SPATIO-TEMPORAL DISTRIBUTION OF WHITE-TAILED DEER (*Odocoileus virginianus*) RELATIVE TO PRESCRIBED BURNS ON RANGELAND IN SOUTH TEXAS

A Thesis

by

MICHAEL GLENN MEEK

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2007

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	Susan M. Cooper
Committee Members,	M. Keith Owens
	Roel R. Lopez
Head of Department,	Thomas Lacher

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ABSTRACT

Spatio-Temporal Distribution of White-tailed Deer (*Odocoileus virginianus*)

Relative to Prescribed Burns on Rangeland in South Texas. (December 2007)

Michael Glenn Meek, B.S., Clemson University

Chair of Advisory Committee: Dr. Susan M. Cooper

Overgrazing and fire suppression has left much rangeland in poor condition for various wildlife species. Prescribed fire is one range improvement practice used to restore degraded wildlife habitat. I determined the effect of prescribed fire on white-tailed deer (*Odocoileus virginianus*) spatial and temporal distribution, in the presence of cattle grazing. Three 40 ha patches, constituting 10% and 6% of the land area in the lesser and greater Yellow Bluff pasture, respectively, were burned in September 2005. To determine habitat use and distribution of deer relative to these burns 3 bucks and 3 does were netted from a helicopter and fitted with Global Positioning System (GPS) telemetry collars (Lotek™ GPS_3300S) for a period of 30 days during each season. For estimation of spatial distribution of deer, the collars were programmed to take a position fix every hour to reduce problems associated with spatial autocorrelation. For 12 days within this period the collars recorded animal location every 5 minutes to compare habitat use with 6–9 GPS collars (GPS_3300LR) placed on cattle. This allowed me to examine fine-scale movements of deer relative to cattle.

Trials were conducted prior to the burn and in each season for one year after the burn. Areas to be burned were not favored by deer. A month after the burn in Fall 2005 there was an increase in use of the burned areas by deer. Deer preference for burned areas fell in Spring and Summer 2006, but in Fall 2006 females dramatically increased their use of the burns. This is possibly an artifact of small sample size and the random selection of individuals. Interaction between deer and cattle was minimal, as they inhabited different areas. When cattle moved within approximately 50 m of a stationary deer the deer was likely to move away. Vegetation measurements showed no significant change in shrub cover and density and a decline in available herbaceous forage on both treatment and control sites in the second year. The lack of vegetative response because of drought conditions was likely the cause of the lack of response by the deer to the burns.

DEDICATION

For my grandparents

Endurance, Strength, Hard Work, & Family

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I would like to thank my committee chair and advisor, Dr. Susan M. Cooper, for her tireless encouragement and advice during the last few years. As with any good advisor / student relationship, she has become a close, lifelong friend. Also, thanks to my committee members, Dr. M. Keith Owens and Dr. Roel R. Lopez, for their support and guidance in the course of this research. Thank you for all of your help with statistics and GIS, and providing a lab for me to work in at College Station.

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Also, I would like to thank my fellow graduate students at Texas A&M University whom I consider lifelong friends and colleagues, particularly all you down in the Lopez Lab. Also, thanks to the Wildlife & Fisheries Sciences and Rangeland Ecology & Management departments' faculty and staff who made my time in College Station an enjoyable, worthwhile, and exciting experience.

I especially appreciate the financial support provided by the Joe Skeen Institute for Rangeland Restoration and the US Forest Service Rocky Mountain Research Station to conduct this research. And, of course, I thank Mike Harris, the ranch owner, and his lessee, John Sewell of Turkey Creek Outdoors, for allowing me to conduct my graduate research on their property. The helicopter pilots and net-gunners that captured the deer had way too much fun doing it, and I wish them many years of fun and excitement, stay safe.

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INTRODUCTION

Over the last two decades the aim of rangeland management in South Texas has drastically changed as hunting leases for white-tailed deer (*Odocoileus virginianus*) have become a substantial form of additive income sometimes more profitable than cattle grazing (Wyse and Anderson 2000). Formerly, the excessive sheep and cattle grazing resulted in deterioration of rangeland due to overuse of grasses. Also, a strict agency mandate of fire suppression and slight changes in the climate (Mayeux et al. 1991) led to the subsequent domination of the landscape by woody shrubs (Archer et al. 1988, Archer 1989). Based on Cook (1908), Scifres and Hamilton (1993) state that South Texas vegetation is very transitional from the wet coastline to the drier interior. Eventually, honey mesquite (*Prosopis glandulosa*) savannas retreated giving way to thornscrub from the west and woody species from the east (Scifres and Hamilton 1993). Also, there is a consensus that grasslands are the result of interactions between the soil, climate, fire, and biotic pressures (Wright and Bailey 1982), and there is no evidence to suggest that South Texas is the exception.

Much effort is being expended for range restoration for wildlife, yet the success of restoration may be limited by an overabundance of deer (Russell et al. 2001, Rossell et al. 2005). Supplemental feeding of deer is a common management practice, and together with containment of deer within high fences, may lead to deer densities that exceed the natural carrying capacity of the land. Even with high rates of supplemental feeding of corn, soybeans, and protein pellets, it has been shown that deer will continue

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This thesis follows the style of the *Journal of Wildlife Management*.

to browse on natural vegetation and over-utilize the browse surrounding the feeders (Doenier et al. 1997, Cooper et al. 2006). In any rangeland restoration project it is important to consider the impact that resident herbivores will have on regrowth potential of the vegetation.

Initially, shrub encroachment and fire exclusion increased the available habitat for the highly prized white-tailed deer in the 1930s and 1940s (Halls 1984). Due to the white-tailed deer's habitat requirements for cover and browse they have not historically inhabited open grass rangeland in large numbers but were restricted to creeks and draws with greater shrub cover (Inglis et al. 1979). However, current shrub cover may be too dense and decrease sunlight and rainfall that reaches the ground hence limiting the growth of protein-rich forbs which are essential in deer's diet (Wright et al. 2002).

For this reason, brush management is essential to landowners interested in furthering wildlife production. Brush reduction can be achieved by mechanical means (e.g., roller-chopping, root-plowing), herbicide application, or prescribed fire. Traditionally, mechanical methods have been the most commonly used techniques and are largely effective, but not cost-efficient. Because the rangeland ecosystem evolved under a regime of natural fires (Scifres and Hamilton 1993), the vegetation is expected to respond favorably to burning (Ruthven et al. 2000), and the use of patch burns emulates the way natural forces, such as lightning, would disturb the landscape. Fire produces a heterogeneous landscape providing all types of cover and browse for deer.

If deer concentrate their feeding activities on burned areas they may influence vegetative recovery and the restoration process. Deer can be a destructive force in the environment if populations are unchecked by natural or anthropogenic means (Anderson and Katz 1993, deCalesta 1994, Russell et al. 2001, Brockway and Lewis 2003, Rossell et al. 2005, Cooper et al. 2006, Pellerin et al. 2006).

Another potentially confounding effect is the presence of sympatric herbivores such as domestic livestock. Deer and cattle competition has been documented in forested rangelands (Jenks et al. 1996, Kingery et al. 1996, Brockway and Lewis 2003), and on shrublands (Ortega et al. 1997, Depew 2004). Thus, the use of burned areas by deer may be influenced by the presence of cattle on our study site. Various studies have shown that deer possibly avoid areas with cattle (Cohen et al. 1989) and they may overlap nutritionally (Jenks et al. 1996, Kingery et al. 1996). This could hinder rangeland restoration efforts because cattle graze on most rangeland in the USA.

I propose that previous studies using traditional VHF radio-telemetry influenced the movement of each species and therefore affected the results of the study. Methods to minimize the amount of disturbance during a scientific study are important, especially a study that is determining habitat selection and utilization distribution of wild animals. The use of Global Positioning System (GPS) collars will reduce anthropogenic disturbances and provide a greater amount of more accurate data than traditional VHF telemetry. Nevertheless, there are limitations; a GPS collar's battery life is a major factor in determining the length and scale of a study. Also, the use of GPS collars is cost prohibitive and limits sample size. The high cost of the collars requires prompt retrieval of collars and can be logistically daunting if the collars are not equipped with automatic drop-offs. Also, the occurrence of missing data when the animal is in dense cover or during certain times of the day can affect the statistical and spatial analysis; however this seems to be improving with each generation of GPS collars. Even with all of these issues, GPS telemetry is attractive in situations where time and or labor is scarce, reducing the amount of time spent tracking animals. This is replaced with a few labor-intensive days during the initial collaring and later retrieval.

Research Objectives

I used GPS telemetry to investigate how range restoration by prescribed burning affects the spatio-temporal distribution of white-tailed deer and whether their use of burned areas is influenced by the presence of cattle. My research objectives are:

1) To determine the effect of prescribed burns on the distribution of white-tailed deer. I hypothesize that the deer will increase use of the treatment and concentrate activities around the burned patches.
2) To assess the distribution of deer when they are most active and likely feeding. This will determine if the burn areas are being used for browsing or cover. I hypothesize that deer will preferentially forage on the burned areas because of the flush of fresh plant growth.
3) To examine the extent to which deer distribution is affected by the presence of cattle and vegetation characteristics. I hypothesize that avoidance of cattle will occur as previous studies have indicated, and that deer will be attracted to the burns by vegetation regrowth.

STUDY AREA

This study was conducted on the Harris Ranch, located 35 km west of Uvalde, Texas (Uvalde County) on the West Prong of the Nueces River (Fig. 1). The 6,764 ha ranch (29º 15' 0.02'' N, 100º 5' 54.01'' W) is situated in the Edwards Plateau ecoregion at the northern edge of the South Texas Plains. The Edwards Plateau region is dominated by shallow soils covering caliche (calcareous) subsoils with rough surface textures (Gould 1975). The South Texas Plains region is described as softly rolling terrain containing clay to sandy loam soil types. Vegetation communities on this ranch include: guajillo ridge (53%), mixed woodland (23%), mesquite savanna (17%), cropland (4%), and oak woodland (3%). The ranch has a long history of intense overgrazing by cattle leading back to its historical use as a destination for cattle drives and a marshalling ground for herds before being loaded on the adjacent railroad (M. Harris, Landowner, personal communication).

The area's rainfall pattern is bimodal with peaks in June and September, with drought conditions likely in late summer. Mean annual rainfall is approximately 620 mm (Fig. 2), and The Weather Channel (2007) reports mean annual high and low temperatures are 27.5°C and 13.5°C, respectively . As part of the restoration process, the number of cattle on the ranch has recently been reduced from 400 to 200 cow-calf animal units. Deer density is approximately 1 animal per 6 ha on this ranch. Deer have access to year-round supplemental feed (soybeans) at 19 free-choice feeders distributed throughout the ranch; in addition, a little corn is distributed during hunting season from October through January. Also, water is available at 19 sites across the ranch as well.

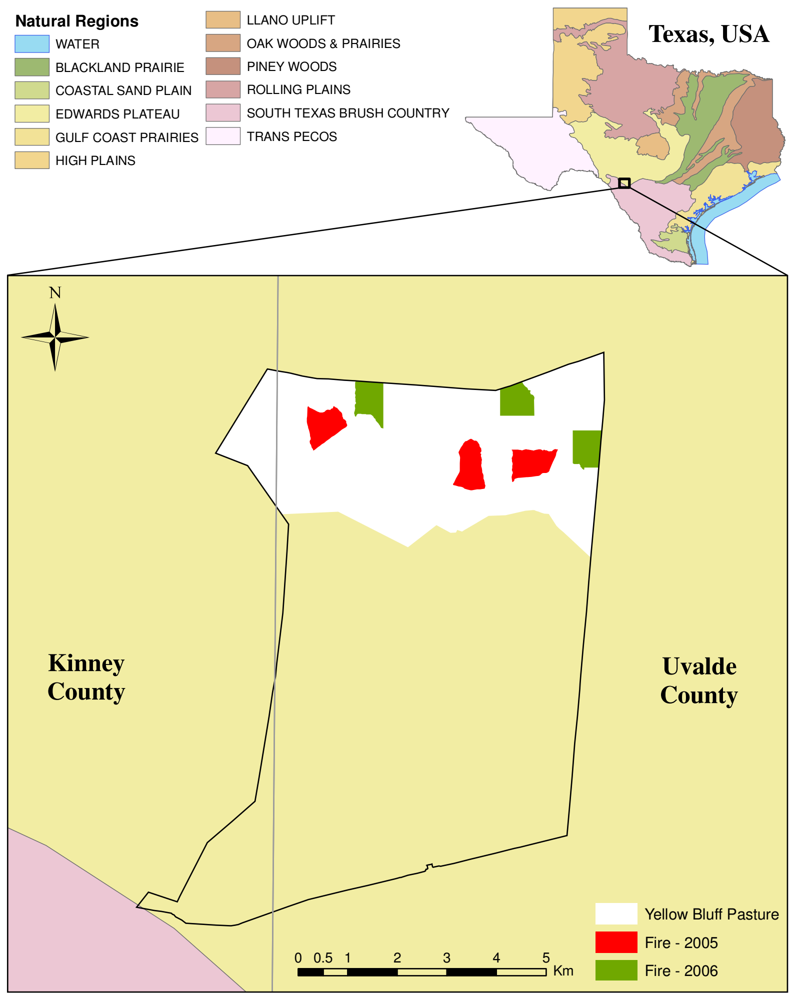


Figure 1. Location of the research ranch at the interface between the Edwards Plateau and South Texas Plains. The ranch is bisected by Uvalde and Kinney counties. The study site is in white and burn patches for 2005 and 2006 are red and green, respectively. A burn ban prevented the 2006 burns.

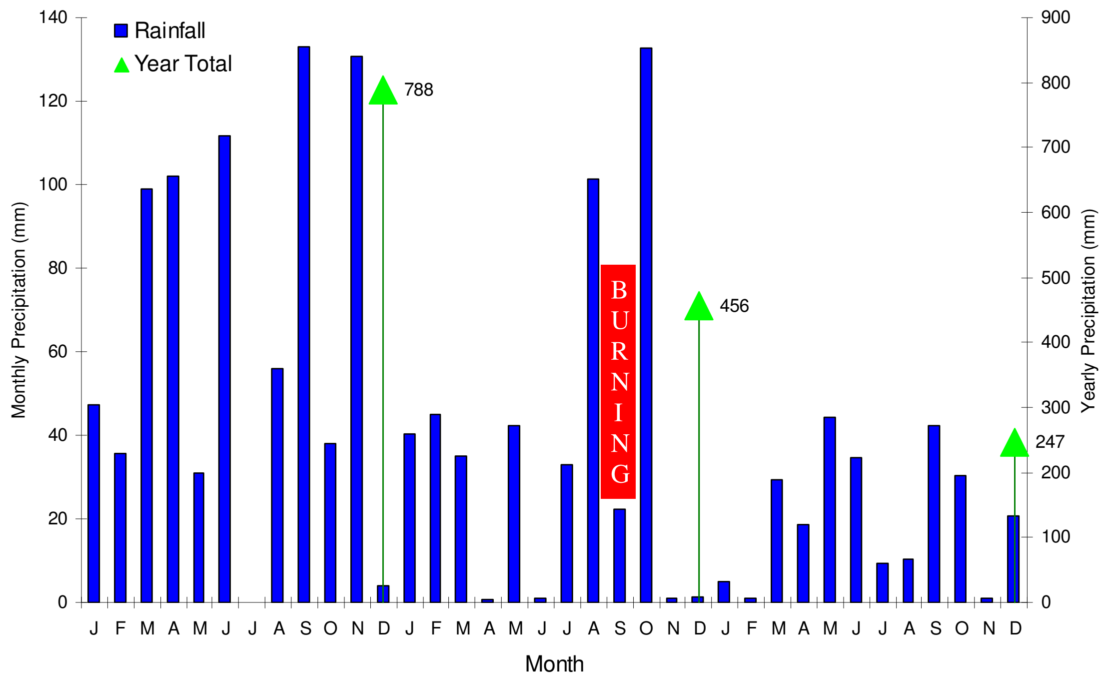


Figure 2. Precipitation totals from Yellow Bluff pasture rain gauge in millimeters. Monthly totals are graphed in blue with yearly totals represented by green triangles. Data ranges from January 2004 through December 2006.

