Status and Long-Term Use of Artificial Escape Dens by Swift Foxes in Northwest Texas

By

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Chapter I

Introduction

The following work represents partial fulfillment of the requirements for the degree of Masters of Science in Wildlife, Aquatic, and Wildlands Science and Management in the Graduate College at Texas Tech University. Research for this thesis was conducted on artificial den sites of swift foxes (*Vulpes velox*) established in 2002 and 2003 by McGee et al. (2006) in northwest Texas and northeast New Mexico. The purpose of this research was to evaluate the effectiveness of artificial dens in aiding swift foxes to avoid predation, primarily by coyotes (*Canis latrans*). The effectiveness of these dens was examined when they were established by McGee et al. My study focused on use of the artificial dens and their condition 10 years after they were established. Study sites descriptions are given in Chapters II and III. Chapters II and III represent draft manuscripts intended for publication in peer-reviewed journals. Chapter II discusses my assessment of the condition and use by swift foxes of artificial escape dens 10 years post-establishment. Chapter III examines characteristics of vegetation at concurrently used artificial escape dens and natural dens of swift foxes after 10 years. With the guidance of my advisory committee, particularly of my major advisor, I designed this study, collected the data, and produced manuscripts from the research. Authorship for the following manuscripts were determined based on contributions as well as the guidelines outlined by Dickson and Connor (1978) and the CBE Style Manual Committee (2006). Authorship for these manuscripts are as follows:

<u>Chapter II.</u> Colton D. Laws, Greg Pavur, Philip S. Gipson, John Baccus, and Kevin Mulligan.

Chapter III. Colton D. Laws, Philip S. Gipson, Souparno Ghosh, John Baccus, and Kevin Mulligan.

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Chapter II
Assessment of the condition of artificial escape dens and use by swift foxes 10 years post-establishment

Abstract

Swift foxes (*Vulpes velox*) occurred in 79 counties in Texas during the early 1900s; they currently only inhabit the two most northwestern counties, Dallam and Sherman. The major cause of swift fox mortality is attributed to coyote (*Canis latrans*) depredation. During 2002 to 2004, 191 artificial escape dens were established on the Rita Blanca National Grassland (RBNG), the Kiowa National Grassland (KNG), and a private ranch to aid swift foxes in escaping from coyotes. Swift foxes used escape dens through 2004 and their survival appeared to increase. We initiated a study in 2012 to determine the physical condition and use of these artificial dens by swift foxes. We found 72.8% of these artificial dens had become unusable by swift foxes because of obstructions within dens and/or complete burial by soil. Ten artificial dens sustained physical damage, seven had cracks along the pipe, two had crushed entrances when apparently stepped on by cattle, and teeth marks on one den suggested damage by a predator. We found evidence of swift fox use at only one artificial den in RBNG. Swift foxes had used artificial escape dens when they were established. It appears that long-term use of escape dens by swift foxes will require periodic maintenance to clear obstructions that interfere with their use.

Introduction

The expansion of agricultural development (Egoscue, 1979) has greatly reduced the distribution of swift foxes within their historic range throughout the short- and mid-grass prairies of North America. Increase tillage of the prairie contributed to habitat loss and the use of poisons to control larger-size carnivores, such as coyotes (*Canis latrans*) and wolves (*Canis lupus*) caused mortalities to swift foxes (Scott-Brown et al., 1987). Secondary poisoning of other animals, such as prairie dogs (*Cynomys ludovicianus*) caused secondary mortalities to swift foxes feeding on dead animals (Miller et al., 1994). Swift fox numbers remained lower than the historic levels even after the elimination of poisoning campaigns following implementation of Executive Order 11643 (Samuel and Nelson, 1982). Some swift fox populations increased possibly related to the decline in the number of farms and ranches that helped reduce human activities harmful to foxes (Floyd and Stromberg, 1981). However, expanding coyote populations apparently reduced population expansions by swift foxes in some areas (Kitchen et al., 1999). Numbers of swift foxes remain lower than historic levels in most parts of their range and the species presently occurs in only two counties, Dallam and Sherman, in Texas (Schwalm et al., 2012).

The primary source of swift fox mortality has been attributed to coyote depredation (Kitchen et al., 1999). Coyotes do not often consume swift foxes but appear to kill them to reduce competition (Allardyce and Sovada, 2003). Coyote abundance positively correlated with prey abundance, while swift fox abundance negatively correlated with coyote presence and vegetation height in southeastern Colorado (Thompson and Gese, 2007). Because of the depredation by coyotes on swift foxes, a prior study was conducted in northwestern Texas to test the effectiveness of artificial escape den sites as a means of increasing swift fox survival by reducing depredation by coyotes (McGee et al., 2006).

