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EVAULATION OF SURVEY METHODS AND DEVELOPMENT OF SPECIES  
DISTRIBUTION MODELS FOR KIT FOXES  
IN THE GREAT BASIN DESERT

by

Steven J. Dempsey

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Biology

Approved:

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UTAH STATE UNIVERSITY  
Logan, Utah

2013

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## ABSTRACT

Evaluation of Survey Methods and Development of Species Distribution Models  
for Kit Foxes in the Great Basin Desert

by

Steven J. Dempsey, Master of Science

Utah State University, 2013

Major Professor: Eric M. Gese  
Department: Wildland Resources

Historically, kit foxes (*Vulpes macrotis*) once occupied the desert and semi-arid regions of southwestern North America, ranging from Idaho to central Mexico. Their range-wide decline has warranted the kit fox to be listed as endangered in Colorado, threatened in California and Oregon, and designated as a state sensitive species in Idaho and Utah. Once considered the most abundant carnivore in western Utah, the kit fox has been in steep decline over the past decade, creating a demand to determine kit fox presence. Currently there is little consensus on which survey methodology is best to detect kit fox presence. We tested 4 survey methods (scat deposition, scent station, spotlight, trapping) along 15 5-km transects within a minimum known population of radio collar kit fox. Home range sizes for kit foxes on the study site were extremely large, averaging 20.5 km<sup>2</sup>. Scat deposition surveys had both the highest detection probabilities ( $\bar{x} = 0.88$ ) and were the most closely related to known fox abundance ( $r^2 =$

0.50,  $P = 0.001$ ). For detecting kit foxes in a low density population we suggest using scat deposition transects during the breeding season. This method had low costs, was resilient to weather, had low labor requirements, and entailed no risk to the study animals.

Next in determining kit fox presence is estimating kit fox distribution. We developed resource selection functions (RSF) using presence data from the noninvasive scat surveys to model kit fox distribution. We evaluated the predictive performance of RSFs built using three popular techniques (Maxent, fixed-effects and mixed-effects general linear models) combined with common environmental parameters (slope, aspect, elevation, soil type). Both the Maxent and fixed-effects models performed to an acceptable level with relatively high area under the curve (AUC) scores of 0.83 and 0.75, respectively. The mixed-effects model over valued higher elevations and had poor model fit. This study demonstrated that it was possible to create valid and informative predictive maps of a species distribution using a noninvasive survey method for detecting a carnivore existing at low density. By demonstrating the application of noninvasive surveying to model habitat quality for a small mesocarnivore, wildlife management agencies will be able to develop predictive maps for species of interest and provide more knowledge to help guide future management decisions.

## PUBLIC ABSTRACT

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methodology had low costs, was resilient to weather, had low labor requirements, and entailed no risk to the study animals.

Next we determined kit fox distribution. We developed resource selection functions (RSF) using presence data from noninvasive scat deposition surveys to model kit fox distribution across the study area. Noninvasive survey methods are ideal as they do not require contact or capture of the target species. We evaluated the predictive performance of RSFs built using three popular techniques and common environmental parameters. Two models performed to an acceptable level with relatively high accuracy, while the third model over-valued higher elevations and had poor model fit. This study demonstrated that it was possible to create valid and informative predictive maps of a species distribution using a noninvasive survey method for detecting a carnivore existing at low density. By demonstrating the application of noninvasive surveying to model habitat quality, managers will be able to develop maps for species of interest and provide more information to help guide future management decisions.

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Steven Dempsey

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## CHAPTER 1

### INTRODUCTION AND LITERATURE REVIEW

Historically, kit foxes (*Vulpes macrotis*) once occupied the desert and semi-arid regions of southwestern North America, ranging from Idaho to central Mexico (McGrew 1976). Their range-wide decline has warranted the kit fox to be listed as endangered in Colorado, threatened in California and Oregon, and designated as a state sensitive species in Idaho and Utah (Meaney et al. 2006). Although listed and protected in several states, a comprehensive study of kit fox abundance across its range is lacking, with the majority of studies focused on the endangered subspecies, the San Joaquin kit fox (*V. macrotis mutica*), leaving a need for greater knowledge of monitoring methods for the species across its entire range. Once considered the most abundant carnivore in western Utah (Egoscue 1956, 1962), the kit fox has been in steep decline over the past decade (Thacker et al. 1995, Arjo et al. 2007, Utah Department of Natural Resources 2011).

Carnivores are difficult to survey due to their low densities, are generally nocturnal and elusive, and wary of humans (Thacker et al. 1995, Gese 2001, Gese 2004, Gompper et al. 2006, Long et al. 2007). Current methods for monitoring kit fox populations require ideal conditions for consistent and reliable results (Smith et al. 2005). Methods currently used for censusing kit foxes and their close relative the swift fox (*V. velox*), include capture-recapture (Thacker et al. 1995, Warrick and Harris 2001, Harrison et al. 2002, Schauster et al. 2002, Finley et al. 2005, Ralls et al. 2010), spotlight surveys (Thacker et al. 1995, Ralls and Eberhardt 1997, Warrick and Harris 2001, Harrison et al. 2002, Schauster et al. 2002), scent station surveys (Thacker et al. 1995, Warrick and

Harris 2001, Harrison et al. 2002, Schauster et al. 2002), scat deposition transects with and without scat detection dogs (Thacker et al. 1995, Harrison et al. 2002, Schauster et al. 2002, Smith et al. 2005, Ralls et al. 2010), track counts (Harrison et al. 2002), activity index (Schauster et al. 2002), and howling response (Harrison et al. 2002). Generally these methods have been evaluated in study areas with a relatively high fox density. How well these methods will perform for monitoring fox abundance in a low-density, widely dispersed kit fox population is unknown.