The study site is the northern pasture, the Yellow Bluff (2,091 ha, greater Yellow Bluff). This pasture is bordered on the south by the West Prong of the Nueces River, which is ephemeral and rarely contains water, providing little to no barrier for movement of deer. The river was fenced in October 2005 to protect riparian vegetation and the quality of subsurface water from cattle, reducing the pasture size for cattle to 1,212 ha (lesser Yellow Bluff) although deer pass easily over this fence. The pasture is high-fenced on its northern, western, and eastern borders with a natural bluff formation along the southern border which is passable by deer through limited corridors. Range sites associated with the 4 most common soil types of the 17 occurring on the ranch are

Loamy Bottomland, Stony Ridge, Shallow Ridge, and Clay Loam (Table 1). Shrub vegetation for these range sites is described following the Soil Conservation Service Soil Survey for Uvalde County, Texas (Stevens and Richmond 1970). The Kinney County Soil Survey (Newman et al. 1967) was also reviewed for the small western area of the ranch that crosses the county line. Stevens and Richmond (1970) describe a range site as "a distinctive kind of rangeland that differs from other kinds of rangeland in its potential to produce native plants." Furthermore, they explain that "different soils are grouped into range sites according to their ability to produce different kinds or proportions of plants or according to their total annual yield." These different sites support plant communities with associations that are significantly different from any other site. Unique management of each range site is necessary to support the proper kind and number of animals.

The respective county soil surveys list the potential vegetation communities on these various range sites. Loamy Bottomland ("Overflow" in Kinney County soil survey) range site vegetation is potentially mostly grasses with live oak (*Quercus virginiana*) and sugar hackberry (*Celtis laevigata*) trees. Stony Ridge range sites contain shrubs, such as guajillo (*Acacia berlandieri*), whitebrush (*Aloysia gratissima*), blackbrush (*Acacia rigidula*), pricklypear cactus (*Opuntia lindheimeri*), and other mixed shrubs in less abundance. Shallow Ridge range sites are characterized by mixed-shrub communities, consisting primarily of cenízo (*Leucophyllum frutescens*), guajillo, and Texas persimmon (*Diospyros texana*). Clay Loam range sites are dominated by honey

Table 1. Range sites present in the Greater[a] and Lesser[b] Yellow Bluff pasture ranked by area size (ha) and percent cover (%) in the Greater Yellow Bluff pasture (USDA SCS Soil Survey of Uvalde and Kinney County, Texas, USA, 1970 and 1967, respectively).

	Greater Yellow Bluff		Lesser Yellow Bluff	
Range site	Area (ha)	% cover	Area (ha)	% cover
Loamy bottomland[c]	574.97	27.49	183.91	15.17
Clay loam	464.98	22.23	400.28	33.01
Stony ridge	393.18	18.80	261.94	21.60
Shallow ridge	365.56	17.48	224.52	18.51
River bed	146.76	7.02		
Deep upland	75.54	3.61	75.55	6.23
Low stony hill	33.87	1.62	33.35	2.75
Shallow (Rio Grande Plain)	21.97	1.05	21.81	1.80
Shallow (Edwards Plateau)	11.34	0.54	11.34	0.94
No range site[d]	3.37	0.16		
Igneous hill	0.10	0.00		
Total	2091.63	100.00	1212.69	100.00

[a]Area that includes the fenced-off river bed of the West Prong of the Nueces River.

[b]The current fenced pasture that does not include the river bed.

[c]Includes “Overflow” range site as listed in Kinney County Soil Survey.

[d]Badland (Bd) Soil: unsuitable for cultivation, poor potential for range, and sparse cover of scattered shrubs, short grasses, and forbs. A range site was not assigned by the soil survey.

mesquite and chaparral-type plants. Drainage areas on the study site commonly contain live oak, hogplum (*Colubrina texensis*) and sugar hackberry interspersed with mesquite and Texas persimmon.

METHODS

In conjunction with the Rangeland Innovations for Sustainable Environments (RISE) project, we conducted three 40 ha prescribed burns in September 2005 that covered 10% of the lesser and 6% of the greater Yellow Bluff pasture. A pre-burn assessment of deer and cattle distributions was performed in August 2005 in the greater Yellow Bluff. Subsequent seasonal trials followed the regrowth and maturation of the vegetation during immediate green-up (Nov 2005), spring green-up (Mar 2006), mid-summer drought (Jul 2006), and fall recovery (Oct 2006). This study was approved by the University Laboratory Animal Care Committee at Texas A&M University under Animal Use Protocol permit 2004-49 and Texas Parks & Wildlife Department permit SPR-1196-842.

In attempting to revitalize the rangeland, we utilized small-scale patch disturbance in the form of prescribed burns to reduce the cover of woody plant species and possibly redistribute nutrients to the soil. Schacht et al. (1996) demonstrated that any positive effects of fire are short-term and are minute on grasslands, but in shrubland opening the overstory should allow greater production of grasses and forbs, thus improving forage quality for herbivores (Scifres and Hamilton 1993).

For each trial, I placed GPS collars (GPS_3300S, Lotek Wireless, Inc.™, Newmarket, Ontario, Canada) on 6 deer and 9 cows (GPS_3300LR). The cost of the collars restricted the use of more collars, so the 6 deer were treated as sample replicates. I arranged for the capture of 1 buck and 1 doe in each of the approximate eastern, central, and western sections of the pasture to obtain a distribution of individuals. I contracted a professional firm to capture the deer using a net-gun fired from a helicopter. I then blindfolded the deer to reduce stress, attached numbered ear tags to identify collared individuals, and fitted the GPS collar. For deer and cows, different individuals were collared for each season. I programmed the deer collars to collect a position fix every hour for 30 days to estimate deer spatial distribution. Within these 30 days I programmed the collars to increase data collection to every 5 minutes for 12 consecutive days for fine-scale assessment of activity patterns and foraging locations and to assess the effects of close contact with cattle. I selected the 9 cows at random from the herd (n = 35–40) with the provision that they should come from separate subgroups within the herd. I activated the cow collars to collect data concurrently with the deer collars every 5 minutes for the same 12 days. I tracked the animals by triangulation once or twice per week during each trial to monitor the general area that they were using in case of a collar failure and to aid in the location of the collars once they dropped off. Deer collars were equipped with a factory-programmed mini drop-off with a time delay release set to 5 weeks, and cow collars used a buckle for attachment. I set the VHF beacon on the collars to emit a mortality signal once the collar had been immobile for 6 hours. I collected released collars by homing in on them using a Telonics Inc.™ VHF receiver and Yagi-Uda directional antenna.

I differentially corrected raw data using the program N4 from Lotek (2006) and base station files from the National Geodetic Survey (2007). I projected all GIS files in NAD 1983 UTM Zone 14N. Differentially corrected data points are accurate to ±5 meters or less (Lotek 2006). I analyzed the collar data with ArcGIS™ 9.1 and ArcView™ 3.2 (ESRI 2005). In ArcView 3.2, I used the Animal Movement Extension (Hooge and Eichenlaub 1997) to calculate fixed-kernel density home ranges of 50% and 95%. This range estimation method is non-parametric and makes no assumptions concerning the statistical distribution of data (Worton 1989). This method is more suitable than a minimum convex polygon (MCP) or bivariate-normal range estimation method because it provides lower bias and greater flexibility in handling complex distribution patterns (Gitzen et al. 2006). More importantly, the kernel method supplies an estimated probability density function that corresponds to an animal's utilization distribution (Van Winkle 1975, Gitzen et al. 2006). Simply, the kernel method estimates utilization distributions for an animal based on the intensity or probability of habitat use (Jennrich and Turner 1969). The major features of the ranch were mapped over the past years; such as roads, feeders, water stations, vegetation, and range sites. I also used 1-m resolution 2004 Digital Orthophoto Quarter Quadrangles (DOQQs) obtained from the Texas Natural Resources Information Systems website (2006).

Deer Distribution and Habitat Use

I used 1-hour time interval position fixes to determine the spatial distribution of deer across the study area. This interval increases independence and minimizes spatial autocorrelation of sample points (Frair et al. 2004). A 1-hour interval should allow the deer enough time to cross their annual range as estimated by Cooper et al. (2006) during a previous study on this ranch. I layered deer home ranges over the DOQQs to visually identify habitat usage because there were no other attributes associated with the DOQQ raster file other than color based on vegetation type. Then the deer data was viewed with vector data containing vegetation and range site characteristics. To determine whether deer used burned areas in proportion to their availability in the study area, I calculated the number and proportion of position fixes for each deer that fell within the burned areas. I used Chi-squared (χ^2) tests to compare this with the expected number of fixes if the animal used the burned and unburned areas in proportion to their availability (i.e., 6% of the location fixes would fall within the burned areas in relation to the greater Yellow Bluff). For this analysis if there was a significant difference ($P < 0.05$) then I reviewed the observed and expected values. If the observed value was larger than the expected then I interpreted this as a selection for the burned areas. Vice versa, if the observed value was smaller than the expected then I would interpret this as a selection against the burns. However, if a result was not significantly different then I interpreted this to mean the deer was using the burns as they were available on the landscape. I was comparing burned to the control sites so the degree of freedom was one.

Resource selection is a hierarchal process, and occurs at several levels. The first order of resource selection is at the geographical level, the second is the selection of the home range, and the third order, and focus of this study, is area selection within the home range (Johnson 1980). Cooper et al. (2006) estimated that annual ranges of deer on this ranch averaged about 700 ha and would therefore include at least one treatment area. The deer should be aware of the burns in their annual ranges and whether or not to include burns in their seasonal range. I then used SAS™ PROC CATMOD (Categorical Data Modeling) to examine differences between the responses of bucks and does to the burns at different times after the burns.

It is expected that an individual deer may not utilize the entire pasture during just one season, therefore they may not encounter all of the burned areas. However, where a burned area does fall within the home range of a deer, the deer may concentrate its activities within the burned area. I calculated the extent to which deer used burned areas within their monthly range and whether the core use area was focused on the treatment sites.

Deer Distribution during Active Periods

Secondly, I determined whether deer may concentrate their foraging activity on the burns and thus may affect the regrowth potential of vegetation. For this analysis I used the 5-minute deer data to provide accurate, fine-scale information of daily activities. The GPS collars contain activity sensors that measure dual-axis motion (X [horizontal] and Y [vertical]). I examined the mean frequency of activation of the activity sensors in each season to determine if times of activity (moving) could be distinguished from inactivity (resting) to provide a closer approximation to the time the deer are feeding, because deer are more likely to be foraging during these active periods. Deer are known to be a crepuscular species with circadian activity peaks around dawn and dusk (Montgomery 1963) and to feed in the two hours directly after sunset and before sunrise (Coulombe et al. 2006). I presumed deer preferentially fed on burned areas if the proportion of feeding or active time on the burns was greater than the proportion of burned areas across the greater Yellow Bluff pasture (6%). As in objective 1, I used a Chi-squared test to compare observed and expected numbers of position locations in burned and unburned areas.

Effects of Cattle and Vegetation on Deer Distribution

I compared the 12 days of 5-minute deer data with the 5-minute cattle data to determine the fine-scale effects of cattle movement on deer. I used ArcView 3.2 and ArcGIS 9.1 to map the spatial distribution of cattle and deer and compare the habitat selection of the two species. Then, I queried these data to determine when a collared deer was within 100 m and 15 minutes of a collared cow. I visually examined these segments of data using the Tracking Analyst Extension in ArcGIS 9.1.

I evaluated 4 contact events between deer and cattle. These events include: a deer and cattle may both be in motion (DM CM); a deer may be moving near a stationary cow (DM CS); a moving cow may move near a stationary deer (DS CM); and a deer and cow may both be stationary (DS CS). Within the DS CM category I observed the reaction of the stationary deer to an encroaching cow. If a stationary deer is disturbed by a cow and moves away then this is a negative interaction. If the deer does not respond then this is classified as a neutral interaction, and movement towards the cow is a positive interaction.

To determine forage availability for deer in the burned and unburned plots, I gathered information from 12 existing vegetation transects (6 treated and 6 untreated) already established as part of the RISE project. These transects were randomly generated using the Random Sampling Tools Extension developed by the Minnesota Department of Natural Resources (2007) in ArcView 3.2 and balanced both inside and outside the eastern and central burn patches. Along these transects we measured woody brush density, brush cover, and herbaceous ground cover.

To measure brush density we used belt transects that are 30 m × 2 m. Every individual stem with its own root system within the 60 m^2 was counted and recorded. I divided plants into preferred and non-preferred deer forage categories (Table B–1) based on information from Taylor et al. (1997) and local expertise. I added the data from the 3 transects for each site and treatment. I determined brush cover using the line-intercept method along that same 30 m transect (Bonham 1989). The length that a branch or stem intercepted the vertical axis of the transect line was recorded for each branch and stem. Then I calculated the percent cover of vegetation on each site and averaged the 3 transects for each site. I computed means and standard errors for shrub cover and compared shrub density and cover between treatment, year, and treatment × year interaction using SAS PROC GLM (General Linear Model).

To evaluate herbaceous ground cover I used data from five quadrats along each transect. Five 0.5 m^2 quadrats were situated along each transect to measure percent cover and production of herbaceous ground cover, e.g., grasses and forbs. The first quadrat was randomly placed between 0 and 5 m, and then the remaining four quadrats were placed every 5 m. Also, placement of the quadrats was done so that they would not include any large woody shrub stems, sprouts were fine, but mature brush was avoided as grass and forbs were the main concern for these samples. Species composition and percentage coverage were recorded for forbs and grasses. Categories of ground cover are considered statistically different if the standard errors do not overlap. When this was not clear a *t*-test was performed.

RESULTS

Deer Distribution and Habitat Use

During the month-long trials no individual deer used the entire pasture area. Average monthly ranges did not exceed 335 and 146 ha for males and females, respectively. Although home ranges of males were often larger than those of females, due to large individual variation these differences were not statistically significant (e.g., trial 1, $t_4 = 2.33$, $P = 0.10$). Core range size of deer, which by definition includes 50% of their location fixes, was approximately 10% of the area of their monthly range (Table 2). Within the respective 95% kernel distribution animals may have several disconnected 50% core use areas, as long as the intensity of use is met. During the study, there were 2 occurrences of collar failure and 1 animal that left the study area. For Spring 2006, a doe collar stopped transmitting a VHF signal after it dropped off, so I was unable to locate it. In Summer 2006, a buck traveled north and left the study area extent, and during Fall 2006 a buck collar malfunctioned and only collected 70 of a possible 4000 locations.

