COMPARISON OF FINE SCALE VEGETATIVE PARAMETERS AT ACTIVE AND INACTIVE GULF COAST KANGAROO RAT BURROW SITES

by

Meagan Marie Bell, B.S.

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Committee Members:

Thomas R. Simpson, Chair

Joseph Veech

Todd Swannack

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ABSTRACT

The Gulf Coast kangaroo rat (*Dipodomys compactus*) is an endemic Texas species belonging to the family Heteromyidae. Many heteromyid species, especially kangaroo rats, are highly specialized nocturnal granivorous rodents with external fur lined cheek pouches, bipedal cursorial locomotion, and adaptations for arid and desert conditions. Despite being one of six Texas endemic mammals, few studies have been conducted on habitat requirements, movement, and basic ecology of the Gulf Coast kangaroo rat with no long-term research. From April 2016 to March 2017, I have seasonally monitored burrowing activity of Gulf Coast kangaroo rats and recorded vegetative parameters at 63 randomly selected sites on a working cattle and wildlife ranch located in Guadalupe County, Texas. Sites with active burrows or a history of occupancy were monitored monthly. Within a 10-m radius plot at each site and using the Daubenmire frame cover estimate technique, I recorded percent cover of the following cover classes: bare ground, standing dead vegetation, litter, living grass, and living forbs. Additionally, I identified to the lowest taxonomic level the dominant live green grass and forb species in each Daubenmire frame and recorded the height of the tallest live grass, live forb, and standing dead vegetation. Using a spherical densitometer, I determined the percent woody canopy coverage at each Daubenmire frame. Twenty-two of 63 sites were occupied. Using Nested ANOVA, I found significantly greater cover of litter, taller standing dead, and taller grass ($p < 0.001$) at unoccupied sites, while percent cover of forbs, percent cover of bare ground, and distance to the nearest woody canopy was significantly greater ($p <$

0.001) at occupied sites. Using AICc model selection, the favored logistic model to predict the probability of site occupancy was positively influenced by percent bare ground and forb coverage. Percent woody canopy cover, litter, and grass negatively affected this probability of Gulf Coast kangaroo rat occupancy. This model can aid with future efforts to determine areas to protect Gulf Coast kangaroo rats or other similar species. Comparing the dominant plants at occupied and unoccupied sites, I found greater percentages of plantain (*Plantago spp*.), rosette grass (*Dichanthelium spp*.), paspalum (*Paspalum spp*.), sand bur (*Cenchrus spinifex*), and hogwort (*Croton capitatus*) at occupied sites. Except for plantain, these large seeded species are known colonizers of disturbed habitats and which may offer rich food sources. Together, these results suggest Gulf Coast kangaroo rats select for open disturbed areas, supporting plants that produce relatively large seeds that are easily extracted from sandy soils.

I. INTRODUCTION

The Gulf Coast kangaroo rat (*Dipodomys compactus*) is an endemic Texas species belonging to the family Heteromyidae (Vaughan et al. 1957, Schmidly 2004, Linzey and Hammerson 2008, Schmidly and Bradley 2016). Many heteromyid species, especially kangaroo rats, are highly specialized nocturnal granivorous rodents with external fur lined cheek pouches, bipedal cursorial locomotion, and adaptations for desert like conditions (Vaughan et al. 1957). Gulf Coast kangaroo rats are medium-sized five-toed kangaroo rats considered to be one of the most "primitive" (Baumgardner 1991) heteromyid rodents based on teeth morphology (Bailey 1905, Jannett 1976, Schmidly 2004, Schmidly and Bradley 2016). First described by True (1889), the taxonomic status of the Gulf Coast kangaroo rat and its relationship with Ord's kangaroo rat (*D. ordii*) has been debated until 1981 when it was classified as an independent species (Bailey 1905, Grinnell 1921, Davis 1942, Setzer 1949, Hall 1951, Johnson and Selander 1971, Stock 1974, Schmidly and Hendricks 1976, Baumgardner and Schmidly 1981, Baumgardner 1991). Despite being one of six Texas endemic mammals, few studies have been conducted on habitat requirements, movement, and basic ecology of the Gulf Coast kangaroo rat (Schmidly 2004, Rissel 2011, Oakley 2012, Phillips 2012, Schmidly and Bradley 2016).

Due to their burrowing and nocturnal activities, Gulf Coast kangaroo rats are an inconspicuous species. Because of the difficulty studying this species and prior classification confusion with Ord's kangaroo rat, few studies have focused on Gulf Coast kangaroo rats, resulting in a lack of knowledge about their life history and ecological requirements (Baumgardner 1991, Rissel 2011, Oakley 2012, Phillips 2012). Texas Parks and Wildlife Conservation Action Plan lists Gulf Coast kangaroo rats as vulnerable because the species occupies coastal areas subject to large anthropogenic changes (TPWD 2005). Furthermore, the inland population also occupies agriculture areas affected by anthropogenic changes, which could further jeopardize this species' survival (Heske and Campbell 1991, Oakley 2012, Phillips 2012). By understanding the ecological requirements of the species and which habitat requirements are compatible with certain agriculture and ranching operations, biologists could assist land owners in the preservation of the species. Such action then might preclude the need to add a species to the federal list (TPWD 2005, United States Fish and Wildlife Service 2017). Finally, more ecological studies of Gulf Coast kangaroo rats will add to our general knowledge on heteromyids and could possibly aid in the determination of the best management of other species of kangaroo rats.

Distribution of the Gulf Coast kangaroo rat extends from Mustang and Padre islands inland and westward to the Rio Grande river, and northward to Bexar, Gonzales, and Guadalupe counties (Schmidly 2004, Linzey and Hammerson 2008, Schmidly and Bradley 2016, Fig. 1). Two subspecies are recognized, *D. c. compactus* on the barrier islands and *D. c. senneti* on the mainland (Baumgardner 1991). *D. c. compactus* inhabits large, barren slopes in shifting sand dune environments (Schmidly 2004, Linzey and Hammerson 2008, Rissel 2011), while the mainland subspecies, *D. c. senneti*, favors burrowing in bare, disturbed, and overgrazed areas with little tree canopy cover, leaf litter, and herbaceous vegetation (Oakley 2012, Phillips 2012).

Figure 1. Distribution of Gulf Coast kangaroo rats. The counties shaded as gray represent the distribution of the Gulf Coast kangaroo rat (Schmidly and Bradley 2016).

Environmental characteristics such as vegetation, climatic conditions, competition, and predation can affect the distribution of kangaroo rats. Baumgardner and Schmidly (1985) stated that when Ord's kangaroo rats and Gulf Coast kangaroo rats occurred in the same location, Gulf Coast kangaroo rats persisted on open loose soils while Ord's kangaroo rats occurred on compacted soils with greater vegetative cover. This observation suggests that Gulf Coast kangaroo rats are better adapted to sparsely vegetated, disturbed locations (Baumgardner and Schmidly 1985). Additionally, Gulf Coast kangaroo rats, Ord's kangaroo rats, Phillips' kangaroo rat (*D. philipsii*), Desert kangaroo rats (*D. deserti*), and Heermann's kangaroo rats (*D. heermanni*) appear to prefer open, barren, sandy environments as an early successional species (Jones and Genoways 1975, Kelt 1988, Best et al. 1989, Garrison and Best 1990, Baumgardner 1991, Schmidly 2004).

Nevertheless, most research about habitat requirements of heteromyids has focused on kangaroo rats other than Gulf Coast kangaroo rats. Studies comparing lightly disturbed or undisturbed pastures to heavily grazed, open pastures found that Merriam's kangaroo rats (*D. merriami*), Panamint kangaroo rats (*D. panamintinus*), Santa Cruz kangaroo rats (*D. venustus*), and Texas kangaroo rats (*D. elator)* had higher abundances in grazed locations or areas recently disturbed (Hawbecker 1940, Bock et al. 1984, Intress and Best 1990, Best 1992, Hayward et al. 1997, Goetze 2005). Hallett (1982) found that Ord's kangaroo rats and Merriam's kangaroo rats occurred only in open and edge habitat where they overlapped with quadrupedal rodents, rather than in closed-canopy shrub land habitat. A dietary study in New Mexico also found that Ord's kangaroo rats occurred predominately in open and edge habitats based on fecal samples containing chemically marked seeds from these locations (Lemen and Rosenweig 1978). Overall, few studies to date have investigated the habitat characteristics of Gulf Coast kangaroo rats.

Kangaroo rats, including the Gulf Coast kangaroo rats, are mostly nocturnal species impacted by lunar cycles, taking advantage of low light to evade predators and decrease water loss in an arid climate (Vaughan et al. 1957, Kennedy et al. 1973, Kaufman and Kaufman 1982, Phillips 2012). Brown et al. (1988) investigated the effect of owls and moonlight cues on Merriam's kangaroo rats and Banner-tail kangaroo rats (*D. spectabilis*) and found that both species utilized open canopy habitats when owls were absent and shrub-land edge habitat when owls were present, regardless of light cues. Sparsely vegetated areas in both habitats enabled kangaroo rats, with their large auditory bullae and bipedal locomotion, to evade predators more efficiently than in thick ground cover, which can impeded their locomotion (Lemen and Rosenweig 1978, Thompson 1982, Brown et al. 1988, Longland and Price 1991, Pierce et al. 1992). Using moonlight as an indicator for predation risk, Kotler (1984) and Bowers (1988) also found that Merriam's kangaroo rats decreased their foraging time and altered their seed selection type during higher lunar illumination periods than lower illumination phases. Therefore, the risk of predation might alter the habitat and foraging activities of Gulf Coast kangaroo rats.

Habitat selection and use by kangaroo rats may also be influenced by dietary preferences. Although kangaroo rats consume herbaceous material, they are predominately granivorous because of the high-energy content, increased metabolic water production, and long term viability found in seeds (Vaughan et al. 1957, Flake 1973, Reichman 1975, Schmidly 2004). Research on seed size preferences for different heteromyid rodents found a positive correlation between heteromyid mean body weight and mean seed size, following the optimal foraging theory (Brown and Lieberman 1973). Henderson (1990) noted that longer seeds that were higher in protein content were the most important predictors of seed preference for Ord's kangaroo rats. This suggests that diet might influence which areas are occupied by kangaroo rats, including Gulf Coast kangaroo rats (Brown and Lieberman 1973, Brown et al. 1979).

In a seed and soil patch experiment on wild caught and captive rodents, Merriam's kangaroo rats harvested significantly more seeds from patches with fine, light soils (Price and Waser 1985). Merriam's kangaroo rats also preferred areas with fine, light soil patches in both open and closed environments (Price and Waser 1985). In a natural environment, open spaces, regardless of opening size, had significantly finer, denser soils than those of edge habitats (Price and Waser 1985). Thus, kangaroo rats' foraging efficiency in extracting seeds that are heavy and large might influence their usage of open habitats with light and fine soils (Thompson 1982, Price 1983, Price and Heinz 1984, Price and Waser 1985).

Due to inconspicuous nature of this Texas endemic mammal, modeling the likelihood of the presence or absence of Gulf Coast kangaroo rats is vital to determining best management practices to preserve its critical habitat (Andersen and Beauvais 2013). Bender et al. (2010) used a Resource Selection Function model based on two years of occurrence of Ord's kangaroo rat with slope, elevation, proximity to rivers, sandy environment and sparsely vegetated areas to derive a predictive occurrence map of Ord's kangaroo rat. In following years, this map was verified by post population monitoring in those predicted areas (Bender et al. 2010). However, researchers have not considered modeling habitat conditions for the abandonment and re-establishment of Gulf Coast kangaroo rat burrows for extended periods of time, including microhabitat and foraging requirements.

In this study, I gathered monthly data on occupancy and burrow placement, paired with data on fine scale temporal changes in habitat parameters, including vegetative, species of grasses and forbs, and other changes. I conducted this study to determine the relationships between these seasonal changes in vegetation and microhabitat characteristics with changes in the distribution of active and inactive burrows. My objectives were: a) to record and compare fine-scale microhabitat factors present at sites occupied and unoccupied by Gulf Coast kangaroo rats, b) to construct a model predicting the likelihood of site occupancy by Gulf Coast kangaroo rats based on microhabitat factors, c) record and compare dominant plant species at sites occupied and unoccupied by Gulf Coast kangaroo rats, and d) observe changes in Gulf Coast kangaroo rats occupancy and activity over time. I expected Gulf Coast kangaroo rats to be present at open disturbed sites with sparse vegetation and open canopy cover. I also expected Gulf Coast kangaroo rats to occur in areas with large seed producing native grasses and forbs; however, I did not anticipate there to be a difference in Gulf Coast kangaroo rats preference between native and invasive vegetation due to their preference for heavily grazed locations, which typically promotes more invasive species. I expected the occurrence of Gulf Coast kangaroo rats to change rapidly based on the weather, cattle rotation, seasonal plant community changes, and various natural and anthropogenic disturbances.

II. MATERIALS AND METHODS

Study Area

Diamond Half Ranch (29.429 N, 97.951 W) in Guadalupe County, Texas, is a 2,303 ha working cattle ranch with a judgement deferred grazing system in which cattle are rotated based on quality and quantity of grass. The ranch also manages for wildlife and conducts a white-tailed deer hunting program in the fall and winter. Many disturbance factors are ongoing on the ranch that may affect the presence and activities of Gulf Coast kangaroo rats, including cattle grazing, chicken offal fertilizing operations, and seismograph and oil production activity. Dominant soils in order of prevalence on the property are Patilo and Arenosa soil (PaD), Arenosa fine sand (ArD), Nebgen-Jedd complex (NcF), Demona loamy fine sand (DmC), and Winthorst fine sandy loam (WdC3), with some water (United States Department of Agriculture: Web Soil Survey, http://websoilsurvey.sc.egov.usda.gov, accessed 10th June 2016). See Table 1 for a more complete description of the soil composition. Based on preliminary surveys, dominant herbaceous plants are bermudagrass (*Cynodon dactylon*), little bluestem (*Schizachyrium soparium*), hogwort (*Croton capitatus*), lazy daisy (*Aphanostephaus spp.*), and rosette grass (*Dicanthelium spp.*). The dominant woody vegetation is post oak (*Quercus stellata*), Texas persimmon (*Diospyros texana*), agarita (*Mahonia trifoliolata*), prickly pear (*Opuntia spp.*), and tasajillo (*Cylindropuntia leptocaulis*).

Table 1. Soil types found at Diamond Half Ranch. This includes composition, profile, and percentage of site (United States Department of Agriculture: Web Soil Survey, http://websoilsurvey.sc.egov.usda.gov. accessed 10th June 2016).

Soil Type	Percent Slope	Number of Hectares	Percentage
ArD	1-8 %	271.6	12.0%
DmC	1-5%	39.9	1.8%
NcF	3-20%	62.7	2.8%
PaD	1-8%	1850.8	81.7%
W	-	1.5	0.1%
WdC3	1-5% (eroded)	38.2	1.7%
Totals		2264.7	100.0%

Sampling Procedures

I collected data from April 2016 to April 2017. During this year, Texas was affected by a natural weather phenomenon, the El Niño - Southern Oscillation (ENSO, GHCND: USC00416368; National Oceanic and Atmospheric Administration: National Climatic Data Center, (https://www.ncdc.noaa.gov/), accessed March 26, 2017). A weather station near Diamond Half Ranch recorded mild maximum (28.03° C) and minimum (14.53° C) temperatures, close to climatic averages (26.20° C, 14.02° C), over the course of the study with a total of 126.21 cm of rainfall, 36.29 cm over the normal (89.92 cm, Fig. 2, Appendix A.1).

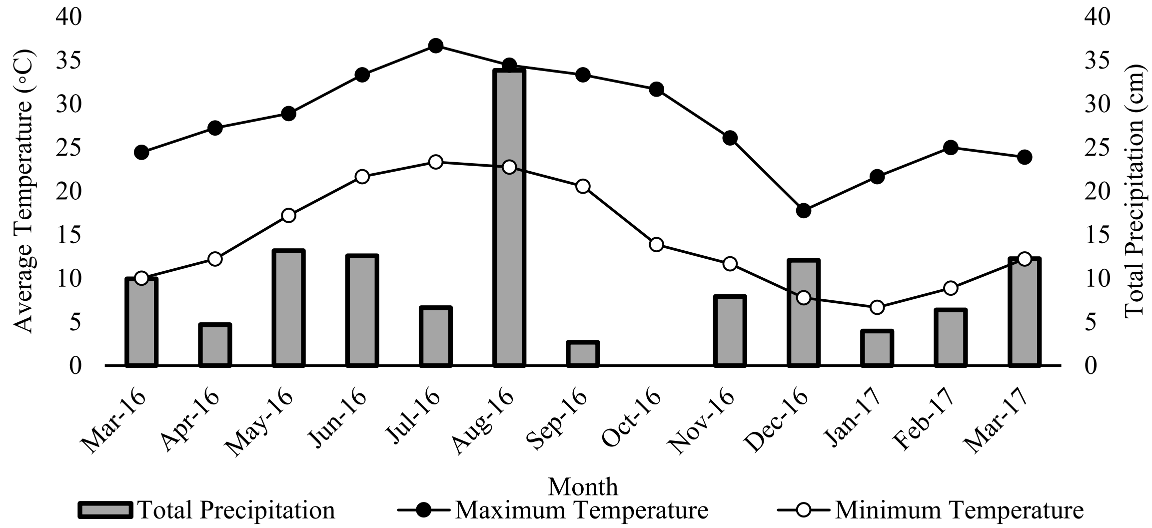

Figure 2. Monthly climatic data at Diamond Half Ranch. The bars represent the total precipitation received each month, referring to the right y-axis. The lines represent the maximum and minimum temperatures (°C), referring to the left y-axis. These data were obtained from a weather station in Nixon, Texas (GHCND: USC00416368; National Oceanic and Atmospheric Administration: National Climatic Data Center, (https://www.ncdc.noaa.gov/), accessed March 26, 2017).