Previous research on the ecology of the kit fox can be used to guide decisions on where to sample for kit fox presence. In early reports on the kit fox population in western Utah, Egoscue (1962) described the kit fox as using areas that were predominately flat and featureless with sparse vegetation. He also described kit foxes as selecting areas with silt and clay soils or sandy dunes and their den sites being mostly found in greasewood (Egoscue 1962). In a later study on the same geographic area, Arjo et al. (2003) found that most kit fox dens (54.4%,  $n = 88$ ) were now found in grasslands, with a surrounding vegetation height of ~26 cm.

Studies of kit fox populations in other regions have reported the environmental variables important in determining kit fox distribution. Fitzgerald (1996) found kit foxes existed at elevations between 1,463 to 1,829 m and in areas with high clay to clay-loam soils. Vegetation height at capture sites averaged 43 cm, and at den sites were ~ 22 cm and vegetation was generally sparsely distributed. In addition, they found most den entrances had a southerly aspect (Fitzgerald 1996). McGrew (1976) also found kit foxes



to be present in areas with low ground cover (<20%), loamy desert soils, at elevations <1,675 m, and vegetation height at den sites was generally >22 cm.

With advancing technology, attempts have been made to model the environmental variables influencing kit fox space use. Zoellick et al. (1989) reported the geographic range of kit foxes was closely associated with open flat habitats with little vegetative cover. They also determined kit foxes spent more time in greasewood flats than riparian areas. Warrick and Cypher (1998) modeled kit fox occurrence using capture rates, and used a standardized regression approach to evaluate the influence of land development, ruggedness, fenced lands, and burned areas. They also used linear regression to compare space use of foxes with coyote and lagomorph abundance, but found no significant relationship. They determined that topographic ruggedness was the only consistent variable affecting the spatial distribution of kit foxes. Gerrard et al. (2001) provided an early attempt at GIS modeling of habitat use by kit foxes, based on landcover type and roads, in which they ranked grasslands as most important to kit foxes. Utilizing GIS technology, resource selection functions (RSF) can be developed to give habitat values proportional to the probability of use of a resource unit (Boyce et al. 2002). RSF's differ from habitat suitability models in that they are always estimated statistically from data. These RSF's can vary greatly depending on which techniques are used to build the model. To date, few studies have evaluated RSF's built using different techniques for small desert carnivores.

## STUDY AREA

We conducted our research on 879 km<sup>2</sup> of the eastern portion of the U.S. Army Dugway Proving Grounds (DPG), Utah and the adjoining land managed by the Bureau of Land Management, located approximately 128 km southwest of Salt Lake City, in Tooele County, Utah. Elevations ranged from 1302 m to 2137 m. The study site was in the Great Basin Desert and was characterized as a cold desert. Winters were cold, summers were hot and dry, with the majority of precipitation occurring in the spring. The study area consisted of predominately flat playa punctuated with steep mountain ranges. The lowest areas consist of salt playa flats sparsely vegetated with pickleweed (*Allenrolfea occidentalis*). Soils at slightly higher elevations were less salty soils and supported a cold desert chenopod shrub community, predominately shadscale (*Atriplex confertifolia*) and gray molly (*Kochia America*). At similar elevations greasewood (*Sarcobatus vermiculatus*) communities would be found with mound saltbrush (*Atriplex gardneri*) and Torrey seepweed (*Suaeda torreyana*). Higher elevations consisted of vegetated sand dunes including fourwing saltbush (*Atriplex canescens*), greasewood, rabbitbrushes (*Chrysothamnus* spp.), shadscale, and horsebrush (*Tetradymia glabrata*). Near the bases of the higher steep mountains were shrubsteppe communities of sagebrush (*Artemisia* spp.), rabbitbrush, Nevada ephedra (*Ephedra nevadensis*), greasewood, and shadscale. The highest elevation was a Utah juniper (*Juniperus osteosperma*) community including black sagebrush (*Artemisia nova*) and bluebunch wheatgrass (*Elymus spicatus*) (Arjo et al. 2007).

## RESEARCH PURPOSE

Currently there is little consensus on which survey methodology is best to detect kit fox presence. We tested 4 survey methods (scat deposition, scent station, spotlight, trapping) on the DPG, to determine detection probabilities for each method and evaluate how well they correlate to kit fox abundance as determined from known available radio-collared animals. These methods were selected due to either being cited as the best technique or being the most commonly used. The most efficacious method from our study was used to build RSF's using three different techniques. We developed RSF's for kit foxes using the maximum entropy (Maxent) technique (Phillips and Dudík 2008), and two general linear model (GLM) approaches: traditional fixed effects (Boyce et al. 2002) and mixed effects models (Bolker et al. 2009). Detections from the most efficacious survey methods were considered "use" and environmental covariates were extracted from available GIS databases. This study provided increased knowledge on the differences in detection between survey methods and created a predictive model for kit fox occupancy in Great Basin Habitats found within DPG and western Utah. Thus, enabling wildlife managers to apply this model and use the most effective survey methodology in efforts to determine kit fox presence and abundance.