Different fox species have been studied using artificial dens. Rudzinski et al. (1982) provided arctic foxes (*Vulpes lagopus*) with artificial dens in enclosures to test interactions between arctic foxes and red foxes (*Vulpes vulpes*). Red foxes were more aggressive and stole artificial dens from the arctic foxes. A study of food catching behavior was conducted with red foxes in enclosures built around artificial dens (Jeselnik and Brisbin, 1980). Artificial den structures have also been used with success for the San Joaquin kit fox (*Vulpes macrotis mutica*) (Cypher et al., 2011), a close relative of the swift fox. Over 100 artificial dens were established throughout California to improve sites that contained limited suitable cover for the kit fox. Kit fox visits to the artificial dens were difficult to monitor, but artificial dens benefited the kit fox. Warrick et al. (2007) recommended the placement of artificial dens in orchards and along canals to improve available habitat for kit foxes. These areas had no diurnal use but limited nocturnal use by kit foxes.

Artificial den structures have been widely used to enhance survival and reproductive success of other species. They can provide protection from predation and are favored as natal dens for some species. The Missouri Department of Conservation (2015) recommends the installation of culverts and plastic pipes near tall grass or weeds as artificial dens for rabbits on private property. Artificial dens have also enhanced survival of captive-released black bears in North Carolina (Stiver et al., 1997). Stuewer (1948) recommended that artificial dens be provided for raccoons because numbers of large, den-providing trees were decreasing. Grey squirrels in Maryland enlarged population size by 65 – 100% on areas with artificial dens (Burger, 1969). Zhang et al. (2007) examined used and unused natal den sites of giant pandas (*Ailuropoda melanoleuca*). They recommended that land managers conduct surveys of available den sites to determine if there were enough suitable locations for breeding pandas. If a shortage of sites existed, Zhang et al. (2007) recommended the installation of artificial dens to improve breeding habitats. Swaisgood et al. (2011) also recommended the use of an adaptive management approach to giant panda management with the addition of artificial dens to improve habitat.

McGee et al. (2006) installed artificial escape dens on the Rita Blanca (RBNG) and Kiowa National Grasslands (KNG) in 2002 and 2003 and monitored swift foxes by radio-telemetry. They compared survival rates of swift foxes on sites with artificial escape dens (treatment) and sites without artificial dens (control). Swift fox survival was higher on treatment sites. No study has assessed whether swift foxes still use artificial escape dens established in 2002 and 2003 by McGee et al. Our study team visited these artificial escape dens to determine the physical condition and present status of use by swift foxes.

Study Site

Research was conducted in the High Plains ecoregion of the Texas Panhandle and eastern New Mexico (Fig. 2.1). The climate of the region is semiarid. In nearby Dalhart, TX, the mean annual high temperature is 20.6 ºC and the mean precipitation is 39.9 cm (U.S. Climate Data, 2015). A shortgrass prairie community characterizes the habitat of the region with interspersion of stands of yucca and prickly pear cactus in some areas. An occasional tree occurs around homesteads. The primary land use is grazing by cattle with row-crop agriculture occurring proximate to the study sites. Anthropogenic features include improved and unimproved roads, scattered homesteads, agricultural infrastructure, transmission lines, windmills, and barbed-wire fences. One study site in western Sherman County has private ownership. All other study sites are located on the RBNG and KNG.

Methods

Artificial dens consist of PVC pipes that are approximately 4 m long and 20 cm in diameter (McGee et al., 2006). Dens are randomly oriented and separated by distances of 40-350 m. Artificial dens are located in five clusters at varying locations within the area. One cluster is located on a private ranch in Sherman County, Texas. Three clusters are located in different administrative units on the RBNG in Dallam County, Texas. The final cluster is within the boundaries of the KNG in Union County, New Mexico. There are 191 artificial dens at these locations.

We conducted an inventory of the current status of artificial dens to determine whether the longevity of the artificial dens lasts over 10 years. Artificial dens were located using a handheld GPS (Garmin, GPSmap 64) device. We visited each den site and cataloged the status as one of three categories; (1) buried/unusable, (2) useable but no signs of habitation, or (3) useable with signs of habitation. We examined each artificial den for structural damage and recorded the type of damage. We designated artificial dens completely buried by drifted soil or the interior of the den > 60% filled by soil or debris, preventing use by swift foxes to the buried/unusable category. Artificial dens were considered useable with signs of habitation if < 60% filled by debris and evidence of swift foxes found within 5 m of the den. We inspected artificial dens for damage sustained since installation. Dens fell into three categories: (1) buried, (2) damage observed or (3) no damage observed.

We visited each artificial den two times in 2013; once in late May and again in August to determine any apparent difference in use of artificial dens during times of the year were associated with pup rearing and dispersal.

