBED FIRE

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SAND PLUM IN OKLAHOMA: SMALL MAMMAL

OCCUPANCY AND THE ACUTE EFFECTS OF

PRESCRIBED FIRE

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CHAPTER 1

COMPARISON OF TWO TECHNIQUES TO MEASURE STEM DENSITY OF SAND PLUM

ABSTRACT Sand plum (*Prunus angustifolia*) provides woody cover for an array of wildlife species throughout portions of the southern great plains; therefore a structural characteristic such as stem density is an important variable for biologists interested in managing this species. I compared 2 methods of estimating stem densities in south-central Oklahoma during 2009. Estimates were obtained using the point-centered quarter (PCQ) method and a quadrat-count method. For all thickets (n = 24) 9 stem density estimates were obtained per thicket using each method. Thickets showed minimal variation in stem density estimates across samples averaging 4.8/m^2 (95% CL = 4.5–5.1/m^2) for the quadrat-count method, and 5.6/m^2 (95% CL = 5.3–5.9/m^2) for the PCQ method. Also, correlation between the 2 estimate techniques occurred, and the linear regression model given quadrat-count estimates as a function of PCQ estimates showed that stem density estimates derived from the PCQ method were larger than the quadrat count across stem densities.

INTRODUCTION

Sand plum (*Prunus angustifolia*) is a thicket-forming, clonal shrub characterized by its dome-shaped appearance and multi-stem composition. Clonal stands of sand plum range in size from 1 to >1,000 m^2. Depending on the disturbance history of individual thickets stem densities vary greatly. Thickets are typified by shrubby growth form with dense horizontal and vertical structure. In addition to these physical obstructions, thickets contain a large number of stems which makes a total-count approach impractcal (Beasom and Haucke 1975). Therefore, it is practical and more efficient to obtain density estimates by conducting multiple samples and statistical inference.

The point-centered quarter (PCQ) method (Cottham and Curtis 1956) is a commonly applied sampling technique used in a wide range of disciplines from forestry to range management (Mitchell 2007). It is a time-efficient method for estimating tree densities (Cottam and Curtis 1956). Beasom and Haucke (1975) tested this method against other distance sampling techniques and established its validity for determining stem density within oak (*Quercus* sp.) mottes of south Texas.

Another commonly used technique for measuring density is the quadrat-count method in which stems are counted within a plot of known area. This technique has been used extensively in grassland vegetation sampling, but is not so applicable in situations where large quadrats are needed for adequate sampling such as in forests where stems are spread out great distances (Engeman et al. 1994). However, for clonal shrub species a quadrat approach seems relevant due to the proximity of stems and their relatively small area. Dickinson et al. (1993) estimated stem densities of the clonal shrub gray dogwood

(*Cornus racemosa*) and Niering et al. (1986) used this technique to measure stem densities in nannyberry (*Viburnum lentago*) thickets.

My objectives were to estimate stem densities of plum thickets using PCQ and quadrat-count methods. I also determined what relationship existed between the PCQ and quadrat-count estimates.

STUDY AREA

I collected density estimates of 24 plum thickets on a private ranch in south-central Oklahoma about 5 km west of Marietta, USA. The ranch consists of 1,011 ha used for livestock and wildlife research projects**.** Precipitation ranges from 86 to 91 cm annually and mean low temperature of 16 °C in January and a mean high temperature of 28 °C occurring in August. Vegetation on the area is tall grass prairie with big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indian grass (*Sorghastrum nutans*) interspersed with wooded areas of the post oak (*Q. stellata*)-blackjack oak (*Q. marilandica*) forest type. Tree species such as black hickory (*Carya texana*), shumard oak (*Q. shumardii*), chittamwood (*Bumelia lanuginosa*), and sugarberry (*Celtis laevigata*) dominate forested sites.

METHODS

During December 2008 I identified 24 plum thickets within 2 pastures of the study site. I selected stands within a range of area classes (32−313 m^2) I used a 10-m line transect in which a point of origin was established by entering the thicket at its greatest width. I randomly determined a distance of 1 or 2 m to travel into each thicket and establish a point of origin. At the origin a 2.5-m stick of plastic pipe marked at 10-cm increments was placed on the ground parallel to the edge of the thicket. The 2.5-m transect was repeated once in each direction equaling a 5-m transect. Once measurements were taken along the 5-m transect the 2.5-m stick was positioned from the point of origin in the opposite direction from the previous transect. I estimated stem density using the PCQ method. Measurements were taken at 1.25-m intervals along each transect for a total of 9 samples within each thicket. For this method the random point becomes the center point, the area around the point is divided into 4 90° quadrats, and the axes are aligned with the 4 cardinal directions. The distance (r_i) between the central point and the closest living stem in each quadrat was measured with a tape measure to the nearest centimeter (Cottam and Curtis 1956). To calculate density (*D*) I used the equation, D = 1/(sum of the measured distances/4)^2 (Cottam and Curtis 1956).

Using the 10-m transects as described above and the randomly generated points of origin for each thicket I sampled stem densities using the quadrat-count method. The density of stems in each thicket was measured by centering a 1-×-1 m^2 quadrat at the 1.25-m transect interval used to collect PCQ data. This allowed for the collection of 9 stem density measurements per thicket. Stem densities for each quadrat were then averaged.

Data Analysis

To compare the results of each technique I averaged 9 density estimates for each thicket. To give an indication of how much uncertainty is present in the estimate of the true mean I generated CIs at the 95% level for both means. I expected the stem densities for both methods to have a linear relationship. Thus, I applied linear regression analysis to determine the coefficient (*b*) and the constant (*a*) of the equation. I was interested in the reliability of the linear relationship between the estimates, so I determined the correlation coefficient (*r*) between quadrat and PCQ estimates.

RESULTS

Stem density estimates showed minimal variation across samples averaging $4.8/m^2$ (95% CL = 4.8–5.1/m^2) for the quadrat-count method and $5.6/m^2$ (95% CL = 1.0–5.9/m^2) for the PCQ method (Table 1.1). The linear regression model given quadrat-count estimates (y) as a function of PCQ estimates (x) was $y = 3.2 + 0.49x$ (95% CL = 1.5−4.6 for intercept and 0.1−0.9 for slope, Fig. 1.1). The equation implies that the PCQ method for stem density estimates typically will be larger than the quadrat-count. The quadrat-count and the PCQ estimates were correlated ($r^2 = 0.27$, Fig. 1). Therefore, the PCQ estimate explained 27% of the variation in the quadrat-count.

DISCUSSION

Although the techniques under study produced similar results, an important consideration of quadrat sampling is that adequate sample size is directly dependent upon the density being measured (Pollard 1971). Given the stem density characteristics of plum, in which distances between stems were consistently <1 m, a sampling frame or quadrat of 1 m is sufficient. The quadrat-count method is an easily obtained measure which provides precise measurements within the given area of sampling.

In contrast, the PCQ method can become problematic where closest stems are difficult to differentiate between quarters, thus giving inaccurate estimations of density (Pollard 1971, Engeman et al. 1994). Furthermore, the PCQ method required a measuring device in which observational error was likely. I also used a fine-scale unit of measure (cm) to gather distance measurements; this is problematic because minor placement errors lead to varying distance measures. In contrast, sampling with the quadrat-count method provided a single numeric value which could easily be repeated if a mistake occurred.

Although relative efficiency was not examined in this study, considerable more time and effort was employed for the PCQ method. This was due in part to the structural composition of sand plum, its morphological characteristics, and the collection of data at each point.

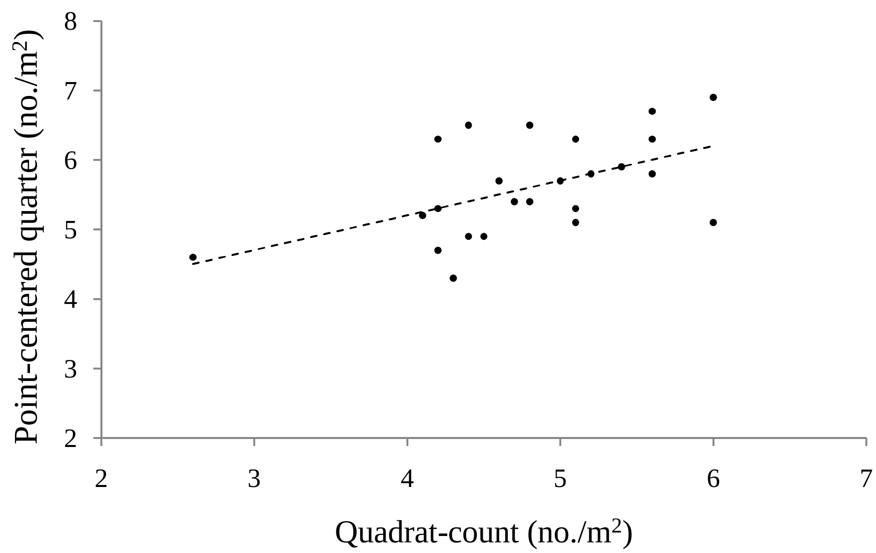
MANAGEMENT IMPLICATIONS

Acceptable stem density estimates can be derived by either estimation technique compared in this study. Although the results imply that stem density of plum on the study site had similarities across thickets, this may not occur in other areas with varying disturbance histories or across landscapes. The quadrat-count technique has an advantage over the PCQ method in that estimates can be made quickly with less likelihood of sampling error. However, the design of the PCQ method enables the sampler to reduce sampling bias of other variables of interest. For example, by using the closest stem in each quarter estimates may be obtained for stem diameters and heights. Therefore, those wishing to estimate stem density may consider which technique to use based on the data they want to collect in a given area.