I used 55 of the 60 original Global Positioning System (GPS) points randomly selected by Oakley (2012), five could not be used due to property boundary changes. To increase the sample size, I added additional sites in recently cleared areas, along roadways, and pastures around the ranch, bringing the number to 63 points (Fig. 3). A site was defined as the area within a 10 m radius circle centered at each GPS point by a permanent stake. I measured and recorded seasonal vegetative data at three month intervals at the 63 sites. This amounted to 19,792 m^2 areas measured. I classified sites as occupied if Gulf Coast kangaroo rat burrows were found at any time during surveys within 10 m; I classified all other sites as unoccupied. Active burrows were readily recognizable by the lack of spider webs and debris blocking the entrance, the presence of tail drag marks, and cut vegetation near the burrow entrances (Cooper and Randall 2007). I used burrows as an indicator for Gulf Coast kangaroo rat presence and the number of active burrow openings per active site as an effective way to non-invasively monitor Gulf Coast kangaroo rat activity. To further analyze occupied sites, I sub-classified occupied sites each month as active or inactive based on the activity status of Gulf Coast kangaroo rat burrows within a 10 m radius circle centered on the GPS point. I recorded vegetative data monthly at these active or inactive sites.

At each of the sites, I recorded data within four quarters (divided by cardinal directions) of a 10 m radius circle centered on a permanent stake placed at the GPS coordinate. Using the Daubenmire frame technique (Daubenmire 1959), I randomly placed two frames in each quarter and one frame at the center of the circle. In these frames, I assessed the percent cover of the following cover classes: bare ground, standing dead vegetation, litter, living grass, and living forbs (Daubenmire 1959). Additionally, I identified to the lowest taxonomic level possible the dominant live green grass and forb species in each Daubenmire frame and recorded the height of the tallest live grass, live forb, and standing dead vegetation. Using a spherical densitometer, I determined the percent woody canopy coverage at a random Daubenmire frame in each quarter and the center frame (Lemmon 1956). From the center point, I measured the distance to the nearest woody canopy cover for each quarter. All the vegetative data were averaged for each site for each survey time period.

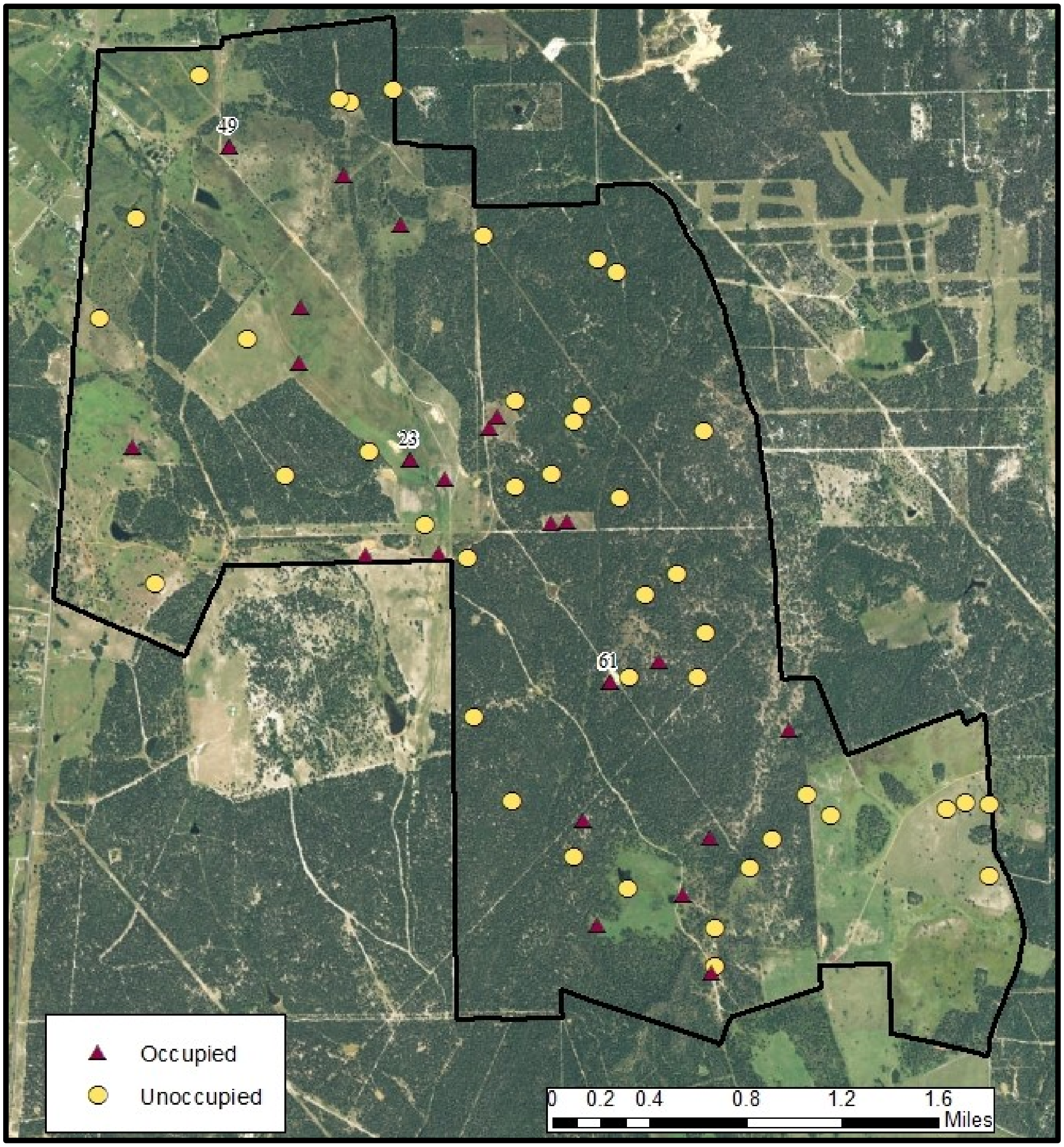

Figure 3. Map of the 63 sites across Diamond Half Ranch. The maroon triangles represent the 22 occupied sites. The yellow circles represent the 41 unoccupied sites. The labels represent points that are further discussed in the following text.

Within each 10 m radius circle, I also recorded the number and position of active and inactive burrows, the distance to each individual burrow or burrow cluster from the center point, and measured the size of the burrow clusters. I drew the position of burrows and burrow clusters on a circular plot for each site. To obtain a visual perspective of the Gulf Coast kangaroo rats' view of overhead canopy in different habitats, I used the GoPro Hero + to take images from the kangaroo rat's eye level (GoPro, Inc., San Mateo, CA). The GoPro Hero + has a camera angle of about 17.2 mm.

Statistical Analyses

I performed all statistical analyses in program R (R Version 3.2.5, www.R-Project.org, accessed October 21, 2016, R Core Team 2013) and all spatial analysis in ArcMap (Environmental Systems Research Institute, Inc., Redlands, CA). To assess microhabitat differences between occupied and unoccupied sites and also separately between active and inactive burrow sites, I calculated means, standard error (SE), and 95% confidence intervals (CI) of microhabitat parameters.

To more closely approximate the normal distribution, the percent cover of bare ground, litter, grass, forbs, and standing dead vegetation were arcsine transformed (Sokal and Rohlf 1984). To control for Type I error, I used a one-way multivariate analysis of variance (MANOVA) to determine if microhabitat variables differed between occupied and unoccupied points for each season and the entire year. The occupied and unoccupied sites represented a two-level independent factor, while the microhabitat parameters represented the nine dependent variables. Because there were significant results from the MANOVA I proceeded with further significance testing. I used a nested two-factor analysis of variance (ANOVA) to test for differences between occupied and unoccupied sites for each microhabitat parameter separately and to test for differences among seasons and differences between the occupied and unoccupied sites within each season.

To determine the probability of any location being occupied (containing burrows at least once over the course of a year), I used a logistic regression analysis. Logistic regression serves as the most appropriate model due to the categorical-binary nature of the response variable, "occupied" or "unoccupied" (Crawley 2007, Zuur et. all 2009). Logistic regression provides the probability that a given site is occupied (has a burrow) based upon its particular combination of microhabitat variables. In this case the closer the value is to one the higher the probability the site is an occupied one, while closer to zero indicates less likely.

To create this logistic regression model, I used information theoretic criteria model selection approach, because I wanted to best approximate this complicated system through a set of possible candidate models created from prior knowledge of ecologically relevant parameters, previously determined (Burnham and Anderson 1998). I chose a total of nine candidate models to compare to one another based on data from all 63 points for each of the four seasons (N = 252). I included woody canopy cover, distance to the nearest canopy cover, or a combination as a predictor variable in every models since Gulf Coast kangaroo rats appear to avoid any woody canopy cover based on field observations and previous studies (Oakley 2012). Additionally, height of vegetation, percent cover of litter, grass, and forb were included in different combinations due to their observed avoidance possibly due to the vertical and horizontal cover that can hinder their activity (Oakley 2012). Lastly, I included percent ground coverage in majority of the models due to its inverse relation with the previous stated variables and the selection of areas by Gulf Coast kangaroo rats containing this factor (Oakley 2012).

I used Akaike information criterion corrected for small sample size (AIC_c) model selection approach to determine the best model that described the variability in the data. When the sample size is small with respect to the number of parameters ($n / K < 40$, n = sample size, K = number of parameters), Burnham and Anderson (1998) recommended AIC_c which corrects the information criterion value with a larger penalty. I used the ΔAIC_c cutoff values to rank candidate models in which an ΔAIC_c of 0 to 2 means the models are competing. If a model has an ΔAIC_c from 4 to 7 than there is weak evidence for that model to fit the data; however if a model has a ΔAIC_c greater than 10 then there is little to no evidence for that model to fit the data in comparison to the other models (Burnham and Anderson 1998, Crawley 2007). I used the likelihood ratio test to determine how well the chosen model fits the data (Crawley 2007). To show how well the chosen logistic regression model may predict the response variable or the strength of the fit, I used Nagelkerke R^2 (Nagelkerke 1991). The closer the value is to one the better the strength of the fit based on the previous likelihood ratio test.

To ascertain whether the model is accurate in predicting site occupancy, I conducted a cross validation. Each season was removed in turn from the dataset and the model was applied to the remaining to obtain predicted values. These were then compared against the actual observed value, using various cutoff values in increments of 0.1. A cutoff value is the value used to separate the range of probability given by the logistic equation into a binary response, occupied or unoccupied. In this case a value less than the cutoff was considered as representing an unoccupied site and a value greater as occupied. Using the ‘caret’ R package, I computed various contingency tables to determine sensitivity and specificity of the model (Kuhn 2008). Sensitivity is probability that the model correctly predicts occupancy, while specificity is the probability that the model correctly predicts unoccupied sites . From the contingency tables, I graphed a receiver operating characteristic curve (ROC) for each season with the area under the curve (AUC) visually demonstrating the relative accuracy of the model to discriminate between occupied and unoccupied sites with each month removed (Hosmer and Lemeshow 2000). Finally, I calculated an optimum cutoff value that gives both the maximum specificity and sensitivity as well as the maximum accuracy (Hosmer and Lemeshow 2000).

To examine the relationship of percent occurrence of forb and grass species with the presence of Gulf Coast kangaroo rats, I selected the five dominant plants at occupied and unoccupied sites for each season. A dominant plant was defined as one of the top five plants with the highest percent occurrence at occupied and unoccupied sites for each season based on field recordings within Daubenmire frames. I defined percent occurrence as the number of times a plant was recorded in a Daubenmire frame out of the total number of frames possible for that site type. Due to overlap in the categories of the top five dominant plants, there were 15 dominant plants for all further plant species analyses. These included plants that were dominant in one or more seasons at either or both occupied and unoccupied sites. To determine similarity of dominant plant species at occupied to unoccupied sites and active to inactive sites, I calculated a simplified Morisita’s index of similarity (Krebs 1999). This index accounted for the proportions of those dominant plant occurrences, ranging from zero (no similarity) to one (complete similarity; Krebs 1999).

III. RESULTS

I classified 34.9% (22) of 63 points as occupied at some time in the year. This included a 6,912 m^2 area surveyed. Nineteen (30.2%) of those were occupied in April 2016, while an additional three (4.8%) became occupied by February 2017. Over the course of the study, the percentage of occupied sites with active burrows declined from 81.8% (18) in April 2016 to a low of 9.09% (2) in September and October 2016. From October 2016 to February 2017, the percentage of active sites increased to 59.09% (13, Fig. 4). Additionally, the number of active burrows per active site, an index of the activity level, followed a similar pattern, with 9.8 active burrows per active site (176/18) in April 2016 declining to only three per active site (6/2) in October 2016 back up to 12 (134/11) in March 2017.

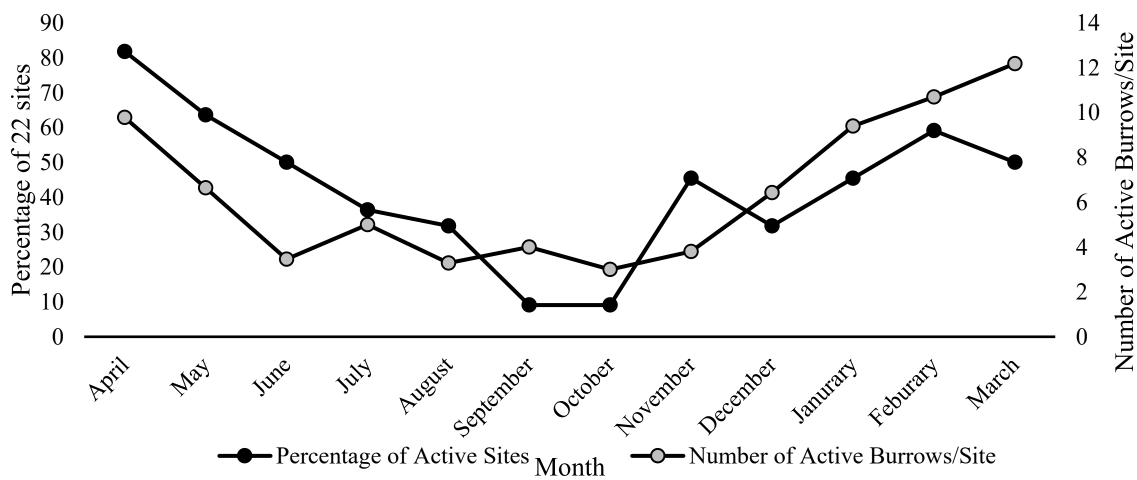

Figure 4. Changing Gulf Coast kangaroo rat activity level. The changing activity level is shown in two different ways. First, the percent of occupied sites with active burrows present (black dots) on the left y-axis. Second, the number of active burrow openings per active site as an index of the activity level (gray dots), on the right y-axis.

Microhabitat Parameters Affecting Occupancy and Activity

Based on 95% confidence intervals, mean percent bare ground, percent forb, and distance to the nearest woody canopy cover were greater at sites occupied by Gulf Coast kangaroo rats (21.48%, 24.91%, 67.31 m, respectively), while percent litter, percent woody canopy cover, and height of tallest grass were greater at unoccupied sites (43.24%, 41.74%, 42.73 cm, respectively; Table 2, Appendix A.2 and A.3). The 95% confidence intervals show sites with active burrows had greater average percent bare ground (25.6%) than inactive sites. At inactive sites, percent grass cover (23.33%), and height of standing dead (24.54 cm) and grass (29.87 cm) were greater. Furthermore, woody canopy cover was greater at inactive sites than at active sites (3.28% vs 0.73%, Table 3, Appendix A.4 and A.5).

Table 2. Means (*M*) of microhabitat parameters at occupied and unoccupied sites with the standard errors (*SE*) and 95 percent confidence intervals (CI) of those means. Bold font designates those microhabitat characteristics with significant differences due to non-overlapping 95% confidence intervals.

	Occupied			**Unoccupied**		
Type	***M***	***SE***	**95 % CI**	***M***	***SE***	**95% CI**
Bare Ground (BG, %)	**21.48**	**1.91**	**17.67-25.28**	**8.92**	**1.14**	**6.67-11.16**
Litter (L, %)	**23.85**	**2.03**	**19.82-27.88**	**43.24**	**1.93**	**39.44-47.05**
Standing Dead (SD, %)	4.49	0.38	3.73-5.26	5.22	0.33	4.56-5.88
Forb (F, %)	**24.91**	**1.79**	**21.35-28.47**	**11.98**	**1.16**	**9.69-14.27**
Grass (G, %)	23.02	1.76	19.52-26.51	26.65	1.67	23.37-29.94
Woody Canopy Cover (WCC, %)	2.45	0.98	0.51-4.39	41.74	2.75	36.31-47.16
Distance Nearest WCC (DNWCC, m)	**67.31**	**6.28**	**54.82-79.80**	**24.84**	**3.19**	**18.53-31.15**
Tallest Standing Dead (SD, cm)	25.15	2.51	20.17-30.14	27.70	1.78	24.17-31.22
Tallest Grass (TG, cm)	**31.14**	**2.49**	**26.19-36.09**	**42.73**	**2.58**	**37.63-47.83**
Tallest Forb (TF, cm)	32.07	1.90	28.28-35.85	35.42	2.10	31.27-39.57

Table 3. Means (*M*) of microhabitat parameters at active and inactive sites with the standard error (*SE*) and the 95 percent confidence intervals (CI) of those means. Bold font designates those microhabitat characteristics with significant differences due to non-overlapping 95% CI.