Results

We designated all artificial dens located on the private ranch as in > 60% of the artificial dens buried/unusable category (Table 2.1). The designation of all the artificial dens on the ranch as unusable could be related to the prevalence of winds that carry soil into dens and combined with a lack of screening vegetation to block soil and debris from filling the dens.

The usable but no signs of habitation category referred to artificial dens with < 60% fill by soil or debris but showed no evidence of swift fox activity within 5 m of the artificial den. With one exception, the remaining artificial dens that did not fall into the buried/unusable category were usable with no sign of habitation (Table 2.1). This suggests that swift foxes do not frequently use the artificial dens or swift foxes are absent.

Only one artificial den (0.52%) contained signs of swift fox use (Table 2.1). This den was located on the RBNG. We found a swift fox scat at one entrance to the artificial den and a trail camera located nearby captured a photograph of a swift fox. A swift fox or foxes used this den on a more long-term basis than other artificial dens in the area.

We inspected artificial dens for damage sustained since installation (Table 2.2). If the artificial den was completely buried by soil or debris, it was not possible to inspect for signs of damage. In most locations, we assigned only a few of the artificial dens to this category. The only exception was on the private ranch, where 19 of 36 artificial dens were buried.

The majority of artificial dens sustained no visible damage since installation. Only three artificial dens on the RBNG and seven on the KNG showed visible signs of damage (Table 2.2). Most damage was superficial and did not appear to interfere with utilization of artificial dens by swift foxes. Only two artificial dens that we examined in the KNG showed substantial damage. Both appeared to have been stepped on by a large animal, most likely cattle, or run over by a vehicle. Large pieces of the entrance had broken off. On the RBNG, one den was partially dug up at one entrance and showed signs of being chewed on. It is likely that a predator, such as a coyote, attempted to reach a trapped smaller animal that was taking refuge. Because this occurred in the same unit where evidence of continued swift fox use of dens was found, it is possible that these artificial dens are still providing swift foxes with refuge from coyote predation.

Discussion

Unlike seasonal use of dens by most species, swift foxes utilize dens year-round (Egoscue, 1979). Swift foxes typically construct multiple dens in their home ranges for the purposes of pup rearing (natal dens) and escape from predators (Allardyce and Sovada, 2003). Swift fox dens are usually shallow and temporary in cultivated fields, while those in rangelands are deeper and more permanent (Kilgore, 1969).

Escape dens are important for avoiding predation as coyotes kill swift foxes to eliminate competition rather than a food resource (Kitchen et al., 1999). Artificial dens have been used to increase survival and reproductive success in multiple species including ducks, black bears, pandas, rabbits, and raccoons (Sargeant and Arnold, 1984, Stiver et al., 1997, Stuewer, 1948, Zhang et al., 2007). Other North American fox species have also benefitted from establishment of artificial dens (Rudzinski et al., 1982, Jeselnik and Brisbin, 1980, Warrick et al., 2007). Artificial dens have been shown to increase survival of San Joaquin kit foxes in areas overlapping coyote home ranges (Cypher et al., 2011).

McGee et al. (2006) found that artificial escape dens increased swift fox survival in treatment sites on the RBNG. A swift fox family group moved into a previously unoccupied area after installation of artificial dens on the RBNG, indicating that presence of artificial dens was attractive to swift foxes.

The results of our study indicated that, without maintenance, artificial dens tend to fill with debris. The large proportion of artificial dens buried or > 60% filled with debris severely limited swift foxes' utilization of artificial dens. McGee et al. (2006) indicated a higher level of use of artificial dens than we found. There are three explanations for the difference. These include (1) a reduced number of artificial dens considered usable with signs of inhabitance, (2) fewer swift foxes inhabiting the study area, and (3) loss of habitat.

One artificial den contained evidence of continued swift fox use in the RBNG. This suggests that while the use of artificial dens by swift foxes is limited, those that are usable still provide benefits to the swift fox population. While there was little evidence of use of artificial dens by swift foxes, many other species were using the artificial dens, including some of those that were > 60% filled with debris. Direct observations or evidence of use of artificial dens in the study site were found to include rabbits, skunks, small mammals, snakes, lizards, amphibians, arachnids, and insects. This indicates that artificial dens provide shelter and protection to the biological community as a whole, not just for swift foxes as was originally intended. Future studies could be conducted to document the use of artificial dens by species other than swift foxes.

In the years since installation, relatively few of the artificial dens sustained damage and most that were damaged only had minor cracks at the entrances. This indicates that artificial dens could provide long-term shelter to swift foxes after installation with periodic maintenance to remove debris. Those artificial dens that were substantially damaged appeared to have been crushed. Personal communications with U.S. Forest Service employees (Atkinson and Linner, 2017) indicated that the damage was likely done when vehicles drove across the dens. Limiting vehicle access to areas containing artificial dens or clearly indicating den locations could reduce these incidents.