Table 1.1 Stem density estimates of sand plum thickets (*n* = 24) using the point-centered quarter method and the quadrat-count method in south-central Oklahoma, USA, 2009.

	Quadrat-count				Point-centered quarter			
Thicket	$\bar{x}$	SE	Min	Max	$\bar{x}$	SE	Min	Max
1	4.8	0.7	1.0	9.0	6.5	0.6	3.0	9.0
2	4.2	0.8	1.0	9.0	5.3	0.9	1.0	10.0
3	4.7	0.7	1.0	8.0	5.4	0.9	2.0	9.0
4	4.1	0.4	3.0	6.0	5.2	0.9	2.0	10.0
5	4.5	0.5	1.0	6.0	4.9	0.8	1.0	9.0
6	4.3	0.8	2.0	10.0	4.3	0.4	2.0	7.0
7	5.2	0.7	2.0	8.0	5.8	1.2	2.0	13.0
8	4.6	0.5	1.0	6.0	5.7	1.3	3.0	13.0
9	5.6	0.6	3.0	9.0	6.7	0.7	3.0	9.0
10	2.6	0.5	0.0	5.0	4.6	0.9	1.0	11.0
11	5.1	0.5	2.0	7.0	5.1	0.5	3.0	8.0
12	6.0	0.6	4.0	10.0	5.1	0.4	3.0	6.0
13	4.2	0.6	2.0	8.0	4.7	0.6	2.0	8.0
14	4.8	0.6	1.0	8.0	5.3	0.6	2.0	8.0
15	5.4	0.7	2.0	8.0	5.9	0.6	2.0	7.0
16	4.4	0.2	3.0	5.0	7.0	1.13	3.0	14.0
17	5.6	0.4	4.0	8.0	5.8	0.3	4.0	8.0
18	5.0	0.5	3.0	7.0	5.7	0.6	3.0	9.0
19	4.2	0.3	2.0	6.0	6.3	1.21	1.0	12.0
20	4.4	0.5	2.0	7.0	4.9	0.6	2.0	8.0
21	5.6	0.4	4.0	8.0	6.3	0.7	3.0	9.0
22	5.1	0.5	3.0	8.0	6.3	1.5	3.0	18.0
23	6.0	0.4	4.0	8.0	6.9	0.8	2.0	10.0
24	5.1	0.3	4.0	7.0	5.3	0.6	3.0	9.0

Figure 1.1 Relation of stem density estimates between the point-centered quarter method and the quadrat-count method within sand plum thickets (n = 24) in south-central Oklahoma, USA, 2009.



CHAPTER 2

EFFECTS OF SAND PLUM ON SMALL MAMMAL OCCUPANCY IN OKLAHOMA

ABSTRACT Sand plum (*Prunus angustifolia*) is an important plant for wildlife species in the Southern Great Plains. To examine the use of sand plum by small mammals, I used live-trap-and-release techniques in 2 Oklahoma counties during spring 2009. Occupancy models were constructed a priori based upon known habitat affinities of several species. These models were used to examine how habitat variables associated with open pasture and plum thickets influenced species presence. Occupancy of Ord's kangaroo rat (*Dipodomys ordii*), fulvous harvest mouse (*Reithrodontomys fulvescens*), and northern pygmy mouse (*Baiomys taylori*) was best predicted by habitat characteristics associated with plum thickets and by sand plum presence. These characteristics typically included minimal substrate accumulation, high angle of obstruction and visual obstruction estimates, and increased amounts of exposed soil. In contrast, the hispid cotton rat (*Sigmodon hispidus*) and white-footed mouse (*Peromyscus leucopus*) displayed a more general pattern with a high probability of occupancy in open areas and woody cover other than plum. With the exception of the hispid cotton rat and white-footed mouse the results suggest that plum provides an important habitat component to a variety of small mammal species within prairie ecosystems.

INTRODUCTION

Sand plum (*Prunus angustifolia*) is a thicket-forming, clonal shrub identified as an important plant for northern bobwhites (*Colinus virginianus*) in rangeland settings (Guthery et al. 2005). Management of this shrub has gained interest recently especially for those wishing to benefit quail populations where woody cover is limited.

Although the importance of this shrub to quail is evident, empirical data concerning the use of plum by other wildlife species is generally lacking. Blair (1938, 1939) described several small mammal species that were trapped in plum thicket associations of northeastern and northwestern Oklahoma. However, the plum thicket associations referred to in this work lacked detail and were based only on capture frequencies. Other studies mention plum as occasional food sources for an array of wildlife species (Pearson 1952, Litvaitis 1981, Brown and Kirkman 1990). A more recent study concluded that 9 avian species nest in plum (Dunkin et al. 2010). The results of this study showed that the age of plum was related to species use.

In a further endeavor to gain understanding of the biological significance of this shrub to other wildlife, I conducted occupany modeling for small mammals. I used presence-absence data to build simple interpretable models based on relevant biological data present in the literature for an array of candidate species (Burnham and Anderson 2002, Thompson 2010). I also gathered data on site and survey-specific variables within and outside of plum thickets to determine what characteristics of plum and nearby vegetation were associated with the occupancy of small mammal species.

STUDY AREA

I surveyed small mammals and collected plum data on private ranches in Harper and Love counties, Oklahoma, USA. The Harper County site is in northwest Oklahoma about 40 km north of Woodward. The ranch consists of 5,667 ha primarily used as a commercial hunting and grazing operation. Precipitation ranges from 66 to 76 cm annually and mean a low temperature of -8 °C occurs in January with a mean high temperature of 36 °C occurring in July. Vegetation on the area is that typically found on mixed-grass prairie; it is dominated by little bluestem (*Schizachirium scoparium*), side-oats grama (*Bouteloua certipendula*), blue grama (*B. gracilis*), Indiangrass (*Sorghastrum nutans*), and sand sagebrush (*Artemisia filifolia*) with interspersed thickets of sand plum, patches of eastern cottonwood (*Populus deltoides*), and northern hackberry (*Celtis occidentalis*).

The Love County site is in south-central Oklahoma about 28 km south of Ardmore, USA**.** The ranch consists of 1,011ha used for livestock and wildlife research projects**.** Precipitation ranges from 86 to 91 cm annually and a mean low temperature of 16 °C occurs in January with a mean high temperature of 28 °C occurring in August. Vegetation on the area is tall grass prairie associated with big bluestem (*Andropogon geradii*), little bluestem, and Indiangrass interspersed with wooded areas of the post oak (*Quercus stellata*) blackjack oak (*Q. marilandica*) forest type. Tree species such as black hickory (*Carya texana*), shumard oak (*Q. shumardii*), sugarberry (*C. laevigata*), and northern hackberry dominate forested sites.

METHODS

Data Collection

I conducted a pilot study to examine if small mammals could be encountered with 3 consecutive trap-nights across a range of sampling stations, and to aid in the identification of species at each study site. Results indicated 3 consecutive nights were adequate.

Once the study began I determined the position of 120 sampling stations at each study site using GPS with each station being ≥20 m apart. To determine the effects of plum on small mammal occupancy I placed sampling stations within and outside of sand plum thickets. I used a standard sampling design in which all trap stations were set and checked for 3 consecutive nights. Consecutive surveys of the sampling unit within a relatively short time were implemented to meet the assumption that the population was closed at the time of sampling (MacKenzie et al. 2002).

At each station a trap array consisting of 5 Sherman live traps (H. B. Sherman Traps, Tallahassee, FL, USA) with a 3-m interval (Fig. 1) was trapped during May and June 2009 and 2010. The data were compiled into detection histories for each trap array equaling 1 for detection and 0 for non-detection. Small mammal sampling and handling were implemented under the authority of the Oklahoma State University Institutional Animal Care and Use Committee protocol number AG-08-13.

Variables within each station were sampled along 2 6-m transects which were between each trap intersecting at the center trap and forming 90° angles from each other (Fig. 2.1). I measured the depth of surface litter every 20 cm along each transect using a 50-cm wooden dowel marked at 1-cm increments. I also estimated cover variables every 10 cm along the transect using the line-intercept method (Canfield 1941). Variables including coverage of perennial grasses, annual grasses, forbs, woody plants, and exposed soil were converted to a percent coverage by dividing the number of occasions along the transect by the total number of 10 cm increments.

A 3-dimensional representation of cover was provided using the angle of obstruction (Kopp et al. 1998). At each trap location angle measurements were taken to the nearest obstructing vegetation at 8 compass radii. The angle of obstruction was defined as the angle measured from horizontal (0°) to the top of the object causing the obstruction. Angles were measured at 5 cm above ground with a digital carpenter's level attached to a 1-m pole. Angle measurements were then averaged for each trap location, after which they were averaged for each sampling station.

Using the Nudds (1977) profile board modified by Guthery et al. (1981), measurements were taken to give visual obstruction profiles at each trap location. The 6.8-cm-wide profile board had 12 strata, each stratum being 10 cm tall. Estimates were taken at a distance of 7 m, while kneeling at a height of 1.5 m perpendicular to each transect. Percent visual obstruction was then estimated for each stratum. To incorporate the profile board variable into the models I transformed the density estimates obtained at each station into a single continuous variable by determining the area under the curve (AUC). For this method I used the sum of the mean percent obstruction for each of the 12 strata on the profile board.