	Active			Inactive		
Type	***M***	**SE**	**95% CI**	***M***	**SE**	**95% CI**
Bare Ground (BG, %)	**25.60**	**1.45**	**22.72-28.47**	**18.16**	**1.30**	**15.60-20.73**
Litter (L, %)	26.38	1.90	22.61-30.14	28.33	1.79	24.78-31.87
Standing Dead (SD, %)	4.68	0.35	3.99-5.37	4.30	0.25	3.80-4.79
Forb (F, %)	22.42	1.50	19.45-25.40	21.31	1.54	18.27-24.35
Grass (G, %)	**17.76**	**1.06**	**15.66-19.86**	**23.33**	**1.43**	**20.51-26.15**
WCC (%)	**0.73**	**0.34**	**0.07-1.40**	**3.28**	**0.85**	**1.60-4.95**
Distance Nearest WCC (DNWDD, m)	73.12	5.14	62.95-83.30	57.62	4.64	48.44-66.81
Tallest SD (TSD, cm)	**17.65**	**1.52**	**14.63-20.67**	**24.54**	**1.89**	**20.79-28.29**
Tallest Grass (TG cm)	**23.49**	**1.35**	**20.80-26.17**	**29.87**	**1.79**	**26.32-33.41**
Tallest Forb (TF, cm)	33.06	1.59	29.91-36.21	35.65	1.55	32.58-38.71

Based on the MANOVA, I found significant microhabitat differences between occupied and unoccupied sites within the year (Pillai = 0.337, $F_{9,242}$ = 13.656, $P < 0.001$) and each season (spring, Pillai = 0.597, $F_{9,53}$ = 98.706, $P < 0.001$; summer, Pillai = 0.658, $F_{9,53}$ = 11.316, $P < 0.001$; fall, Pillai = 0.445, $F_{9,53}$ = 4.720, $P < 0.001$; winter, Pillai = 0.294, $F_{9,53}$ = 3.209, $P < 0.05$). The results of the two-factor nested ANOVA show there were significant differences among the seasons for each microhabitat parameter except distance to the nearest woody canopy cover (DNWCC). Within each season, there were significant differences ($P < 0.01$) for all microhabitat variables between occupied and unoccupied points except for percent standing dead and grass cover (Table 4, Appendix A.6 and A.7).

Table 4. Nested two-factor ANOVA results for microhabitat parameters differences among seasons and occupied and unoccupied sites within seasons, “(Season O/U).” The percent data were arcsine transformed.

Microhabitat Parameter	Type*	SS	MSE	*F*	*P*
Bare Ground	Season	0.466	0.155	5.735	0.001
	Season (O/U)	1.181	0.295	10.900	<0.001
Litter	Season	4.400	1.467	27.600	<0.001
	Season (O/U)	3.192	0.798	15.020	<0.001
Standing Dead	Season	0.096	0.032	26.497	<0.001
	Season (O/U)	0.007	0.002	1.489	0.206
Forb	Season	1.034	0.345	15.280	<0.001
	Season (O/U)	1.328	0.332	14.710	<0.001
Grass	Season	5.495	1.832	67.008	<0.001
	Season (O/U)	0.201	0.050	1.834	0.123
Tallest Standing Dead	Season	56593	18864	66.445	<0.001
	Season (O/U)	7636	1909	6.724	<0.001
Tallest Grass	Season	133851	44617	122.101	<0.001
	Season (O/U)	10516	2629	7.194	<0.001
Tallest Forb	Season	53526	17842	50.110	<0.001
	Season (O/U)	6033	1508	4.236	0.002
DNWCC	Season	1240	413	0.176	0.912
	Season (O/U)	104014	26004	11.081	<0.001

*The degrees of freedom for season were 3 and 244, while within season the occupied (O) compared to unoccupied (U) were 4 and 244.

Within the 22 occupied sites, activity status, as indicated by active burrows, changed over the course of the year. To illustrate the relationship between activity and microhabitat changes, results from three sites are displayed (Fig. 5). Point 49 and 23 remained inactive longer than point 61, but these sites had active burrows in the spring, at the start and end of the study. Despite site differences due to various external factors, the general trend shows that as percent bare ground declined and as height of vegetation, percent forb, percent litter, and percent grass increased, sites became inactive. As, the percent grass, percent forb, percent litter, and height of vegetation decreased with an increase in percent bare ground the site became active.

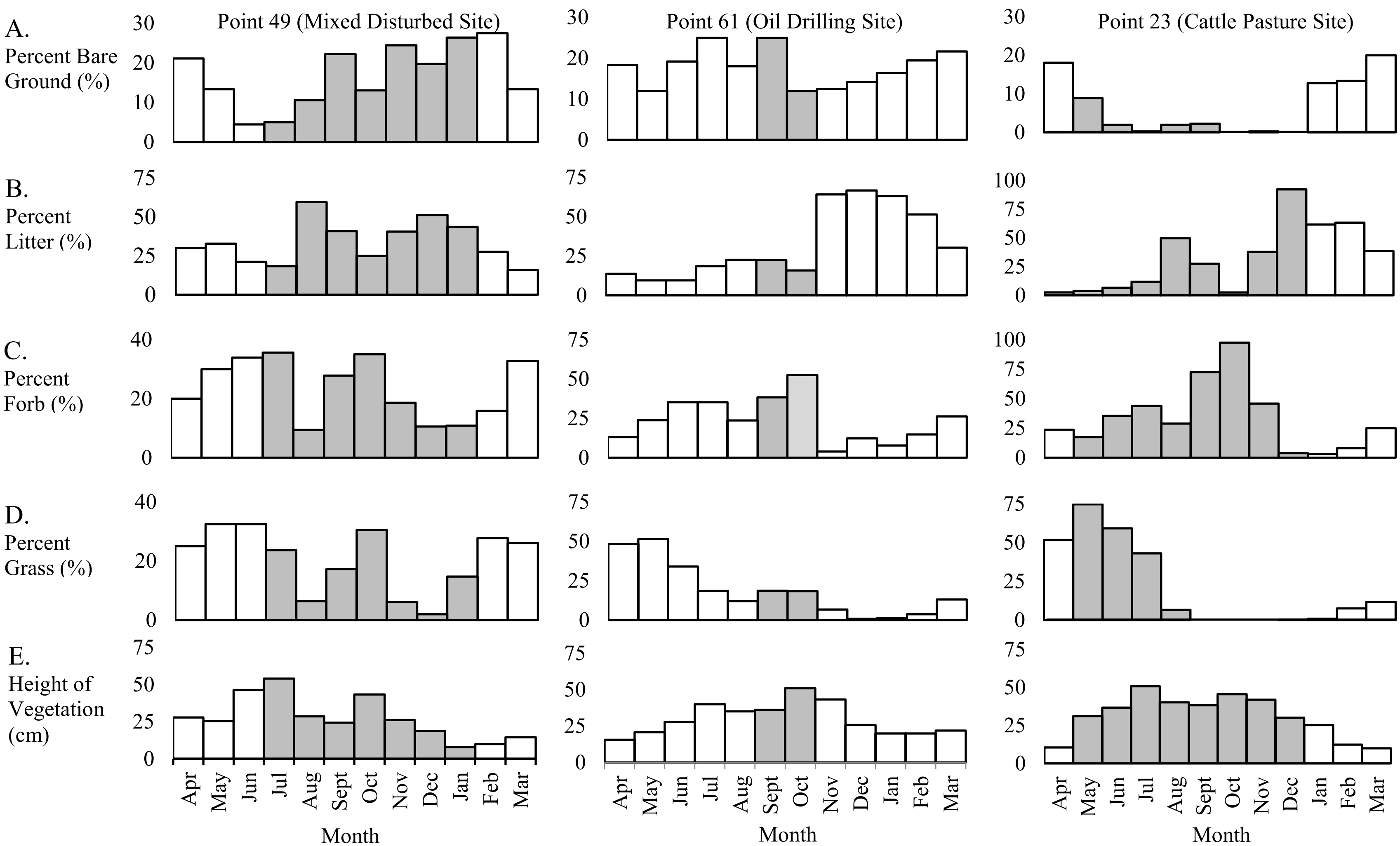

Figure 5. Changes of the activity status with temporal changes in microhabitat parameters at three example sites. White bars represent active site status and gray bars represent inactive status for the period April 2016 to March 2017.

Predicting Occupancy

Based on using AIC_c, two competing models have a ΔAIC_c of 1.94 (Table 5). The first model has a 0.67 likelihood that the model fits the data relative to the other models with an evidence ratio of 2.48 in comparison to the second model.

Table 5. AIC_c Model Selection Table.

Model	k	LogLik	AIC_c	ΔAIC_c	Weight
WCC + BG + L + G+ F	6	-99.49	211.30	0.00	0.67
WCC + BG + G	4	-102.51	213.20	1.94	0.27
WCC + BG+ L	4	-104.94	218.00	6.70	0.02
WCC + BG + L + TSD + TF + TG	7	-101.92	218.30	6.97	0.02
WCC + DNWCC + BG + L	5	-104.59	219.40	8.09	0.01
WCC	2	-110.65	225.40	14.02	0.00
WCC + DNWCC + BG + L	5	-110.60	227.30	15.96	0.00
DNWCC + TSD + TF + TG	5	-108.98	228.20	16.88	0.00
DNWCC	2	-143.60	291.20	79.92	0.00

*Note woody canopy cover (WCC), bare ground (BG), litter (L), grass (G), forb (F), tallest standing dead (TSD), tallest forb (TF), tallest grass (TG), and distance to the nearest woody canopy Cover (DNWCC) are acronyms.

Therefore, the chosen model to predict the probability of a location to be classified as occupied, containing active burrows within 13 m for one month out of the year, is as follows:

$$Occupancy_{\pi i} = \frac{e^{(2.022 - 0.068WCC + 0.007BG - 0.027L - 0.039G + 0.003F)}}{1+e^{(2.022 - 0.068WCC + 0.007BG - 0.027L - 0.039G + 0.003F)}}.$$

The probability of occupancy is positively impacted by the percent cover of bare ground (BG) and forbs (F), while percent cover of woody canopy (WCC), grass (G) and litter (L) negatively affect this probability. Based on a likelihood ratio test, percent woody canopy cover, bare ground, and grass cause a statistically significant drop in the deviance.

Despite a lack of a significant decrease in deviance with the addition of percent litter and forb parameters, these factors were included for the chosen model as shown by the previous evidence ratio (Table 6). Therefore, this model fits the given data, with a Nagelkerke $R^2 = 0.546$.

Table 6. Likelihood Ratio Test results showing the coefficient used in the model equation and if there is a significant drop in the deviance with each additional parameter.

Parameter*	Coefficient	Standard Error	Deviance	Residual df	Residual dev	$P (>\chi^2)$
Null model				251	326.06	
Intercept	2.022	1.627				
WCC	-0.068	0.014	104.76	250	221.30	<0.001*
BG	0.007	0.018	11.37	249	209.94	<0.001*
L	-0.027	0.021	0.07	248	209.87	0.79
G	-0.039	0.019	10.84	247	199.03	<0.001*
F	0.003	0.017	0.04	256	198.99	0.84

* woody canopy cover (WCC), bare ground (BG), litter (L), grass (G), and forb (F)

Based on the receiver operating characteristic curve (ROC), when each season was removed and predicted by the remaining seasons, the model was fairly accurate for summer, fall, and spring based on the area under the curve (AUC = 0.929, AUC = 0.901, AUC = 0.874, respectively for each season; Fig. 6). Winter had a high AUC of 0.757 but deviated from the other three seasons as an outlier (Fig. 6). Additionally, each season's optimum cutoff representing the maximum sensitivity and specificity varied; except for winter (0.064), the optimum cutoff values appear to be around about 0.5 (0.318 to 0.705, Table 7). Similarly, excluding winter (0.064), the optimum cutoff values for the maximum accuracy of the models are near to 0.55 (0.416 to 0.705, Table 7, Fig. 7).

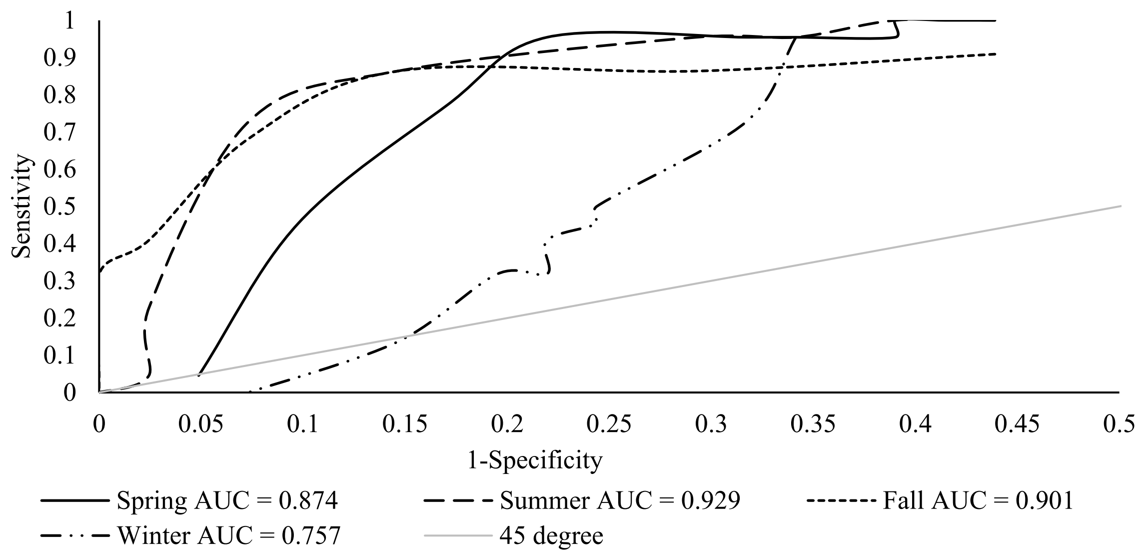

Figure 6. Receiver operating characteristic curve (ROC) with the area under the curve (AUC), showing the relative accuracy of the model discrimination between occupied and unoccupied sites with each season removed. The closer AUC is to one the better the model can discriminate between occupied and occupied status. A season following the line of unity (45° angle, true positive = false positive, AUC = 0.5) indicates that the model is not as accurate in predicting occupied sites.

Table 7. Cutoff values for the model when each season was removed for the optimum sensitivity/specificity and the maximum accuracy.

Month Removed	Optimum Cutoff	Sensitivity at Optimum cutoff	Specificity at Optimum cutoff	Maximum Accuracy	Cutoff for Maximum Accuracy
Spring	0.705	0.955	0.780	0.841	0.705
Summer	0.475	0.955	0.854	0.889	0.591
Fall	0.318	0.864	0.854	0.857	0.416
Winter	0.064	1.000	0.659	0.778	0.064

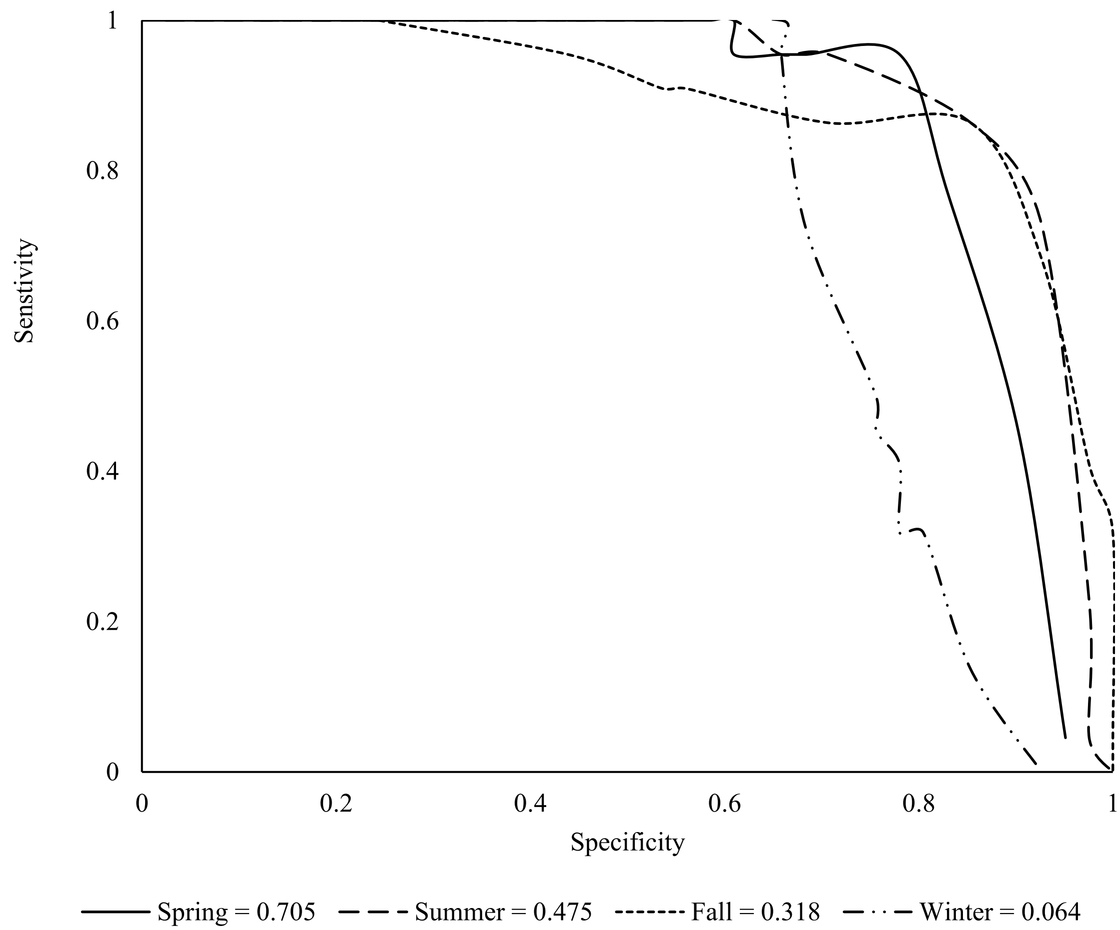

Figure 7. Sensitivity vs. specificity, showing how these values change with various cutoff values. A specificity of one shows the point in which all sites are correctly classified as unoccupied. A sensitivity of one shows the point in which all sites are correctly classified as occupied. The desire is to choose a cutoff value that gives both a high sensitivity and specificity, or the model correctly predicts the actual outcome. The optimum cutoff values are presented in the legend.