The most common problem we encountered relating to use of artificial dens by swift foxes was den burial or filling by debris. We recommend periodic surveys of the artificial dens to find those that are filling or being buried. These artificial dens should be dug up and/or emptied to remove debris and allow for easier access by swift foxes. This type of maintenance was conducted by the U.S. Forest Service on one cluster of artificial dens not located in the study area (personal communication, Hanson and Linner). This effort appeared to have increased utilization of the artificial dens by swift foxes. Future studies could focus on swift fox utilization of artificial dens on the RBNG, KNG, the private ranch, and other sites before and after maintenance efforts.

In conclusion, evidence of swift fox use at one artificial den indicates that those dens that are still useable by swift foxes continue to benefit swift foxes and other species in the study area. Periodic maintenance of the artificial dens would likely increase their use by swift foxes and provide cover for the near future.

Management Implications

Artificial escape dens appeared to be an effective method of increasing swift fox survival at the time of installation. Burial of the dens or obstructions within them may be reducing the dens' utility to swift foxes. Periodic maintenance of the artificial escape dens should be performed to uncover those that have been buried, remove debris from the den interiors and entrances, and repair or replace damaged dens. This will ensure that the artificial dens will remain available for use by swift foxes in the long-term.

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Appendix

Table 2.1. Categories of artificial dens based on possibility of use and evidence of use by swift foxes.

Location	**Total # of Dens**	**# Buried/ Unusable**	**# Potentially Useable/No Sign**	**# Potentially Useable with Sign**	**Not Located**
Private Ranch	36	36	0	0	0
Rita Blanca 22	36	31	5	0	0
Rita Blanca 23	36	19	16	1	0
Rita Blanca 34	36	26	9	0	1
Kiowa	47	27	19	0	1

Table 2.2. Observed damage to artificial dens 10 years post installation. The Den Buried category includes dens that were totally buried and could not be examined.

Location	**Total # of Dens Located**	**Den Buried**	**No Damage to Den**	**Den Damaged**
Private Ranch	36	19	17	0
Rita Blanca 22	36	6	30	0
Rita Blanca 23	36	1	32	3
Rita Blanca 34	35	2	33	0
Kiowa	46	0	39	7