Data Analysis

I used the detection histories gathered from the survey as well as the measured variables within each trap station in program PRESENCE (MacKenzie et al. 2006) to describe occupancy of plum by small mammal species for both years. Program PRESENCE utilizes the AIC (Akaike's Information Criterion) statistic, which defines a point where trade-offs between bias and variance are optimized. Results are presented in a ranking of the "best" model in which the AIC value is the smallest (Burnham and Anderson 2002).

According to Burnham and Anderson (2002) models with ΔAIC < 2 are said to be plausible. Therefore, I presented the models for each of the candidate species that had ΔAIC values < 2. For each species I evaluated the performance of the best ranked model by calculating the probability of occupancy for each site using the coefficients for covariate estimates (β) of the model. An occupancy model score >0.5 was assumed to indicate presence. Predicted and observed occupancy were compared to estimate the reliability of the best model.

Candidate Models. — I developed a list of expected small mammal species that were associated with habitat characteristic of both study sites (Caire et al. 1989). Sites included grazed and ungrazed pastures which contained mixed-grass uplands with inter-mixed brushy patches. I identified 10 potential model covariates (Table 1) and one covariate of interest that were based on literature or were suspected to be associated with small mammal species presence. To model factors associated with small mammal occupancy (Ψ) and detectability (p) I established a global model for each species that incorporated several variables. In addition, I created simpler models for each species to examine variables of interest (Tables 2.2–2.6). The first basic model in which (Ψ) and (p) were constant across all trap stations and survey periods was incorporated for each of the candidate species and referred to as the null model. Also, detection was widely considered to fluctuate during trapping periods for a number of small mammal species, so I created a basic model in which (Ψ) was constant and (p) was influenced by trapping period (**DAY**). I also created an alternative model for each species that was based on our interest in the influence of sand plum on species occurrence (**PLUM**). Variables were examined for correlation, and an arbitrary value ($r \geq 0.5$) was chosen to decide if variables were strongly correlated and should be excluded from models. This decreased the number of dependent variables within the models, and reduced the number of model covariates to 9.

The variables incorporated into each of the candidate models were continuous habitat variables (Table 2.1) with the exception of (**PLUM**). This covariate was incorporated as a binary variable for presence (1) or absence (0).

The hispid cotton rat (*Sigmodon hispidus*) and northern pygmy mouse (*Baiomys taylori*) are both associated with high amounts of ground cover (Kaufman and Fleharty 1974). Therefore, models containing the litter depth (**Ld**) variable were applied to both species (Table 2.2, 2.3). Also, the hispid cotton rat is documented as excluding northern pygmy mouse from areas (Stickle and Stickle 1949, Raun and Wilks 1964); therefore, I added the categorical variable (**SIGMO)** to the northern pygmy mouse model. The covariate angel of obstruction (**AO**) was incorporated in the model for the hispid cotton rat because grass height and density is an important habitat component (Goertz 1964, Kaufman and Fleharty 1974).

Although Ord's kangaroo rat (*Dipodomys ordii*) has a wide geographic distribution, its affinity for exposed soils is apparent (Maxwell and Brown 1968, Honeycutt et al. 1981), so I incorporated the exposed soil variable (**ES**) into the candidate model (Table 2.4).

Other species were candidates for this study which have habitat characteristics associated with grassy fields with varying levels of shrub or brush cover. These species were fulvous harvest mouse (*Reithrodontomys fulvescens*) and white-footed mouse (*Peromyscus leucopus*). Due to the amount of literature describing both of these species as strongly associated with shrub cover I included coverage of other woody cover (**WOOD**) in occupancy models (Table 2.1).

RESULTS

I surveyed 120 trap stations on the southern Oklahoma site for both years 2009 and 2010. Plum occurred within 43 of the trap stations whereas perennial grasses were the dominant vegetation in 61 of the stations, 13 stations were dominated by other woody plants, and 3 stations were dominated by exotic grasses. Also during this time period I surveyed 120 trap stations on the northwestern Oklahoma site of which plum occurred in 40 stations, 34 stations were dominated by perennial grasses, 31 stations were dominated by other woody plants, and the remaining 19 stations occurred in dunes with high proportions of exposed soil. Small mammal trapping within the combined 240 stations revealed no detections of like species across study sites; therefore, results presented for individual species are area specific.

During the 2009–2010 trapping period I detected 84 individual hispid cotton rats at 58 of the 120 trap stations in southern Oklahoma. According to the highest ranked model occupancy rates differed among stations with plum and changes in angle of obstruction Ψ(**PLUM**, **AO**) *p* (**.**) (Table 2.2). The β estimate suggest that plum presence negatively affected occupancy (Table 2.7) while angle of obstruction positively influenced presence (Table 2.7,Figure 2.2). The next model in order of ranking suggested that plum, angle of obstruction, and litter depth influenced occupancy Ψ (**PLUM**, **AO**, **LD**) *p* (**.**) (Table 2.2). In this model litter depth had a positive influence on occupancy (Figure 2.2). The best model performed well when compared to the data. It correctly predicted occurrence or non-occurrence in 71.7% of cases (Table 2.8).

I detected 32 individual northern pygmy mice at 24 of the 120 trap stations in southern Oklahoma. Detection probability of the northern pygmy mouse was influenced by trapping period and based on the highest ranked model Ψ(**LD**) *p*(**DAY**) probability of occupancy was negatively influenced by (**LD**) (Table 2.7, Figure 2.3). This model also showed that (**DAY**) had both positive and negative effects on detection. The other plausible model also showed detection probability as a function of *p*(**DAY**); however, occupancy was influenced by another habitat variable Ψ(**PLUM**, **LD**) (Table 2.3). The highest ranked model correctly predicted occurrence or non-ocurrence in 74.1% of cases (Table 2.8).

I detected 12 individual Ord's kangaroo rats at 11 of the 120 trap stations in north-west Oklahoma. The highest ranked model Ψ(**PLUM**, **ES**) *p*(**.**) indicated that plum and exposed soil positively affected site occupancy (Table 2.7; Figure 2.4). The model correctly predicted occurrence or non-occurrence in 79.9% of cases (Table 2.8).

Within 34 of the 120 trap stations in south-central Oklahoma I captured 41 individual fulvous harvest mice. The highest ranked model Ψ(**PLUM**, **PRO**, **LD**) *p*(**.**) was the global model (Table 2.5). However, the top 3 ranked models (Table 2.5) had ΔAIC values <2, which implies model selection uncertainty (Burnham and Anderson 2002). The top-ranked model correctly predicted occurrence or non-occurrence in 22.5% of cases (Table 2.8), which shows the model was of little value (Table 2.8).

I detected 28 individual white-footed mice within 25 of the 120 trap stations at the northwest Oklahoma study site. According to the highest ranked model Ψ(**WOOD**, **COVA**) *p*(**.**) woody coverage other than plum and the coverage of annuals influenced occupancy. The β estimates for woody coverage (Table 2.7) and coverage of annuals

(Table 2.7) indicated positive effects on occupancy (Figure 2.6). The top ranked model correctly predicted occurrence or non-occurrence in 65.8% of cases (Table 2.8).

DISCUSSION

I used occupancy models to investigate the influence of sand plum on small mammal occurrence and to examine what variables affect occupancy. Depending on the species I discovered a range of outcomes for the influence of plum. Obviously, not all species were positively influenced by the presence of plum. The negative influence of plum on the hispid cotton rat was somewhat expected mainly because the species has an affinity for dense herbaceous cover, which is generally lacking within plum thickets. However, the results provided further insight into how this species may be influenced with increases or decreases in brushy cover such as plum.

Raun and Wilks (1964) associated the northern pygmy mouse with high amounts of grass litter and grass density; however, the best models contradicted the literature. The highest ranked model suggested that litter depth had a negative influence on occupancy, so according to this model one would expect to see a decrease in species occupancy as litter depth increases. It is unclear why this occurred. It has been suggested that hispid cotton rats exclude northern pygmy mice from suitable habitat (Schmidley 1983), but the model that incorporated hispid cotton rat presence as a function of occupancy was not a plausible model. The next ranked model showeda slightly positive influence of plum on species presence, which was unexpected and also contradicted published reports for this species and its habitats. If the best ranked model accurately described species occupancy, then this model is likely to have some explanatory value as well because decreases in litter depth measurements are encountered as sampling occurs further to the interior of a plum thicket.

The results supported previous descriptive studies on species such as Ord's kangaroo rat as well as provided further detail into their habitat associations. For example, a description of this species as a plum obligate was given by Baird (1938), but the results of this study suggest that plum itself may not be the only variable influencing occupancy. The top-ranked model indicated that plum and increasing amounts of exposed soil is more likely to influence occupancy. This also was an expected outcome based on our knowledge of the species and its presence within dune habitats. Furthermore, the plum sampled at this site occurred on dunes with fine textured sands and high amounts of exposed soil (>60%). Although this species has been associated with dune habitat in Wyoming, (Maxwell and Brown 1968) to my knowledge it has not been described in Oklahoma. Therefore, I conjecture that increases or decreases in plum occurring on loose sands with high amounts of exposed soil may have an effect on Ord's kangaroo rat occupancy.

The best model for the fulvous harvest mouse clearly was useless because the percentage of correct predictions was low. This illustrates a danger of model selection: there is always a best model, even if all the models tested are worthless.