Plants and Gulf Coast kangaroo rat Occupancy

Of the plants occurring at the 63 sites, 137 identifications were to species level, 15 were to genus level, and one to family, Cyperaceae, by grouping 512 individuals

(Appendix A). There were 9.25 percent of individual plants (1,364 out of 14,742) that could not be identified. Comparing the dominant plants for the entire year, there was a higher percent occurrence (e.g. percent of Daubenmire frames) of paspalum (*Paspalum spp.*), plantain (*Plantago spp.*), rosette grass, sandbur (*Cenchrus spinifex*), and hogwort at occupied sites than at unoccupied. Little bluestem occurred in a higher percentage at unoccupied sites, while coastal bermudagrass was about equal in percent occurrence (Fig. 8). The simplified Morisita's index of similarity between occupied and unoccupied sites for the entire year was 0.74.

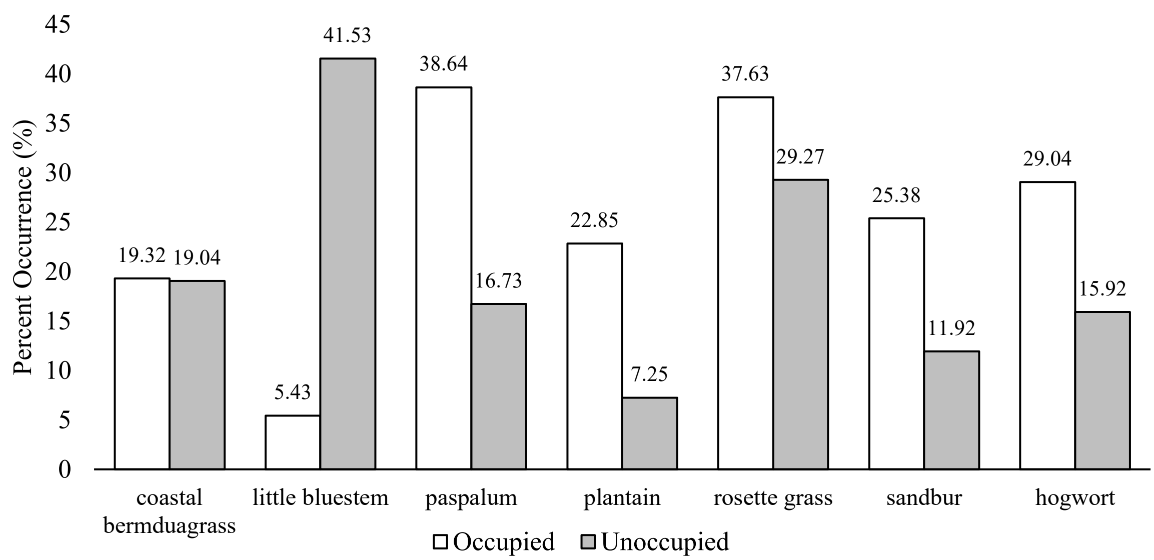

Figure 8. Overall yearly comparison of percent occurrence of dominant plants at occupied and unoccupied sites. The simplified Morisita's index of similarity is 0.74.

Sites that had active burrows present had a higher percent occurrence of lazy daisy and plantain; while sites with inactive or no burrows present had a higher percent occurrence of partridge pea, paspalum, sandbur, and hogwort (Fig. 9). There was a high similarity between the dominant plants found at active and inactive sites shown by a 0.91 simplified Morisita's index of similarity.

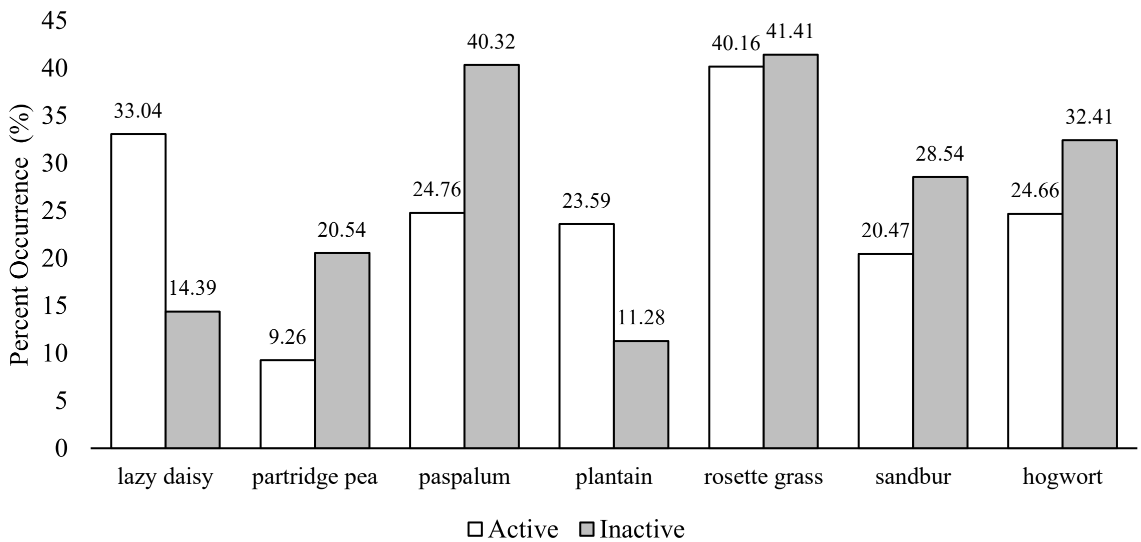

Figure 9. Comparison of percent occurrence of dominant plants at active and inactive sites at Diamond Half Ranch. The simplified Morisita's index of similarity is 0.91.

In the winter there was an overall low percentage occurrence of dominant plants (<20%) with respect to the other three seasons. Despite some variation in the dominant plants found in each season, there was higher percent occurrence in general of sixweeks fescue (*Vulpia octoflora*), lazy daisy, plantain, primrose (*Oenothera spp.*), paspalum, rosette grass, sandbur, sedge (Cyperaceae), hogwort, partridge pea (*Chamaecrista fasciculate*), and purple sandgrass (*Triplasis purpurea*) at occupied sites. Shepherd's needles (*Scandix pectin-veneris*), little bluestem, and costal bermudagrass occurred in greater percent occurrence at unoccupied sites (Fig. 10).

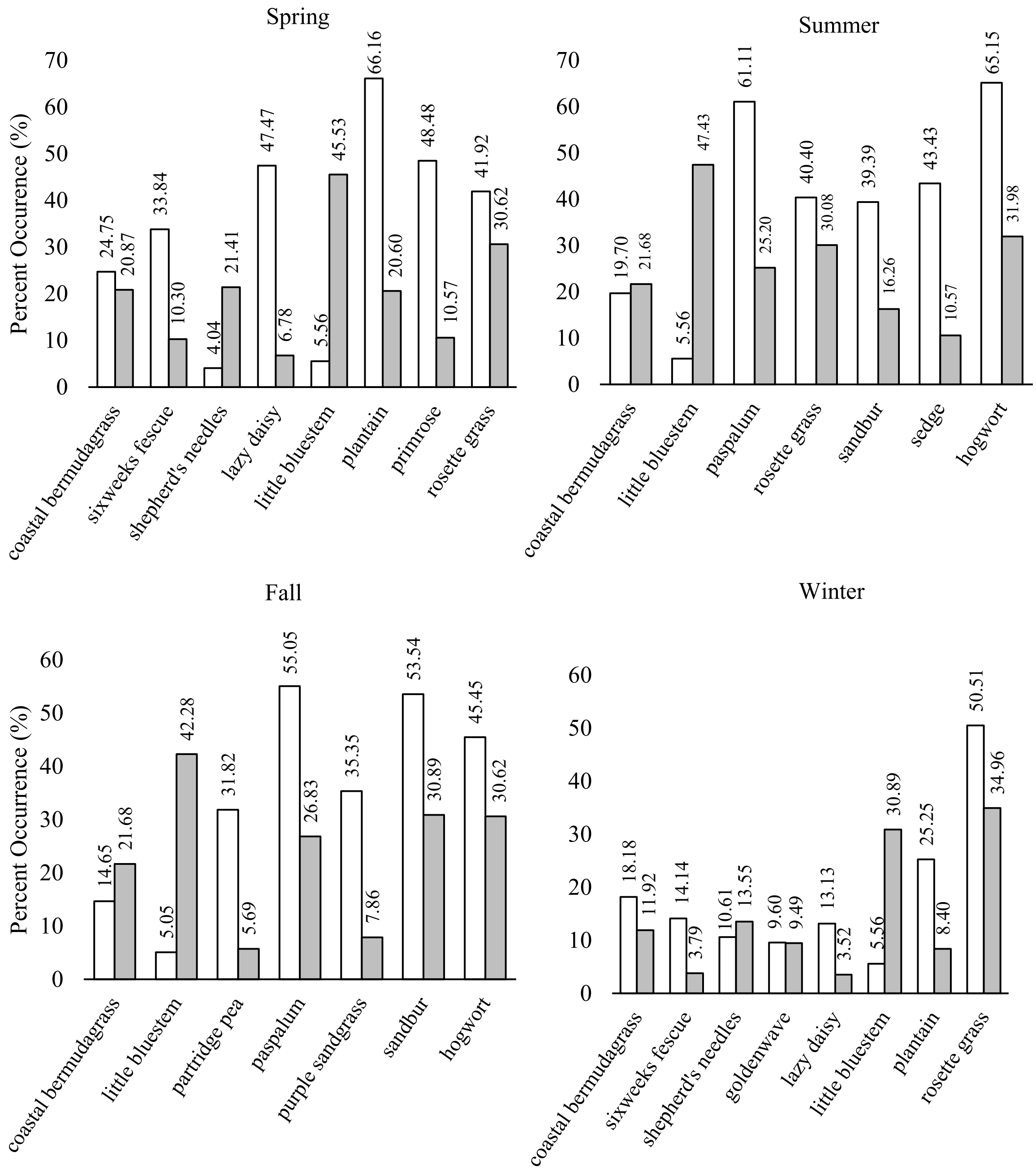

Figure 10. Comparison of percent occurrence of dominant plants at occupied and unoccupied sites within each season, showing the seasonal variation in the dominant plants. Winter overall had a low percent occurrence with majority under 20 percent.

IV. DISCUSSION

Microhabitat Parameters Affecting Occupancy and Activity

My analyses of the data suggest that there are significant microhabitat differences between sites occupied by Gulf Coast kangaroo rats and those without their presence within and across seasons. Occupied sites had less woody canopy cover and greater distance to the nearest woody canopy cover than sites that were never occupied (Oakley 2012, Fig. 11: A-B). The closest burrow entrance I found to woody canopy cover was 7 m, showing that Gulf Coast kangaroo rats can tolerate some woody canopy cover as long there is enough open area in at least one direction (Fig.11: E). These results resemble other studies in which the presence of Merriam's kangaroo rats was higher in open canopy areas and decreased in closed areas or as the distance between shrubs decreased (Price 1978, Wondolleck 1978, Thompson 1982). Likewise, a previous study suggested thinning shrub species for management purposes to increase the abundance of the endangered Stephen's kangaroo rats' (*D. stephensi*, Price et al. 1994). Therefore, Gulf Coast kangaroo rats may select sites due the absence of vegetation that creates visual obstruction and concealment provided for raptors (Brown et al. 1988, Longland and Price 1991).

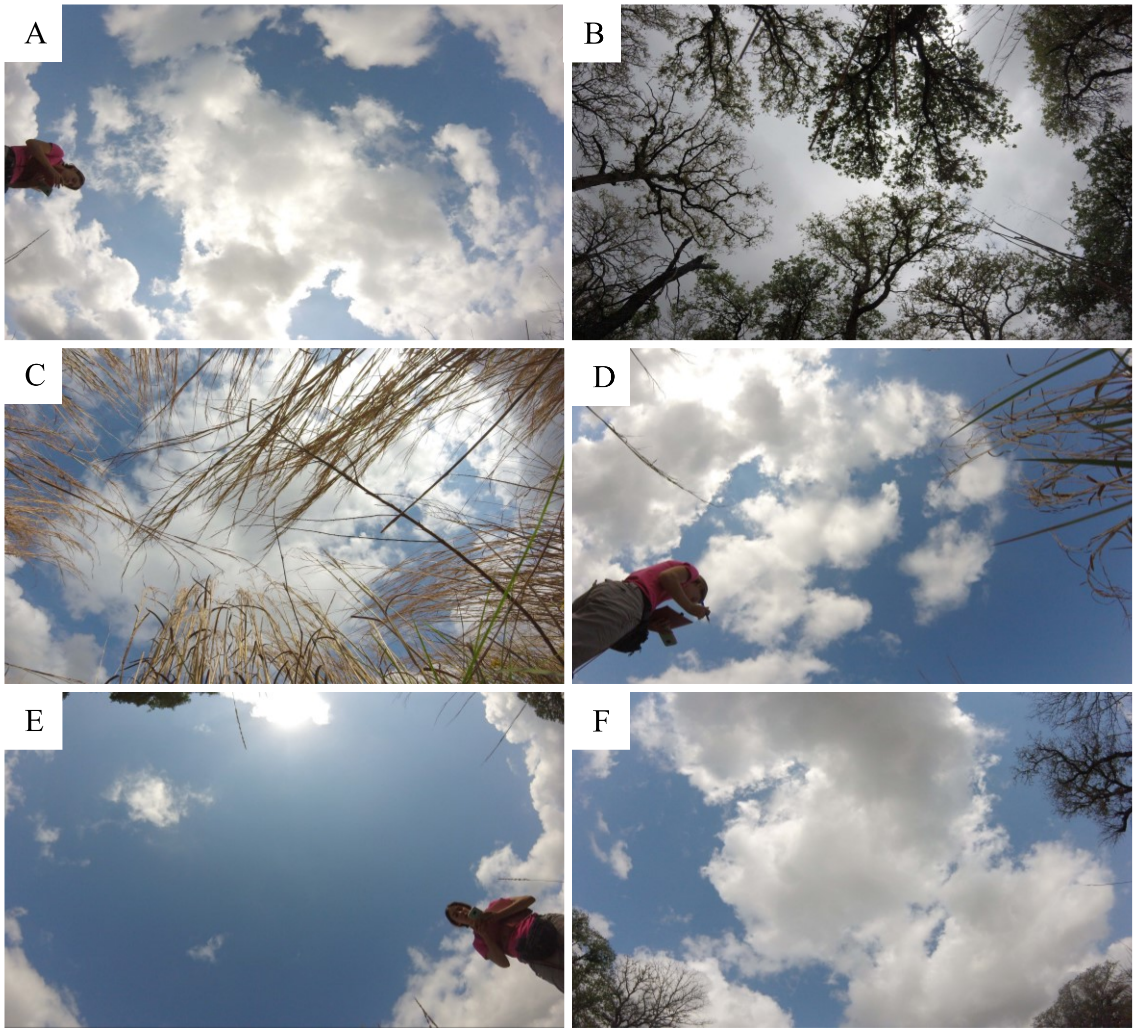

Figure 11. Go Pro Images. A: Gulf Coast kangaroo rat burrow at an occupied site (taken March 22, 2017; point 61). B: View from an unoccupied site under woody canopy cover (taken March 22, 2017; point 56). C: View from an unoccupied site with little bluestem (taken March 22, 2017). D: View from a Gulf Coast kangaroo rat burrow under a little bluestem (taken March 22, 2017; point 61). E: View from a Gulf Coast kangaroo rat burrow 7 m away from woody canopy cover (taken March 22, 2017; near point 61). F: View from a Gulf Coast kangaroo rat burrow along a roadside with a 27.3 m woody canopy cover opening).

Furthermore, occupied sites had significantly greater percentage of bare ground and forbs, while unoccupied sites had significantly greater ground covered by litter and taller vegetation, similar to previous results found by Oakley (2012). During the months in which I found active burrows at occupied sites, there was a slightly greater percent cover of bare ground. At occupied sites with either inactive or no burrows present, I found slightly greater percent litter, percent grass, and taller vegetation. Gulf Coast kangaroo rat activity, as indicated by active burrows, also changed across the year on a monthly basis, declining in the fall and increasing again in the spring, with corresponding changes in microhabitat parameters. Most notable in the months leading to the decline in Gulf Coast kangaroo rat detection there was an increase in precipitation (126.21 cm vs. 89.92 cm), especially in August receiving 27.05 cm over the monthly normal (33. 86 cm vs. 6.81 cm, Fig. 2, National Oceanic and Atmospheric Administration: National Climatic Data Center, (https://www.ncdc.noaa.gov/), accessed March 26, 2017). Likewise, Rissel (2011) observed a similar drop in detection of Gulf Coast kangaroo rats during the fall, attributing it to the increase precipitation from the climatic normal during the course of the study. O'Farrell (1978) observed changes in the home range size of Ord's kangaroo rats, Merriam's kangaroo rats, and Chisel-toothed kangaroo rats (*D. microps*) over the course of the season; however their ranges increased in the fall and spring, which he attributed to reproduction and social interactions. Therefore, these observed changes in Gulf Coast kangaroo rat burrow placement might be due to a variety of climatic influences, microhabitat parameters, and social factors.