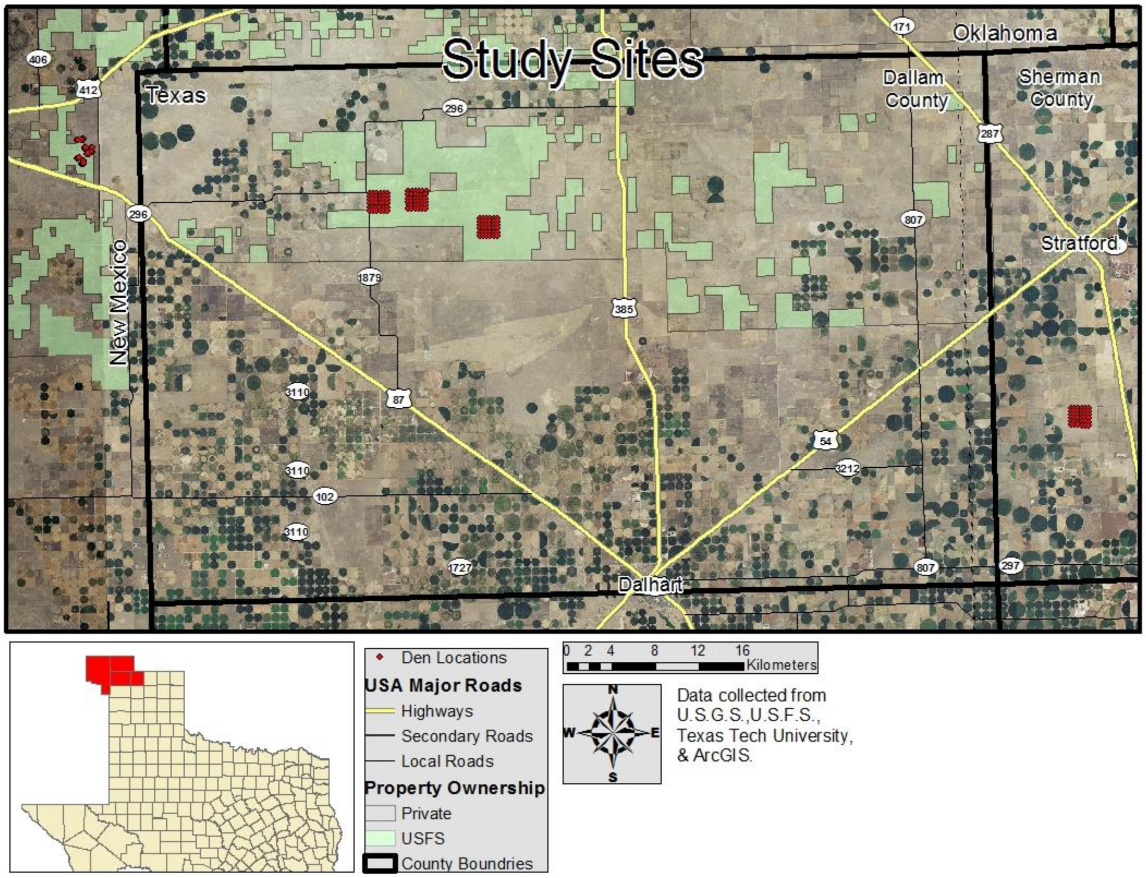

Figure 2.1. Study sites in Dallam and Sherman Counties, Texas, including artificial den locations and county boundaries.

Chapter III
Characteristics of vegetation at artificial escape dens and natural dens of swift foxes that were concurrently used 10 years ago

Abstract

Swift foxes (*Vulpes velox*) have declined in Texas and currently occur in only Dallam and Sherman counties. Swift foxes typically live in short-grass, native prairie habitats where vegetation grows < 30 cm in height and rarely utilize other habitats. The population in northwestern Texas reached dire circumstances in the early 2000s. Artificial escape dens made of PVC pipes were installed in the Rita Blanca National Grassland (RBNG) between 2002 and 2004 to provide swift foxes escape sites from predation by coyotes (*Canis latrans*). Studies in 2002 through 2004 indicated that swift foxes used the artificial dens and survival of the foxes increased as well as the population. We initiated a study in 2013 to determine the present vegetative characteristics at artificial den entrances, random points within 5 m of artificial dens, natural den entrances used in 2002 through 2004, and control sites. We found that the percentage of bare ground, average vegetation height, visual obstruction at 10 m and at artificial den entrances had changed compared to the values for these variables when the artificial dens were installed. We attributed the changes in vegetation to an increased capacity of artificial dens to hold water after a precipitation event compared to the drainage that occurs at natural dens. We recommend annual maintenance surveys at artificial den sites to maintain vegetation at < 30 cm in height in the area of artificial dens.

Introduction

Reductions in swift fox populations occurred in their historic ranges throughout the short- and mid-grass prairies of North America after the expansion of modern tillage practices and expanded predator control (Egoscue, 1979). Populations of swift foxes declined as the result of habitat loss and the use of poison to control larger carnivores, such as coyotes (*Canis latrans*) and wolves (*Canis lupus*; Scott-Brown et al., 1987). With elimination of the use of poisons following implementation of Executive Order 11643, which banned use of toxicants to control predators by federal programs and the cancellation of registrations for key poisons by the Environmental Protection Agency (EPA), swift fox populations increased in some areas in the 1970s (Hawthorne, 2004, Samuel and Nelson, 1982). Swift fox populations remain generally lower than historic levels and the species presently occurs in only two counties, Dallam and Sherman, in Texas (Schwalm et al., 2012).

Because the primary cause of swift fox mortality is coyote depredation (Kitchen et al., 1999), a team of wildlife biologists from Texas Tech University conducted a study to test the effectiveness of artificial escape den sites as a means of increasing swift fox survival by reducing depredation by coyotes in northwestern Texas (McGee et al., 2006). Coyotes kill swift foxes to eliminate competition and usually do not consume the carcass (Allardyce and Sovada, 2003). The construct of natural swift fox dens in rangelands are usually deeper and more permanent than those in in cultivated fields, which are shallow and temporary (Kilgore, 1969). Thompson and Gese (2007) found that swift fox abundance negatively correlated with coyote presence and vegetation height.

McGee et al. installed artificial escape dens on the Rita Blanca National Grassland (RBNG) and a nearby private ranch and monitored swift foxes through radio-telemetry between 2002 and 2004. They placed artificial dens in a grid pattern in one location on a privately owned ranch and three locations on the RBNG. Each grid, hereafter called clusters, contained 36 artificial dens arranged in a 6 x 6 square. McGee et al. (2006) compared survival rates and movements of swift foxes on grids with artificial escape dens (treatment) and sites without artificial dens (control). In one case, swift foxes moved onto a previously unoccupied area after establishment of artificial dens on the site. Swift fox survival was higher on treatment sites (McGee et al., 2006).