The results for the white-footed mouse produced an unexpected outcome. This species has a wide geographic range with many sub-species and can be considered a habitat generalist. Shrub and brushy habitat is documented across its distribution often with a canopy present (Van Duesen and Kaufman 1977). Due to the scientific descriptions of the species and its habitat requirements, I concluded this species would be encountered within plum. Although some captures were made in plum thickets, the best ranked model indicated a positive influence of woody cover other than plum. The woody cover on this particular study site was exclusively sand sagebrush and provided substantial coverage within certain areas of the site. As previously stated roughly 26% of the trap stations were dominated by sand sagebrush compared to 30% by plum. Sand sagebrush is not clonal but in areas where disturbances such as fire and disking have been minimal can grow large and often form dense multiple stems with canopies especially when adjacent shrubs are present. Also, this model suggested the coverage of annuals as having a positive effect on occupancy. This is likely due to the proportion of annual broomweed (*Amphiachyris dracunculoides*) that occurred within trap stations, especially those outside of plum. It is reasonable to assume that the absence of this shrub vegetation would lead to an increase in occupancy of plum; however, further field work is needed to substantiate this claim.

MANAGEMENT IMPLICATIONS

Results indicated that certain small mammal species occupy plum at varying rates. It is important to understand what species use plum which in turn helps us to comprehend how species may be impacted as result of management practices. Individuals interested in promoting plum for gamebird objectives can expect to find some species associated with brushy habitats while other species will avoid brushy cover. By promoting plum on the landscape I conclude that small mammal species diversity should increase as compared to an area with limited brush. This is an important consideration for the predator-prey relationship and the growing attention it is receiving in quail management throughout the country.

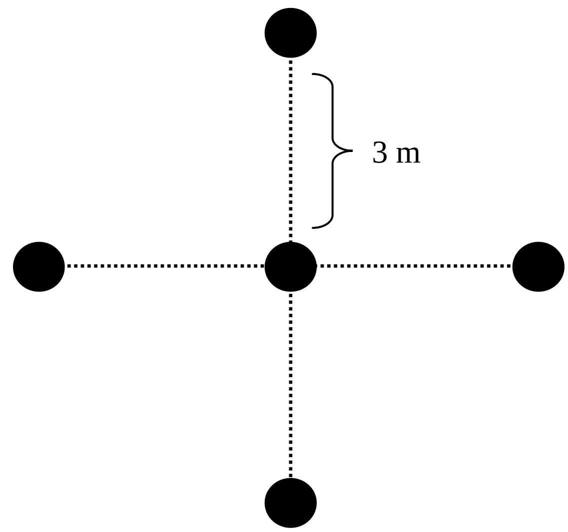


Figure 2.1. Array showing the placement of Sherman live traps (black circles) used to sample small mammals in southern and northwestern Oklahoma, USA, during March and April 2009 and 2010. Line transects (dashed lines) were used between the central trap and the outer traps for vegetation measurements.

Table 2.1. Independent variables and their abbreviations measured at small-mammal trap stations in southern and northwestern Oklahoma during March and April 2009 and 2010.

Variable	Abbreviation
Plum (presence or absent)	**PLUM**
Woody cover other than plum (%)	**WOOD**
Angle of obstruction (%)	**AO**
Profile density (%)	**PRO**
Depth of litter (cm)	**LD**
Annual plant coverage (%)	**COVA**
Exposed soil coverage (%)	**ES**
Sigmodon (present or absent)	**SIGMO**
Trapping period (day)	**DAY**

Table 2.2 Rankings of models using Akaike's Information Criterion (AIC) in program PRESENCE estimating site occupancy (Ψ) for *Sigmodon hispidus* in 2009 and 2010 in southern Oklahoma, USA. See Table 1 for definitions of variables.

Model	AIC	ΔAIC	AIC weights	Model Likelihood	K	−2log-likelihod
Ψ(**PLUM, AO**),p(.)	321.67	0.00	0.50	1.00	4	313.67
Ψ(**PLUM, AO, LD**),p(.)	323.30	1.63	0.22	0.44	5	313.30
Ψ(.),p(.)	324.79	3.12	0.11	0.21	2	320.79
Ψ(.),p(**DAY**)	325.08	3.41	0.09	0.18	4	317.08
Ψ(**PLUM**),p(.)	325.74	4.07	0.07	0.13	3	319.74

Table 2.3. Rankings of models using Akaike's Information Criterion (AIC) in program PRESENCE estimating site occupancy (Ψ) for *Baiomys taylori* in 2009 and 2010 in southern Oklahoma, USA. See Table 1 for definitions of variables.

Model	AIC	ΔAIC	AIC weights	Model Likelihood	K	−2log-likelihod
Ψ(**LD**),p(**DAY**)	93.72	0.00	0.70	1.00	5	83.72
Ψ(**PLUM, LD**),p(**DAY**)	95.45	1.73	0.30	0.42	6	83.45
Ψ(.),p(.)	109.54	15.82	0.00	0.00	2	105.54
Ψ(**PLUM**),p(.)	110.31	16.59	0.00	0.00	3	104.31
Ψ(**SIGMO**),p(.)	111.23	17.51	0.00	0.00	3	105.23

Table 2.4. Rankings of models using Akaike's Information Criterion (AIC) in program PRESENCE estimating site occupancy (Ψ) for *Dipodomys ordii* in 2009 and 2010 in north-western Oklahoma, USA. See Table 1 for definitions of variables.

Model	AIC	ΔAIC	AIC weights	Model Likelihood	K	−2Log-likelihhod
Ψ(**PLUM, ES**),p(.)	80.63	0.00	0.93	1.00	4	72.63
Ψ(**PLUM**),p(.)	85.81	5.18	0.07	0.08	3	79.81
Ψ(**ES**),p(.)	92.72	12.09	0.00	0.00	3	86.72
Ψ(.),p(.)	95.39	14.76	0.00	0.00	2	91.39
Ψ(.),p(**DAY**)	98.49	17.86	0.00	0.00	4	90.49

Table 2.5. Rankings of models using Akaike's Information Criterion (AIC) in program PRESENCE estimating site occupancy (Ψ) for *Reithrodontomys fulvescens* in 2009 and 2010 in southern Oklahoma, USA. See Table 1 for definitions of variables.

Model	AIC	ΔAIC	AIC weights	Model Likelihood	K	–2Log-likelihhod
Ψ(**PLUM, PRO, LD**),p(.)	245.05	0.00	0.44	1.00	5	235.05
Ψ(**PLUM**),p(.)	245.62	0.57	0.33	0.75	3	239.62
Ψ(**PLUM,PRO**),p(.)	246.29	1.24	0.23	0.54	4	238.29
Ψ(.),p(.)	258.17	13.12	0.00	0.00	2	254.17
Ψ(.),p(**DAY**)	261.69	16.64	0.00	0.00	4	253.69

Table 2.6. Rankings of models using Akaike's Information Criterion (AIC) in program PRESENCE estimating site occupancy (Ψ) for *Peromyscus leucopus* in 2009 and 2010 in southern Oklahoma, USA. See Table 1 for definitions of variables.

Model	AIC	ΔAIC	AIC weights	Model Likelihood	K	−2Log-likelihhod
Ψ(**WOOD, COVA**),p(.)	175.77	0.00	0.72	1.00	4	167.77
Ψ(**WOOD, COVA**),p(**DAY**)	177.70	1.93	0.28	0.38	5	167.70
Ψ(.),p(**DAY**)	192.89	17.12	0.00	0.00	4	184.89
Ψ(.),p(.)	193.67	17.90	0.00	0.00	2	189.67
Ψ(**PLUM**),p(.)	194.85	19.08	0.00	0.00	3	188.85

Table 2.7. Best ranked models estimating occupancy rate and the parameter estimates (β) of covariates for 5 species of small mammals in 2009 and 2010 in northwestern and southern Oklahoma, USA. See Table 1 for definitions of variables.

Species	Model	Covariate	β	SE
Hispid cotton rat	Ψ(**PLUM, AO**),p(.)	**PLUM**	-0.31	0.42
		AO	0.51	0.21
Northern pygmy mouse	Ψ(**LD**),p(**DAY**)	**LD**	-0.86	0.49
Ord's kangaroo rat	Ψ(**PLUM, ES**),p(.)	**PLUM**	2.68	1.67
		ES	2.57	0.87
Fulvous harvest mouse	Ψ(**PLUM, PRO, LD**),p(.)	**PLUM**	2.01	0.83
		PRO	1.37	0.89
		LD	-0.99	0.59
White-footed mouse	Ψ(**WOOD, COVA**),p(.)	**WOOD**	0.95	0.49

Table 2.8. Matrix of prediction categories used to evaluate model performance for 5 species of small mammals studied in Oklahoma, USA, during 2009 and 2010. Percentages are based on the total number of predictions (120) occurring within each category, e.g., ++ means species was present and model predicted its presence. See Table 1 for definitions of variables.

Species Model	Percent			
	(++)	(+-)	(-+)	(--)
hispid cotton rat Ψ(**PLUM**, **AO**),p(.)	42.5	24.1	4.2	29.2
northern pygmy mouse Ψ(**LD**),p(**DAY**)	25.9	10.8	14.8	48.5
Ord's kangaroo rat Ψ(**PLUM, ES**),p(.)	40.0	12.3	15.2	32.5
fulvous harvest mouse Ψ(**PLUM, PRO, LD**),p(.)	16.7	39.2	38.3	5.8
white-footed mouse Ψ(**WOOD, COVA**),p(.)	32.5	19.4	14.8	33.3

Figure 2.2. The relationship between angle of obstruction and the probability of occupancy in 2009 and 2010 for *Sigmodon hispidus* in southern Oklahoma, USA, based on the highest ranked model Ψ(**PLUM**, **AO**) *p* (**.**).