The higher percentage of forbs at occupied sites and seasonality of activity might indicate a preference by Gulf Coast kangaroo rats for seeds of forb species. Reichman

(1975) found that forb seeds composed 76% of Merriam's kangaroo rats' diet over a two-year period. Litter and vegetation height may create a physical barrier at the ground level for Gulf Coast kangaroo rats, impeding their bipedal locomotion across the landscape (Lemen and Rosenweig 1978, Thompson 1982). Some Gulf Coast kangaroo rat burrows occurred under some vegetative cover, such as little bluestem grass, but in general this grass made up a small percentage of their possible visual field (Fig. 11: C-D). It appears that Gulf Coast kangaroo rats avoid areas with excessive horizontal or vertical cover that can serve as concealment for predators. Rather they favor open areas with an abundance of forb species to facilitate their movement through their habitat and acquisition of food sources (Rowland and Turner 1964, Reichman 1975, Brown et al. 1988, Pierce et al. 1992).

Due to the higher than normal rainfall during this study, there was a dense and persistent growth of grasses in the summer and winter across the study area at occupied and unoccupied sites. During this time, Gulf Coast kangaroo rats disappeared from initially occupied sites. A study in New Mexico found the distribution of Ord's kangaroo rats, who have an association with grasses, was positively impacted by overgrowth of grasses in the second wet year in comparison to the first (Schroder and Rosenzweig 1975). Despite showing the opposite response, this study demonstrates that the impact of a wet year on the vegetation cover can alter the distribution and presence of kangaroo rats (Schroder and Rosenzweig 1975).

Based on both quantitative data and field observations, it appears once a site has a suitable microhabitat for Gulf Coast kangaroo rats, it remains suitable for occupancy in the long-term. However, in the short-term, Gulf Coast kangaroo rats are highly dynamic and mobile, with the presence of active burrows based on more ephemeral factors, such as excessive grass growth. They may choose to inhabit a particular site based on these more fine-scale parameters that can impact their movements through the environment with their bipedal locomotion and availability of food sources (Lemen and Rosenweig 1978, Thompson 1982).

For example, despite the lack of burrows within the 10 m radius circle in some months at several occupied sites, burrows were still found in the same pasture, ranging from 20 to 50 m away from the center stake. Some of the unoccupied sites, which never had burrows within this radius, had burrows in the same field about 30 to 100 m away. These observations suggest that Gulf Coast kangaroo rats may expand or contract their home range similar to what Jones (1989) found with Merriam's kangaroo rats. As studies suggest for other kangaroo rats, Gulf Coast kangaroo rats may move around to different parts of a pasture based on various intraspecific interactions, resources, and habitat characteristics, instead of staying in the same locality (French et al. 1968, Cooper and Randall 2007). Radio-tracking and fluorescent dye studies could be employed to confirm this suggestion, but these types of studies can cause mortality or have only a short term tracking time for other species of kangaroo rats (Lemen and Freeman 1985, Harker et al. 1999, Germano 2010).

Predicting Occupancy

Based on the likelihood ratio test, the selected model fit the variability in the data fairly well with a large amount of the variability in presence/absence explained. This model is similar to results found in the MANOVA. Percent woody canopy cover had the largest negative impact on the probability of a site being occupied. In fact, based on personal observation, Gulf Coast kangaroo rat burrows were never observed under the canopy cover line. Furthermore, the percent ground cover of grass negatively impacted occupancy, while percent ground cover of litter and forb to a lesser extent positively impacted occupancy. Unlike Bender (2010), who tested the model on a new set of points, it was not possible in this study's time frame; however, this model was relatively accurate in predicting probability of site occupancy for all months with the exception of winter. This discrepancy can partly be explained by the seasonal changes that occur in winter that are greater than in the other three seasons making it more difficult to predict occupancy during winter months (National Oceanic and Atmospheric Administration: National Climatic Data Center, (https://www.ncdc.noaa.gov/), accessed March 26, 2017). Therefore, based on the verification of this model, a cutoff of about 0.55, or 55% probability of being occupied, is recommended to binary classify a site as occupied (>0.55) or unoccupied (<0.55). In terms of management, the model could be used to help maintain the proper microhabitat conditions in areas known to have Gulf Coast kangaroo rats and areas where they could potentially establish. Additionally, this equation may serve as a surrogate model to aid in the determination of habitats suitable for less abundant related species of conservation concern.

Observations of Gulf Coast kangaroo rats

Additionally, Gulf Coast kangaroo rats appear to be able to move long distances. For example, site 23 located in a large cattle pasture in the front of the property, had active burrows in April, the first month of surveying, while being grazed by cattle. In

May, the cattle were moved into another pasture and Gulf Coast kangaroo rats also disappeared that month from site 23 (Fig. 3). During this time and following months there was an overgrowth predominately of coastal bermudagrass, sandbur, and hogwort reaching to a meter in height and creating a thick barrier. Cows were not reintroduced until mid-December. In the January survey, along a new fresh cow trail about 0.5 m wide running through the center of the site, new Gulf Coast kangaroo rat burrows were located just 2 m off this trail. Similarly, previous studies found Merriam's kangaroo rats significantly preferred grazed pastures that had more heterogeneity, open ground cover, and fewer shrubs than protected sites with dense grass stands (Reynolds 1958,Bock et al. 1984, Jones and Longland 1999). Reynolds (1958) further found that Merriam's kangaroo rats can maintain and even improve rangelands in southern Arizona that are in good to stable condition by caching seeds, but can push poor rangelands to worse conditions (for livestock) by increasing mesquite (*Prosopis glandulosa*) and cactus (*Opuntia spp.*) species. In contrast to these results, other studies found either no difference or higher abundance of Merriam's and Banner-tailed kangaroo rat in cattle exclosures when the vegetation did not differ (Heske and Campbell 1991, Valone et al. 2002). This suggests that Gulf Coast kangaroo rats, like other kangaroo rat species, are compatible with a rotational cattle operation on properly maintained lands, without over-use, in which cattle grazing creates the amount of disturbance and movement corridors necessary for kangaroo rats (Bock et al. 1984, Heske and Campbell 1991, Hayward et al. 1997).

In the summer of 2012, an opening was cleared for oil drilling along a seismograph line extending from open pastures on the west side of the ranch where Gulf

Coast kangaroo rats were previously found by Oakley (2012). Prior to clearing, the area was a post oak (*Quercus stellata*) woodland with a dense woody canopy cover that the Gulf Coast kangaroo rats avoided. All equipment was removed by the summer of 2013. By January 2015, during my preliminary survey of the property, Gulf Coast kangaroo rat burrows were scattered across this opening. Currently, it is one of the most active sites, site 61, on the property, with numerous active burrows in every month of the study except in September and October, when only 2 of 22 sites had active burrows (Fig. 3). Gulf Coast kangaroo rats most likely dispersed to this location along the seismograph line connecting this opening to occupied areas.

Furthermore, in the winter to early spring, burrows became more obvious and abundant along the roadsides, even in the woodlands where there was a canopy cover opening of at least 16 m across. These roadways with respect to unoccupied areas have a small percent of their visual field obstructed by woody canopy cover, and possibly served as dispersal corridors (Fig. 11:F). Allred and Beck (1963) suggested long distances traveled (1,126 m and 2,929 m) by two Merriam kangaroo rats were dispersal events triggered by various disturbances and population pressures. Likewise, Brehme et al. (2013) found that three captured Dulzura kangaroo rats (*D. simulans)* traveled on dirt roads for long distances after they were released, with one even burrowing on the road. This demonstrates that Gulf Coast kangaroo rats, similar to other kangaroo rats, can use both artificial (e.g., roadsides and road right of ways) and natural corridors to inhabit or colonize a new area, possibly serving as part of the source-sink population dynamic (Roberts and Packard 1973, Kaufman and Kaufman 1982, Jorgensen et al. 1995, Brehme et a. 2013).

Plants and Gulf Coast kangaroo rat Occupancy

Considering the top 15 dominant plants, there are seasonal differences based on their life cycle and duration of growth. For example, certain plants occurred in the late winter to spring, like lazy daisy and sixweeks fescue, while others dominate in the summer, like sedge, or in the fall, like partridge pea, at occupied sites. Besides general growth patterns, these seasonal differences could have been impacted by the moist and mild climate that was experienced throughout year, due to El Niño, which could have also impacted Gulf Coast kangaroo rats' selection for certain plant species (Frank 1988, National Oceanic and Atmospheric Administration). Experimentally, Frank (1988) concluded that in low humidity conditions, as in summer, kangaroo rats required a high carbohydrate diet, medium to low lipids, and low protein intake to maintain high water production. In higher humidity conditions, as in winter with less concern for water acquisition, protein and lipid intake increased to meet minimum requirements (Frank 1988). As a result, the relative humidity and temperature impact on total water acquisition thorough evaporative water loss may underlie heteromyid, including Gulf Coast kangaroo rats' seed preference to maintain a favorable water balance (Lockard and Lockard 1971, Price 1983, Frank 1988). The top 5 dominant plants for the entire year had either a perennial or weak perennial duration, except plantain, lasting for at least three growing seasons (Diggs et al. 1999, Shaw 2012). Combined with the climatic impacts from El Niño, those perennial plants may have been able to survive longer in a non-dormant state, showing up as a live dominant plant for the entire year (Table 8).

Table 8. Dominant plants for the entire year and each season.

Plant	Year	Spring	Summer	Fall	Winter
shepherd's-needle		+			+
lazy daisy		+			+
goldenwave					+
sedge			+		
hogwort	+		+	+	
partridge pea				+	
primrose		+			
plantain	+	+			+
sandbur	+		+	+	
coastal bermudagrass	+	+	+	+	+
rosette grass	+		+		+
paspalum	+		+	+	
little bluestem	+	+	+	+	+
purple sandgrass				+	
sixweeks fescue		+			+

Furthermore, to analyze the differences in species of plants occurring at occupied or unoccupied sites, I examined seed size. I photographed or used previously photographed seeds and then measured length and width from the photos. Using the frequency distribution of seeds found in cheek pouches of *Dipodomys* species from Brown's and Lieberman's (1973) study, I classified seeds less than 2 mm or those with no girth as small, and seeds that were 2 mm or greater as large (Table 9). The seed size of these dominant plants overall was greater than 1.1 mm, with most greater than 2 mm. In general, other studies have found a positive correlation between seed size, mass, and nutrient content, with larger seeds typically heavier and higher in nutrient content (Allsopp and Stock 1995, Vaughton and Ramsey 2001).

In general, those plants that occurred at occupied sites in greater frequency are classified as large seeded species. These large seeds, based on previous studies, most likely have high nutrient reserves that are desired by heteromyids and could serve as possible food sources for Gulf Coast kangaroo rats (Allsopp and Stock 1995, Vaughton and Ramsey 2001). Additionally these plant species, as described in field guides, are typical colonizers of disturbed, sandy, or roadside habitat (Diggs et al. 1999, Gould 2008, Shaw 2012). Therefore, the observation of Gulf Coast kangaroo rats occurring in open disturbed habitats may be partly explained by the availability of these large seeds as a food source (Brown and Lieberman 1973, Henderson 1990).

Table 9. Plant characteristics of the chosen 15 dominant plants. A variety of resources were used (Diggs et al. 1999, Gould 2008, Shaw 2012, Lady Bird Johnson Wildflower Center 2017, United States Department of Agriculture: Plants Database).

Plant	Seed Size (mm)	Girth	Seed Size	Type of Habitat	Duration*
Shepherd's-needle	4.00	+	L	Moist Soils	A
lazy daisy	2.25	+	L	Disturbed/Roadsides	A
goldenwave	1.55	+	S	Disturbed/Sandy	A
sedge	1.50	+	S	Moist areas	A/P
hogwort	4.00	+	L	Disturbed/Roadsides	A
partridge pea	3.25	+	L	Disturbed/Roadsides	A
primrose	2.50	+	L	Disturbed	A/Short-lived P
plantain	1.20	+	S	Disturbed	A
sandbur	5.00	+	L	Disturbed	A/ Short-lived P
coastal bermudagrass	1.50	-	S	Disturbed	P
rosette grass	2.00	+	L	Disturbed/Sandy	P
paspalum	2.00	+	L	Disturbed	P
little bluestem	3.00	-	S	Undisturbed	P
purple sandgrass	3.50	+	L	Disturbed/Sandy	A/ P
sixweeks fescue	2.50	+	L	Disturbed	A

*A = Annual, P= perennial

Furthermore, selection for large seeds may be due to the ease at which Gulf Coast kangaroo rats can extract such seeds in an open sandy environment (Brown and Lieberman 1973, Price 1978, Price 1983, Price and Heinz 1984, Price and Waser 1985). Notable exceptions include goldenwave (1.55 m), plantain (1.2 mm), and sedge (1.5 mm), which were classified as small seeded species, but occurred in higher percentages at occupied sites. Nevertheless, those seed sizes were consumed readily by Merriam's kangaroo rats (Brown 1973), and therefore might also be consumed by Gulf Coast kangaroo rats. The high presence of the sedge species might be an artifact of the weather due to El Niño. Nevertheless, a food study analysis needs to verify the diet of Gulf Coast kangaroo rats.

Despite the classification of shepherd's needles as a large seeded species, it occurred in higher percentages at unoccupied sites in the spring and winter. This invasive plant occurs characteristically in relatively low-lying moist areas, opposite of the habitat where Gulf Coast kangaroo rats occur, possibly explaining its low frequency at occupied sites (Enquist 1987). Likewise, little bluestem occurs in greater frequency at unoccupied sites. This plant probably does not serve as a reliable food source for Gulf Coast kangaroo rats, having small, wind-dispersed seeds. Furthermore, little bluestem occurs at undisturbed sites (Gould 2008). Little bluestem's vertical coverage (with a height reaching up to 200 cm) might mimic woody canopy cover and could be an additional limiting factor for Gulf Coast kangaroo rats (Fig. 11: C-D). Thus, Gulf Coast kangaroo rats may avoid areas with dense little bluestem due to the lack of a viable food source and the vertical and horizontal barrier that could impede their locomotion (Henderson 1990, Thompson 1982). Additionally, coastal bermudagrass, which produces small seeds, occurred equally at occupied and unoccupied sites; however, based on field observations, when coastal bermudagrass growth was dense, no active burrows were present at the site. This is possibly due to the barrier it would create that could impede the bipedal locomotion of Gulf Coast kangaroo rats (Lemen and Rosenweig 1978, Pierce et al 1992). Therefore, this observation of equal percent occurrence might be a result of the definition of occupied used in this study, including any site that had at least one burrow in the study duration regardless of month to month changes.

Furthermore, occupied and unoccupied sites showed a greater difference in terms of dominant species composition than occupied sites with different activity status (Morisita's index of similarity 0.74 vs 0.91). This supports the concept that once a site was occupied, it can serve as suitable habitat in the long-term for Gulf Coast kangaroo rats, with active or inactive status each month separated by smaller deviations in habitat factors. For example, the higher percent occurrence of lazy daisy and plantain at occupied sites with active burrows for that month can be explained by their sparse growth habits known to colonize disturbed sites (Lady Bird Johnson Wildflower Center 2017). On the other hand, there was a higher percent occurrence of paspalum, sand bur and hogwort at occupied sites in the months when inactive or no burrows were present. This may be explained by the vertical cover paspalum and hogwort created in reaching up to about a meter in height. Nevertheless, when these plants senesce and collapse, they can serve as a large seed source for Gulf Coast kangaroo rats (Diggs, et al. 1999, Table 9). Sandbur in some areas can create a barrier similar to coastal bermudagrass, possibly impeding Gulf Coast kangaroo rat bipedal locomotion (Rowland and Turner 1964). Therefore, different growth stages or density of the dominant species typically found at occupied sites might impact Gulf Coast kangaroo rat activity status by affecting their ease to move across the landscape, their perceived threat of predation, or the availability of food sources (Brown et al. 1988, Longland and Price 1991, Pierce et al. 1992).

Conclusion

Overall, Gulf Coast kangaroo rats appear to select open disturbed areas supporting plants that produce relatively large seeds easily extracted from sandy-based soils. As a highly dynamic and mobile species, Gulf Coast kangaroo rats may select areas with suitable qualities for occupancy and move around within those areas based on more fine scale and ephemeral factors. Furthermore, cattle grazing, anthropogenic changes, and weather patterns might underlie these results. Gulf Coast kangaroo rats appear to be compatible with general ranching operations, positively impacted by reduction of vegetative cover by livestock grazing and possibly shrub and woody canopy cover thinning in some areas. The model presented in this study can serve in future efforts to determine areas of critical habitat for Gulf Coast kangaroo rats. Overall, the selection of no woody canopy cover and bare ground habitat in disturbed locations, characteristic of large seed producing plants, presented in this study further adds to the cumulative knowledge on the Gulf Coast kangaroo rat. Furthermore, it appears the some range management practices used on Diamond Half Ranch in south Texas helped maintain these selected features and can be used as valuable tool to manage for this rather inconspicuous species and possibly other heteromyids.