Swift foxes used native, short-grass prairie habitats almost exclusively but rarely use Conservation Reserve Program (CRP) lands and cultivated fields (Kamler et al., 2003) in our study area. Swift foxes are more likely to be killed by coyotes at the edge or outside of their home ranges (Olson and Lindzey, 2002) where they are less familiar with the landscape. Swift foxes usually locate their dens at or near the tops of hills in areas of short-grass or mid-grass prairie with moderate to heavy grazing (Uresk and Sharps, 1986). Harrison (2003) observed that swift foxes in New Mexico showed preference for habitats near roads, presumably because of increased prey abundance in these areas. Swift foxes prefer habitats with vegetation heights $\leq$ 30 cm with a 5 to 10 m dispersion between shrubs (Harrison and Schmitt, 2003).

Our initial observation of the artificial dens (McGee et al, 2006) showed detectable differences in the density and structure of vegetation at artificial den sites compared to vegetation at more than a 5-m distance (Fig. 3.1). This led us to examine and compare the characteristics of vegetative communities at artificial dens and natural dens in use at the time of artificial den installation.

Study Site

Our team conducted research in Dallam County in the High Plains Ecoregion of the Texas Panhandle on the RBNG (Fig. 2.1). The climate of the region is semiarid. In nearby Dalhart, TX, the mean annual high temperature is 20.6 ºC, and the mean annual precipitation is 39.9 cm (U.S. Climate Data, 2015). The shortgrass prairie community on the study area is characteristic of the habitat in the region dominated by blue grama (*Bouteloua gracilis*), buffalo grass (*B. dactyloides*), and sideoats grama (*B. curtipendula*) with intermittent stands of yucca (*Yucca campestris*), prickly pear cactus (*Opuntia spp*.) and clumps of shrubs. Occasional trees occur around homesteads. The primary land use is grazing by cattle with irrigated row-crop agriculture occurring proximate to study sites. Anthropogenic features include improved and unimproved roads, scattered homesteads, agricultural infrastructure, electrical transmission lines, windmills, and barbed-wire fences. The study sites are located on four units of the RBNG. One unit contains only artificial escape dens and controls, one unit contains only natural swift fox dens and controls, and the remaining two units contain artificial dens, natural dens, and controls. For our purposes, we refer to these units as Unit I, II, III and IV, respectively.

Methods

In order to compare vegetative characteristics between artificial dens, natural dens, and control sites, we selected points of measurement. We measured the vegetation at randomly selected artificial dens at each cluster at each entrance and at two random points within 5 m of each selected artificial den (Fig. 3.2). We excluded completely buried artificial dens because they were difficult to locate and measure. Active natural swift fox dens at the time of artificial den installation and within the boundaries of the artificial den clusters were examined at the entrances located farthest apart for comparison with artificial dens. We measured randomly selected control sites, placed systematically around the edges of each den cluster, at four locations within 5 m of each selected control point.

We measured with a 0.25 m^2 quadrat at each point (Fig. 3.3). Measurements recorded at each point include; percentage of bare ground (BG), mean height of vegetation (MVH), and visual obstruction (VO) using a backing board at a distance of 10 m. We compared data from artificial dens to data for natural dens and controls to determine detectable changes in vegetative communities associated with artificial dens.

Statistical Analysis

Due to small sample sizes, we used Shapiro-Wilk tests for normality between and among experimental groups in each unit (Zar, 1999). We used Kruskal-Wallis H tests to calculate differences between study sites for BG, MVH, and VO because this test does not assume normality between groups or homogenous sample sizes (Zar, 1999). We also calculated differences in samples collected at artificial den entrances and at points within 5 m of artificial dens. We used a Spearman R correlation to test for correlations between MVH and VO variables within Units. We considered differences to be significant when $P < 0.05$.

Results

Difference appeared between BG at controls (S_4) located in different RBNG units ($P < 0.001$). Differences in MVH also occurred between units for S_4 ($P < 0.001$). Visual Obstruction was dissimilar between units for S_4 ($P < 0.001$). Because each of these tests indicated distinctive vegetative characteristics between S_4 of each unit, we could not depict direct comparisons among units. Therefore, we analyzed each unit separately.

We detected correlation between the means of vegetative height and visual obstruction in Units I, II, III and IV ($r = 0.413$, $P < 0.001$, $r = 0.602$, $P < 0.001$, $r = 0.566$, $P < 0.001$, and $r = 0.714$, $P < 0.001$, respectively).

Unit I

A disparity became evident in BG of artificial den entrances at (S_1) and S_4 (P = 0.002) in Unit I. There was no difference in BG of points within 5 m of artificial dens at S_2 and S_4 in Unit I (P = 0.197). There was a difference between BG at S_1 and S_2 (P = 0.002). There was a difference between MVH for S_4 and S_1 (P = 0.015); however, there were no differences between MVH for S_4 and S_2 (P = 0.348) and S_1 and S_2 (P = 0.139). There were distinctions between VO at S_4 and S_1 (P = 0.039) and at S_1 and S_2 (P = 0.025); however, there was no distinction between VO for S_4 and S_2 (P = 0.270).