Categorical analysis of proportion of locations in the burned areas for bucks and does show that there were significant differences both in the use of burned areas between trials ($\chi^2_4 = 379.13$, $P \leq 0.001$) and between gender ($\chi^2_1 = 76.37$, $P \leq 0.001$). Therefore, I will consider the responses of bucks and does separately.

Table 2. Monthly 95% ranges (ha) and 50% Core areas (ha) of white-tailed deer in each season, South Texas, USA, Jul 2005–Nov 2006.

			95% Monthly Range		50% Core Range	
Gender	Trial	*n*	$\bar{x}$	SE	$\bar{x}$	SE
Males	1[a]	3	148.6	42.8	13.9	3.8
	2[b]	3	248.4	63.0	17.7	7.1
	3[c]	3	236.7	43.4	24.2	4.5
	4[d]	2	334.9	169.0	42.9	19.6
	5[e]	2	135.5	24.9	14.7	3.6
Females	1	3	37.5	4.9	3.9	1.4
	2	3	64.6	22.8	6.1	2.7
	3	2	101.6	16.4	15.6	4.7
	4	3	74.6	24.9	6.7	3.6
	5	3	145.8	22.1	19.9	9.9
Both	1	6	93.1	31.5	8.9	2.9
	2	6	156.5	50.9	11.9	4.3
	3	5	169.1	41.1	19.9	3.6
	4	5	204.7	84.3	24.8	11.0
	5	5	140.7	15.5	17.3	5.7

[a]23 Jul–21 Aug 2005

[b]5 Nov–4 Dec 2005

[c]8 Mar–6 Apr 2006

[d]7 Jul–5 Aug 2006

[e]12 Oct–10 Nov 2006

In trial 1 (pre-treatment, Aug 2005), 2 bucks' and 1 doe's 95% kernel distribution extended into the burns (Fig. 3), but intensity of use was low, none of the deer had 50% core areas that were focused on the burned areas. This indicated that these pre-treatment areas were not selected by deer. Bucks used the future treatment patches less than expected by the burns' proportional area in the pasture ($\chi^2_1 = 39.08$, $P \leq 0.001$). Does used future burn patches in proportion to availability ($\chi^2_1 = 1.12$, $P = 0.290$).

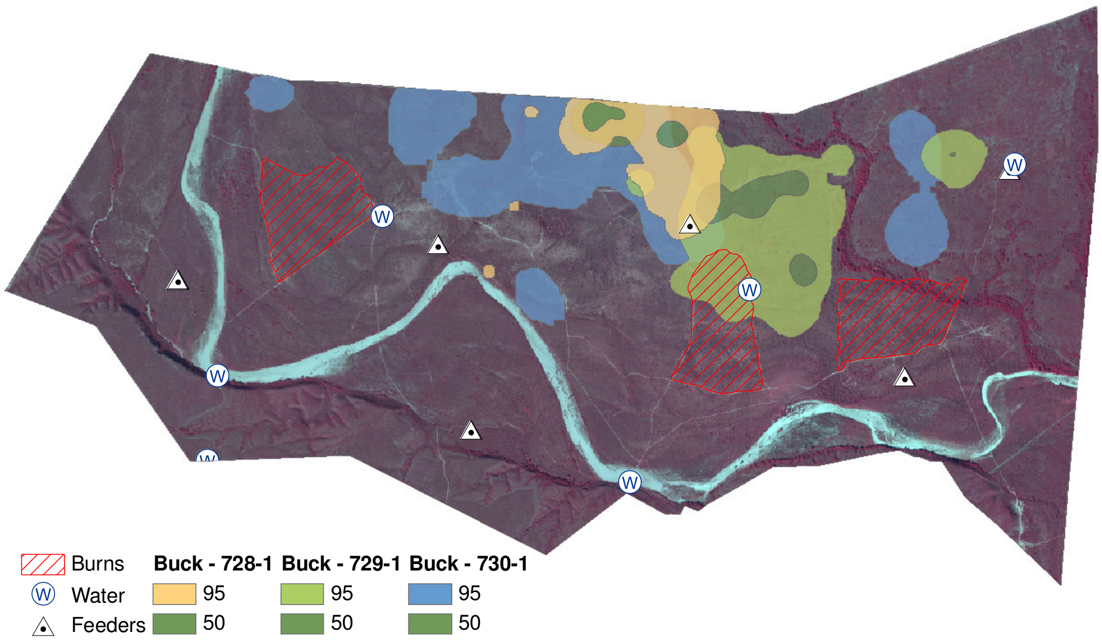
In trial 2 (post-treatment, Nov 2005), 5 of the 6 deer had some proportion of their kernel distribution within the burned areas (Fig. 4). Two bucks encompassed their respective burned plots within their 95% monthly ranges. In this first post-burn trial, both bucks and does favored the burned patches ($\chi^2_1 = 71.50$, $P \leq 0.001$ and $\chi^2_1 = 22.35$, $P \leq 0.001$, respectively). Yet, none of the core use areas fell within the burns.

In trial 3 (post-treatment, Mar 2006), 3 of the 5 individuals (2 bucks, 1 doe) utilized the burns (Fig. 5), but once again, none of the deer focused their core areas on the burned plots or had any part of their core area in the burns. Proportionally, bucks under-utilized the burns ($\chi^2_1 = 6.93$, $P = 0.009$) and does used the burned patches as they were available ($\chi^2_1 = 2.33$, $P = 0.127$).

In trial 4 (post-treatment, Jul 2006), one buck's range encompassed an entire burn patch and a small proportion of his core area was in the burn, but he did not focus on the burn patch (Fig. 6). The buck also used a small part of two other burned areas. This resulted in the bucks using the burned patches as available ($\chi^2_1 = 2.35$, $P = 0.125$). Does tended to avoid the burned patches ($\chi^2_1 = 47.10$, $P \leq 0.001$).

In trial 5 (post-treatment, Oct 2006), 4 of 5 deer had part of their 95% monthly range in the burns (Fig. 7). However, 2 does included most of a burn patch in their monthly range. These 2 does also had a large proportion of their 50% core areas in the burns as well, 12 and 11 ha. Bucks tended to avoid ($\chi^2_1 = 18.02$, $P \leq 0.001$) the burned patches during this trial while does favored these areas ($\chi^2_1 = 538.88$, $P \leq 0.001$).

In summary, the deer had little to no attraction to the future treatment areas. This changed after the treatment in trial 2, when both bucks and does were observed to favor the burned patches. Trials 3 and 4, however, saw the deer return to the prior avoidance or use-as-available distribution of the pre-burn trial 1. Trial 5 was odd in that bucks avoided the burned patches while 2 of the does heavily favored them. Except for this last trial, even when deer did utilize the burned areas, the core areas where deer spent 50% of their time tended to be outside the burned patches.



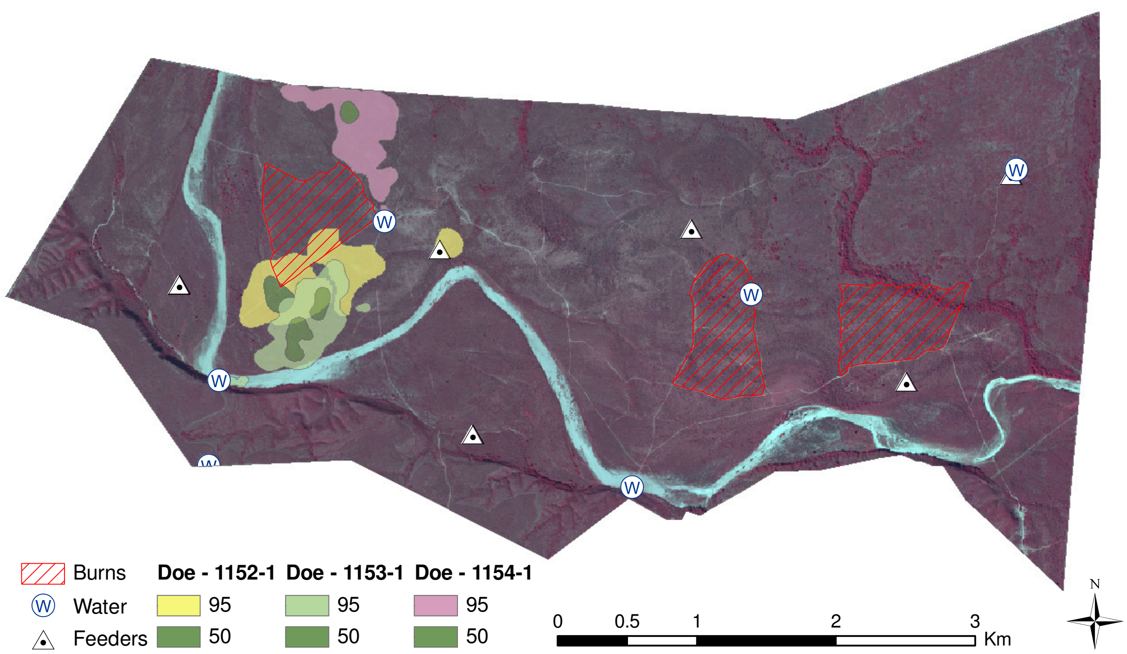


Figure 3. Fixed-kernel density estimates of summer seasonal home ranges of males (top) and females (bottom) in trial 1 (Aug 2005, pre-burn). These distributions are based on hourly fixes collected over 30 days.

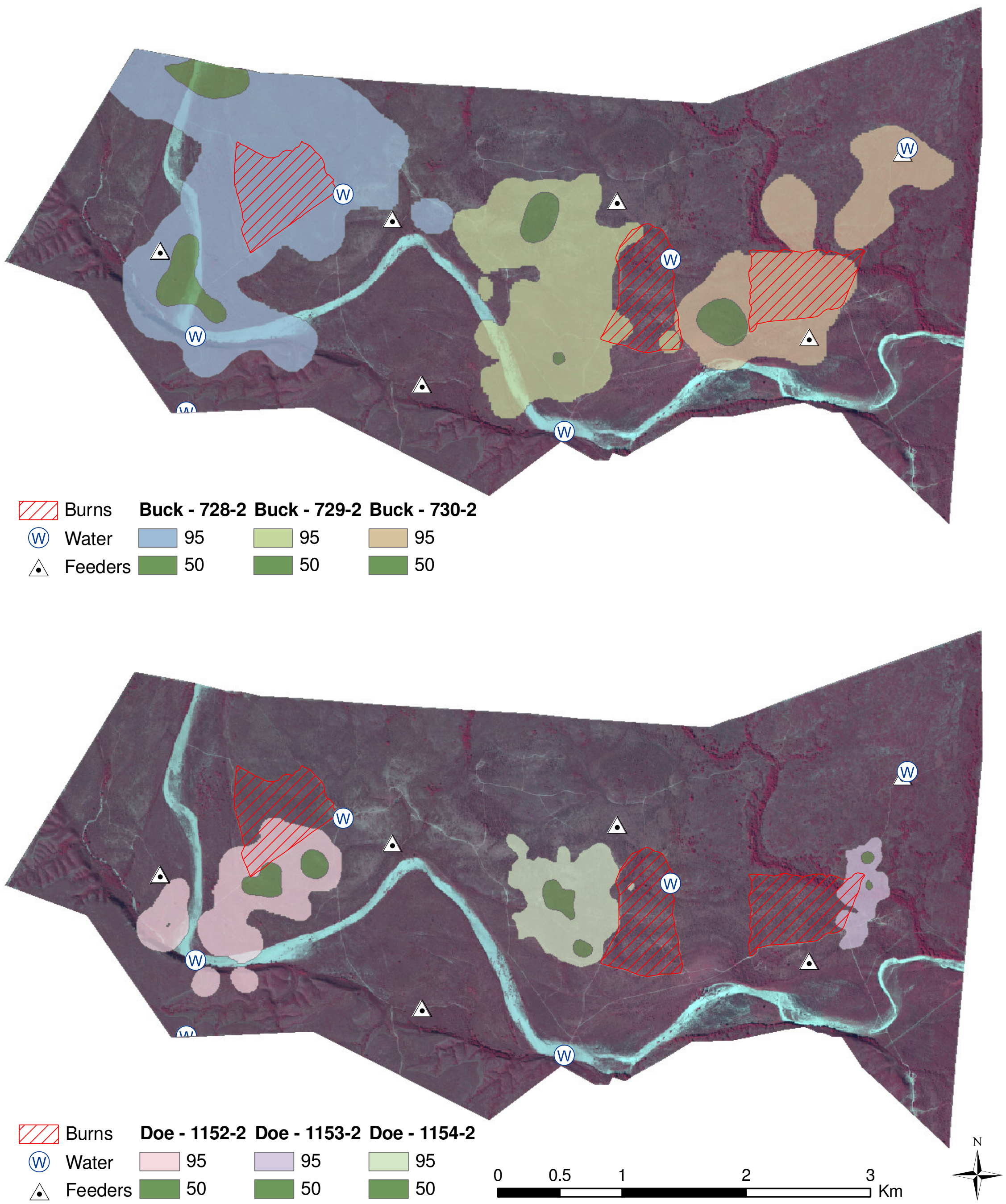


Figure 4. Fixed-kernel density estimates fall seasonal home ranges of males (top) and females (bottom) in trial 2 (Nov 2005). These distributions are based on hourly fixes collected over 30 days.