APPENDIX SECTION

APPENDIX A. EXTRA FIGURES AND CHARTS

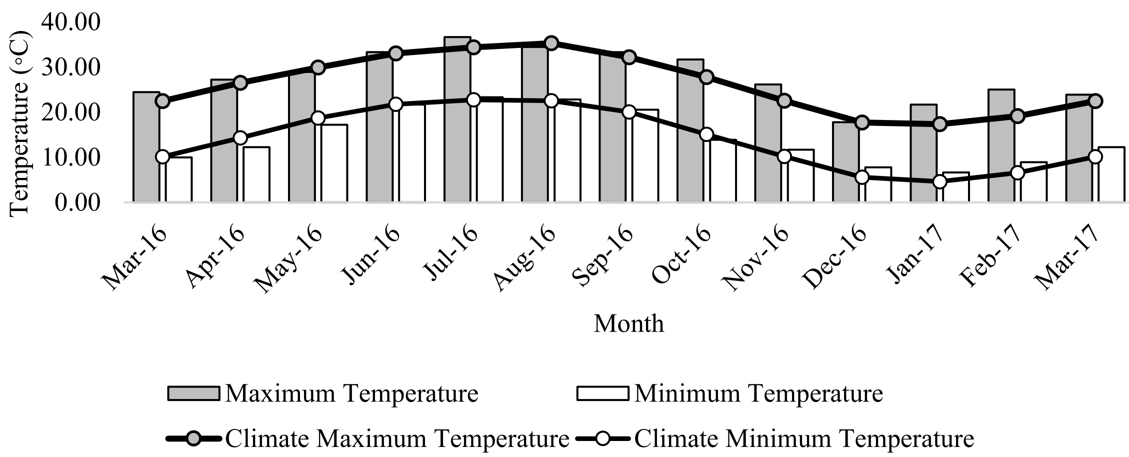

Figure A.1. Maximum and minimum temperatures experienced this year against the climatic normals based on 2010 data from a weather station in Nixon, Texas (National Oceanic and Atmospheric Administration).

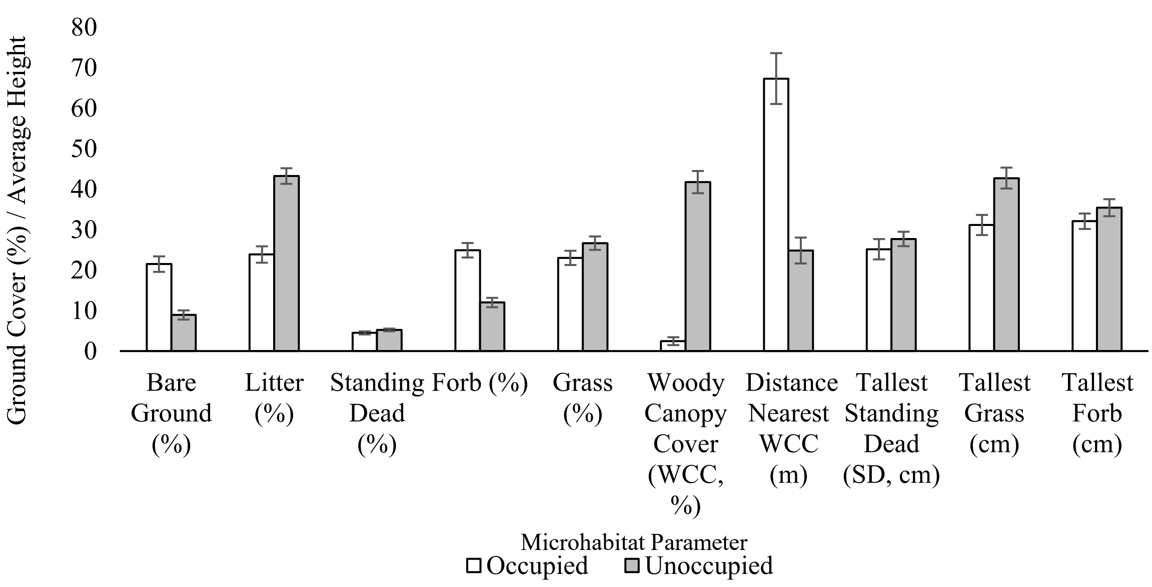

Figure A.2. Comparison of the means of microhabitat parameters between occupied and unoccupied sites with the standard errors of the mean. The white bars represent occupied sites. The gray bars represent inactive sites. The black line represent the standard errors.

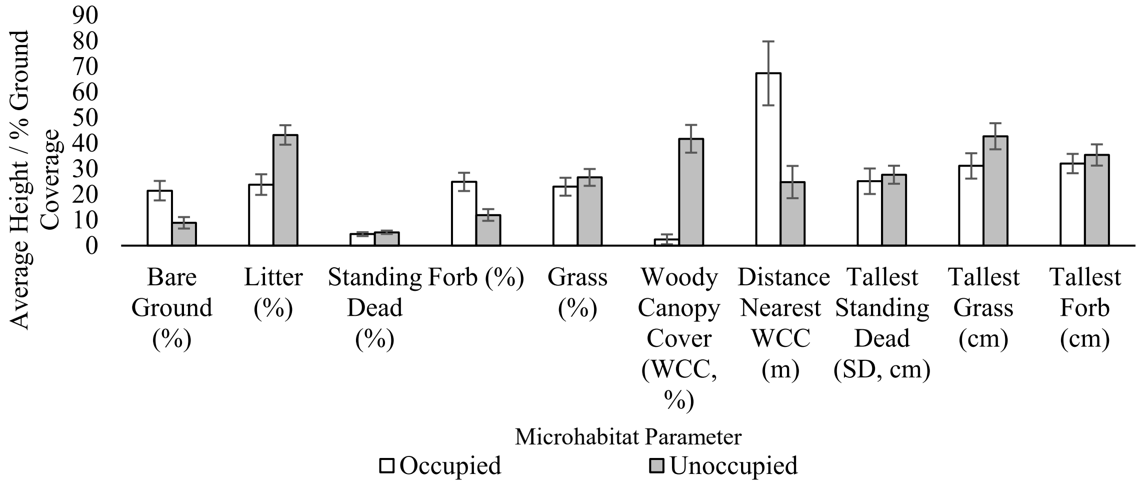

Figure A.3. Comparison of the means of microhabitat parameters between occupied and unoccupied sites with 95% confident intervals (CI). The white bars represent occupied sites. The gray bars represent unoccupied sites. The black line represents the 95% (CI).

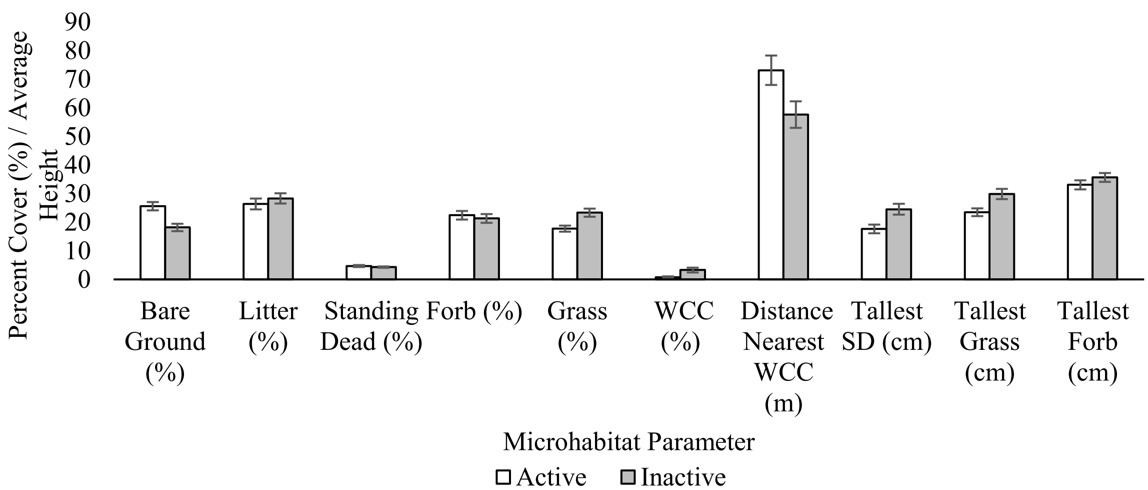

Figure A.4. Comparison of the means of microhabitat parameters between active and inactive sites with the standard errors of the mean. The white bars represent active sites. The gray bars represent inactive sites. The black line represent the standard errors.

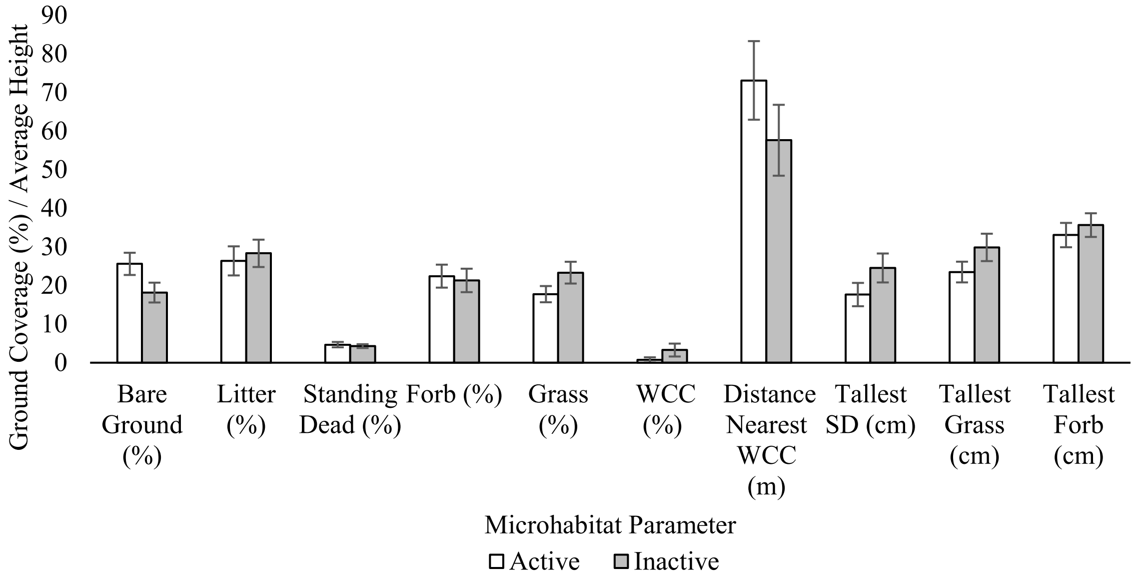

Figure A.5. Comparison of the means of microhabitat parameters between active and inactive sites with the 95% confidence intervals (CI). The white bars represent active sites. The gray bars represent inactive sites. The black line represent the 95% (CI).

Table A.6. Seasonal microhabitat differences between occupied and unoccupied sites.

	Occupied				Unoccupied			
Microhabitat	spring	summer	fall	winter	spring	summer	fall	winter
Bare Ground (%)	34.82	16.52	15.82	18.75	12.17	6.96	6.48	10.05
Litter (%)	15.01	14.95	17.01	48.43	46.46	34.84	32.67	59.00
Standing Dead (%)	2.85	4.37	2.69	8.06	4.45	3.77	4.17	8.48
Forb (%)	34.57	29.32	25.39	10.34	21.53	7.53	10.65	8.22
Grass (%)	15.57	29.23	37.93	9.34	19.23	34.42	46.27	6.69
WCC (%)	1.37	1.30	5.09	2.04	44.86	43.91	37.19	40.99
DNWCC (m)*	73.89	66.90	61.85	66.61	27.14	23.54	24.93	23.75
Tallest SD (cm)	17.56	34.55	45.58	2.92	31.27	46.00	30.95	2.57
Tallest Grass (cm)	16.86	42.28	56.42	9.01	24.68	63.24	71.52	11.48
Tallest Forb (cm)	17.52	34.01	30.33	46.40	18.05	24.00	36.33	63.29

*DNWCC is an acronym for distance to the nearest woody canopy cover.

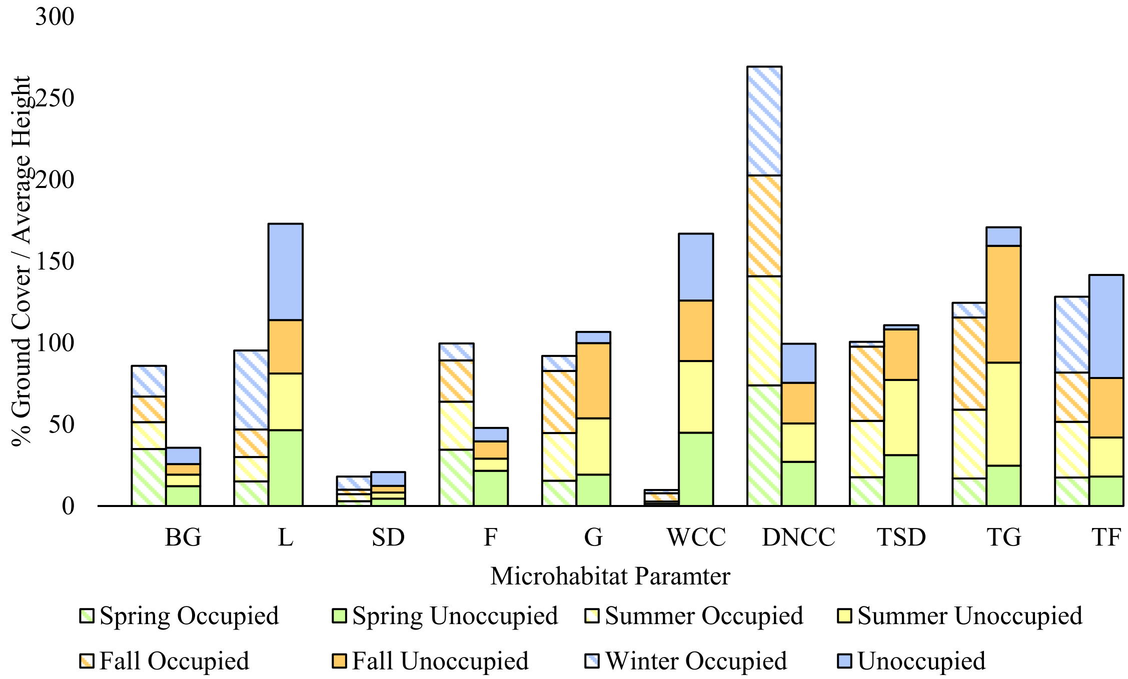

Figure A.7. Visualization of seasonal microhabitat differences between occupied and unoccupied sites.

APPENDIX B. LOGISTIC REGRESSION R-CODE SCRIPT

```
#load packages
library(lmtest)
library(MuMIn)

#Load Data
Ocu=read.csv(file.choose())
str(Ocu) #n=252, Pre-coded 0 = unoccupied and 1 = occupied

#logistic Models
m1=glm(Occunapcy~CC,family=binomial, data=Ocu)
m2=glm(Occunapcy~Distance.Nearest.CC,family=binomial, data=Ocu)
m3=glm(Occunapcy~CC+Distance.Nearest.CC,family=binomial, data=Ocu)
m4=glm(Occunapcy~CC+TallestSD+Tallest.Forb+Tallest.Grass,family=binomial, data=Ocu)
m5=glm(Occunapcy~CC+Bare.Ground+Litter,family=binomial, data=Ocu)
m6=glm(Occunapcy~CC+Bare.Ground+Litter+Grass+Forb,family=binomial, data=Ocu)
m7=glm(Occunapcy~CC+Bare.Ground+Litter+TallestSD+Tallest.Forb+Tallest.Grass,family=binomial, data=Ocu)
m8=glm(Occunapcy~CC+Distance.Nearest.CC+Bare.Ground+Litter,family=binomial, data=Ocu)
m9=glm(Occunapcy~CC+Bare.Ground+Grass,family=binomial, data=Ocu)
mnull=glm(Occunapcy~1,family=binomial, data=Ocu)
252/7 #n/k <40 use AICc
model.1=model.sel(m1,m2,m3,m4,m5,m6,m7,m8,m9, rank=AICc)
```

#Check the two competing models

```
summary(m6)
189.99/246 #residual deviance = 0.7723171
anova(m6,test="Chisq")
summary(m9)

lrtest(m9,m6) #Likelihood ratio Test to determine which of the competing nested models
anova(m6,test="Chisq")
```

#Nagelkerke r squared

```
logLik(m6)
likS<-exp(-99.4943)
likS
logLik(mnull)
liknull<-exp(-163.0324)
liknull
rsq=1-((liknull/likS)^(2/252))
rsq
maxrsq=1-(liknull^(2/252))
maxrsq
0.3960541/0.7258029 #Nagelkerke r squared is 0.54566
```

#code to check data example April

```
install.packages('caret',dependencies = TRUE)
library(caret)
library(ROCR)
apr=read.csv(file.choose())
str(apr)
confusionMatrix(apr$X0.01,apr$Obs)
```

#ROC Curve and Max Cutoff

```
pred=prediction(jul$Pre,jul$Obs2)
class(pred)
slotNames(pred)
sn=slotNames(pred)
sapply(sn,function(x) length(slot(pred,x)))
sapply(sn,function(x) class(slot(pred,x)))
ss=performance(pred,"sens","cutoffs")
plot()
ss@alpha.values[[1]][which.max(ss@x.values[[1]]+ss@y.values[[1]])]
abline(v=0.4746004)
```

#make ROC curve

```
roc.perf=performance(pred,measure="tpr",x.measure="fpr")
plot(roc.perf)
abline(a=0,b=1)
```

#optimal cutoff Maximum Senstivity and Maximum specificity

```
opt.cut = function(roc.perf, pred){
  cut.ind = mapply(FUN=function(x, y, p){
    d = (x - 0)^2 + (y-1)^2
    ind = which(d == min(d))
    c(sensitivity = y[[ind]], specificity = 1-x[[ind]],
      cutoff = p[[ind]])
```

```
}, roc.perf@x.values, roc.perf@y.values, pred@cutoffs)
}
print(opt.cut(roc.perf, pred))
abline(v=0.06369941)
cost.perf=performance(pred,"cost")
pred@cutoffs[[1]][which.min(cost.perf@y.values[[1]])]
```

#Accuracy Graph with Maximum Cutoff for Maximum Accuracy

```
acc.perf = performance(pred, measure = "acc")
plot(acc.perf)
ind = which.max( slot(acc.perf, "y.values")[[1]] )
acc = slot(acc.perf, "y.values")[[1]][ind]
cutoff = slot(acc.perf, "x.values")[[1]][ind]
print(c(accuracy= acc, cutoff = cutoff))
abline(v=0.06369941)
```

#AUC

```
auc.perf = performance(pred, measure = "auc")
auc.perf@y.values
```

APPENDIX C. MONTHLY HABITAT CHARACTERISTICS

List of habitat characteristics each month at occupied sites that changed.