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## CHAPTER 2

### FINDING A FOX: AN EVALUATION OF DETECTION METHODS FOR A SMALL DESERT CARNIVORE

#### ABSTRACT

Historically, kit foxes (*Vulpes macrotis*) once occupied the desert and semi-arid regions of southwestern North America, ranging from Idaho to central Mexico. Once the most abundant carnivore in the western desert, the species is now considered rare. Survey methods have been evaluated for kit foxes, but often in populations where abundance is high and there is little consensus on which technique is best to monitor abundance. We conducted a 2 year study to evaluate 4 methods suggested to be best for detecting kit foxes and examined the detection rates relative to minimum kit fox abundance (determined by radio-collared animals). The study was conducted on the U.S. Army Dugway Proving Grounds and the bordering BLM lands in Utah. We evaluated scat deposition surveys, scent station surveys, spotlight survey, and trapping. All surveys were conducted on 15 5-km transects during the three biological seasons of the kit fox. Home range sizes for kit foxes on the study site were extremely large, averaging 20.5 km<sup>2</sup>. Scat deposition surveys had both the highest detection probabilities ( $\bar{X} = 0.88$ ) and were most closely related to minimum known fox abundance ( $r^2 = 0.50$ ,  $P = 0.001$ ). The next best method for kit fox detection was the scent station survey ( $\bar{X} = 0.73$ ), which had the second highest correlation to fox abundance ( $r^2 = 0.46$ ,  $P < 0.001$ ). For detecting kit foxes in a low density population we suggest using scat deposition transects during the breeding season. This method had both the highest detection probability and correlation



to kit fox abundance. Scat deposition surveys have low costs, resilience to weather, low labor requirements, and pose no risk to the study animals. The breeding season was ideal for monitoring kit fox population size, as detections consisted of primarily the resident population and we had the highest detection probabilities during this season. In areas with sympatric canids, careful training of technicians may be required, but risk of overlapping scat dimensions should be lowest during the breeding season as most sympatric canids are also fully grown by the subsequent breeding season.

## **INTRODUCTION**

Historically, kit foxes (*Vulpes macrotis*) once occupied the desert and semi-arid regions of southwestern North America, ranging from Idaho to central Mexico (McGrew 1976). Their range-wide decline has warranted the kit fox to be listed as endangered in Colorado, threatened in California and Oregon, and designated as a state sensitive species in Idaho and Utah (Meaney et al. 2006). Although listed and protected in several states, a comprehensive study of kit fox abundance across its range is lacking, with the majority of studies focused on the endangered subspecies, the San Joaquin kit fox (*V. macrotis mutica*), leaving a need for greater knowledge of monitoring methods for the species across its entire range. Once considered the most abundant carnivore in western Utah (Egoscue 1956, 1962), the kit fox has been in steep decline over the past decade (Thacker et al. 1995, Arjo et al. 2007, Utah Department of Natural Resources 2011). Carnivores are difficult to survey due to their low densities, are generally nocturnal and elusive, and wary of humans (Thacker et al. 1995, Gese 2001, 2004, Gompper et al. 2006, Long et al. 2007a). Current methods for monitoring kit fox populations require ideal conditions for

consistent and reliable results (Smith et al. 2005). Current methods used for surveying kit foxes and their close relative the swift fox (*V. velox*), include capture-recapture (Thacker et al. 1995, Warrick and Harris 2001, Harrison et al. 2002, Schauster et al. 2002a, Finley et al. 2005, Ralls et al. 2010), spotlight surveys (Thacker et al. 1995, Ralls and Eberhardt 1997, Warrick and Harris 2001, Harrison et al. 2002, Schauster et al. 2002a), scent station surveys (Thacker et al. 1995, Warrick and Harris 2001, Harrison et al. 2002, Schauster et al. 2002a), scat deposition transects with and without scat detection dogs (Thacker et al. 1995, Harrison et al. 2002, Schauster et al. 2002a, Smith et al. 2005, Ralls et al. 2010), track counts (Harrison et al. 2002), activity index (Schauster et al. 2002a), and howling response (Harrison et al. 2002). Generally these methods have been evaluated in study areas with a relatively high fox density. How well these methods will perform for monitoring fox abundance in a low-density, widely dispersed kit fox population is unknown. We tested 4 survey methods (scat deposition, scent station, spotlight, trapping) on the U.S. Army Dugway Proving Grounds (DPG), Utah, to determine detection probabilities for each method and evaluate how well they correlate with kit fox abundance as determined from available radio-collared animals. The kit fox population on the DPG is considered declining in abundance, low density, and widely dispersed (Arjo et al. 2007, Kozlowski et al. 2008, 2012).

## **STUDY AREA**

Research was conducted on 879 km<sup>2</sup> of the eastern portion of the DPG and the adjoining land managed by the Bureau of Land Management, located approximately 128 km southwest of Salt Lake City, in Tooele County, Utah. Elevations ranged from 1302 m

to 2137 m. The study site was in the Great Basin Desert and was characterized as a cold desert. Winters were cold, and summers were hot and dry with the majority of precipitation occurring in the spring (Arjo et al. 2007). The study area consisted of predominately flat playa punctuated with steep mountain ranges. We classified the landscape into 7 vegetation communities: chenopod, greasewood, pickle weed, grassland, stable dune, shrub-steppe, and urban; see Kozlowski et al. (2008) for a detailed description of vegetation communities.