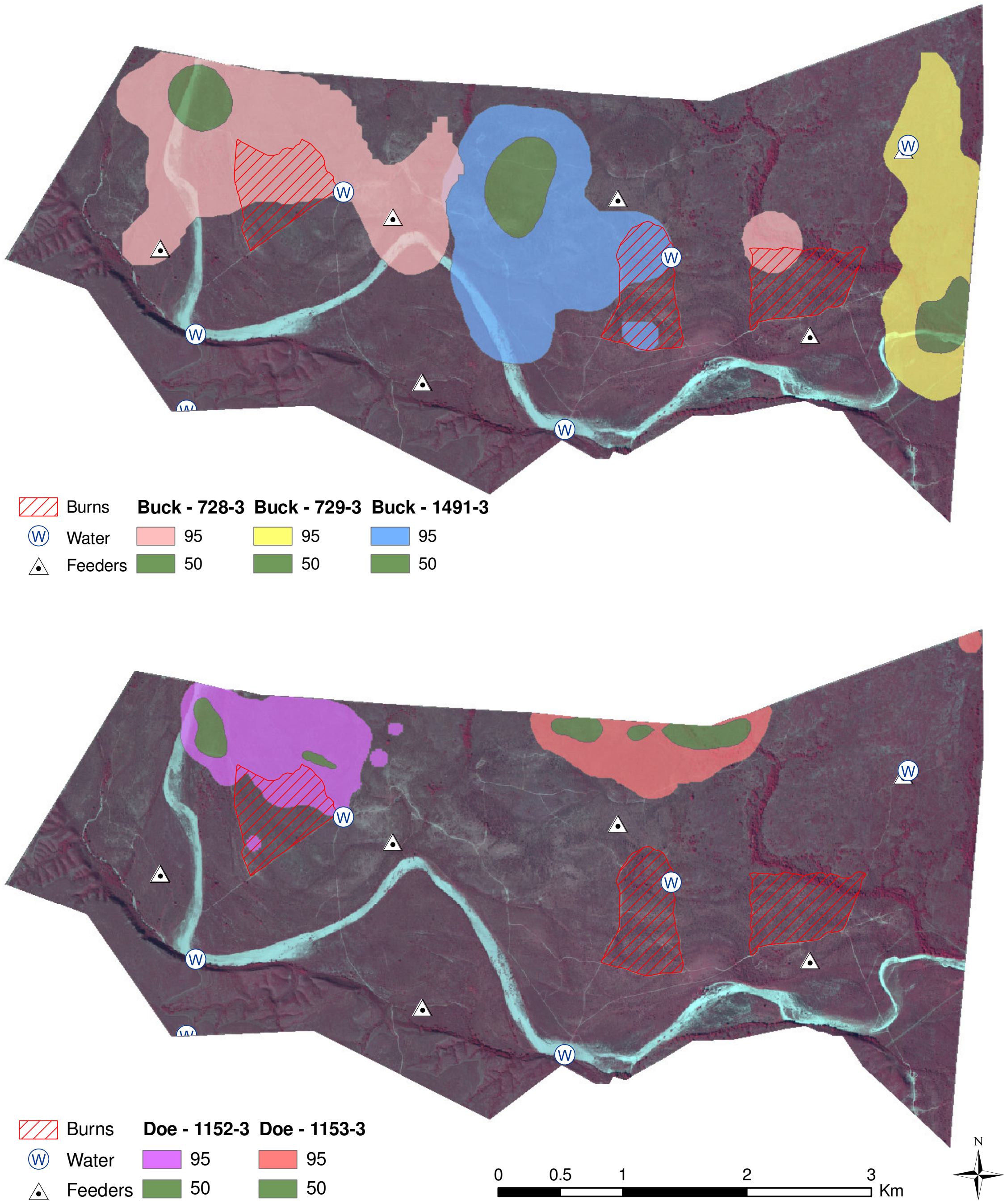


Figure 5. Fixed-kernel density estimates spring seasonal home ranges of males (top) and females (bottom) in trial 3 (Mar 2006). These distributions are based on hourly fixes collected over 30 days.

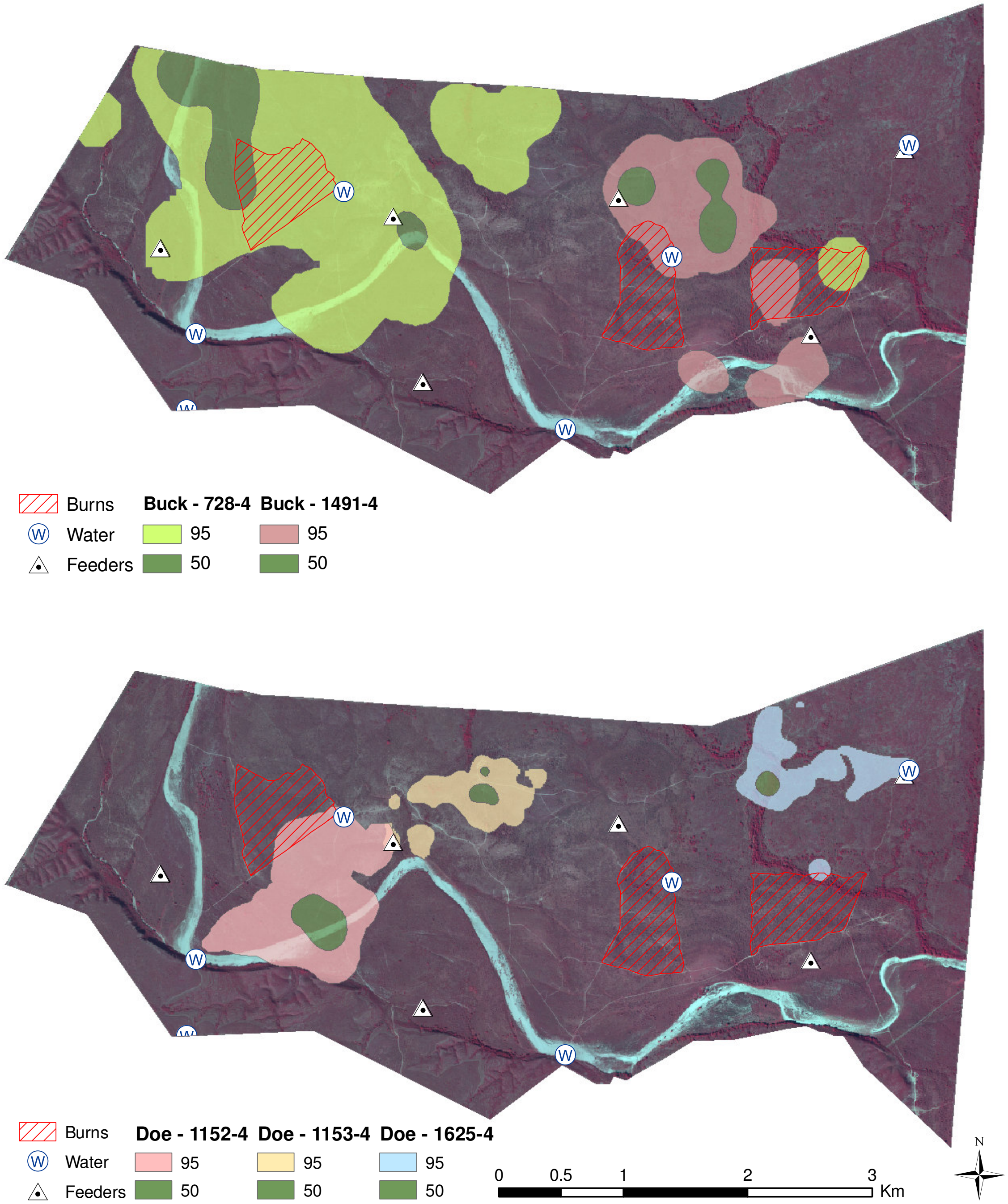


Figure 6. Fixed-kernel density estimates summer seasonal home ranges of males (top) and females (bottom) in trial 4 (Jul 2006). These distributions are based on hourly fixes collected over 30 days.

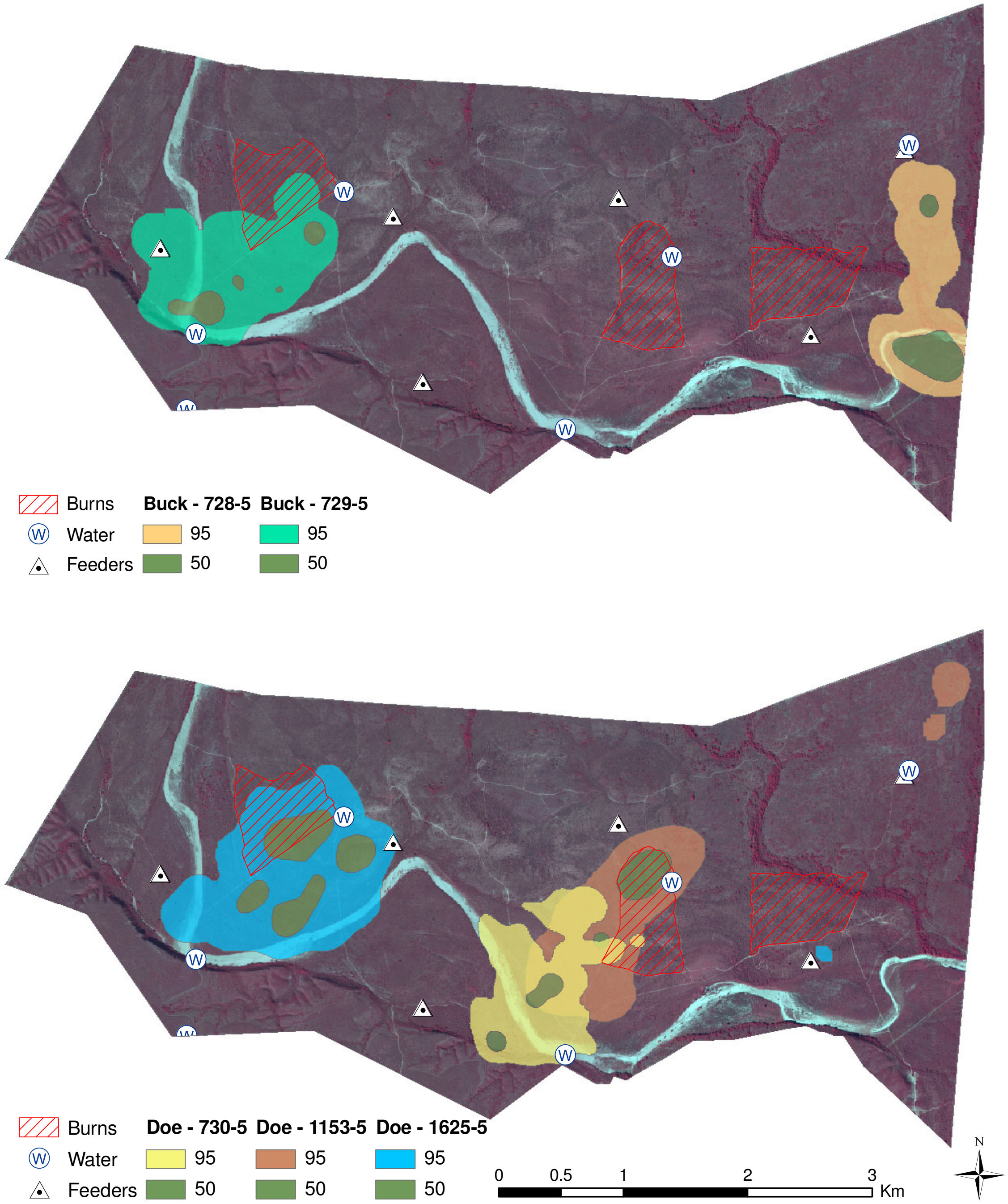


Figure 7. Fixed-kernel density estimates fall seasonal home ranges of males (top) and females (bottom) in trial 5 (Oct 2006). These distributions are based on hourly fixes collected over 30 days.

Deer Distribution during Active Periods

Peak activity times for bucks and does were observed to be the same based on collar activity sensor data, so I combined the activity data. Activity sensors have historically been inaccurate and unreliable forms of data. This is dependent on the fit of the collar, species collared, and level of technology of the collar. These sensitivities were examined by Coulombe et al. (2006) and found that the horizontal and vertical sensors of Lotek GPS_2200R collars correctly identified periods of activity and inactivity approximately 83% and 92% of the time, respectively. Activity peaks were observed for all trials around sunrise and sunset (Fig. 8–10). Sunrise and sunset data was acquired from the U.S. Naval Observatory (2007) and averaged for the each trial.

Based on these data I chose to investigate deer distributions relative to the burned patches during the 2 hours of highest activity in the morning and evening hours, for a total of 4 hours per day. These 4 hours of activity were extracted from the 5-minute spatial data for the each deer during each trial. Chi-squared test results indicated that the only trial in which deer were located within the burn more frequently than expected during active periods was for females in November 2006 (Table 3), a year after implementation of the burn. Therefore, deer were likely not selecting to feed in the treated areas.

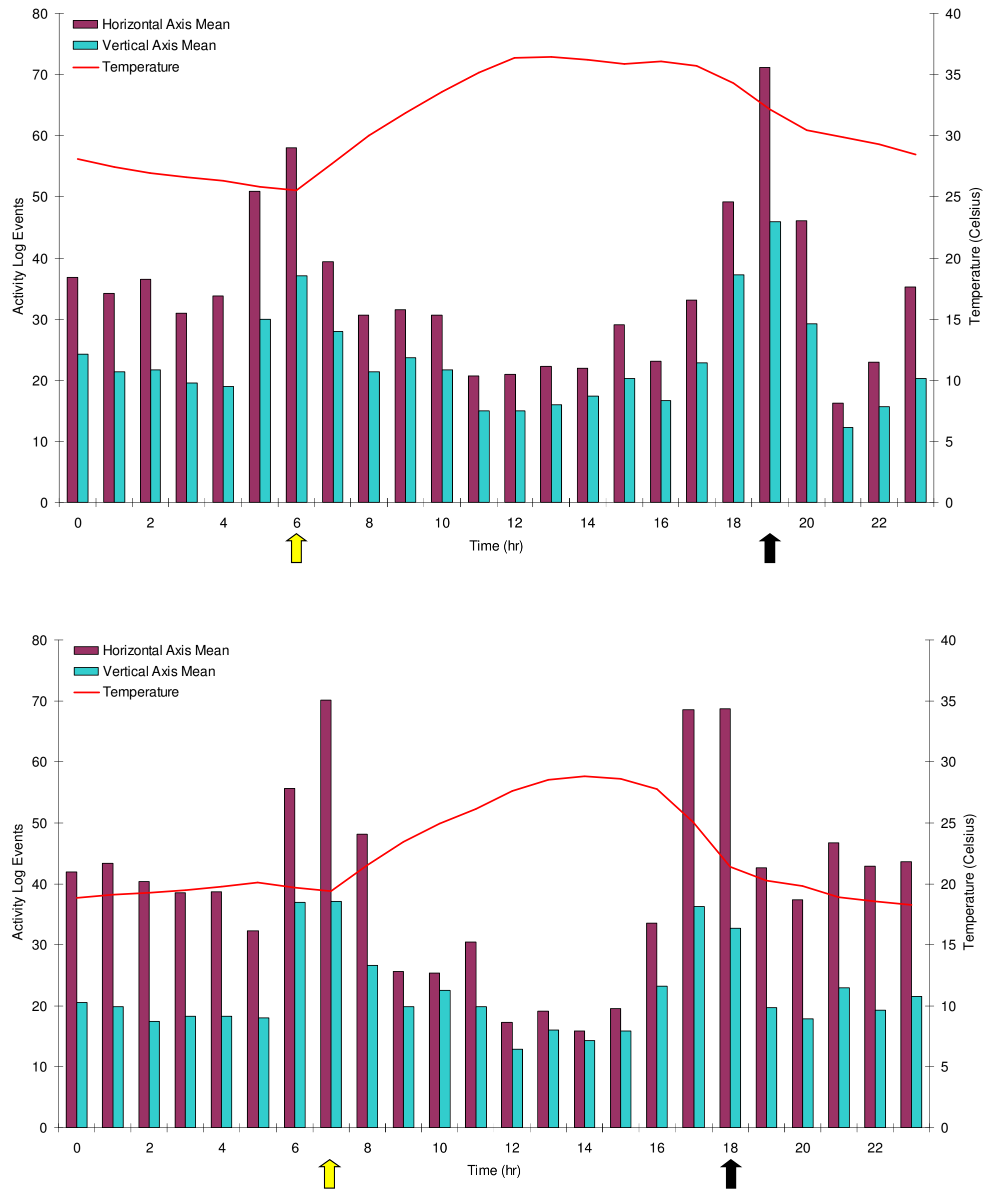
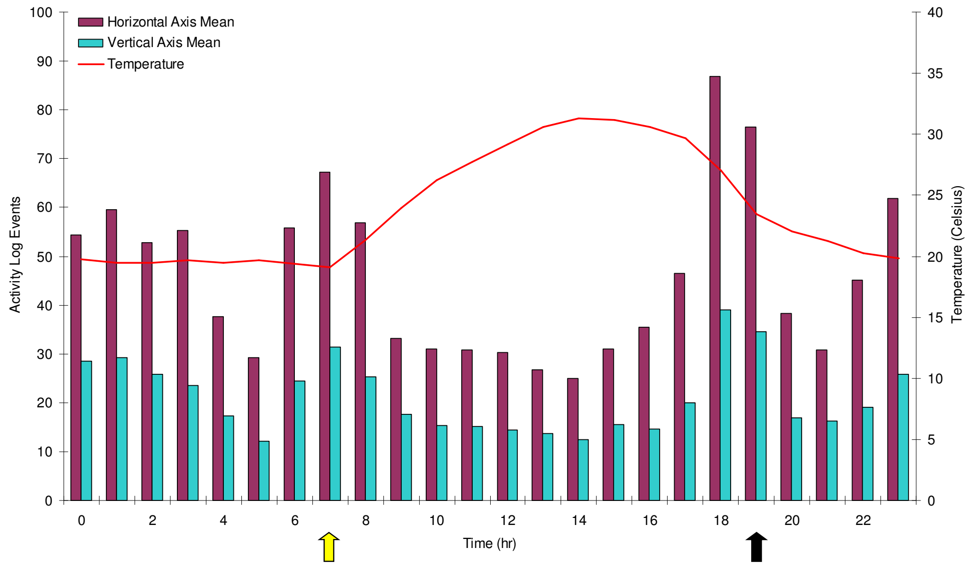


Figure 8. Activity sensor daily averages for Summer (top) and Fall 2005 (bottom) before and after the treatment, respectively. The yellow and black arrows represent the average trial sunrise and sunset, respectively.