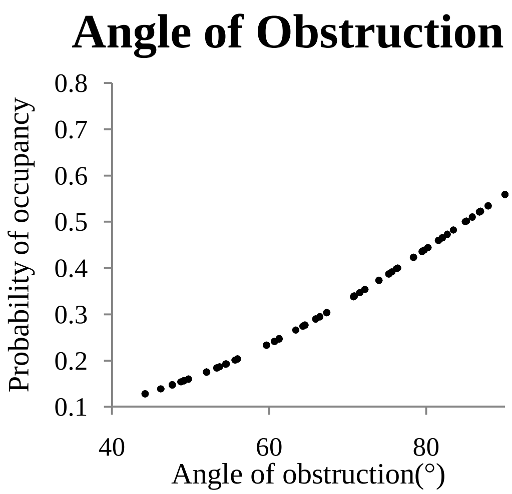


Figure 2.3. The relationship between litter depth and the probability of occupancy in 2009 and 2010 for *Baiomys taylorii* in southern Oklahoma, USA, based on highest ranked model Ψ(**LD**) *p* (**DAY**).

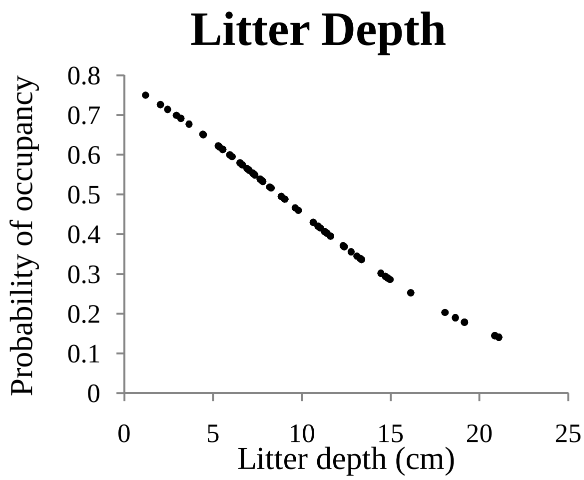


Figure 2.4. The relationship between exposed soil and the probability of occupancy in 2009 and 2010 for *Dipodomys ordii* in northwestern Oklahoma, USA, based on highest ranked model Ψ(**PLUM**, **ES**) *p* (.).

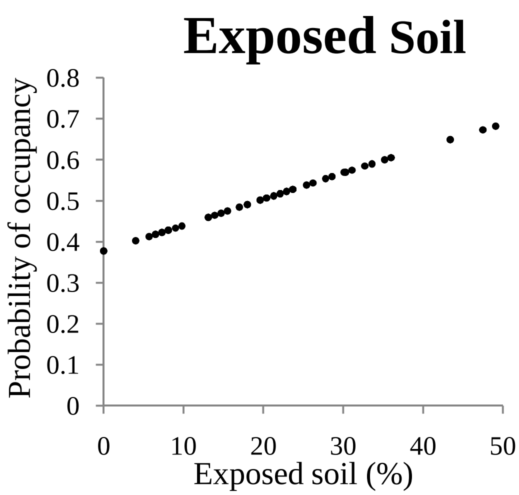


Figure 2.5. The relationship between profile board density estimates and the probability of occupancy (A) and between litter depth and the probability of occupancy (B) in 2009 and 2010 for *Reithrodontomys fulvescens* in southern Oklahoma, USA, based on highest ranked model Ψ(**PLUM**, **PRO**, **LD**) *p* (.).

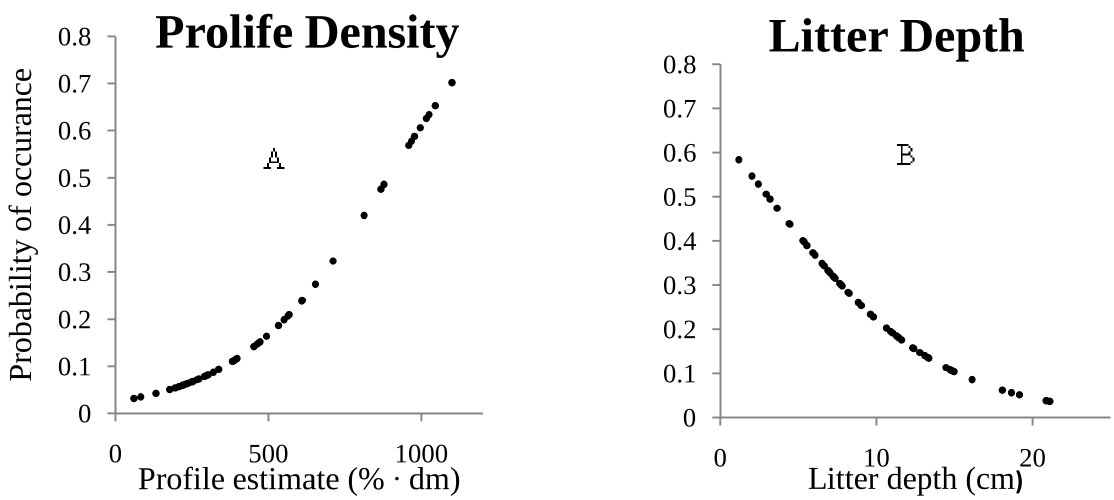
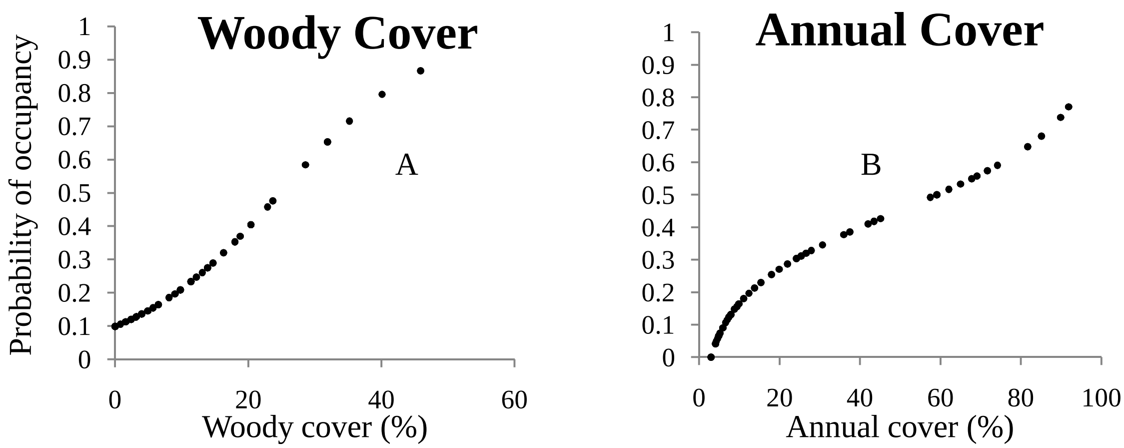


Figure 2.6. The relationship between woody coverage estimates and the probability of occupancy (A) and between annual plant coverage and the probability of occupancy (B) in 2009 and 2010 for *Peromyscus leucopus* in northwestern Oklahoma, USA, based on highest ranked model Ψ(**WOOD, COVA**),p(.).



CHAPTER 3

ACUTE EFFECTS OF PRESCRIBED BURNING ON SAND PLUM IN OKLAHOMA

ABSTRACT Prescribed fire is commonly used to meet a wide range of wildlife management objectives. Therefore, it is important to understand the effects of this management tool on important wildlife plants such as sand plum (*Prunus angustifolia*). I studied the characteristics that drive top-kill and the acute effects of prescribed fire on the structural and compositional properties of plum in 2 south-central Oklahoma counties during 2009–2010. Thickets with lower pre-burn stem densities were associated with higher levels of percent top-kill ($r^2 = 0.78$; $n = 31$). No induced mortality was identified for all thickets ($n = 31$), and all burned thickets returned to their pre-burn area measurements within 1 growing season post-burn. Based on estimates obtained by averaging the mean of multiple samples for each thicket, stem densities increased above pre-burn levels from 5.0/m^2 to 10.3/m^2 within 2 growing seasons post-burn. Stem density estimates from another study site indicated that pre-burn levels were 6.2/m^2 and 10.1/m^2 at the end of 1 growing season post-burn. Resprouts showed rapid growth in height 1 growing season post-burn averaging 37.8 cm. Finally, ground vegetation sampling within burned thickets showed minimal change in perennial grass coverage during the first year post-burn.

Resprouts showed rapid growth in height 1 growing season post-burn averaging 37.8 cm. Finally, ground vegetation sampling within burned thickets showed minimal change in perennial grass coverage during the first year post-burn. However, an increase from 33.1% to 53.1% occurred after 2 growing seasons post-burn. My results indicate that prescribed fire of the intensities observed was not immediately detrimental to sand plum thickets, but caused changes in stem density and understory vegetation composition.

INTRODUCTION

In regions dominated by grassland vegetation woody shrubs are a vital habitat component for northern bobwhites (*Colinus virginianus*). Shrub species in these ecosystems are often low- growing, multi-stemmed plants that are tolerant to above-ground disturbances. Shrubs such as sand plum (*Prunus angustifolia*) also exhibit structural characteristics that make them valuable to bobwhite quail. For example, this clonal shrub offers a dense vegetative canopy supported by an aggregation of stems that provide areas of thermal refugia for quail (Guthery et al. 2005). It has also been documented as providing escape cover for quail (Schemnitz 1964). The importance of this shrub on the landscape leads managers to promote and enhance plum coverage. However, the effects of some management practices on plum are largely speculative. An example is the use of prescribed fire. By using prescribed fire managers are able to promote favorable vegetation for quail, reduce accumulations of ground litter, and decrease unwanted woody plants. However, plant species such as plum are highly selected for by quail and the acute effects of prescribed fire on the structural characteristics of plum are important to understand from a management perspective. Furthermore, disturbances to plum thickets may affect the plant cover of the ground strata under the canopy of thickets.