## **METHODS**

### *Capture and handling*

We captured kit foxes initially via transect trapping and opportunistically at previously known den sites, using box traps (Tomahawk Live Trap LLC, Hazelhurst, WI) baited with hot dogs. Traps were deployed in the evening and checked early morning each day. Captured foxes were coaxed into a canvas bag placed at the edge of the trap, then restrained by personnel wearing thick leather gloves (Arjo et al. 2003). Foxes were weighed, sexed, ear tagged, and fitted with a 30-50 g radio-collar (Advanced Telemetry Systems, Isanti, MN). Collars included a mortality sensor that activated after 6 hours of non-motion and weighed <5% of body mass (Eberhardt et al. 1982, Schauster et al. 2002a, b). All foxes were handled without the use of immobilizing drugs and were released at the capture site.

### *Telemetry*

Animal locations were collected  $>3$  times per week using a portable receiver (Communications Specialists, Inc., Orange, CA) and a handheld 3-element Yagi antenna. We triangulated an animal's location using  $\geq 2$  compass bearings, each  $>20^\circ$  but  $<160^\circ$  apart, for each animal within 20 minutes (Arjo et al. 2007, Kozlowski et al. 2008). Positions were then calculated using program Locate III (Pacer Computing, Tatamagouche, Nova Scotia). For each week, we temporally distributed telemetry sampling by collecting two crepuscular (hunting) locations and one den (resting) location. To reduce auto-correlation and retain temporal independence between locations each crepuscular sample was separated by  $>12$  hours and a difference of  $>2$  hours in the time of day of each location (Swihart and Slade 1985*a, b*, Gese et al. 1990). We collected one weekly den location for each animal by homing in on the signal during daylight hours.

### *Home range determination*

To determine space use of kit foxes, we created seasonal home ranges for all kit foxes with  $\geq 30$  locations (Gese et al. 1990, Aebischer et al. 1993). Biological seasons were defined by behavior and energetic needs of kit foxes: breeding 15 December – 14 April, pup-rearing 15 April – 14 August and dispersal 15 August – 14 December (Egoscue 1962, Schauster et al. 2002*b*, Kozlowski et al. 2003). Home range polygons were created using the Home-Range Analysis and Estimation (HoRAE) toolbox for the Open Jump geographic information system (Steiniger and Hunter 2012). We created 95% point kernel density estimates (KDE) using a fixed kernel (standard sextante biweight) and the ad hoc method (Worton 1989, Berger and Gese 2007) for determination of the

smoothing parameter  $h$  (e.g.,  $h_{ref}$ ,  $90\%h_{ref}$ ,  $80\%h_{ref}$ ,  $70\%h_{ref}$ , etc.). This method was designed to prevent over/under-smoothing and selection of the tightest fitting contiguous home range polygon before developing discrete patches (Berger and Gese 2007, Jacques et al. 2009, Kie et al. 2010). We then loaded these polygons into ArcMap 10.0 (Environmental Systems Research Institute Inc., Redlands, CA) to calculate kit fox home range size. Seasonal differences in female and male home ranges were tested with analysis of variance (ANOVA).

### *Surveys*

We attempted to conduct 4 different surveys (scat deposition, scent station, spotlight, and trapping) during each of the 3 biological kit fox seasons (breeding, pup-rearing, and dispersal) for 2 years. Each survey was conducted along 15 5-km established transects (Fig. 2-1). Transects were distributed randomly along available roads with the constraints of being as linear as possible and having year round access (limitations included military closures and low lying seasonally inundated greasewood areas). Scent station, spotlight, and trapping surveys were repeated over 4 consecutive nights, weather conditions permitting. Scat deposition surveys required scat to be deposited on transects allowing for an accumulation of scats over 2 weeks.

### *Scat deposition survey*

Scat deposition surveys were conducted by initially walking the transect to clear any scat from the road surface, then returning approximately 14 days later to walk and count the number of scats deposited (Warrick and Harris 2001, Schauster et al. 2002a).

Following recommendations from Schauster et al. (2002a) and Knowlton (1984), each transect was walked in both directions to reduce missed detections of scats. Scat location and type (species) was recorded on a handheld GPS unit and the scat was collected. This provided a count of the total number of scats per transect (surveys were a constant 5-km length and 14-day duration).

#### *Scent station survey*

We placed scent stations at 0.5 km intervals on alternating sides along each 5 km transect (Warrick and Harris 2001, Schauster et al. 2002a). A scent station consisted of a cleared 1m circle of lightly sifted sand (Linhart and Knowlton 1975) with a Scented Predator Survey Disk (SPSD) with Fatty Acid Scent (FAS) placed in the center. The SPSD with FAS was recommended for “ease of use, attractiveness to kit fox, and their low cost” (Thacker et al. 1995). FAS saturated SPSD’s are preferred over the use of liquid lures because they allow for control of a consistent attractiveness between batches (Roughton and Sweeny 1982). Stations were checked each morning for tracks of kit foxes, coyotes (*Canis latrans*), bobcats (*Lynx rufus*), leporids, small mammals, and other potential prey species. Stations were then resifted and the SPSD replaced. To help maintain a consistent attractiveness, SPSD’s were removed from use once they were noticeably deteriorated, broken, or after a full season of use. Inoperable station nights (due to inclement weather) were resampled for an additional 1-2 days in an attempt to complete the 4 nights of surveying. If transects remained inoperable after the additional days, the survey was abandoned along that transect and results for that transect were not

used in subsequent analysis. This survey provided a proportion of visited scent stations (i.e., total number of visits or detections divided by the number of operable stations).