Unit II

We found a difference in BG between natural den entrances S_3 and S_4 (P = 0.011) in Unit II. There was no disparity between MVH of S_3 and S_4 (P = 0.787) and VO for S_4 and S_3 (P = 0.646).

Unit III

In Unit III, we discovered a dissimilarities in BG for S_4 and S_1 (P = 0.009), S_4 and S_2 (P = 0.020) and between S_1 and S_2 (P < 0.001). There was no difference between BG at S_4 and S_3 (P = 0.932). There was a difference between BG at S_1 and S_3 (P = 0.038). There were contrasts in MVH in S_4 and S_1 (P = 0.007), S_1 and S_2 (P = 0.003), and S_1 and S_3 (P = 0.005). There were no differences between S_4 and S_2 (P = 0.245) and S_4 and S_3 (P = 0.428) for MVH. There were differences between VO at S_4 and S_1 (P = 0.013) and S_1 and S_2 (P = 0.020) but no differences in VO measurements at S_4 and S_2 (P = 0.408), S_4 and S_3 (P = 0.650), and S_1 and S_3 (P = 0.056).

Unit IV

There were no divergences between BG for S_4 and S_1 ($P = 0.235$), S_1 and S_2 ($P = 0.720$) or between S_1 and S_3 ($P = 0.143$) in Unit IV. Percentage Bare Ground between S_4 and S_2 was different ($P = 0.020$) as well as between S_4 and S_3 ($P < 0.001$). There was a difference between the MVH for S_4 and S_1 ($P = 0.045$). The MVHs for S_4 and S_2 ($P = 0.198$) and S_4 and S_3 ($P = 0.091$) S_1 and S_3 ($P = 0.663$) and S_1 and S_2 ($P = 0.354$) were similar. There were differences between VO for S_4 and S_1 ($P = 0.001$), S_4 and S_3 ($P = 0.042$), and S_1 and S_2 ($P = 0.026$). No difference was detected for VO between S_4 and S_2 ($P = 0.435$) or between S_1 and S_3 ($P = 0.138$).

Discussion

Percentage Bare Ground

In Units I and III, BG between artificial den entrances was different from controls. This was probably a result of digging involved in the creation of the artificial dens. In Units I and III, differences in BG were significant between artificial den entrances and points within 5 m of artificial dens. In Unit I, BG did not diverge from controls and treatment points within 5 m of artificial dens. This seemed to indicate that artificial dens have a minimal effect on BG away from entrances to artificial dens.

In Units II and IV, the BG at natural den entrances varied from the BG at controls. In Unit III, BG at artificial den entrances and natural den entrances was significantly different. These results indicate that natural dens and artificial dens tend to have different effects on BG.

Mean Vegetation Height

In Units I, III and IV, there was a difference in MVH between artificial den entrances and controls. Unit III showed a difference in MVH between artificial den entrances and points within 5 m of artificial dens. Changes in MVH at artificial den entrances were likely due to the capacity of artificial dens to hold water after a rainfall event. The entrances to the artificial dens stay wet longer than the surrounding soil and could provide preferable growing conditions for vegetation.

In Unit III, no difference was detected between natural den entrances and controls; however, there was a difference between artificial den entrances and natural den entrances. In Unit IV, there is no difference between natural den entrances and artificial den entrances or between natural den entrances and controls. Natural dens in the study area have been abandoned and no longer actively sheltered swift foxes. Abandonment by foxes may have contributed to the majority of the surveyed natural dens collapsing. It is likely that these natural dens cannot hold water in the same way that artificial dens do and therefore do not provide the same benefit to vegetative growth.

Visual Obstruction at 10 m

In Units I, III, and IV, there was a difference between VO at artificial den entrances and controls as well as between artificial den entrances and points within 5 m of artificial dens. This could have resulted from increased water holding capacity of artificial den entrances.

The only Unit that showed a difference between natural den entrances and controls or between natural den entrances and artificial den entrances was Unit IV. It is likely that the abandoned natural dens do not affect VO in the same way that artificial den entrances do because swift foxes no longer dig at the entrances to remove obstacles and disrupt vegetation growth.

We found that MVH and VO positively correlated in all units. As the mean vegetative height increased, Visual Obstruction also increased. As Kamler et al. (2003) and Uresk and Sharps (1986) noted, swift foxes are less likely to utilize areas with vegetation ≥ 30 cm in height. It is likely that artificial den locations become less attractive to swift foxes as vegetation density and height increase. Future studies could examine negative habitat characteristics that appear to develop at artificial dens by comparing vegetative characteristics at currently active natural swift fox dens and artificial dens.