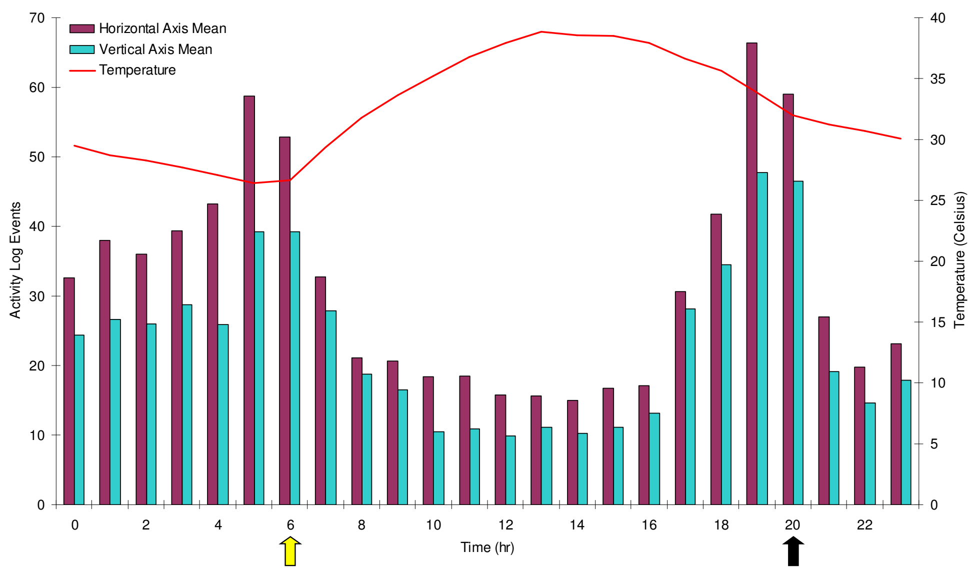


Figure 9. Activity sensor daily averages for Spring (top) and Summer 2006 (bottom). The yellow and black arrows represent the average trial sunrise and sunset, respectively.

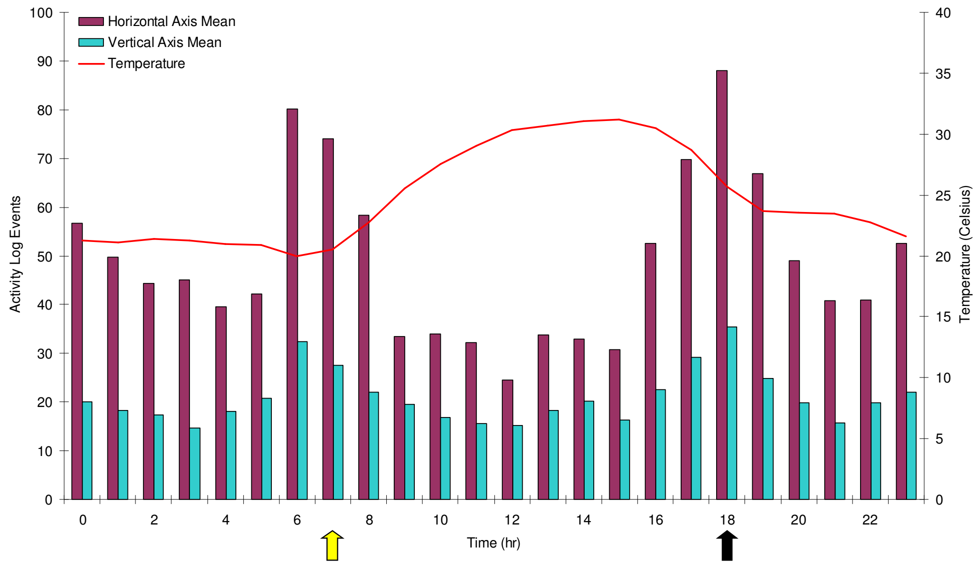


Figure 10. Activity sensor daily averages for Fall 2006. The yellow and black arrows represent the average trial sunrise and sunset, respectively.

Table 3. Chi-squared (χ^2) and *P*-values based on hourly point distribution of white-tailed deer within burns during active periods around dawn and dusk, South Texas, USA.

Trial	Sex	χ^2	*P*	Preference
August 2005	Male	12.447	0.001	No
	Female	0.078	NS	As Available
	All	3.627	NS	As Available
November 2005	Male	0.388	NS	As Available
	Female	7.849	0.010	No
	All	1.187	NS	As Available
March 2006	Male	47.605	0.001	No
	Female	26.377	0.001	No
	All	38.282	0.001	No
July 2006	Male	4.672	0.050	No
	Female	50.786	0.001	No
	All	26.421	0.001	No
October 2006	Male	35.817	0.001	No
	Female	294.028	0.001	Yes
	All	88.494	0.001	Yes

Deer and Cattle Interaction

In trial 1 the cows (*n* = 9) used much of the southern part of the pasture and avoided the north central and eastern parts (Fig. 11). As in all trials heavy use was seen along fences and roads. The cows' negligible use of the treatment patches was mainly on roads that transected these areas. A water source on the central burn patch was the main draw for cattle to this area. Deer (*n* = 6) during this trial were mostly in the northern part of the pasture where there was little presence of cattle, except for one deer which traveled to a water source on the river regularly. As with the cattle, deer use of the burns was negligible, and overall there was little use by either group of the eastern part of the pasture, especially the eastern burn patch.

In trial 2 the river bed was fenced off from the cattle for riparian zone protection. The area accessible to cows will be referred to as the lesser Yellow Bluff pasture. This led to a slightly denser distribution of cattle, but the deer were unaffected as it was not a high-fence. Cows (*n* = 9) were heavily concentrated in the northwestern and north-central parts of the lesser Yellow Bluff (Fig. 11). The northern and western fences were traversed heavily by them as well, and travel to the water source on the central burn patch was significant and along the roads through the burn that leads to the water. Deer were in clumps in areas that were under-utilized by cattle. The deer also retained access to the 2 water sources south of the lesser Yellow Bluff pasture fence. Distribution is also noticeable in the eastern burn patch, but again neither deer nor cattle used the northeastern part of the pasture.

In trial 3 cattle (*n* = 8) were more concentrated on water sources on the central and western burn patches (Fig. 12). They were also more evenly distributed across the pasture with more activity in the central burn, but the eastern part of the pasture remained unused. Deer (*n* = 5) used much of the pasture, but the southern area (dry river bed) was under-utilized. Use of water sources was heavy and seemed to determine much of the distribution. Again, areas of intense cow use do not overlap with intense deer use.

In trial 4 cattle (*n* = 6) were concentrated on the west side of the pasture, with little activity around burns except near water sources (Fig. 12). Cattle were absent east of the central burn and sparse around the central burn patch. Deer (*n* = 5) were evenly distributed across the pasture and intensive areas of habitat use were away from cattle. The main areas of overlap were around water sources.

In trial 5 cattle (*n* = 9) were evenly distributed across the lesser Yellow Bluff pasture, including the eastern part that was avoided in all of the previous trials (Fig. 13). Cows intensely utilized the central burn, especially near the water source. There was slight use of the eastern and western burns along roads and fences that were within or near the burns. Deer (*n* = 5) used areas on the river bed away from cattle and around water sources. The western and eastern deer used areas away from cattle, while the central deer's distribution overlapped with cattle on the central burn patch, especially near the water source.

Typically, throughout the study, deer avoided areas where cattle were unless there was a water source nearby. Where there is geographic overlap, deer and cattle are often separated temporally.

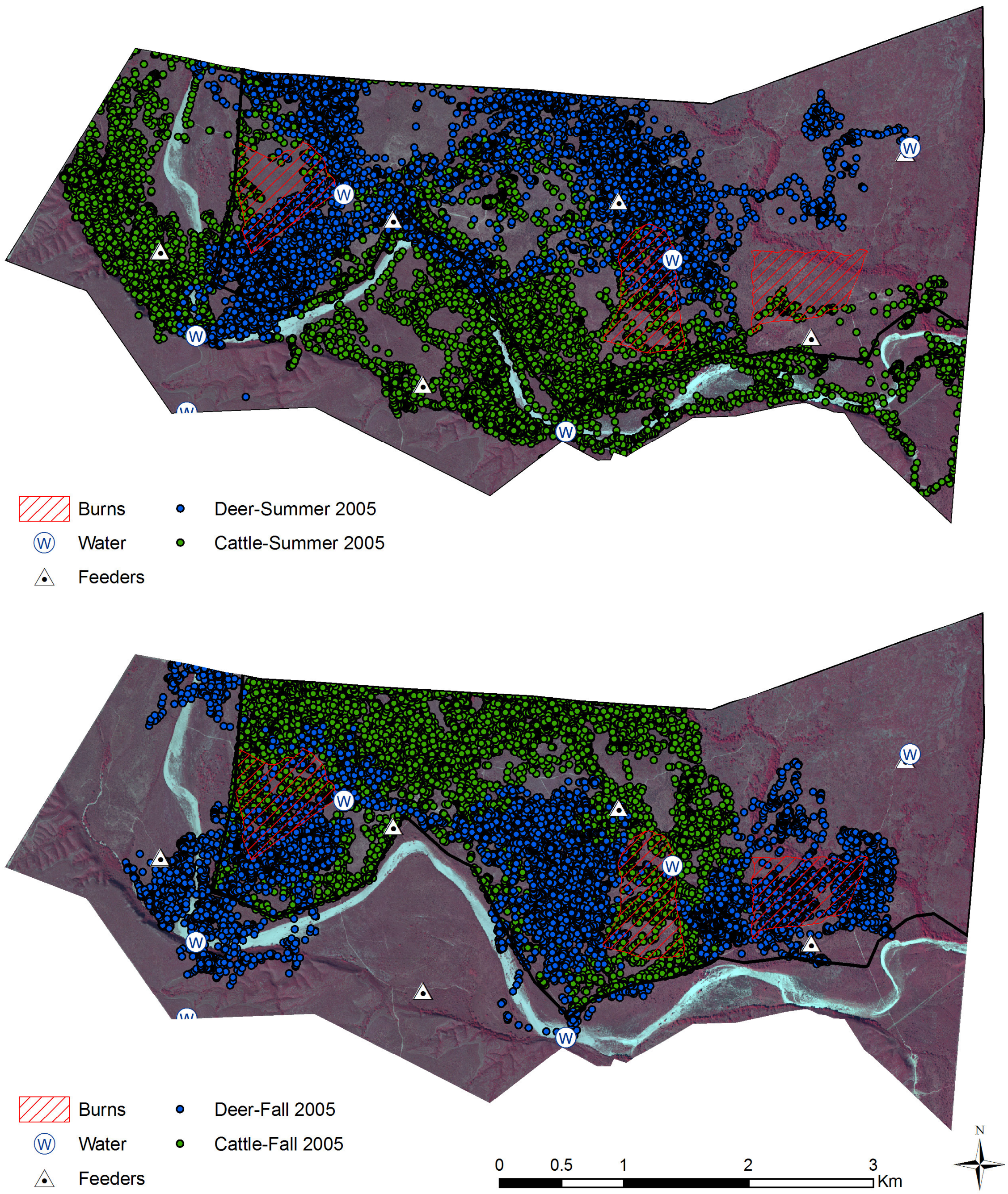


Figure 11. Point distribution of deer (blue) and cattle (green) 5-minute data for 12 days during Summer 2005 (top) and Fall 2005 (bottom).