#### *Spotlight survey*

While driving a vehicle along the transect route at approximately 10-15 km/hr, 2 observers scanned their respective side of the road with a 3 million candlepower spotlight (Ralls and Eberhardt 1997, Warrick and Harris 2001, Schauster et al. 2002a). Once an animal was sighted the driver stopped the vehicle and the species was identified. Species, location, distance, and bearing to the animal were recorded for kit foxes, coyotes, bobcats, and leporids. The survey provided a count of the total number of foxes detected divided by the number of nights surveyed.

#### *Trapping survey*

In addition to opportunistically trapping for radio-collaring foxes, a trapping survey was conducted with box traps placed at 0.5 km intervals along each 5 km transect (Schauster et al. 2002a). Traps were baited with half of a hot dog, wired down towards the rear of the trap. Traps were partially covered with vegetation to deter a kit fox from digging under the trap for the bait. Traps were checked daily, re-baited after two days or when a significant portion of the bait had deteriorated or had been eaten by small mammals. Traps were deployed in the evening and closed during the day to limit the amount of exposure to the animals (Thacker et al. 1995). Animals captured in this survey were processed following the handling protocol previously described. This survey provided an index of foxes captured divided by the number of operable trap nights.

### *Detection probability*

For each biological season we computed detection probabilities of each survey method with the occupancy estimator in Program MARK (White and Burnham 1999) that accomdates covariate information and missed observations (MacKenzie et al. 2002). To account for a measure of space use, each transect was buffered by 1/3 of the average radius of kit fox home range; adapted from Schauster et al. (2002a). A fox was considered available for detection if it was alive during the survey dates and it had locations within the transect buffer during that biological season. We fit models using 4 encounter occasions of 4 groups of survey methods (scat deposition, scent station, spotlight, and trapping), along with 3 covariates (survey year, number of radiomarked foxes available for detection, fox presence or absence). Fox presence or absences was binary and determined as presence if  $\geq 1$  fox was available for detection based on the criteria above. The best model was selected by AIC ranking (Burnham and Anderson 2002).

## **RESULTS**

### *Opportunistic capture and telemetry*

From December 2009 to April 2012, we accumulated 6,221 trap nights and captured 45 (26 females, 19 males) foxes across the study area 106 times. Grouping all captures from opportunistic, den captures of pups, and the trapping surveys; 58%, 27%, and 17% of captures occurred during the breeding, pup-rearing, and dispersal seasons, respectively. Of the 45 foxes captured, 17 were killed by predators, 11 from



indeterminate causes, 4 from vehicle collisions, and 13 foxes were alive at the end of the study. We restricted trapping until late in the pup-rearing season to allow the foxes to mature enough to permit radio-collaring (i.e., they were old enough to be within our <5% body mass requirement for radio-collaring). During the study we obtained 4,498 fox locations (1487 in breeding, 1464 in dispersal, 1547 in pup-rearing) allowing for the calculation of 66 seasonal home ranges (21 in breeding, 24 in dispersal, and 21 in pup rearing) (Fig. 2-1). However, due to mid-season dispersal events, 2 foxes with >30 locations were not included in home range determinations.

#### *Home range estimation*

We found that seasonal 95% KDE home range sizes for the radio-collared kit foxes averaged 20.5 km<sup>2</sup> ( $n = 64$ ,  $SD = 15.1$ ). Home range size during the dispersal season was largest with a mean of 23.3 km<sup>2</sup> ( $n = 23$ ,  $SD = 16.1$ ), followed by breeding and pup-rearing, 20.8 km<sup>2</sup> ( $n = 20$ ,  $SD = 17.8$ ) and 17.2 km<sup>2</sup> ( $n = 21$ ,  $SD = 9.4$ ), respectively (Table 2-1). In general, females had larger home range sizes than males in all seasons (Table 2-2). The largest difference was observed in the breeding season ( $P=0.026$ ), followed by the pup-rearing ( $P = 0.172$ ) and dispersal ( $P = 0.230$ ). The number of foxes available for detection along transects varied by survey type, season, and year, from a maximum of 9 foxes available along one transect during the dispersal season of 2010 to 5 transects on which there never was a known fox present during any season or year. Although individual transects may have not had known foxes present along them, there were always known foxes available for detection along a portion of the transects (Table 2-3).

### *Surveys*

We attempted to conduct 4 consecutive nights of surveying during each of the biological seasons along all 15 transects. High winds, snowfall, and melting and freezing cycles limited our ability to complete some surveys during the winter months. Scent stations were the most affected by weather. Most notably, of the attempted 660 survey nights possible during the breeding season of 2011, only 462 (70%) stations were operable. Initially designed for lagomorph counts, the spotlight survey was only conducted for 3 consecutive nights during the pup rearing season of 2010 and the dispersal season of 2010. We modified our methodology and performed the spotlight surveys over 4 nights the remainder of the study. Scat deposition was not initially included in the survey and was added after the first biological season. Due to concerns of overheating and the demands of natal care of female foxes, the trapping survey was not conducted during the pup-rearing season (captures during the pup-rearing season were late season den captures to radio-collar pups before dispersal, not trapping surveys). Two methods (scent stations and trapping surveys) were point sampling techniques with 11 discrete locations for detection. The remaining 2 techniques (scat deposition and spotlight surveys) allowed for detection along the entire length of the transect. Additionally, 2 techniques (scat deposition and scent stations) allowed for an individual animal to be detected multiple times along the transect, while during trapping or spotlight surveys an individual may only be detected once.