My objectives were to collect data and relate fire behavior to plum response, evaluate the acute effects of prescribed burning on the structural and compositional properties of plum, and to determine the correlation between stand characteristics and varying levels of disturbance. Structural characteristics of concern were thicket area, thicket height, stem density, re-sprout diameter, and re-spout height. Compositional properties included coverage of herbaceous vegetation and exposed soil under the canopy of plum thickets.

STUDY AREA

I collected data on 31 burned plum thickets from 2 sites in southern Oklahoma. The Love County site was a private ranch in south-central Oklahoma about 5 km west of Marietta, USA. The ranch consists of 1,011 ha used for livestock and wildlife research projects**.** Precipitation ranges from 86 to 91 cm annually and mean temperatures range from a low of 16 °C in January to a high occurring in August of 28 °C. Vegetation on the area is that of the tall grass prairie associated with big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indiangrass (*Sorghastrum nutans*) interspersed with wooded areas of the Post Oak-Blackjack oak (*Quercus stellata*, *Q. marilandica*) forest type. Tree species such as black hickory (*Carya texana*), shumard oak (*Q. shumardii*), sugarberry (*Celtis laevigata*) dominate forested sites. The pastures on this site were excluded from grazing 1 year prior to the beginning of the study.

The Murray County site was about 5 km south of Ardmore, USA. This area was the Lake Murray State Park Field Trial Grounds which consists of 842 ha used primarily for field trial activities, recently adopted by The Samuel Roberts Noble Foundation as a quail habitat restoration and maintenance program. Management prior to this study included yearly haying; however, mowing was stopped 2 years prior to the study beginning. Precipitation, temperature, and vegetation were similar to that of the previous site.

METHODS

During November and December 2008 I identified 24 sand plum thickets on the Love County site. Of these thickets 12 were burned and 12 served as unburned controls. During November 2009 I identified and mapped 40 plum thickets on the Carter County site in which 19 were the burned and 21 were controls. Thickets were delineated by walking the edge of each thicket using a Topcon™ Hiper Ga (Topcon Positioning Systems Inc., Livermore, California, USA) surveyor grade Global Positioning System (GPS), and digitized in a Geographic Information System (GIS) to determine thicket area. Plum thickets were defined as aggregates of stems originating from a parent plant or a continuous stand of the same plant species. A single stand was defined as a continuous aggregation of stems with a distance <1 m between stems (Dunkin et al. 2008).

I estimated fuel loads around each thicket by clipping 0.25 × 0.25-m quadrats 1 m from the edge of thickets prior to ignition. Clippings were taken from the head-fire side of each thicket to obtain fuel loads which occur at the point in which flames contacted the thickets. Twidwell et al. (2009) determined this to be a better indicator of the fuel load that drives fire behavior and fire effects on woody plants. Clippings were dried at 60° C for 72 hours . Prescribed fires were conducted on the Love County site during April 2009 and the Murray County site during January through April 2010. Burns were conducted within a set of prescription parameters at both study sites. The prescriptions called for relative humidity measurements ranging between 30−60%, air temperatures between 35−75° F, and wind speeds 5−15 mph. Thickets were ignited along the windward edge of each thicket. The head-fire was initiated by one drip-torch operator about 20 m from the edge of each thicket and the fire line was about 30m in length. During each ignition wind speed, relative humidity, and ambient temperature were monitored using a Kestrel™ 2000 series weather meter (Niche Retail LLC., Sylvan Lake, Michigan, USA). Also, I estimated the rate of spread on the head-fire side of each burn by timing with a stopwatch the amount of time taken for the flame base to travel between two 2.5-m tall steel posts 10 m apart. A strip of plastic flagging was tied to the top of each post to insure the posts where aligned in the proper wind direction at the time of ignition. Markings placed on the steel post at 1-m intervals allowed for visual estimates of flame height.

Sampling of the structural properties of plum occurred during May and June 2009 and 2010. Average thicket height was determined by taking measurements with a steel tape at each of the cardinal directions 1 m inside the edge of each thicket and also in the center. Measurements were taken from ground level to the maximum height of live plum at each point. Pre-burn thicket height was measured after burning. This was accomplished using the same sampling technique applied to gather post-burn heights. I took measurements from ground level to the maximum height of burnt plum branches at each point. Thicket area was sampled post-burn by using the same equipment and techniques as described for obtaining initial thicket area. I was also interested in determining the area of remaining live plum canopy within each burned thicket. Therefore, I entered burned thickets and delineated unburned portions of each thicket with the GPS equipment and added them as a layer in a GIS application. This proportion of live crown remaining after the burn was used to determine the percent top-kill for each thicket.

I used a 10-m line transect to sample all of the burned and unburned thickets using the line-intercept method (Canfield 1941). A point of origin was established by entering the thickets at their greatest width. The control thickets were entered from the same cardinal direction in which the head fire approached the burned thickets. I randomly determined a distance of 1 or 2 m to travel into each thicket and establish a point of origin. At the origin a 2.5-m stick marked at 10-cm increments was placed on the ground parallel to the unburned edge of the thicket. Vegetation measurements including density of top-killed stems, resprout diameter and height, and coverage of cool and warm season vegetation were made. The 2.5-m transect was repeated once in each direction equaling a 5-m transect. Once measurements were taken along the 5-m transect the 2.5-m stick was positioned from the point of origin in the opposite direction from the previous transect. Frequencies of cool and warm season vegetation was estimated every 10 cm along the transect. Cool and warm season vegetation sampling occurred during May and August 2009 and 2010.

The density of stems and resprouts were estimated using the point-centered quarter method at 1.5-m intervals along the transect. The random point becomes the center point, the area around the point was divided into 4 90° quadrats, and the axes were aligned with the 4 cardinal directions. The distance between the central point and the closest living stem in each quadrat was measured to the nearest centimeter (Cottam and Curtis 1956). The closest resprout within each quadrat was also measured for resprout height and diameter. Resprout height was measured with a steel tape and diameter was measured with dial calipers 10 cm aboveground. I used this technique also to estimate the pre-burn density of stems. Measurements in this instance were taken by the same technique described previously; however, distances to the nearest charred stem were used to obtain pre-burn stem density estimates.

Data Analysis

I evaluated the response of plum to prescribed fire by using descriptive statistics. I determined the means across treatments and controls and utilized 95% CI's to describe the variation across sample means for each study site. Correlation coefficients were used to examine what if any characteristics of a plum thicket would best predict top-kill. Treatments were pooled across study sites for correlation analysis of the predictors that influence top-kill of plum thickets.

RESULTS

Crown scorch and Top-kill

Thickets were mapped to determine the percentage of crown scorch immediately after burning. During the first growing season all crown scorched areas of the sampled thickets had no green foliage on the stems and resprouts were present at their bases. Therefore, I referred to this measurement as percent top-kill. Percent top-kill for burned thickets was sorted into 4 classes. The first class was 0–25% top-kill and accounted for 7 of the sampled thickets. Next was the 26–50% class which accounted for only 4 thickets followed by the 51–75% class accounting for 3 thickets. The final class of 76–100% top-kill accounted for the remaining 17 thickets.

Fuel load estimates taken along the head-fire side of each burned thicket ranged from 196-1,392 kg · ha^{-1} (Table 3.1). These estimates and percent top-kill were weakly correlated (r^2 = 0.18, n = 31, Figure 3.1A); however, it became apparent during treatments that other biotic factors may have predictive influence on percent top-kill. Therefore, I examined pre-burn stem density and pre-burn thicket height for correlation with top-kill. Pre-burn stem density was strongly correlated (r^2 = 0.78, n = 31, Figure 3.1B) with percent top-kill as well as pre-burn thicket height (r^2 = 0.49, n = 31, Figure 3.1C).

Stem and Resprout Characteristics

No induced mortality was identified for sampled thickets (n = 31), and all burned thickets returned to their pre-burn area measurements within 1 growing season post-burn. Sand plum thickets of the Love County site were measured into the second growing and also maintained pre-burn area measurements (n = 12). Average thicket height decreased by 1.3 m within 1 growing season, and within 2 growing seasons height was 0.3 m less than pre-burn heights (Table 3.2). Thicket height response was similar for the Carter County site which reduced by 2.4 m after 1 growing season (Table 3.3).

I averaged the mean of 9 samples per thicket across all 12 samples on one study site, and determined that stem densities increased by 6.5/m^2 above pre-burn levels during 1 growing season post-burn (Table 3.2). Within 2 growing seasons post-burn I observed minimal change in stem density by 1.1/m^2 from the previous year (Table 3.2). I also collected stem density responses from the Carter County site, but was only able to gather pre-burn data and first year post-burn responses. Stem density responses were observed with a difference of 3.9 m above pre-burn estimates at the end of 1 growing season (Table 3.3).

I also averaged the mean of 36 resprout heights per thicket across samples and determined that resprout height averaged 50.9 cm and diameters averaged 0.7 cm within 1 growing season post-burn (Table 3.2). Heights and diameters increased during the 2nd growing season post-burn by 99.9 cm and 1.08 cm respectively (Table 3.2). Resprout heights and diameter growth estimates were similar at the Carter County site in which I observed resprout heights averaging 37.3 cm and diameters averaging 0.5 cm after 1 growing season post-burn (Table 3.3).