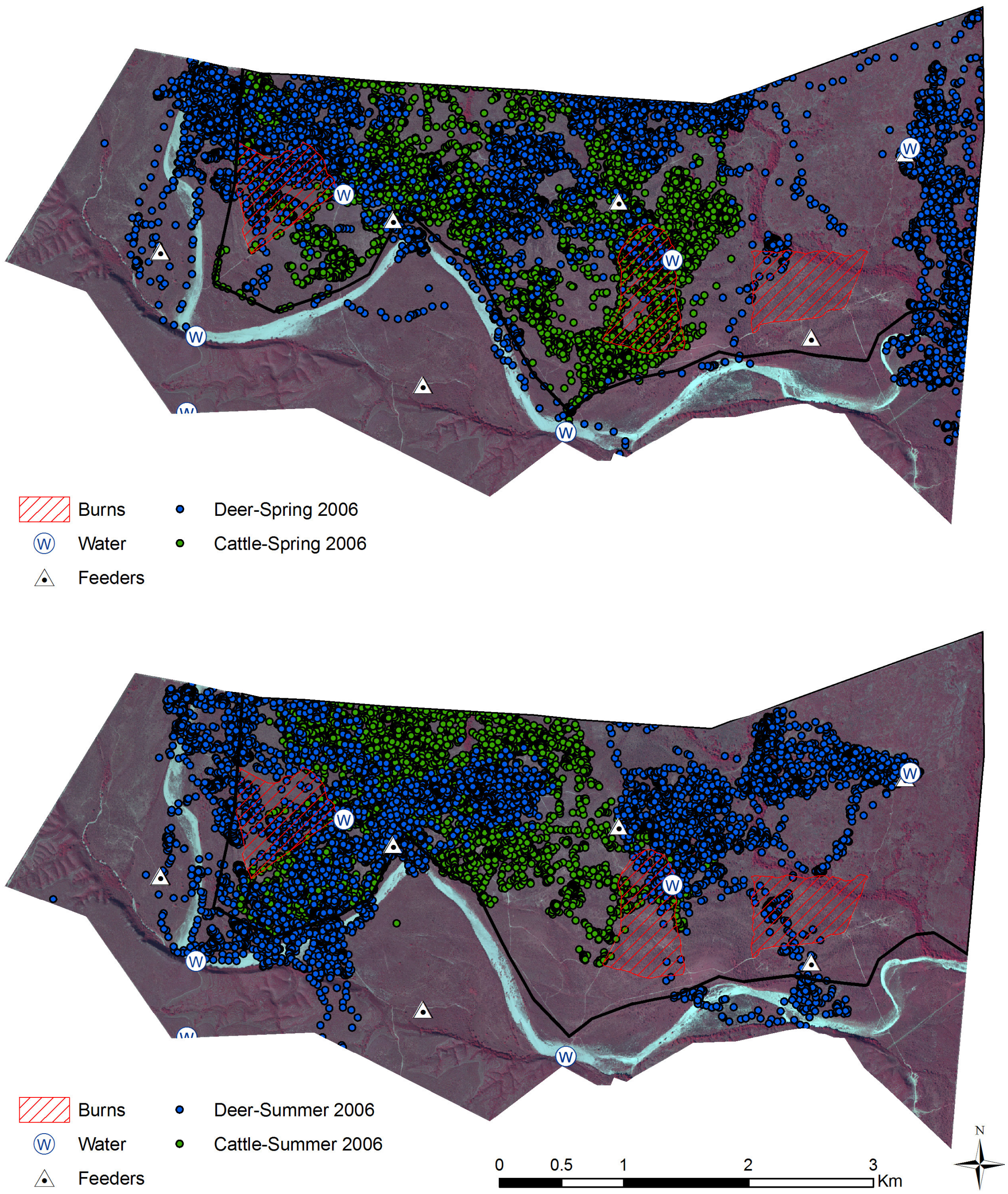


Figure 12. Point distribution of deer (blue) and cattle (green) 5-minute data for 12 days during Spring 2006 (top) and Summer 2006 (bottom).

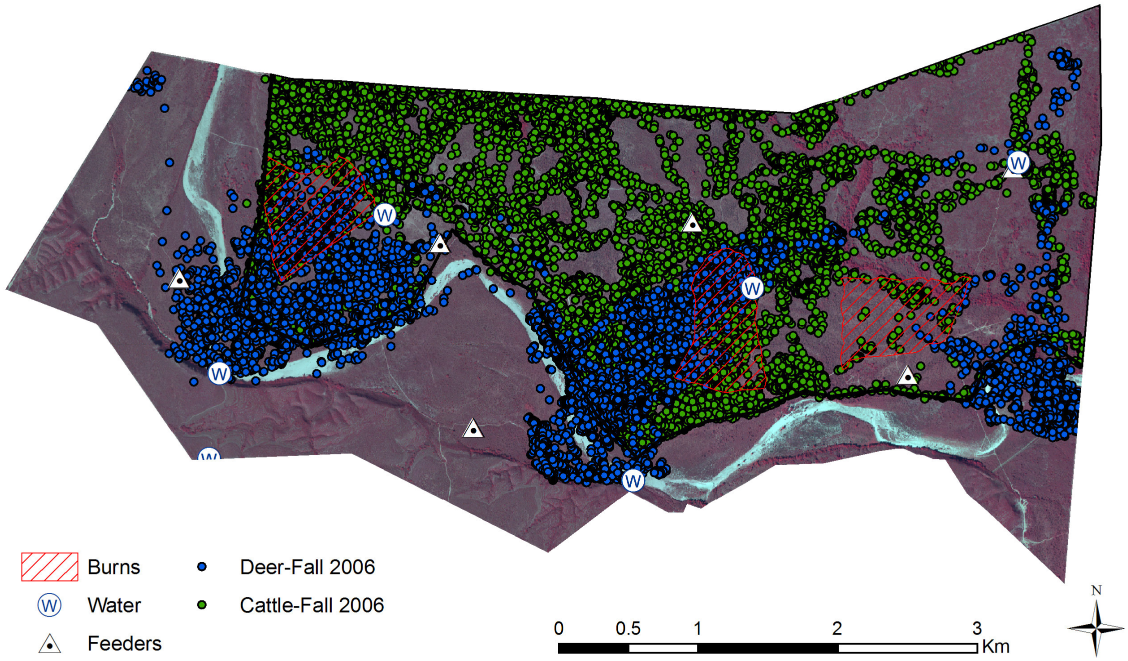


Figure 13. Point distribution of deer (blue) and cattle (green) 5-minute data for 12 days during Fall 2006.

Close Interaction

The rarity of close contact events between cattle and deer led me to choose to pool the data for all trials for this analysis. The four contact event situations (n = 121) took place mostly from 30–80 m (Fig. 14). For each of the four close contact events there was no significant difference between a contact event with a single cow or multiple collared cows between trials (Table 4). Due to small sample size and unknown locations of non-collared cows in the herd I combined the single and multiple cow contact data.

In situations where both the deer and cow were moving (n = 58) the closest contact was one event at 10 m and more often animals were 30 m apart (n = 10). A deer moving near a stationary cow occurred 32 times with events at all distances except 10 and 20 m. The maximum number of contacts was 10 (50 m). Only one event (80 m) occurred when both the deer and cow were stationary.

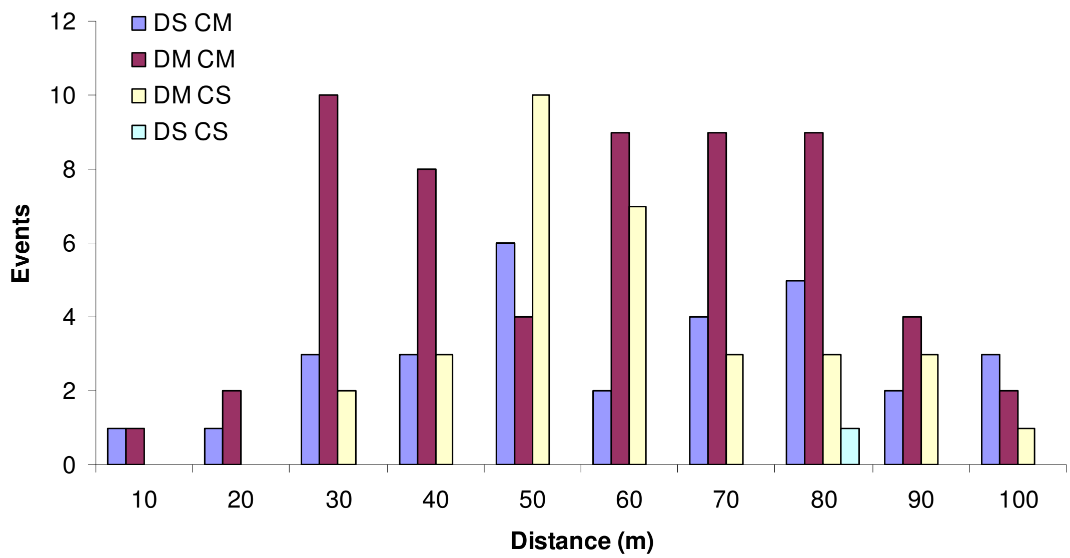


Figure 14. Close contact events (≤100 m within 15 min) between white-tailed deer and cattle during this study. The data was pooled from all seasons. DS and DM represent a stationary and moving deer, respectively. CS and CM represent a stationary and moving cow(s), respectively.

Table 4. Individual analysis of contact events comparing the effect of the known presence of single versus multiple cows on white-tailed deer in South Texas, USA.

Contact Type	*t*	df	*P*	Result
DM CM[a]	0.19	56	0.850	NS
DM CS[b]	0.34	30	0.736	NS
DS CM[c]	–0.84	28	0.408	NS
DS CS[d]				
All	2.68	119	0.008	SIG

[a]Deer Moving, Cow Moving
[b]Deer Moving, Cow Stationary
[c]Deer Stationary, Cow Moving
[d]Deer Stationary, Cow Stationary (n = 1)

I inspected the stationary deer–moving cow events closer. Across all of the seasons this event occurred 30 times and within this classification I determined whether the deer stayed in the same location or if it moved in relation to the cow. I found that there was approximately an equal chance of deer either moving (n = 15) or staying (n = 15) still when a cow came within 100 m (Fig. 15). Also, I found that when cattle came within 46 ± SE 5 m of a resting deer it tended to move away, but deer remained in place when the cattle passed at 64 ± SE 7 m. There was a significant difference between the two results (t_{28} = 2.11, P = 0.044) and taking into account the standard errors, the two outcomes are separated by a minimum of 6 m and a maximum of 30 m. The 2 events at 10 and 20 m were attributed to bucks that were at feeders and separated from the cattle by a fence.

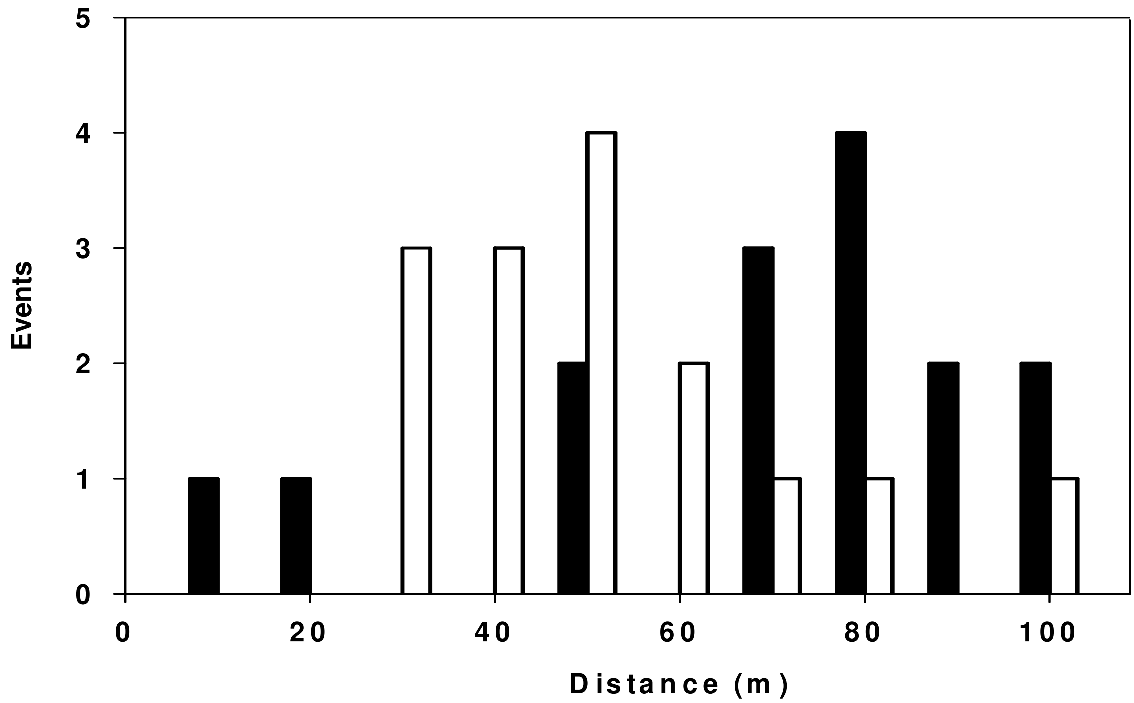


Figure 15. Close contact events (≤100 m within 15 min) between stationary white-tailed deer and moving cattle in the study area. Black bars represent the events when deer did not move in response to an approaching cow. White bars represent the events when deer moved away from an approaching cow.

Vegetation Composition

I found no difference in the number of stems produced by shrubs in the control and treated areas for 2005 and 2006 ($F_{3,4}$ = 2.98, P = 0.16). This relationship was the same for preferred shrubs ($F_{3,4}$ = 2.39, P = 0.21) and non-preferred shrubs ($F_{3,4}$ = 0.91, P = 0.511). Thus burning did not significantly change the quantity of food and shelter for deer provided by shrub density (Fig. 16). Shrub cover (Fig. 17) increased in the first treatment site, which was the opposite of what we expected. However, this difference was not significant ($F_{3,4} = 0.33$, $P = 0.804$), just as all the other changes in shrub cover were not either. Percent cover of bare ground increased ($t_{10} = 4.86$, $P \leq 0.001$) while grasses decreased on control sites ($t_{10} = 2.95$, $P = 0.015$) and forbs decreased on treatment sites ($t_{10} = 10.27$, $P \leq 0.001$) from 2005 to 2006 (Fig. 18). Also, small shrub sprouts decreased on treatment sites from 2005 to 2006 ($t_{10} = 6.015$, $P \leq 0.001$). In 2005, forb coverage was slightly different between the treatment and control sites ($t_{10} =$ 2.22, $P = 0.051$) and in 2006 there were a few more shrub sprouts on control sites ($t_{10} =$ 3.15, $P = 0.01$). No difference in productivity could be attributed to the prescribed burns.

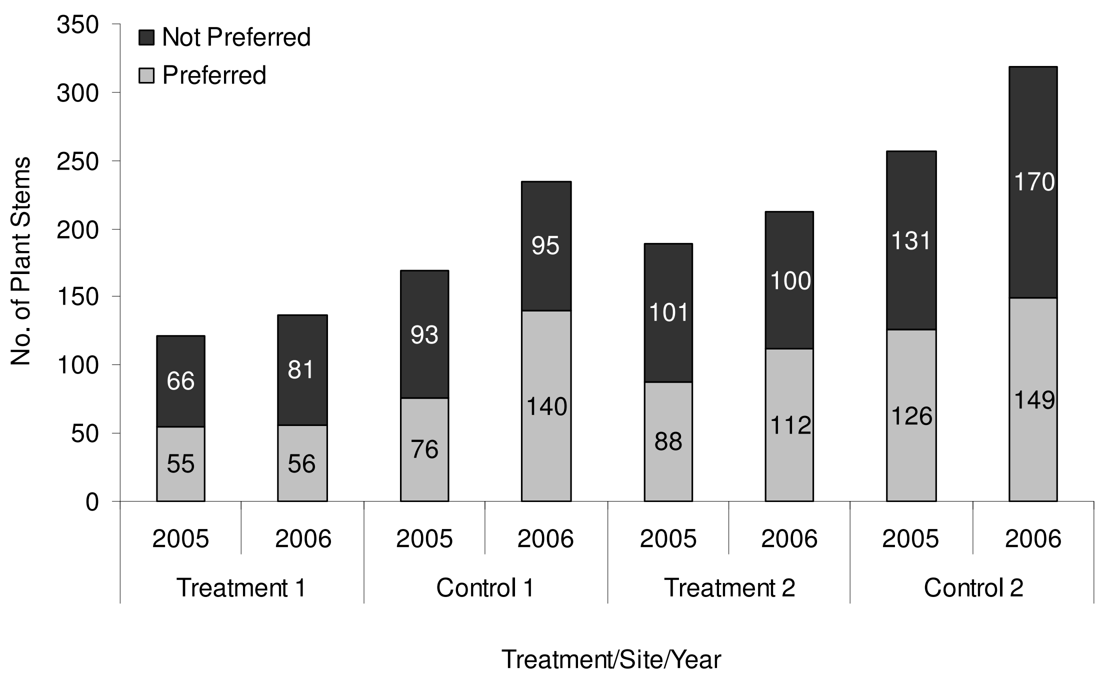


Figure 16. Shrub density (plant stems/60 m^2) composition of 3 transects within 2 of the treatment areas and 3 transects outside of the treatment areas in similar vegetation composition.