In conclusion, it appears that artificial dens do affect vegetative communities immediately around the dens. This effect appears to be strongest at artificial den entrances. Natural dens also appear to influence vegetation but the effects are not as pronounced. Swift foxes may avoid areas with vegetation > 30 cm in height. Managers may want to conduct annual vegetation surveys to ensure that vegetation at artificial dens is not becoming too tall for swift foxes. Cattle grazing can be an effective tool to help control vegetation height in swift fox habitat.

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Appendix

Figure 3.1. Photo of vegetation at an artificial swift fox den on the Rita Blanca National Grasslands in Dallam County, Texas.

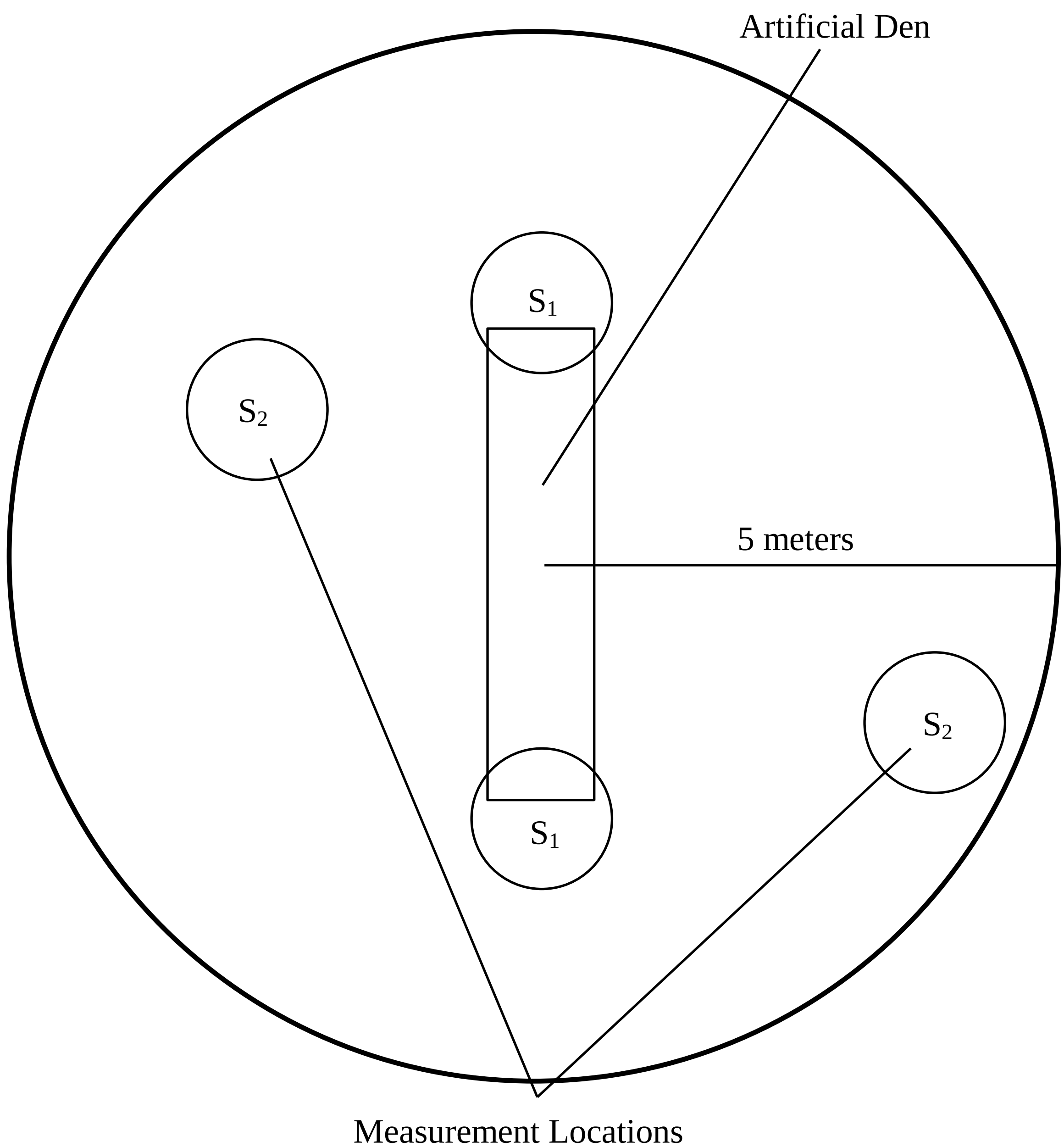

Figure 3.2. Diagram of sample locations for vegetation measurements at artificial dens. Locations S_2 were randomly located within five meters of the artificial den structure.

Figure 3.3. A vegetation sampling location with a backing board in a 0.25 square meter quadrat at a control location in the Rita Blanca National Grassland.