Compositional Characteristics

Understory vegetation sampling within burned thickets showed minimal change during the first growing season post-burn. Perennial grass coverage changed by 10.7% from May to August during the first growing season post-burn (Table 3.4). Within 2 growing seasons post-burn perennial grass coverage increased by 20.0% (Table 3.4). Perennial grass coverage increased at the Carter County site during 1 growing season by 8.1%; however, average grass coverage was initially lower within thickets sampled during May (Table 3.5). Coverage of exposed soil showed minimal change within thickets during the first year post-burn at both sites. Sampling during the first growing season post-burn showed a difference of 6.0% from May to August (Table 3.4), and averages after 2 growing seasons post-burn showed a decrease of 8.0% from initial estimates (Table 3.4). Exposed soil at the Carter County site from May to August changed by 2.4% 1 year post-burn (Table 3.5). Coverage of forbs within burned thickets at the Love County site had little variation throughout the study. The estimates from May to August showed a difference of 1.8% during the first growing season (Table 3.4) followed by a change of 3.3% after 2 growing seasons post-burn (Table 3.4). Similar results occurred at the Carter County site with a difference of 2.1% May to August (Table 3.5).

Sampling within unburned thickets at the Love County site showed steady proportions of perennial grass coverage throughout both growing seasons differing by only 1.3% after 2 growing seasons post-burn (Table 3.6). Perennial grass coverage also showed no variation at the Carter County site during the growing season, and a difference of 1.1% was estimated from May to August (Table 3.7). Coverage of exposed soil maintained initial estimates throughout the growing seasons in both Love and Carter counties. Estimates of exposed soil coverage changed by 1.2 % from May to August followed by a change of 0.2% after the second growing season post-burn (Table 3.6). Similarly, exposed soil at the Carter County site changed by 1.0% after 1 growing season (Table 3.7). Forb coverage remained similar within the unburned thickets with no variation during this study. A difference of 0.4% was estimated during the first growing season, and relative difference after 2 growing seasons showed a change of 1.1% (Table 3.6). At the Carter County site there was no change as well with average forb coverage changing by 0.8% during the growing season (Table 3.7).

I observed 38 species of plants growing within burned and unburned thickets (Table 3.8). The most common graminoid species encountered within burned and unburned thickets was little bluestem (*Schizachyrium scoparium*), purpletop (*Flavus tridens*), and *Cyperus* spp. Common forbs occurring within thickets were common ragweed (*Ambrosia artemisiifolia*), slender yellow wood sorel (*Oxalis dillenii*), and spotted spurge (*Euphorbia maculata*).

DISCUSION

Although fuel loads were correlated with percent top-kill, pre-burn thicket height and stem density were better predictors of percent top-kill. Thickets with taller pre-burn measurements may have influences on top-kill by limiting the amount of heat that contacts the upper foliage. Another possibility is an indirect effect because taller thickets generally have less understory fuel in the form of herbaceous vegetation. Lett and Knapp (2003) measured decreased amounts of light beneath shrub islands and suggested that grasses are inhibited by the shade within the understory. With the absence of fine fuels fire is inhibited from the interior most portions of thickets, and the potential for fire to topkill shrubs is limited (Heisler et al. 2003). Pre-burn stem density also may influence fire behavior and characteristics within a thicket. Although there were no pre-burn data concerning vegetation within thickets, I observed thickets with lower stem densities having higher amounts of perennial grass coverage. This idea is supported by research conducted within roughleaf dogwood (*Cornus drummondii*) thickets. Heisler et al. (2003) determined that grass and thicket co-occurrence led to increases in shrub mortality after fire. This circumstance would inevitably lead to greater temperatures in thickets when compared to higher density stands that contain little to no fine fuels. This also leads to the conclusion that fuel loads within a thicket may be a better predictor of crown scorch and top-kill than loads taken from outside. It is also important to consider that weather variables such as ambient temperature and relative humidity likely influence crown scorch and top-kill, but under the conditions of the prescribed fires used there was no discernable influence.

All of the thickets that were burned in this study resprouted within 1 growing season. This was conflicting from anecdotal accounts of complete thicket mortality.

During both years of study precipitation was high and soil moisture was present due to substantial snowfall during the dormant season. It is likely that drought conditions after treatment would have decreased the response both in terms of mortality and resprouting. Thicket heights were decreased with the treatment of fire; however, the thickets that were monitored for two growing seasons were close to their pre-burn height. Given this continued growth rate thicket heights would return to or exceed pre-burn heights within 3 growing seasons. Stem densities increased within all burned thickets after 2 growing seasons at the Love County site. Adams et al. (1982) measured pre-burn and post-burn stem densities of plum and determined increases in stem densities after 1 growing season. Similar results have also been documented with other resprouting shrub species after fire (Boyd and Bidwell 2002, Heisler et al. 2004), and stem densities usually return to their pre-burn densities after a few growing seasons. However, the stem density estimates at the Carter County site for 1 year post-burn had overlapping CI's with pre-burn estimates. It is unclear why this response occurred at this site, but considerable herbivory within plum thickets occurred early in the growing season. This would likely influence stem densities and would be confounded by issues of deer (*Odocoileus* sp.) abundance. Herbivory also had a substantial effect on resprout height estimates. Although no quantitative data are available, resprout heights would have been greater with no herbivory; therefore it is likely that post-burn thicket height would have reached pre-burn heights during the study.

Vegetation sampling within the thickets showed an increase in perennial grass coverage after 2 growing seasons. Similar response was documented by Heisler et al. (2003) in dogwood thickets. When top-kill occurs in plum the understory vegetation responds due to the increase in light. The minimal change in perennial grass coverage that was observed after 1 growing season at the Carter County site may have been due to initial variation in the understory of the thickets. Another explanation may be that growth of the perennial grasses occurred before sampling, thus reducing the measured magnitude of effect during the first growing season. This strengthens the support for pre-burn data which would have given at least a baseline estimate for comparison. This would have also helped explain the differences or the lack of concerning exposed soil and forb coverage.

MANAGEMENT IMPLICATIONS

Managers are often concerned with mortality of plum thickets after burning and practices such as disking and mowing around thickets are common. Under the conditions observed prescribed fire was not immediately detrimental to sand plum thickets. However, thicket height and stem densities were affected and the understory composition changed slightly. Therefore, taller thickets with dense stems may not need protection, but shorter thickets that have lower stem densities and higher amounts of perennial grasses within the thicket may be protected until they reach such stature.

Figure 3.1. Relations between top-kill (%) of sand plum thickets and fuel loads (A), pre-burn thicket height (B), and pre-burn stem density (C), 2009−2010, southern Oklahoma,USA.

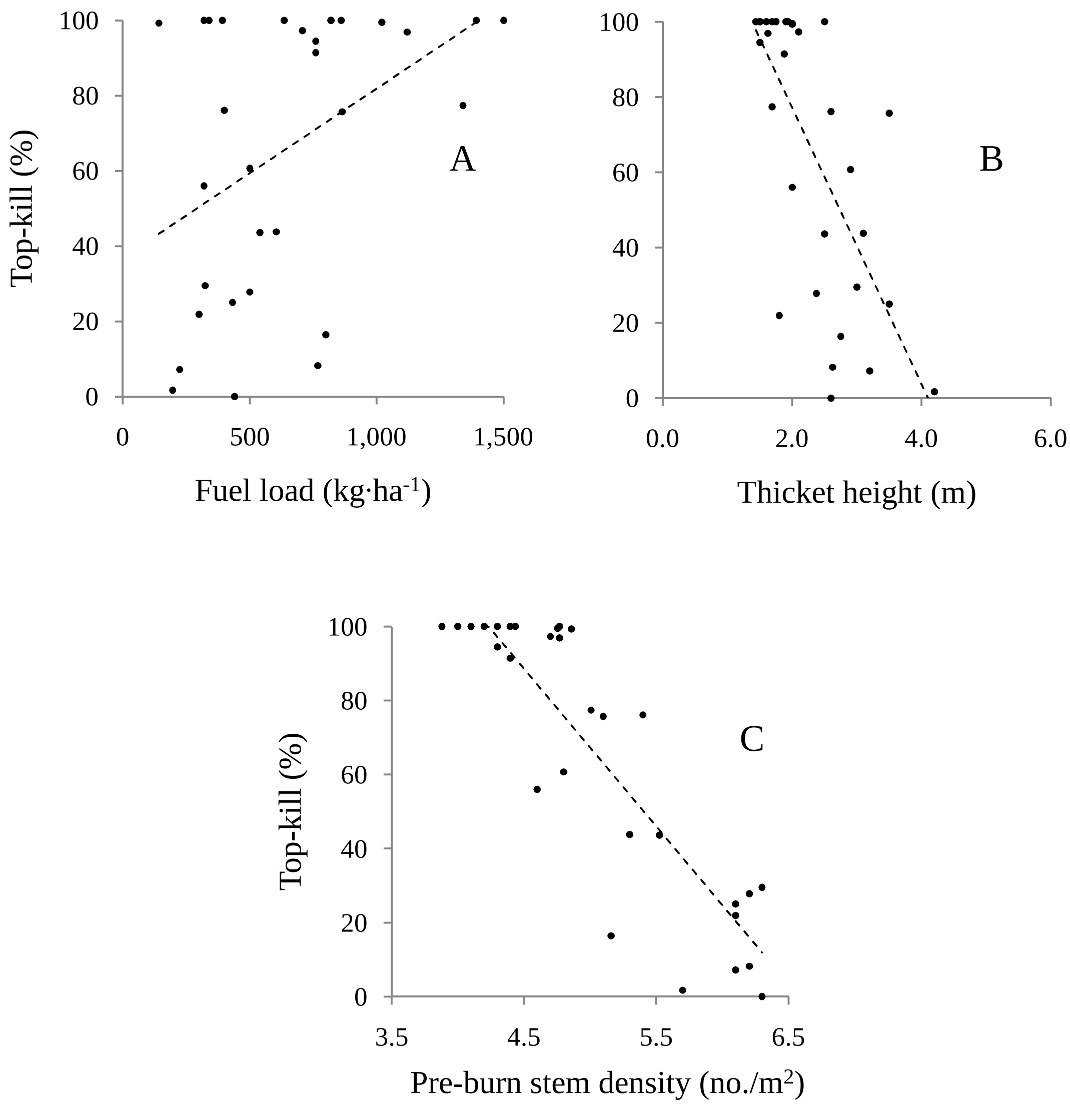


Table 3.1. Thicket number and their corresponding fuel load estimates taken at the head-fire side of each sand plum thicket obtained during 2009 and 2010 in southern Oklahoma,USA.