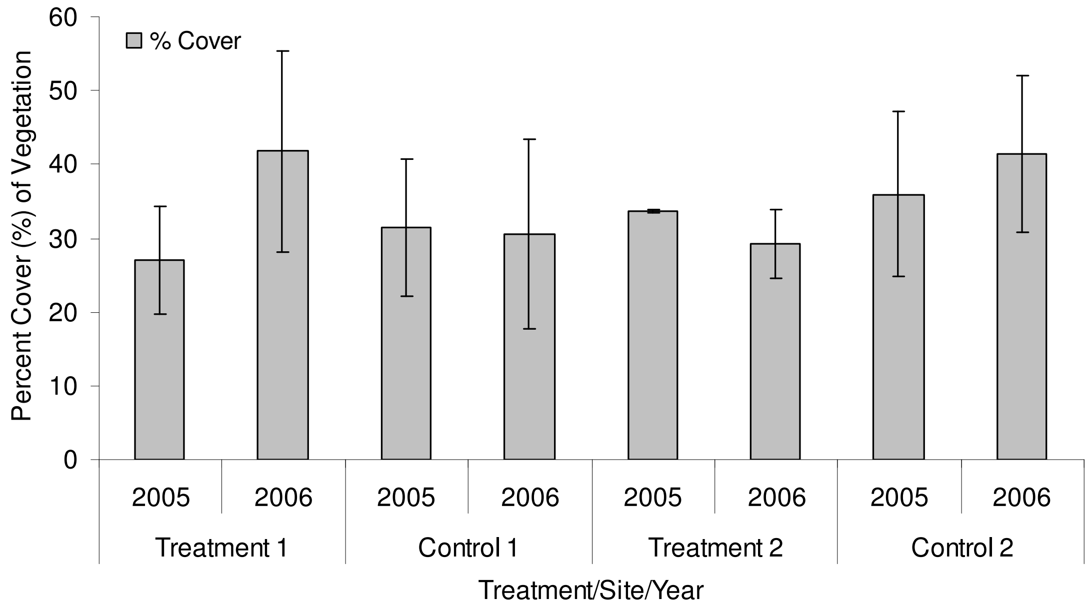


Figure 17. Shrub cover percentage (%) of 3 transects within 2 of the treatment areas and 3 transects outside of the treatment areas in similar vegetation composition.

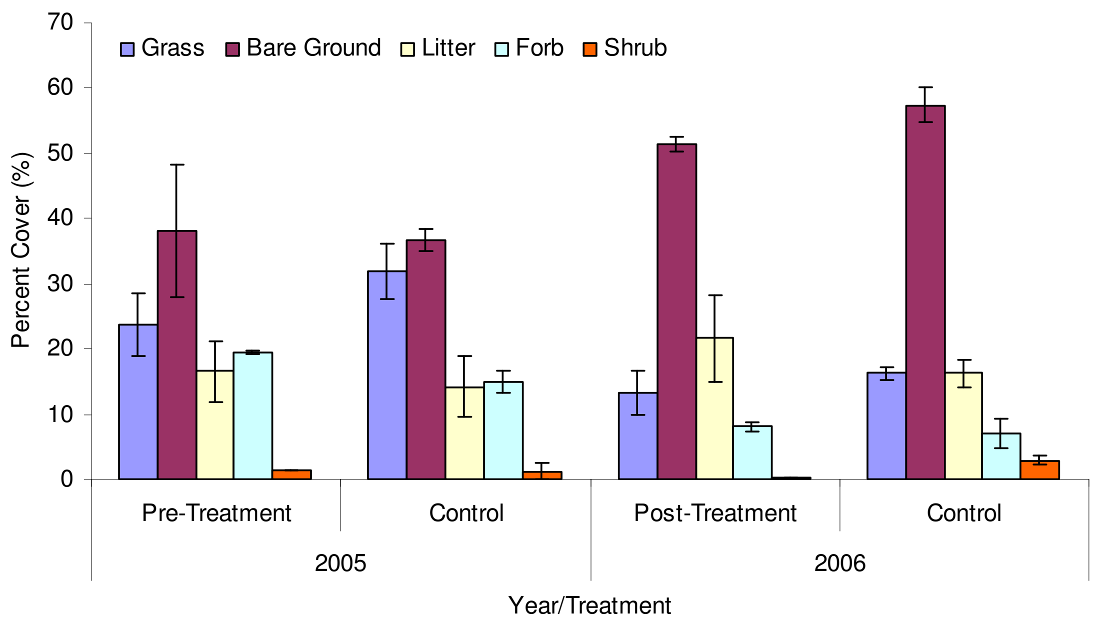


Figure 18. Ground cover percentage (%) in herbaceous vegetation sampling plots (0.5 m^2) in the treatment and control sites before and after the treatment. Amounts shown are averages with standard error bars.

DISCUSSION

The historical expansion and encroachment of woody shrubs into what was once South Texas mesquite savanna (Cook 1908) is reviewed by Scifres and Hamilton (1993). Archer et al. (1988) and Archer (1989) also recount the prior landscape of South Texas. This encroachment decreased the productivity of herbaceous vegetation (forbs and grasses) and depleted the nutrients and water available in the soil (Hamilton et al. 2004), thus reducing habitat quality for livestock and wildlife. High-nutrient forbs are a mainstay of the white-tailed deer's diet and may be integral for antler growth in males during spring (Fulbright and Ortega-S. 2006).

Animal and plant communities in South Texas have evolved with the presence of fire, whether natural or anthropogenic. The adaptation to this natural force has led to fire being a beneficial event; removing the overstory of brush to allow sunlight and precipitation to reach the ground and herbaceous vegetation below, and returning some biomass to the soil in the form of potash as a fertilizing agent. Allowing and encouraging new, fresh vegetation growth is very important to herbivores that inhabit these fire-maintained biomes. The successful use of fire, wild and prescribed, at the Kerr Wildlife Management Area on the Edwards Plateau in Central Texas is observational evidence of the inherent benefits of fire for the ecology of rangelands (Armstrong 2005). Also, in the South Texas Plains, Ruthven et al. (2000) found that fire was effective at increasing forb coverage, but not density, at least in the short term. Therefore, experimental prescribed fires were also expected to produce better forage for white-tailed deer in this study at the interface of the Edwards Plateau and the South Texas Plains ecoregions. However, based on data from another prescribed burn study in the same transitional zone, the effect on vegetation composition may be very small or non-existent (Owens et al. 2002).

Deer Distribution and Habitat Use

Deer distribution prior to implementing the three 40 ha prescribed burns in September 2005 showed there was no preference for, or avoidance of, the treatment areas and the deer used them as they were available. One month after the burns, during trial 2 (Nov 2005), the deer selected for the burned areas as expected. Precipitation one week after the burns had stimulated fresh herbaceous growth. The fresh forbs and grasses likely attracted the deer and influenced their distribution patterns.

Grass is an atypical part of a deer's diet, but the fresh growth is nutrient rich and low in cellulose fiber and lignin. Chamrad and Box (1968) found that deer in coastal South Texas were primarily grazers during the winter–spring period with 90% of their diet from forbs (68%) and grasses (22%). However, the deficiency of forbs may cause browse to be a more substantial part of their diets in the semi-arid regions of South Texas.

Contrary to studies citing the effectiveness of fire to attract wild and domestic herbivores (Rogers et al. 2004, Vermeire et al. 2004, Wallace and Crosthwaite 2005), I found that the effects from the fire were minimal over time beyond a few months. The drought conditions affecting South Texas during this study had a marked effect on the results and with almost no rain from the end of November in 2005 to the end of March in 2006, the herbaceous vegetation had little chance to continue the initial flush of growth seen in Fall 2005.

The October 2006 trial, a year after the burns, saw an unexpected increase in use of the burned areas by does. There was no change in the weather conditions other than the prevalent drought. The fall peak of the area's bimodal rainfall pattern was ending, which brought less than 40 mm of rainfall. This could possibly explain an increase in use of the patches, but it is likely an artifact of small sample size and also attraction to the water troughs in and around the burned areas.

Deer Distribution during Active Periods

Although deer did not use the burns in greater proportion than their availability on the landscape throughout the entire day, they could be feeding preferentially on the burned patches. White-tailed deer use dense vegetation growth for shelter, escape, and resting cover and the burned areas would likely not provide this habitat. Halls (1984) recommends between 40 to 75% of vegetation cover should be left to provide adequate escape and resting cover for whitetails. These prolonged periods of inactivity could likely skew the results of a habitat utilization study such as this one.

Activity sensors in the collars showed that the deer were most active at dawn and just before dusk, following a typical crepuscular activity pattern (Montgomery 1963).

These activity periods were inversely related to the average seasonal temperature. During Spring and Fall 2006, the average activity level of the deer created a third peak around midnight into the early morning. These peaks were never larger than the dawn and dusk peaks, but they were considerable. However, because this did not occur across all seasons we only evaluated those 2 hours in the morning and evening where all of the seasons indicated an increase in activity. Likely, the majority of foraging and browsing is occurring during these 4 hours each day. Coulombe et al. (2006) tested the accuracy of dual-axis motion-sensors in GPS collars (GPS_2200R) and were unable to distinguish periods of movement from those of feeding, therefore we will not attempt to make a strict distinction between the two activities.

For the first 4 seasons, deer either did not prefer the burned areas or only used them as they were available on the landscape. The last season (Fall 2006) saw the females selecting for the burned patches. However, this was one year later and likely not related to the burns. Thus, it is doubtful that these deer are preferentially feeding on the burned patches.

Effects of Cattle and Vegetation on Deer Distribution

I investigated several reasons that might preclude the deer from preferentially selecting for the areas treated by prescribed burning. Some reasons include whether all of the deer had equal access to the burn patches. Geography and territoriality would affect this and possibly cause some individuals to not have access to the burns. Deer, especially females, tend to live in clearly defined home ranges that will expand, contract and overlap with other deer at various times of the year. Female offspring dispersion has been related to a rose petal shape, in that each generation moves outward from the maternal range and will overlap slightly with the previous and current generation's ranges. Although this is a simplified version of home range dynamics, it is effective in relating the general distribution of matrilineages (Porter et al. 1991, Nelson and Mech 1999). Seasonal ranges averaged 153 ha (n = 27) indicating that the local deer may not have a treated area within their seasonal range, however deer use different areas of their home range during different seasons. Cooper et al. (2006) found that annual ranges for deer on this ranch were 775 ha for does and 651 ha for bucks with access to supplemental feed, thus there was a burn treatment area within the estimated annual range of the local deer population. This was larger than my results, but again I was only examining seasonal and not annual distributions. Cooper et al. (2006) noted that this result was also much larger than what was previously estimated for deer in South Texas (Michael 1956). High, inconsistent variability was seen in both genders by Michael (1956) who observed that doe home ranges varied from about 24 to 137 ha and bucks varied from about 97 to 356 ha.

Cattle were grazed in the pasture and there is evidence that deer may avoid cattle (Cohen et al. 1989, Jenks et al. 1996, Kingery et al. 1996), thus if the cattle are occupying the burn treatments then they may exclude deer from the fresh herbaceous growth. Deer and cattle used different parts of the pasture and at different times. Cooper et al. (In prep) found that deer and cattle were separated by habitat they preferred to use and they were often separated by distances of ≥2 km. Cattle habitually selected roads, fences, their adjacent areas, and sites near and around water. Deer on the ranch avoided roads and utilized the rockier areas of the pasture that cattle tended to avoid. Deer and cattle may compete for food, especially during times of environmental stress (Halls 1984), such as a drought.

When deer and cattle came within close contact (<100 m and 15 min) the distance between them was about 30–60 m (n = 12) before deer moved away. This allows for plenty of room for multispecies use of a 40 ha burn without competition. A smaller burn patch may increase interspecific competition reducing available forage for wildlife, especially white-tailed deer.

The most likely reason for the lack of utilization of the burned areas by deer is that the prescribed burn did not improve the forage that was available. As stated before, a severe drought began soon after the burn treatment in South Texas limiting vegetative regrowth. This semi-arid landscape lacks highly flammable brush found in many Mediterranean climates like California, and high fine fuel loads indispensable to carry fires across the ground. This means that often burns are patchy and inconsistent across the landscape. Shrub density and cover were not significantly different from 2005 to 2006. Also, herbaceous vegetation cover of grasses and forbs declined in both the treatment and control areas. This lack of vegetation response in the treatment areas signifies that there is no nutritional advantage for the deer to feed on the burned areas.

CONCLUSIONS

The prevalent drought conditions and lack of vegetation response to burning resulted in little to no influence, especially for the long-term, on the distribution of white-tailed deer. White-tailed deer favor many plant successional stages (Scifres and Hamilton 1993), and brush management provides an opportunity to provide various types of habitats with different vegetative communities. The interspersion of various habitat and vegetation types provides the animal with enough cover to be protected from abiotic and biotic factors (e.g., extremely hot weather, predators), while earlier successional vegetation types provide access to high-quality forage.

Management Implications

The use of prescribed burns for the improvement of range forage for livestock and wildlife is a very valuable asset. However, utilizing this management tool must be done with the utmost care and diligence to produce the desired outcome. As many suggest (Scifres et al. 1983, Scifres et al. 1985, Hamilton et al. 2004), the use of a detailed Integrated Brush Management System (IBMS) is essential to efficient and effective achievement of goals. Many factors must be considered when designing an IBMS, but the rewards are typically a better result than haphazard planning for brush management. An effective way to possibly increase the effectiveness of fire in this ecosystem would be the use of a mechanical roller-chopper to knock down brush and use it to supplement or provide the entire fuel load for a prescribed burn. Once this debris is dry it should provide an adequate source to fuel the fire.

Another limitation of prescribed burning on semi-arid rangeland is the unpredictable, intermittent rainfall that may allow for excellent fine fuel loads, but may also give rise to unpredictable drought conditions causing the local or state officials to enact a burn ban. This effectively halts any hope of using a prescribed burn until rainfall permits it, but at this point it is typically too wet or other weather conditions may not be right. Also, areas with a nearby community may encounter opposition when trying to implement a burn. In South Texas this may not seem to be a problem with such large ranches, but smoke and its effects travel long distances. Also, the lack of rainfall after a successful burn will lead to minimal regrowth of vegetation and thus little advantage to the land manager.

To summarize, the use of prescribed burning as a management tool on semi-arid rangeland may not always be successful or applicable to certain situations due to climatic and social constraints. When prescribed burning is implemented it can have an effect on white-tailed deer distribution and habitat use, for better or worse, however, the longevity of these effects is minimal and dependent on the amount of precipitation after the burn. When treatment areas are larger than about 10,000 m^2 (1 ha), interspecific competition between sympatric cattle and white-tailed deer is minimized and practically eliminated. However, intraspecific competition may still be a factor for both species and steps should be taken to monitor and manage deer numbers as well as responsible stocking of livestock to reduce continued overgrazing and allowing the fine fuels to accumulate.