### *Detection probability*

Detection probabilities were calculated for each transect to determine which survey method was best at detecting fox presence while controlling for differences in occupancy rates. For all biological seasons, the best model for detection probability ( $p$ ) included differences across survey type (i.e., group) and the fox presence covariate. The corresponding best model for occupancy ( $\Psi$ ) was constant across groups and the number of foxes available. This model fitted the expectation that each survey method would have a different  $p$  given the presence or absence of a fox available to be detected. Additionally, by holding  $\Psi$  constant and including a covariate for the minimum number of foxes available, we were able to include a known minimum number of foxes as determined through the space use information.

### *Scat deposition*

We conducted 75 scat deposition surveys with 136 scat detections. Scat deposition produced the most detections (29) along an individual transect. Scat deposition surveys consistently had the highest detection probabilities ( $\bar{X} = 0.88$ ; Fig. 2-2). Scat deposition surveys had the highest correlation (based on  $r^2$  value) with kit fox abundance ( $r^2 = 0.50$ ,  $P = 0.001$ ). The correlation between scat detection and fox abundance was linear and positive (Fig. 2-3A).

### *Scent stations*

Even with logistical difficulties due to weather, scent stations had the second highest detection probabilities ( $\bar{X} = 0.73$ ; Fig. 2-2). Over the 3,718 operable station

nights, we collected 159 fox detections. Scent stations had the second highest correlation with fox abundance which was linear and positive ( $r^2 = 0.46$ ,  $P < 0.001$ ; Fig. 2-3B).

### *Spotlight surveys*

The spotlight survey was the only method that did not detect fox presence during a complete biological season. During the dispersal season of 2011, the spotlight survey produced 0 detections although 18 radio-collared foxes were known to be available along the 15 transects. We completed 327 spotlight survey nights with 15 detections. Spotlight surveys had the lowest number of detections and the lowest overall detection probabilities ( $\bar{x} = 0.52$ ; Fig. 2-2). The relationship of spotlight surveys to fox abundance was positive, but not significant ( $r^2 = 0.21$ ,  $P = 0.195$ ; Fig. 2-3C).

### *Trapping surveys*

Trapping was not conducted during the pup-rearing seasons because of concern for the safety of trapped individuals and possible effects on natal young. We conducted 2,640 capture nights with 16 captures. Trapping had the second lowest detection probabilities ( $\bar{x} = 0.59$ ; Fig. 2-2). The correlation between the indices from trapping surveys was significantly positive with kit fox abundance ( $r^2 = 0.45$ ,  $P = 0.017$ ; Fig. 2-3D).

## **DISCUSSION**

Although once abundant on the DPG, kit fox abundance was low during this study. In a review of 24 other studies that captured kit or swift foxes only 5 report data on capture rates, demonstrating a need for more reporting of capture effort. Combined

capture success from opportunistic trapping and survey trapping on the DPG was the second lowest reported at 0.017 (106 captures/6221 total trap nights, including surveys and opportunistic trapping) which is within the range of reported capture rates of 0.173 (Cypher et al. 2000) to 0.013 (Fitzgerald 1996). This low capture rate may partially be due to our attempt to apply equal trapping effort across the entire study area, including areas known to be poor habitat for kit foxes and low numbers of foxes on the study area. During trapping at den sites, foxes were readily captured in one trap night and on most occasions we were able to capture the entire family group in a single night. One fox became 'trap shy' and the use of the tunnel trap (Kozlowski et al. 2003) was successfully deployed to capture that individual for changing its radio-collar.

Low prey abundance and high intraguild predation by coyotes may be limiting kit fox density on the DPG (Arjo et al. 2007, Kozlowski et al. 2008). Since the 1950's, the DPG has been converted from native Great Basin Desert shrub communities to grasslands (Arjo et al. 2007) which support reduced small mammal diversity and abundance (Arjo et al. 2003). Fox home range size was largely dependent on prey availability (Zoellick and Smith 1992, White and Ralls 1993, White and Garrott 1997, Cypher et al. 2000, Zoellick et al. 2002). In addition to this habitat change, the DPG has seen an increase in coyote abundance (Arjo et al. 2007). Predator- caused mortality was the highest cause of death for kit foxes during this study and coyotes have been shown to limit kit fox density (White and Garrott 1997, Cypher et al. 2000, Arjo et al. 2003, Kozlowski et al. 2008). Mean home range size for kit foxes on the DPG was large (20.1 km<sup>2</sup>). This was similar to the large size found by Arjo et al. (2003) with a mean home range size for of kit foxes

on the DPG (22.6 km<sup>2</sup>). Studies of kit foxes in other regions reported much smaller home ranges between 4.6 km<sup>2</sup> (Zoellick et al. 2002) and 13.7 km<sup>2</sup> (White et al. 1994) with an average of 11.4 km<sup>2</sup> (Zoellick and Smith 1992, White and Ralls 1993, White et al. 1994, Koopman et al. 2000, Zoellick et al. 2002, Arjo et al. 2003, List and Macdonald 2003, Moehrenschrager et al. 2007).

Scat deposition surveys consistently had the highest detection probability and were most closely related to fox abundance. Scat deposition transects allowed for the greatest period of surveying (i.e., 14 days) which likely increased the chance of a sample being deposited and subsequently detected for this rare and widely dispersed species. Additionally, as a passive technique, scat deposition surveys do not require the target species to behave unnaturally (e.g., enter a trap or investigate a scent tab; Schauster et al. 2002a). Our results corresponded with findings of Long et al. (2007a) who found scat deposition surveys to be the best method for detection of carnivores in the north-eastern United States and also was similar to results for swift foxes in New Mexico (Harrison et al. 2002).