			Percent Ground Coverage (%)					Height of Tallest (cm)		
Date	Month	State	BG	Litter	SD	Forb	Grass	SD	Grass	Forb
Point 9										
3/18/16	April	a	43.33	12.22	1.11	27.78	32.78	3.67	15.11	8.11
5/3/16	May	a	19.72	10.83	1.94	56.67	13.33	12.22	18.33	28.00
5/31/16	June	a	16.94	6.39	2.50	51.39	14.72	25.33	45.11	46.00
6/1/16	July	a	15.83	12.22	2.22	35.83	32.78	28.11	53.11	49.56
8/1/16	August	a	33.61	23.61	2.50	20.83	11.94	34.67	34.89	38.67
8/31/16	September	n	18.33	25.28	2.22	35.56	38.33	27.00	55.89	57.56
9/27/16	October	n	14.17	5.28	3.89	25.00	38.06	59.22	70.33	40.33
10/27/16	November	a	6.94	33.89	3.89	6.39	35.28	52.33	56.22	66.00
11/29/16	December	a	12.22	60.83	8.06	1.39	9.44	19.22	35.11	59.22
1/1/17	January	a	8.06	54.17	10.56	10.28	21.11	7.89	29.33	70.22
2/2/17	February	a	41.94	28.89	5.28	3.89	13.33	2.89	11.33	43.22
2/28/17	March	a	15.56	11.94	2.50	26.67	30.28	7.44	16.33	43.78
Point 21										
3/18/16	April	n	56.67	21.11	1.39	31.39	14.72	8.33	13.22	28.89
5/6/16	May	n	32.78	8.06	3.89	27.22	32.78	20.56	29.78	17.33
6/3/16	June	n	27.50	8.06	2.50	10.83	40.56	23.56	44.22	16.11
7/1/16	July	a	30.00	17.50	5.28	5.28	30.00	37.22	36.78	20.22
8/1/16	August	n	34.17	40.83	2.50	0.83	5.28	28.56	20.11	8.00
8/31/16	September	a	38.33	38.06	2.50	0.28	19.72	20.56	23.67	0.78
9/23/16	October	n	30.00	45.83	3.89	0.00	16.11	0.00	27.56	15.89
10/28/16	November	a	40.83	59.17	3.89	0.00	2.22	0.00	14.33	21.11
11/29/16	December	a	34.17	43.06	2.50	1.67	6.39	1.44	6.00	24.67
1/11/17	January	a	30.56	38.06	2.50	22.50	2.22	2.78	8.33	17.11
2/2/17	February	a	35.83	21.11	2.50	25.00	5.28	3.56	4.22	18.00
2/28/17	March	a	28.61	21.11	2.50	28.61	11.39	8.22	6.67	12.00
Point 22										
4/1/16	April	a	28.61	25.28	9.17	20.00	13.33	56.67	34.89	17.67
5/8/16	May	a	25.00	26.11	5.28	26.11	18.33	49.89	42.44	29.78

6/7/16	June	a	15.83	15.00	6.67	28.89	21.11	53.89	51.22	29.11
7/3/16	July	n	23.89	13.33	5.28	22.78	25.00	38.67	42.56	29.11
8/7/16	August	n	18.06	22.50	6.67	14.72	21.11	59.56	59.56	30.11
9/1/16	September	n	36.39	12.22	3.89	17.22	30.00	37.89	52.22	22.89
9/24/16	October	n	16.94	30.28	6.67	9.17	43.06	38.67	81.78	49.00
10/30/16	November	a	23.89	40.56	6.67	3.61	14.72	29.56	61.33	63.44
12/7/16	December	n	28.33	40.56	13.61	3.33	18.33	2.56	22.67	83.44
1/10/17	January	a	27.78	32.50	15.83	1.94	3.89	1.00	10.56	95.33
2/7/17	February	a	20.28	42.50	16.11	6.39	7.78	2.33	11.44	58.33
3/3/17	March	a	16.94	45.83	8.06	10.56	17.22	5.78	24.44	66.78
Point 23										
3/25/16	April	a	18.06	2.50	1.39	51.67	23.61	8.56	10.78	12.11
5/9/16	May	n	8.89	3.89	2.50	74.72	17.50	25.78	34.67	33.00
6/1/16	July	n	0.28	11.94	2.50	43.06	43.89	42.22	60.33	49.56
6/3/16	June	n	1.94	6.67	2.22	59.17	35.28	22.89	40.00	47.44
8/1/16	August	n	1.94	49.72	3.61	6.67	28.89	46.56	31.78	42.22
8/30/16	September	n	2.22	27.50	5.28	0.00	72.50	57.33	53.44	0.00
9/27/16	October	n	0.00	2.50	2.50	0.00	97.50	0.00	83.44	53.44
10/27/16	November	n	0.28	37.78	8.06	0.00	45.83	0.00	61.56	64.00
11/29/16	December	n	0.00	92.22	10.56	0.28	3.89	0.56	25.11	64.89
1/1/17	January	a	12.78	61.67	11.94	0.83	3.06	2.00	12.33	61.33
2/1/17	February	a	13.33	63.33	3.89	7.50	8.06	1.78	10.44	24.78
2/28/17	March	a	20.00	38.61	3.89	11.67	25.00	5.22	10.22	14.33
Point 25										
3/25/16	April	a	27.22	17.22	6.94	32.50	18.61	30.00	20.56	21.44
5/3/16	May	n	31.67	13.33	2.22	43.33	13.61	16.11	25.11	29.67
5/31/16	June	n	15.28	3.89	3.89	46.11	22.50	45.56	29.67	34.78
7/2/16	July	n	10.00	12.22	3.89	28.89	48.61	59.22	69.78	49.78
8/1/16	August	n	13.06	32.78	2.50	28.89	20.00	40.56	30.67	32.44
8/30/16	September	n	21.94	18.61	3.89	35.28	40.56	41.00	54.78	49.22
9/27/16	October	n	2.50	14.44	2.22	43.61	38.06	63.89	67.11	39.00
10/27/16	November	n	20.56	38.06	5.28	8.06	14.44	30.56	42.67	48.89
12/1/16	December	n	18.89	52.78	6.67	4.72	8.06	19.22	25.67	56.00
1/10/17	January	n	4.72	43.33	14.44	6.39	14.72	3.89	10.78	46.89
2/1/17	February	n	21.94	43.06	5.28	10.56	19.72	2.89	12.67	48.89
2/28/17	March	n	18.06	19.72	5.28	21.11	35.00	7.78	18.44	40.44
Point 26										
4/3/16	April	a	4.44	26.67	6.67	30.28	21.11	39.44	24.44	21.33
5/6/16	May	a	21.11	30.00	2.50	43.06	20.00	25.44	38.44	25.67
5/31/16	June	n	11.67	10.83	2.50	51.39	17.50	21.56	32.00	21.00
7/2/16	July	n	6.67	11.94	2.50	54.17	27.78	19.11	29.33	25.11
8/1/16	August	n	5.00	13.61	3.89	52.78	25.28	34.22	26.78	38.56
8/30/16	September	n	6.39	20.00	1.67	67.22	25.28	17.22	25.89	43.33
9/27/16	October	n	2.78	15.83	2.50	67.22	16.11	54.56	63.22	16.78
10/27/16	November	n	5.83	35.56	5.28	38.06	5.28	54.89	38.33	57.00
12/1/16	December	n	4.72	69.44	5.28	1.39	10.56	6.11	13.67	44.00
1/10/17	January	n	4.44	54.17	11.94	8.06	22.50	1.67	8.11	51.56
2/1/17	February	n	14.17	37.78	3.89	11.39	31.67	2.00	7.11	43.22
2/28/17	March	n	11.67	21.11	3.89	20.00	38.06	6.56	15.44	47.44
Point 28										
3/19/16	April	a	45.83	30.00	1.67	45.83	5.28	8.44	4.67	11.67
5/6/16	May	n	27.78	9.44	2.50	22.50	16.11	15.78	19.67	12.44
6/1/16	June	n	28.61	2.50	1.94	27.78	32.78	13.33	25.22	17.89
7/1/16	July	n	11.94	5.28	2.50	28.61	43.61	20.56	24.89	16.67
8/2/16	August	n	13.33	21.11	2.50	17.50	22.50	21.11	18.89	24.11

8/31/16	September	n	25.83	19.72	2.50	22.50	43.06	15.22	25.11	59.22
9/28/16	October	n	7.78	15.00	1.67	22.50	54.17	76.44	57.00	7.89
10/30/16	November	a	6.67	72.22	13.61	2.50	2.50	67.22	13.33	61.44
11/29/16	December	a	5.83	79.72	12.22	2.50	2.50	8.56	7.78	67.78
1/1/17	January	n	4.72	62.22	5.28	11.94	6.11	8.00	6.33	52.11
2/2/17	February	n	17.22	30.28	2.50	35.56	5.28	2.11	4.33	54.11
3/2/17	March	n	10.83	17.50	2.50	31.39	18.33	4.33	9.22	43.00
Point 35										
4/2/16	April	a	58.06	10.28	1.67	31.39	6.67	13.89	14.67	18.56
5/8/16	May	a	38.06	10.56	3.61	35.28	8.06	24.67	24.11	22.78
6/6/16	June	a	36.94	5.28	1.39	30.00	21.11	11.56	28.78	25.11
7/3/16	July	n	27.78	10.56	2.50	34.17	21.39	23.78	31.33	25.89
8/3/16	August	a	39.44	20.00	2.50	21.11	10.83	18.89	23.22	26.33
9/1/16	September	n	27.50	14.72	2.22	35.56	26.39	18.89	38.56	41.56
9/23/16	October	n	31.11	26.11	1.94	19.17	21.67	32.33	31.78	15.78
10/28/16	November	a	34.17	41.94	3.89	3.89	5.28	22.56	21.22	33.22
12/6/16	December	n	55.28	33.89	2.50	1.39	4.17	1.11	7.11	24.44
1/11/17	January	a	60.28	31.67	2.50	3.89	1.67	0.67	3.56	24.33
2/7/17	February	a	66.94	14.44	2.50	9.17	6.67	2.11	5.56	11.78
3/2/17	March	a	49.17	9.17	2.50	14.44	18.61	7.78	19.67	25.22
Point 36										
4/3/16	April	n	11.39	20.00	3.06	56.94	17.22	22.56	23.44	28.33
7/11/16	July	n	0.83	6.39	5.28	35.28	38.06	45.33	62.22	44.33
9/22/16	October	n	0.00	0.83	0.83	64.44	40.56	76.33	89.56	16.78
1/24/17	January	n	1.94	85.56	9.44	0.83	1.67	0.67	6.78	55.22
2/21/17	February	n	0.28	59.44	8.06	6.11	14.44	9.33	21.56	39.67
3/14/17	March	n	0.00	39.72	6.39	13.06	25.28	24.11	31.67	36.89
Point 41										
3/19/16	April	a	51.11	15.56	1.94	32.50	11.94	14.00	16.00	19.44
5/6/16	May	a	28.61	10.56	2.50	30.00	33.06	21.56	45.67	28.89
6/6/16	June	a	14.17	12.22	2.50	43.06	37.78	35.11	47.56	29.89
7/2/16	July	a	18.33	5.28	2.50	43.61	27.78	30.78	51.33	28.78
8/2/16	August	a	6.11	22.50	2.50	20.00	40.28	35.78	27.22	42.44
8/31/16	September	n	5.28	9.44	2.50	35.56	64.44	26.89	51.11	44.11
9/28/16	October	n	5.28	8.06	2.50	27.50	59.44	72.67	61.67	38.11
10/30/16	November	a	4.72	74.72	13.61	2.50	3.89	71.00	32.89	72.11
12/1/16	December	a	4.44	81.39	10.83	2.22	3.89	19.67	14.44	65.67
1/10/17	January	a	0.83	68.33	14.72	8.06	3.89	6.11	6.22	51.00
2/2/17	February	a	5.28	35.56	11.94	35.56	6.67	4.00	7.44	44.89
2/28/17	March	a	10.00	20.00	6.67	43.33	22.50	17.89	13.67	45.00
Point 44										
4/2/16	April	a	20.83	32.78	5.00	26.11	12.22	36.78	29.78	16.78
5/8/16	May	n	20.56	25.00	2.50	31.11	11.94	28.56	23.67	41.44
6/6/16	June	n	16.94	16.11	5.28	22.50	21.11	31.00	27.56	23.44
7/3/16	July	n	8.06	27.50	3.89	21.11	25.00	36.11	51.33	28.33
8/3/16	August	n	13.06	32.50	3.89	16.11	15.83	38.89	39.00	30.33
9/1/16	September	n	13.89	32.50	5.28	28.89	25.28	41.89	42.44	44.67
9/23/16	October	n	11.67	20.00	3.89	35.28	26.11	45.44	65.33	22.33
10/28/16	November	n	13.06	51.39	6.67	11.67	5.00	26.11	38.22	50.78
12/6/16	December	n	19.17	56.39	6.67	6.67	5.28	8.22	20.56	50.56
1/11/17	January	n	13.06	45.83	8.06	15.83	5.00	5.78	12.22	66.78
2/7/17	February	n	7.78	25.28	8.06	36.67	9.17	5.33	8.89	54.56
3/2/17	March	n	10.28	23.61	5.28	28.89	11.94	14.00	21.00	62.33
Point 46										
3/25/16	April	n	1.39	6.67	2.50	46.11	37.78	15.44	18.56	9.33

7/19/16	July	n	1.94	26.11	5.28	30.28	22.50	47.33	50.56	60.33
9/27/16	October	n	0.00	7.50	2.22	66.94	20.00	79.22	78.11	49.67
1/23/17	January	n	0.28	61.94	10.56	9.17	10.56	4.22	14.33	73.00
2/21/17	February	a	0.28	25.56	6.67	22.22	38.33	6.00	16.78	52.33
3/14/17	March	a	0.28	13.06	5.28	15.83	53.89	11.78	19.00	35.67
Point 47										
3/19/16	April	n	38.89	27.78	3.61	27.50	15.00	10.67	13.44	11.56
7/20/16	July	n	17.22	48.33	6.67	15.83	1.67	23.00	15.78	35.33
9/28/16	October	n	21.94	32.78	2.50	0.00	30.00	0.00	32.89	32.22
1/23/17	January	n	15.56	45.83	3.89	26.11	5.28	3.56	6.78	26.67
2/21/17	February	n	27.78	20.00	3.89	28.61	20.83	5.00	8.89	21.33
3/14/17	March	n	22.22	19.72	2.50	24.72	18.61	6.56	14.00	18.89
Point 49										
3/25/16	April	a	21.11	30.00	2.50	25.00	20.00	42.67	22.11	18.56
5/3/16	May	a	13.33	32.78	2.50	32.50	30.00	26.11	30.78	19.33
5/31/16	June	a	4.44	21.11	2.50	32.50	33.89	35.56	50.44	52.78
7/2/16	July	n	5.00	18.33	5.28	23.61	35.56	54.89	56.78	50.00
8/1/16	August	n	10.56	59.44	2.50	6.39	9.44	41.56	17.78	26.33
8/30/16	September	n	22.22	40.83	2.50	17.22	27.78	28.67	18.22	26.11
9/27/16	October	n	13.06	25.00	2.50	30.56	35.00	36.56	45.89	47.67
10/27/16	November	n	24.44	40.56	5.28	6.11	18.61	20.56	24.78	32.89
12/1/16	December	n	19.72	51.11	3.89	1.94	10.56	10.67	9.56	35.33
1/10/17	January	n	26.39	43.61	3.89	14.72	10.83	1.67	5.33	16.33
2/1/17	February	a	27.50	27.50	3.89	27.78	15.83	2.44	6.11	21.11
2/28/17	March	a	13.33	15.83	2.50	26.11	32.78	4.44	11.78	27.22
Point 61										
4/1/16	April	a	18.33	13.61	2.22	48.33	13.06	12.78	13.33	20.67
5/3/16	May	a	11.94	9.44	1.94	51.39	23.89	16.33	23.33	22.89
6/6/16	June	a	19.17	9.44	2.50	33.89	35.28	23.67	27.78	32.22
7/2/16	July	a	25.00	18.61	2.50	18.61	35.28	47.00	32.00	41.00
8/2/16	August	a	18.06	22.50	2.50	11.94	23.61	43.67	33.44	27.56
9/1/16	September	n	25.00	22.50	2.22	18.61	38.33	30.44	44.11	33.78
9/23/16	October	n	11.94	15.83	2.22	18.33	52.50	48.56	67.00	37.33
10/30/16	November	a	12.50	64.17	10.56	6.67	3.89	43.00	35.33	51.56
12/6/16	December	a	14.17	66.67	8.06	0.83	12.22	4.67	20.11	52.00
1/11/17	January	a	16.39	63.06	5.28	1.11	7.78	0.78	8.11	50.67
2/7/17	February	a	19.44	51.39	8.06	3.61	14.72	1.22	13.33	45.00
3/3/17	March	a	21.67	30.28	2.50	13.06	26.11	3.89	22.44	39.44
Point 62										
4/3/16	April	a	61.94	3.61	1.11	23.61	6.67	8.78	8.67	19.00
5/6/16	May	a	44.72	11.39	1.94	35.28	3.89	13.56	16.56	33.78
6/3/16	June	n	38.33	9.44	2.50	32.50	17.22	28.22	39.22	28.67
7/3/16	July	n	27.50	8.06	8.06	18.33	32.50	29.33	32.89	25.22
8/3/16	August	n	30.28	21.11	2.50	18.61	12.22	38.67	31.89	29.67
9/1/16	September	n	28.89	8.06	2.22	26.39	37.78	26.11	37.44	43.56
9/23/16	October	n	17.50	24.72	2.50	13.33	27.22	57.29	46.78	20.89
10/28/16	November	n	30.28	40.83	9.17	1.94	6.67	20.89	30.00	43.22
12/1/16	December	n	30.28	51.39	5.28	0.56	3.61	1.22	9.67	41.78
1/11/17	January	n	17.22	56.67	2.50	3.33	5.28	1.33	3.22	33.89
2/7/17	February	n	27.22	48.33	6.67	1.94	9.44	1.44	8.22	53.00
3/2/17	March	n	27.22	39.44	1.94	2.50	13.33	3.67	14.33	27.56
Point 64										
4/15/16	April	a	45.00	10.56	3.33	38.33	3.61	20.44	14.22	20.56
5/8/16	May	a	46.11	14.44	1.94	33.61	7.78	15.11	32.11	24.44
6/6/16	June	a	35.28	5.28	2.22	26.39	25.00	18.89	51.33	26.33