LITERATURE CITED

Anderson, R. C., and A. J. Katz. 1993. Recovery of browse-sensitive tree species following release from white-tailed deer *Odocoileus virginianus* Zimmerman browsing pressure. Biological Conservation 63:203–208.

Archer, S. R. 1989. Have southern Texas savannas been converted to woodlands in recent history? The American Naturalist 134:545–561.

Archer, S. R., C. J. Scifres, C. R. Bassham, and R. C. Maggio. 1988. Autogenic succession in a subtropical savanna: conversion of grassland to thorn woodland. Ecological Monographs 58:111–127.

Armstrong, B. 2005. Integrating cool-season prescribed burns into a total range livestock and wildlife management program. Pages 17–19 *in* C. G. Brown, and D. Rollins, editors. Proceedings of Fire as a tool for managing wildlife habitats in Texas. Texas Cooperative Extension–San Angelo, 14–16 September 2005, Kerrville, Texas, USA.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John Wiley and Sons, New York, New York, USA.

Brockway, D. G., and C. E. Lewis. 2003. Influence of deer, cattle grazing and timber harvest on plant species diversity in a longleaf pine bluestem ecosystem. Forest Ecology and Management 175:49–69.

Chamrad, A. D., and T. W. Box. 1968. Food habits of white-tailed deer in south Texas. Journal of Range Management 21:158–164.

Cohen, W. E., D. L. Drawe, F. C. Bryant, and L. C. Bradley. 1989. Observations of white-tailed deer and habitat response to livestock grazing in south Texas. Journal of Range Management 42:361–365.

Cook, O. F. 1908. Change of vegetation on the south Texas prairies. U.S. Department of Agriculture, Bureau of Plant Industry Circular. 14. 7 pp.

Cooper, S. M., M. K. Owens, R. M. Cooper, and T. F. Ginnett. 2006. Effect of supplemental feeding on spatial distribution and browse utilization by white-tailed deer in semi-arid rangeland. Journal of Arid Environments 66:716–726.

Cooper, S. M., H. L. Perotto, M. G. Meek, M. Figueroa-Pagan, and M. K. Owens. In prep. Multiple scale analysis of interactions between white-tailed deer and cattle in a semi-arid grazing system. Agriculture, Ecosystems and Environment.

Coulombe, M.-L., A. Masse, and S. D. Cote. 2006. Quantification and accuracy of activity data measured with VHF and GPS telemetry. Wildlife Society Bulletin 34:81–92.

deCalesta, D. S. 1994. Effect of white-tailed deer on songbirds within managed forests in Pennsylvania. Journal of Wildlife Management 58:711–718.

Depew, J. J. 2004. Habitat selection and movement patterns of cattle and white-tailed deer in a temperate savanna. Thesis, Texas A&M University, College Station, USA.

Doenier, P. B., G. D. DelGiudice, and M. R. Riggs. 1997. Effects of winter supplemental feeding on browse consumption by white-tailed deer. Wildlife Society Bulletin 25:235–243.

ESRI. 2005. Environmental Systems Research Institute, Inc. Version 9.1. Redlands, California, USA.

Frair, J. L., S. E. Nielsen, E. H. Merrill, S. R. Lele, M. S. Boyce, R. H. M. Munro, G. B. Stenhouse, and H. L. Beyer. 2004. Removing GPS collar bias in habitat selection studies. Journal of Applied Ecology 41:201–212.

Fulbright, T. E., and J. A. Ortega-S. 2006. White-tailed deer habitat: ecology and management on rangelands. Texas A&M University Press, College Station, USA.

Gitzen, R. A., J. J. Millspaugh, and B. J. Kernohan. 2006. Bandwidth selection for fixed-kernel analysis of animal utilization distributions. Journal of Wildlife Management 70:1334–1344.

Gould, F. W. 1975. The grasses of Texas. Texas A&M University Press, College Station, USA.

Halls, L. K., editor. 1984. White-tailed deer: ecology and management. Stackpole, Harrisburg, Pennsylvania, USA.

Hamilton, W. T., A. McGinty, D. N. Ueckert, C. W. Hanselka, and M. R. Lee, editors. 2004. Brush management: past, present, future. First edition. Texas A&M University Press, College Station, USA.

Hooge, P. N., and B. Eichenlaub. 1997. Animal movement extension to ArcView. Version 2.0. Alaska Science Center–Biological Science Office, U.S. Geological Survey, Anchorage, USA.

Inglis, J. M., R. E. Hood, B. A. Brown, and C. A. DeYoung. 1979. Home range of white-tailed deer in Texas coastal prairie brushland. Journal of Mammalogy 60:377–389.

Jenks, J. A., D. M. Leslie, Jr., R. L. Lochmiller, M. A. Melchiors, and F. T. M. III. 1996. Competition in sympatric white-tailed deer and cattle populations in southern pine forests of Oklahoma and Arkansas, USA. Acta Theriologica 41:287–306.

Jennrich, R. I., and F. B. Turner. 1969. Measurement of non-circular home range. Journal of Theoretical Biology 22:227–237.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Kingery, J. L., J. C. Mosley, and K. C. Bordwell. 1996. Dietary overlap among cattle and cervids in northern Idaho forests. Journal of Range Management 49:8–15.

Lotek. 2006. Lotek Wireless, Inc. Newmarket, Ontario, Canada.

Mayeux, H. S., H. B. Johnson, and H. W. Polley. 1991. Global climate change and vegetation dynamics. Pages 62–74 *in* L. F. James, J. D. Evans, H. H. Ralphs, and R. D. Child, editors. Noxious Range Weeds. Westview, Boulder, Colorado, USA.

Michael, E. D. 1956. Movements of white-tailed deer on the Welder Wildlife Refuge. Journal of Wildlife Management 29:44–52.

Minnesota Department of Natural Resources. 2007 Jan 1. ArcView Resources: Minnesota DNR. <http://www.dnr.state.mn.us/mis/gis/tools/arcview/index.html>. Accessed 1 March 2007.

Montgomery, G. G. 1963. Nocturnal movements and activity rhythms of white-tailed deer. Journal of Wildlife Management 27:422–439.

National Geodetic Survey, Continuously Operating Reference Stations. 2007 March 1. CORS - Continuously Operating Reference Stations. <http://www.ngs.noaa.gov/CORS/>. Accessed 1 March 2007.

Nelson, M. E., and L. D. Mech. 1999. Twenty-year home-range dynamics of a white-tailed deer matriline. Canadian Journal of Zoology 77:1128–1135.

Newman, A. L., J. W. Stevens, T. J. Holder, and D. Arriaga. 1967. Soil survey of Kinney County, Texas. U.S. Soil Conservation Service (*now* Natural Resources Conservation Service), Washington, D.C., USA.

Ortega, I. M., S. Soltero-Gardea, F. C. Bryant, and D. L. Drawe. 1997. Evaluating grazing strategies for cattle: deer and cattle food partitioning. Journal of Range Management 50:622–630.

Owens, M. K., J. W. Mackley, and C. J. Carroll. 2002. Vegetation dynamics following seasonal fires in mixed mesquite/acacia savannas. Journal of Range Management 55:509–516.

Pellerin, S., J. Huot, and S. D. Cote. 2006. Long term effects of deer browsing and trampling on the vegetation of peatlands. Biological Conservation 128:316–326.

Porter, W. F., N. E. Mathews, H. B. Underwood, R. W. Sage, and D. F. Behrend. 1991. Social organization in deer: implications for localized management. Environmental Management 15:809–814.

Rogers, J. O., T. E. Fulbright, and D. C. Ruthven, III. 2004. Vegetation and deer response to mechanical shrub clearing and burning. Journal of Range Management 57:41–48.

Rossell, C. R., B. Gorsira, and S. Patch. 2005. Effects of white-tailed deer on vegetation structure and woody seedling composition in three forest types on the Piedmont Plateau. Forest Ecology and Management 210:415–424.

Russell, F. L., D. B. Zippin, and N. L. Fowler. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations and communities: a review. The American Midland Naturalist 146:1–26.

Ruthven, D. C., III, J. F. Gallagher, and D. R. Synatzske. 2000. Effect of fire and grazing on forbs in the western South Texas Plains. The Southwestern Naturalist 45:89–94.

Schacht, W. H., J. Stubbendieck, T. B. Bragg, A. J. Smart, and J. W. Doran. 1996. Soil quality response of reestablished grasslands to mowing and burning. Journal of Range Management 49:458–463.

Scifres, C. J., and W. T. Hamilton. 1993. Prescribed burning for brushland management: the south Texas example. First edition. Texas A&M University Press, College Station, USA.

Scifres, C. J., W. T. Hamilton, J. R. Conner, J. M. Inglis, G. A. Rasmussen, R. P. Smith, J. W. Stuth, and T. G. Welch. 1985. Integrated brush management systems for south Texas: development and implementation. Texas Agricultural Experiment Station Bulletin B-1493.

Scifres, C. J., W. T. Hamilton, J. M. Inglis, and J. R. Conner. 1983. Development of integrated brush management systems (IBMS): decision-making processes. Pages 97–104 *in* Proceedings of Brush Management Symposium. Society for Range Management, 16 February 1983, Albuquerque, New Mexico, USA.

Stevens, J. W., and D. L. Richmond. 1970. Soil survey of Uvalde County, Texas. U.S. Soil Conservation Service (*now* Natural Resources Conservation Service), Washington, D.C., USA.

Taylor, R. B., J. Rutledge, and J. G. Herrera. 1997. A field guide to common south Texas shrubs. University of Texas Press, Austin, USA.

Texas Natural Resources Information Systems. 2006 Sept 25. TNRIS home page. <http://www.tnris.org/>. Accessed 1 Dec 2006.

The Weather Channel. 2007 Oct 10. Average weather for Uvalde, TX–temperature and precipitation. <http://www.weather.com/>. Accessed 9 Oct 2007.

U.S. Naval Observatory Astronomical Applications Department. 2007 January 26. USNO AAD home page. <http://aa.usno.navy.mil/>. Accessed 24 April 2007.

Van Winkle, W. 1975. Comparison of several probabilistic home-range models. Journal of Wildlife Management 39:118–123.

Vermeire, L. T., R. B. Mitchell, S. D. Fuhlendorf, and R. L. Gillen. 2004. Patch burning effects on grazing distribution. Journal of Range Management 57:248–252.

Wallace, L. L., and K. A. Crosthwaite. 2005. The effect of fire spatial scale on *Bison* grazing intensity. Landscape Ecology 20:337–349.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168.

Wright, B. D., R. K. Lyons, J. C. Cathey, and S. Cooper. 2002. White-tailed deer browse preferences for south Texas and the Edwards plateau. Texas Cooperative Extension. B–6130. 7 pp.

Wright, H. A., and A. W. Bailey. 1982. Fire Ecology. John Wiley and Sons, New York, New York, USA.

Wyse, L., and C. G. Anderson. 2000. Estimated value of agricultural production and related items, 1996–1999, 2000 projected. Texas Agricultural Extension Service, The Texas A&M University System.

APPENDIX A

CATMOD RESULTS

Table A–1. Categorical data modeling analysis (SAS PROC CATMOD) of deer hourly fixes in and out of the burns.

Trial	df	χ^2	*P*
1, 2, 3, 4, 5	4	392.99	≤0.001
Gender	1	76.37	≤0.001
Likelihood Ratio	4	379.13	≤0.001
1 & 2	1	121.69	≤0.001
Gender	1	0.55	0.459
Likelihood Ratio	1	39.69	≤0.001
1 & 3	1	0.15	0.694
Gender	1	8.13	0.004
Likelihood Ratio	1	28.00	≤0.001
1 & 4	1	2.19	0.139
Gender	1	0	0.953
Likelihood Ratio	1	73.53	≤0.001
1 & 5	1	156.60	≤0.001
Gender	1	259.32	≤0.001
Likelihood Ratio	1	27.78	≤0.001
2 & 3	1	115.17	≤0.001
Gender	1	8.88	0.003
Likelihood Ratio	1	0	0.986
2 & 4	1	146.01	≤0.001
Gender	1	26.34	≤0.001

Table A–1. Continued.

Trial	df	χ^2	*P*
Likelihood Ratio	1	19.25	≤0.001
2 & 5	1	3.38	0.066
Gender	1	122.85	≤0.001
Likelihood Ratio	1	249.28	≤0.001
3 & 4	1	3.49	0.062
Gender	1	26.82	≤0.001
Likelihood Ratio	1	14.04	≤0.001
3 & 5	1	149.77	≤0.001
Gender	1	190.38	≤0.001
Likelihood Ratio	1	143.39	≤0.001
4 & 5	1	181.52	≤0.001
Gender	1	155.42	≤0.001
Likelihood Ratio	1	231.51	≤0.001

APPENDIX B

CLASSIFICATION OF SHRUBS

Table B–1. Shrub species of South Texas that are and are not preferred for forage by white-tailed deer.

Palatability	Code	Scientific Name	Common Name
Not Preferred	Algr	*Aloysia gratissima*	Whitebrush
	Cate	*Castela texana*	All-thorn
	Cela	*Celtis laevigata*	Sugar hackberry
	Cosp	*Condalia spathulata*	Knifeleaf condalia
	Dite	*Diospyros texana*	Texas persimmon
	Lama	*Lantana macropoda*	Desert lantana
	Lefr	*Leucophyllum frutescens*	Cenízo
	Lybe	*Lycium berlandieri*	Wolfberry
	Matr	*Mahonia trifoliolata*	Agarito
	Ople	*Mimosa borealis*	Pink mimosa
	Pala	*Pavonia lasiopetala*	Rock rose
	Rhmi	*Rhus microphylla*	Littleleaf sumac
	Saba	*Salvia ballotiflora*	Shrubby blue sage
	Sose	*Sophora secundiflora*	Mountain laurel
	Ulcr	*Ulmus crassifolia*	Cedar elm
	Yuco	*Yucca constricta*	Buckley yucca
Preferred	Acbe	*Acacia berlandieri*	Guajillo
	Acgr	*Acacia greggii*	Catclaw acacia
	Acri	*Acacia rigidula*	Blackbrush acacia
	Cepa	*Celtis pallida*	Spiny hackberry

Table B–1. Continued.

Palatability	Code	Scientific Name	Common Name
	Coho	*Condalia hookeri*	Brasil
	Cote	*Colubrina texensis*	Hogplum
	Dite	*Diospyros texana*	Texas persimmon (fruit)
	Epan	*Ephedra antisyphilitica*	Ephedra
	Guan	*Guaiacum angustifolium*	Guayacan
	Opli	*Opuntia lindheimeri*	Texas pricklypear
	Prgl	*Prosopis glandulosa*	Honey mesquite
	Quvi	*Quercus virginiana*	Live oak
	Rhla	*Rhus lanceolata*	Prairie flameleaf sumac
	Sccu	*Schaefferia cuneifolia*	Desert yaupon
	Ziob	*Zizyphus obtusifolia*	Lotebush

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