Where misidentification and overlap with non-target species are a concern, training observers for accurate scat identification was critical (Harrison et al. 2002, Schauster et al. 2002a, Gese 2004). But if multiple species are of concern, it would be possible to use this technique to efficiently identify multiple target species (Smith et al. 2005) with proper training. DNA analysis could also be used for verification of species and/or determining species abundance (Harrison et al. 2002, Gese 2004, Smith et al. 2005, Long et al. 2007b, Ralls et al. 2010). The use of scat detection dogs may increase

detections rates (Smith et al. 2005, Long et al. 2007*b*) and if the dog is trained to detect a particular species, it could assist in the proper identification of the target species (Smith et al. 2005). During this study, misidentification of scat may be the cause of detections along transects without known foxes. The risk of misidentification was highest during the pup-rearing season when juvenile coyotes and red foxes have the highest overlap in scat diameter with kit foxes. Before conducting scat deposition surveys, readers should consult Ralls et al. (2010) for information on seasonal defecation patterns and related concerns when estimating site occurrence or abundance.

Scent stations surveys had the second highest detection probability of the 4 techniques compared and the second highest correlation with the number of available foxes. We found a large reduction in the detection probability during the breeding season, possibly due to weather affecting the tracking substrate. Snow, and freeze/thaw cycles during the winter months on the DPG can actually freeze the sifted sand, thereby diminishing any sign or tracks left by a visiting fox. Also, periods of high winds were more common during the winter, thereby erasing any presence of tracks. We found making a small imprint in the sand helpful in determining if a scent station was operable. During the breeding season we were only able to complete 85% of survey nights; surveys were more reliably detected during the dispersal and pup-rearing season with operable station nights of 100% and 97%, respectively.

Similar to scat deposition transects, more than one target species may be detected at a scent station (Linhart and Knowlton 1975), although weariness of a species to sifted sand on the station should be considered (Gese 2001). This technique has the highest

potential for observer bias and possible misidentification of tracks; red fox, juvenile coyotes and juvenile bobcats are species available for misidentification. Training of the observer at track identification is crucial to avoid misidentification, especially when there are multiple canids on the landscape. We found that 1-2 cm of sifted sand left the most discernible tracks. When possible, sand composed of particulates with highly contrasting hues should be used over sand with few tones to aid in defining tracks. Our results were consistent with other studies showing a positive correlation of scent station detections to fox abundance (Warrick and Harris 2001, Harrison et al. 2002, Schauster et al. 2002a) although Warrick and Harris (2001) reported fairly erratic results and suggested scent station surveys were only able to detect large changes in the population.

In this widely dispersed kit fox population, spotlight surveys were found ineffective at detecting fox presence and failed to detect a single fox during the dispersal season of 2011, although 18 known foxes were available. During 327 survey nights, we only detected fox presence 15 times. Spotlighting had the lowest detection probability and was not significantly correlated to fox abundance. Obstruction of view from vegetation and topography (Warrick and Harris 2001, Schauster et al. 2002a, Gese 2004) were concerns when using this technique. Along transects with both a road cut (<0.5 m deep) and dense tall vegetation, sighting probability was drastically reduced. Consequently, we had no detections of foxes along those transects although foxes were available for detection throughout the entire study. Additionally, highly mobile, wary species may actively evade detection (Ruelle et al. 2003). This technique failed to detect kit foxes twice when foxes were available for detection and was the weakest performing



technique of the similar methods used by Schauster et al. (2002a) for swift foxes.

Similarly, spotlight surveys were found to be inefficient at detecting swift foxes in New Mexico (Harrison et al. 2002).

The trapping survey was only slightly less correlated to fox abundance than the scent station survey, but had a much lower detection probability than both the scat deposition transects and scent station surveys. One of the main benefits from this technique was the ability to add ear tags to captured foxes to conduct capture-mark-recapture estimation of abundance (Schauster et al. 2002a). Due to a low capture rate, low numbers of foxes, and high mortality from predation, we had very few recaptures and therefore could not perform mark-recapture abundance and survival analyses. Because of concerns for the safety of trapped individuals (high summer temperatures) and possible effects on natal young, trapping surveys were not conducted during the pup-rearing season. Trapping posed the highest risk to the animal of all methods used as we did have 3 minor foot injuries and 4 mouth injuries. We suggest following the recommendation of modifying the mesh size (Schauster et al. 2002a) to a mesh size of 1-2 cm. The effect of repeated trapping of foxes should also be considered (Schauster et al. 2002a). We had a few animals become trap happy and were repeatedly captured, while one fox became trap shy and could only be recaptured using the tunnel trap (Kozlowski et al. 2003).

For detecting kit foxes in a low density population we suggest using scat deposition transects during the breeding season. This method had both the highest detection probability and highest correlation to kit fox abundance. This method had low costs, was resilient to weather, had low labor requirements, and entailed no risk to the

study animals (Schauster et al. 2002a). The breeding season was ideal for monitoring kit fox population size, as detections consisted of primarily the resident population and we had the highest detection probabilities during this season. In areas where overlap with other sympatric canids occurs, careful training of technicians may be required, but the risk of overlapping scat dimensions should be lowest during the breeding season as most sympatric canids are also fully grown by the subsequent breeding season.

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Table 2-1. Mean home range size ( $\text{km}^2$ ) for kit foxes, range, and number of foxes monitored for each biological season and year, Dugway Proving Grounds, Utah, 2010-2012.