7/3/16	July	a	38.06	13.33	5.28	20.00	27.50	29.56	51.00	27.00
8/3/16	August	a	48.61	9.17	3.33	19.44	10.00	21.67	19.44	24.33
9/1/16	September	n	41.94	5.28	1.67	30.00	23.61	13.78	28.44	29.22
9/23/16	October	a	38.06	9.44	2.50	23.61	28.61	43.89	47.89	26.67
10/28/16	November	a	27.50	50.00	10.83	3.61	3.61	26.44	25.78	49.00
12/6/16	December	n	27.78	44.72	6.67	3.89	5.28	4.11	8.00	33.78
1/11/17	January	n	50.00	32.78	2.50	11.39	0.83	1.67	2.78	34.89
2/7/17	February	n	54.17	24.72	3.61	11.39	1.94	2.11	3.67	19.22
3/2/17	March	n	35.56	16.11	2.22	20.83	15.56	5.00	6.89	21.22
Point 65										
4/15/16	April	a	43.61	3.61	0.83	30.56	17.22	3.78	18.78	11.67
5/8/16	May	a	26.11	3.89	2.50	40.56	15.83	19.11	27.11	22.44
6/7/16	June	a	23.61	6.67	2.50	36.67	22.22	23.89	29.78	22.89
7/3/16	July	n	14.17	8.06	5.28	56.67	22.50	26.56	31.33	34.56
8/3/16	August	n	6.11	25.28	2.50	30.28	22.50	30.56	30.11	42.89
9/1/16	September	a	13.89	20.00	0.28	34.44	35.28	2.11	45.11	53.67
9/23/16	October	n	10.56	13.33	1.39	39.17	39.17	72.89	62.00	27.00
10/28/16	November	a	15.83	56.39	2.50	6.39	15.28	43.33	29.89	43.33
12/6/16	December	a	46.94	18.33	2.50	0.28	23.33	1.11	23.67	40.67
1/11/17	January	a	40.28	33.06	16.94	3.61	4.72	0.44	8.56	33.56
2/7/17	February	a	26.67	35.28	9.17	11.94	18.61	2.44	10.56	40.78
3/2/17	March	a	13.89	9.44	3.89	10.83	45.83	6.33	15.22	32.44
Point 66										
4/15/16	April	a	30.00	3.89	1.39	45.83	6.67	6.22	8.11	17.89
5/6/16	May	a	45.83	3.89	2.22	32.78	13.61	11.44	35.33	22.11
5/31/16	June	a	38.33	3.89	2.50	27.50	33.89	14.78	37.33	18.56
7/1/16	July	a	10.83	5.28	5.28	31.67	35.28	36.11	50.44	29.44
8/2/16	August	a	33.33	6.67	2.50	15.83	25.00	26.78	23.22	24.89
8/31/16	September	n	20.00	5.28	2.50	35.56	51.39	27.78	36.44	66.44
9/28/16	October	n	16.11	12.22	1.94	27.50	51.67	79.11	57.67	16.00
10/30/16	November	n	9.44	72.50	10.83	3.89	3.89	79.44	21.89	62.33
11/29/16	December	n	4.72	80.28	8.06	0.56	3.61	4.56	8.56	70.44
1/1/17	January	n	5.28	54.17	3.89	3.89	19.72	4.89	9.11	59.11
2/2/17	February	n	23.61	48.89	3.89	9.72	8.06	1.33	7.11	49.11
3/2/17	March	a	8.06	32.78	2.50	9.44	23.61	6.11	10.44	32.44
Point 67										
4/15/16	April	a	30.28	8.06	1.39	43.06	10.83	9.11	9.67	20.11
5/6/16	May	a	40.56	8.06	2.50	37.78	19.72	20.00	20.11	19.78
6/6/16	June	a	14.44	6.67	2.50	43.33	32.78	28.11	44.33	29.33
7/2/16	July	a	14.44	3.89	2.50	40.83	32.78	30.89	53.00	29.67
8/2/16	August	n	15.83	40.83	2.50	22.50	13.61	35.78	16.89	39.78
8/31/16	September	n	6.39	14.72	2.50	40.83	51.11	30.00	33.89	44.11
9/28/16	October	n	3.06	10.83	2.50	25.00	48.89	65.56	66.00	36.44
10/30/16	November	n	6.39	75.00	12.22	2.50	2.50	64.22	28.89	60.56
12/1/16	December	n	2.78	66.94	12.22	2.22	3.61	14.56	12.89	60.56
1/10/17	January	n	1.94	54.17	12.22	27.50	6.39	1.78	5.00	59.78
2/2/17	February	a	5.00	35.56	11.94	45.83	3.89	3.11	5.22	54.67
2/28/17	March	a	10.28	23.61	5.28	38.06	13.61	5.00	10.78	31.11
Point 68										
4/15/16	April	a	66.67	2.50	0.83	19.72	14.44	1.44	13.56	9.44
5/9/16	May	a	26.67	2.50	1.11	46.11	21.39	4.11	26.67	27.89
6/2/16	July	a	1.67	40.83	7.78	34.17	8.06	39.78	29.44	45.33
6/3/16	June	a	11.11	2.50	1.67	68.61	10.56	10.89	35.11	52.89
8/1/16	August	a	9.17	71.39	3.89	2.22	3.33	30.33	12.78	18.44
8/31/16	September	n	16.11	76.39	2.50	0.00	8.33	50.67	14.22	0.00

9/27/16	October	a	22.50	36.94	5.28	0.00	23.06	0.00	25.33	51.78
10/27/16	November	a	18.06	51.39	5.28	0.28	18.06	1.56	20.22	42.56
11/29/16	December	a	21.11	51.39	3.89	1.39	13.33	0.67	10.44	34.00
1/1/17	January	a	30.28	31.11	2.50	28.89	14.17	2.56	6.89	24.78
2/1/17	February	a	38.06	17.50	2.50	26.39	15.83	3.22	5.00	18.33
2/28/17	March	n	40.28	41.94	2.50	9.17	4.44	3.00	3.89	11.33
Point 69										
4/15/16	April	a	43.33	6.39	3.06	26.11	19.72	12.67	22.89	22.33
5/3/16	May	a	35.28	16.94	3.89	18.61	23.89	19.44	40.56	21.22
6/1/16	June	n	11.39	0.83	0.83	7.50	15.56	8.89	9.33	5.89
6/3/16	July	n	53.89	3.89	3.89	2.22	25.56	14.56	13.89	2.89
8/1/16	August	n	58.06	7.78	1.67	0.00	27.50	5.44	9.33	0.00
8/30/16	September	n	3.33	3.33	0.28	0.00	11.11	3.67	8.67	0.00
9/27/16	October	n	71.11	1.39	1.11	0.28	27.50	0.22	13.00	6.33
10/27/16	November	n	50.83	9.72	1.39	0.83	29.44	0.56	14.89	10.11
11/29/16	December	n	54.44	10.56	9.17	3.06	20.83	1.56	14.44	12.22
1/1/17	January	a	39.72	11.67	5.83	7.22	34.17	0.89	13.56	16.33
2/1/17	February	a	46.67	27.78	7.78	7.78	16.11	1.78	8.00	9.78
2/28/17	March	n	35.28	13.33	2.78	16.94	24.72	7.78	11.56	6.22

APPENDIX D. LIST OF PLANT SPECIES AT DIAMOND HALF RANCH

Family	Genus	Species	Common
Agavaceae	*Yucca*	*arkansana*	Arkansas Yucca
Amaranthaceae	*Froelichia*	*spp.*	Snakecotton
Apiaceae	*Polytaenia*	*texana*	Texas Prairie Parsley
	Scandix	*pectin-veneris*	Shepherdsneedle
Aquifoliaceae	*Illex*	*vomitoria*	Yaupon
Aristolochiaceae	*Aristolochia*	*erecta*	Swanflower
Asclepiadaceae	*Cynanchum*	*barbigerum*	Cynanchum
	Matelea	*reticulata*	Green Milkweed Vine
	Yucca	*rupicola*	Twistleaf Yucca
Asparagaceae	*Achillea*	*millefolium*	Milfoil
Asteraceae	*Ambrosia*	*artemisiifolia*	Annual Ragweed
	Aphanostephus	*spp.*	Lazy Daisy
	Carduus	*nutans*	Musk Thistle
	Chaetopappa	*bellidifolia*	Dwarf White Aster
	Cirsium	*texanum*	Texas Thistle
	Coreopsis	*tinctoria*	Goldenwave
	Croptilon	*divaricatum*	Scratch Daisy
	Daucus	*pusillus*	Rattlesnake-weed
	Evax	*spp.*	Rabbit's Tobacco
	Gaillardia	*amblyodon*	Red Gaillardia
	Gaillardia	*pulchella*	Firewheel
	Gaillardia	*suavis*	Pincushion Daisy
	Gamochaeta	*spp.*	Everlasting Cudweed
	Helenium	*quadridentatum*	Sneezeweed

	Helenium	*amarum*	Yellow Bitterweed
	Helianthus	*annuus*	Common Sunflower
	Heterotheca	*subaxillaris*	Camphorweed
	Hymenopappus	*scabiosaeus*	Woollywhite
	krigia	*virginica*	Dwarf Dandelion
	Packera	*obovata*	Golden Groundsel
	Palafoxia	*spp.*	Palafoxia
	Pluchea	*odorata*	Marsh Fleabane
	Pyrrhopappus	*carolinianus*	Texas Dandelion
	Rudbeckia	*hirta*	Brown-Eyed Susan
	Sclerocarpus	*uniserialis*	Mexican Bonebract
	Senecio	*ampullaceus*	Texas Groundsel
	Sonchus	*spp.*	Sowthistel
	Thymophylla	*pentachaeta*	Parralena
	Verbesina	*encelioides*	Cowpen Daisy
Brassicaceae	*Descurainia*	*pinnata*	Tansy-Mustard
Buddlejaceae	*Polypremum*	*procumbens*	Juniper Leaf
Cactaceae	*Cylindropuntia*	*leptocaulis*	Tasajillo
	Opuntia	*spp.*	Prickly Pear
Campanulaceae	*Triodanis*	*perfoliata*	Clasping Venus' Looking Glass
Caryophyllaceae	*Silene*	*antirrhina*	Sleepy Silene
Chenopodiaceae	*Chenopodium*	*album*	Common Lambsquarter
Commelinaceae	*Commelina*	*erecta*	Widow's Tears
	Tradescantia	*pedicellata*	Granite Spiderwort
Convolvulaceae	*Stylisma*	*pickeringii*	Pickering's Dawnflower
Cyperaceae	-	-	Sedge
Euphorbiaceae	*Acalypha*	*radians*	Cardinal Feather
	Chamaesyce	*cordifolia*	Heartleaf Sandmat
	Cnidoscolus	*texanus*	Texas Bullnettle
	Croton	*argyranthemus*	Healing Croton
	Croton	*capitatus*	Hogwort
	Croton	*glandulosus*	Tropic Croton
	Croton	*monoathogynus*	Prairie Tea
	Stillingia	*texana*	Texas Queen's Delight
Fabaceae	*Astragalus*	*nuttallianus*	Nuttall's Milk-Vetch
	Baptisia	*bracteata*	Longbract Wild Indigo
	Centrosema	*virginianum*	Butterfly pea
	Chamaecrista	*fasciculata*	Partridge Pea
	Dalea	*phleoides*	Slimspike Prairie Clover
	Galactia	*spp.*	Milkpea
	Indigofera	*lindheimeriana*	Lindheimers Indigo
	Indigofera	*miniata*	Scarlet Pea
	Lupinus	*texensis*	Bluebonnet
	Rhynchosia	*americana*	American Snoutbean

	Schrankia	*spp.*	Senstive Briar
	Tephrosia	*lindheimeri*	Lindheimer Hoarypea
	Vicia	*ludoviciana*	Deer Pea Vetch
	Zornia	*bracteata*	Viperina
Fagaceae	*Quercus*	*marilandica*	Blackjack Oak Seedling
Fumariaceae	*Corydalis*	*curvisiliqua*	Scrambled Eggs
Geraniaceae	*Geranium*	*caroliniunum*	Wild Geranium
Hydrophyllaceae	*Nama*	*hispidum*	Sand Bells
	Phacelia	*patuliflora*	Blue Phacelia
Iridaceae	*Sisyrinchium*	*Spp.*	Blue-Eyed Grass
Juncaceae	*Juncus*	*effusus*	Common Rush
Krameriaceae	*Krameria*	*lanceolata*	Ratany
Lamiaceae	*Lamium*	*amplexicaule*	Henbit
	Monarda	*citriodora*	Lemmon Beebalm
	Scutellaria	*drummondii*	Drummond's Skullcap
	Schoenocaulon	*texanum*	Green Lily
	Nothoscordum	*bivalve*	Crowpoison
Lilaceae	*Linum*	*rupestre*	Rock Flax
	Sida	*lindheimeri*	Lindheimer's Sida
Oxalidaceae	*Oxalis*	*dillenii*	Yellow Wood-Sorrel
Onagraceae	*Oenothera*	*laciniata*	Cutleaf Evening-Primrose
	Oenothera	*suffrutescens*	Scarlet Gaura
Plantaginaceae	*Plantago*	*spp.*	Plantain
Poaceae	*Agrostis*	*hyemalis*	Winter Bentgrass
	Aristida	*oligantha*	Oldfield Threeawn
	Aristida	*purpurea*	Purple Threeawn
	Avena	*fatua*	Wild Oat
	Bothriochloa	*laguroides*	Silver Bluestem
	Bothriochloa	*ischaemum*	King Ranch Bluestem
	Bouteloua	*curtipendula*	Sideoats Grama
	Bromus	*catharticus*	Rescuegrass
	Cenchrus	*spinifex*	Sandbur
	Chloris	*verticillata*	Tumble Windmill Grass
	Chloris	*cucullata*	Hooded Windmill grass
	Cynodon	*dactylon*	Coastal Bermduagrass
	Dichanthelium	*spp.*	Rosette Grass
	Digitaria	*ciliaris*	Southern Crabgrass
	Digitaria	*cognata*	Fall Witchgrass
	Digitaria	*patens*	Texas Cottontop
	Digitaria	*spp.*	Digitaria
	Elionurus	*tripsacoides*	Pan-American Balsamscale
	Eragrostis	*curtipedicellata*	Gummy Lovegrass
	Eragrostis	*intermedia*	Plains Lovegrass
	Eragrostis	*secundiflora*	Red Lovegrass

	Eustachys	*petraea*	Stiffleaf eustachys
	Hordeum	*pusillum*	Little Barley
	Limnodea	*arkansana*	Ozarkgrass
	Lolium	*spp.*	Ryegrass
	Panicum	*virgatum*	Switchgrass
	Paspalum	*dilatatum*	Dallisgrass
	Paspalum	*plicatulum*	Brownseed Paspalum
	Paspalum	*setaceum*	Thin Paspalum
	Paspalum	*spp.*	Paspalum
	Phalaris	*caroliniana*	Carolina Canarygrass
	Schizachyrium	*scoparium*	Little Bluestem
	Sorghum	*halepense*	Johnsongrass
	Sporobolus	*clandestinus*	Rough Dropseed
	Sporobolus	*cryptandrus*	Sand Dropseed
	Triplasis	*purpurea*	Purple Sandgrass
	Urochloa	*ciliatissima*	Fringed Signalgrass
	Vulpia	*octoflora*	Sixweeks fescue
Polemoniaceae	*Phlox*	*drummondii*	Drummond's Phlox
Polygonaceae	*Eriogonum*	*multiflorum*	Heartsepal Wild Buckwheat
Portulacaceae	*Portulaca*	*pilosa*	Kiss-me-quick
Rosaceae	*Rubus*	*trivialis*	Dewberry
Rubiaceae	*Diodia*	*teres*	Poorjoe
	Galium	*aparine*	Stickywilly
	Stenaria	*nigricans*	Bluets
Rutaceae	*Zanthoxylum*	*hirsutum*	Tickle-Tounge
Scrophulariaceae	*Veronica*	*persica*	Persian Speedwell
	Penstemon	*cobaea*	Fox Glove
	Verbascum	*thapsus*	Common Mullein
	Castilleja	*indivisa*	Texas Paintbrush
	Nuttallanthus	*texanus*	Texas Toadflax
Selaginellaceae	*Selaginella*	*arenicola*	Riddell's Spikemoss
Smilaceae	*Smilax*	*bona-nox*	Greenbrier
Solanaceae	*Physalis*	*viscosa*	Yellow Ground Cherry
	Solanum	*elaeagnifolium*	Silver-Leaf Nightshade
Urticaceae	*Urtica*	*Chamaedryoides*	Heartleaf Nettle
Verbenaceae	*Callicarpa*	*americana*	American Beautyberry
	Lantana	*urticoides*	Lantana
	Verbena	*halei*	Texas Vervain
Vitaceae	*Vitis*	*mustangensis*	Mustang grape

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