Thicket	Fuel load (kg·ha^{-1})
1	760
2	636
3	1,340
4	1,120
5	820
6	1,392
7	540
8	500
9	768
10	800
11	1,020
12	142
13	1,500
14	320
15	864
16	300
17	604
18	500
19	708
20	820
21	224
22	196
23	324
24	392
25	432
26	400
27	860
28	440
29	340
30	760
31	320

Table 3.2. Structural properties of sand plum thickets (n = 12) before and after prescribed fire during the 2009 and 2010 growing seasons in Love County, Oklahoma, USA.

	Pre-burn			Post-burn growing season 1			Post-burn growing season 2		
Variable	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI
Thicket height (m)	2.1	1.8	2.2	0.7	0.6	0.8	1.5	1.2	1.8
Stem density (no./m^2)	5.0	3.3	6.5	11.4	9.7	13.1	10.3	7.5	13.2
Resprout height (cm)				50.9	47.0	54.9	150.8	121.3	180.2
Resprout diameter (cm)				0.7	0.2	1.3	1.8	1.1	2.3

Table 3.3. Structural properties of sand plum thickets (*n* = 19) measured before and after prescribed fire during the 2010 growing season in Carter County, Oklahoma, USA.

	Pre-burn			Post-burn		
Variable	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI
Thicket height (m)	2.6	2.2	2.9	0.2	0.2	0.2
Stem density (no./m^2)	6.2	5.4	13.2	10.1	5.9	14.3
Resprout height (cm)				37.3	35.1	39.5
Resprout diameter (cm)				0.5	0.1	1.2

Table 3.4. Cool and warm season variable coverage within burned sand plum thickets (n = 12) in Love County, Oklahoma, USA, during the 2009 and 2010 growing season.

	Post-burn growing season								
	1						2		
	May			Aug			Aug		
Coverage (%)	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI
Perennial grasses	33.1	21.3	44.8	43.8	26.2	59.6	53.1	46.7	59.4
Exposed soil	19.5	16.2	23.0	13.5	10.0	17.0	11.5	8.7	14.4
Forb	17.7	13.4	22.0	19.5	15.3	23.6	21.0	17.2	24.9

Table 3.5. Cool and warm season variable coverage within burned sand plum thickets (n = 19) in Carter County, Oklahoma, USA, during the 2010 growing season.

	May			Aug		
Coverage (%)	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI
Perennial grasses	22.1	17.3	26.8	30.2	26.8	36.6
Exposed soil	17.8	14.9	20.8	15.4	13.7	17.8
Forb	15.0	12.6	17.4	16.8	14.5	19.0

Table 3.6. Cool and warm season variable coverage within unburned sand plum thickets (n = 12) in Love County, Oklahoma, USA, during the 2009 and 2010 growing season.

	Post-burn growing season								
	1						2		
	May			Aug			Aug		
Coverage (%)	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI
Perennial grasses	38.7	28.9	49.1	39.1	29.9	48.3	37.4	25.1	49.6
Exposed soil	13.1	10.7	15.5	11.9	9.9	13.9	12.9	11.3	14.6
Forb	14.4	10.0	17.7	14.8	12.5	16.9	15.5	13.2	17.8

Table 3.7. Cool and warm season variable coverage within unburned sand plum thickets (n = 21) in Carter County, Oklahoma, USA, during the 2010 growing season.

	May			Aug		
Coverage (%)	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI
Perennial grasses	16.5	13.5	19.5	17.6	14.5	20.8
Exposed soil	22.7	18.5	26.9	23.7	20.0	27.3
Forb	12.4	10.0	14.9	13.2	11.1	15.2

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APPENDIX. Frequencies of plant species encountered within burned and unburned sand plum thickets (*n* = 40) during 2009 and 2010 in southern Oklahoma, USA.

Species	Burned	Unburned
Big bluestem *Andropogon gerardii*	37	24
Blackberry *Rubus* spp.	7	3
Butterfly pea *Clitoria mariana*	4	2
Carolina anemone *Anemone caroliniana*	1	3
Carolina snailseed *Coculus carolinus*		4
Carolina joint-tail *Coelorachis cylindrica*		3
Coralberry *Symphoricarpos orbiculatas*		13
Eastern gamma grass *Tripsacum dactyloides*	25	12
Green brier *Smilax bona-nox*	24	19
Hairy vetch *Vicia villosa*	8	
Honey locust *Gleditsia triacanthos*	10	3
Indiangrass *Sorghastrum nutans*	11	8
Ironweed *Vernonia baldwinii*	31	15
Japanese broome *Bromus japonicus*	27	
Juncus spp.		6
Little bluestem *Schizachyrium scoparium*	723	532
Mexican hat *Ratibida columnifera*	4	
Spotted spurge *Euphorbia maculata*	37	41

Species	Burned	Unburned
Multiflora rose	4	
Rosa multiflora		
Partridge pea	2	13
Chamaechrista fasiculata		
Purple prairie clover	12	6
Petalostemon purpureum		
Purple top	83	126
Flavus tridens		
Prairie acacia	2	
Acacia angustissima		
Prickly pear		4
Opuntia spp.		
ragweed, Common	102	96
Ambrosia artemisiifolia		
Scribner's panicum	32	19
Dichanthelium oligosanthes		
Silverleaf nightshade	12	7
Solanum elaeagnifolium		
Switch grass		
Panicum virgatum	6	
Spotted spurge		41
Euphorbia maculata		
Texas winter grass		10
Nassella leucotricha		
Vinemesquite	7	
Panicum obtusum		
White clover		17
Trifolium repens		
wildrye, Canada	11	
Elymus canadensis		
Wine cup		6
Callirhoe involucrata		
Slender yellow wood sorel	37	26
Oxalis dillenii		
Spotted beebalm	9	3
Monarda punctata		
yarrow, Common		4
Achillea millefolium		

Species	Burned	Unburned
Yellow foxtail *Setaria pumila*	1	
Yellow nutsedge *Cyperus esculentus*		39

CURRICULUM VITA

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Master of Science

Thesis: SAND PLUM IN OKLAHOMA: SMALL MAMMAL OCCUPANCY AND THE ACUTE EFFECTS OF PRESCRIBED FIRE

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Pages in Study: 63 Candidate for the Degree of Master of Science

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Scope and Method of Study: I collected stem density estimates in plum thickets using two methods to identify the relation between the two, trapped small mammals in and outside of plum thickets to determine what species occupy plum and what influencing characteristics occur in thickets, and collected data before and after prescribed burning to describe changes that occur after fire is applied to plum thickets.

Findings and Conclusions: Thickets showed minimal variation in stem density estimates averaging 4.8/m^2 (95% CL = 4.5–5.1/m^2) for the quadrat-count method, and 5.6/m^2 (95% CL = 5.3–5.9/m^2) for the point-centerd quarter method (PCQ). Correlation between the 2 estimate techniques occurred, the linear regression model given quadrat-count estimates as afunction of PCQ estimates showed stem density estimates from the PCQ method were larger than quadrat count across stem densities. Occupancy of Ord's kangaroo rat (*Dipodomys ordii*), fulvous harvest mouse (*Reithrodontomys fulvescens*), and northern pygmy mouse (*Baiomys taylori*) was predicted by characteristics associated with plum thickets and by plum presence. These included minimal substrate accumulation, high angle of obstruction and visual obstruction, and increased amounts of exposed soil. The hispid cotton rat (*Sigmodon hispidus*) and white-footed mouse (*Peromyscus leucopus*) displayed a more general pattern with a high probability of occupancy in open areas and woody cover other than plum. Thickets with lower pre-burn stem densities were associated with higher levels of percent top-kill ($r^2 = 0.78$). No mortality was identified for all thickets ($n = 31$), and all burned thickets returned to their pre-burn area within 1 season. Based on estimates obtained from the mean of multiple samples for each thicket, densities increased above pre-burn levels from 5.0/m^2 to 10.3/m^2 within 2 seasons. Density estimates from another site indicated pre-burn levels were 6.2/m^2 and 10.1/m^2 at the end of 1 season. Resprouts showed rapid growth in height after 1 season averaging 37.8 cm. Sampling in burned thickets showed minimal change in grass coverage during the first year. However, an increase from 33.1% to 53.1% occurred after 2 seasons.

ADVISER'S APPROVAL: Dr. Fred S. Guthery