<b>Season</b>	$\bar{x}$ ( $\text{km}^2$ )	<b>Range (<math>\text{km}^2</math>)</b>		<b><i>n</i></b>
Pup-rearing 2010	18.84	1.74	28.05	12
Dispersal 2010	26.14	3.14	80.14	14
Breeding 2011	20.56	2.18	66.10	14
Pup-rearing 2011	14.96	2.44	38.95	9
Dispersal 2011	18.78	7.89	47.79	9
Breeding 2012	21.25	6.56	71.56	6

Table 2-2. Average home range size ( $\text{km}^2$ ) of female and male kit foxes during each biological season (breeding, dispersal, pup-rearing), Dugway Proving Grounds, Utah, 2010-2012.

<b>Season</b>	<b>Sex</b>	<b><i>n</i></b>	$\bar{x}$ ( $\text{km}^2$ )
Breeding	Female	12	25.295
	Male	8	8.314
Dispersal	Female	15	22.075
	Male	8	19.128
Pup-rearing	Female	12	25.707
	Male	9	16.483

Table 2-3. Total number of fox available for detection along all transects as determined by telemetry location and transect buffer by survey method (Scent, Capture, Scat, Spotlight) during each biological season (breeding, dispersal, pup-rearing), Dugway Proving Grounds, Utah 2010-2012.

<b>Method</b>	<b>Season</b>	<b><i>n</i></b>	<b>Detections</b>
Scent	Breeding	44	21
	Dispersal	59	65
	Pup-rearing	45	73
Capture	Breeding	44	7
	Dispersal	59	9
	Pup-rearing	-	-
Scat	Breeding	44	48
	Dispersal	59	73
	Pup-rearing	15	15
Spotlight	Breeding	44	3
	Dispersal	59	1
	Pup-rearing	50	14

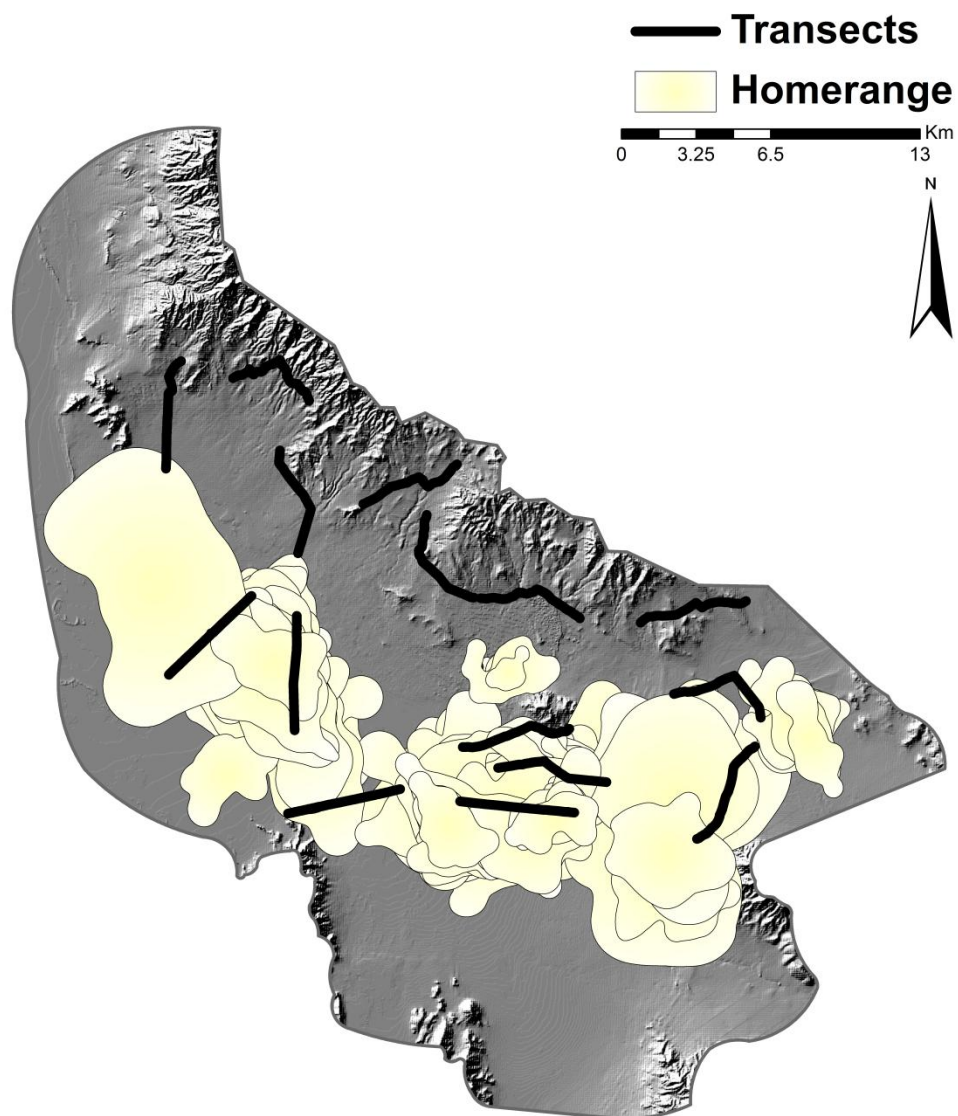


Figure 2-1. Transects and all kit fox home ranges created from telemetry locations, Dugway Proving Grounds, Utah, 2010-2012.

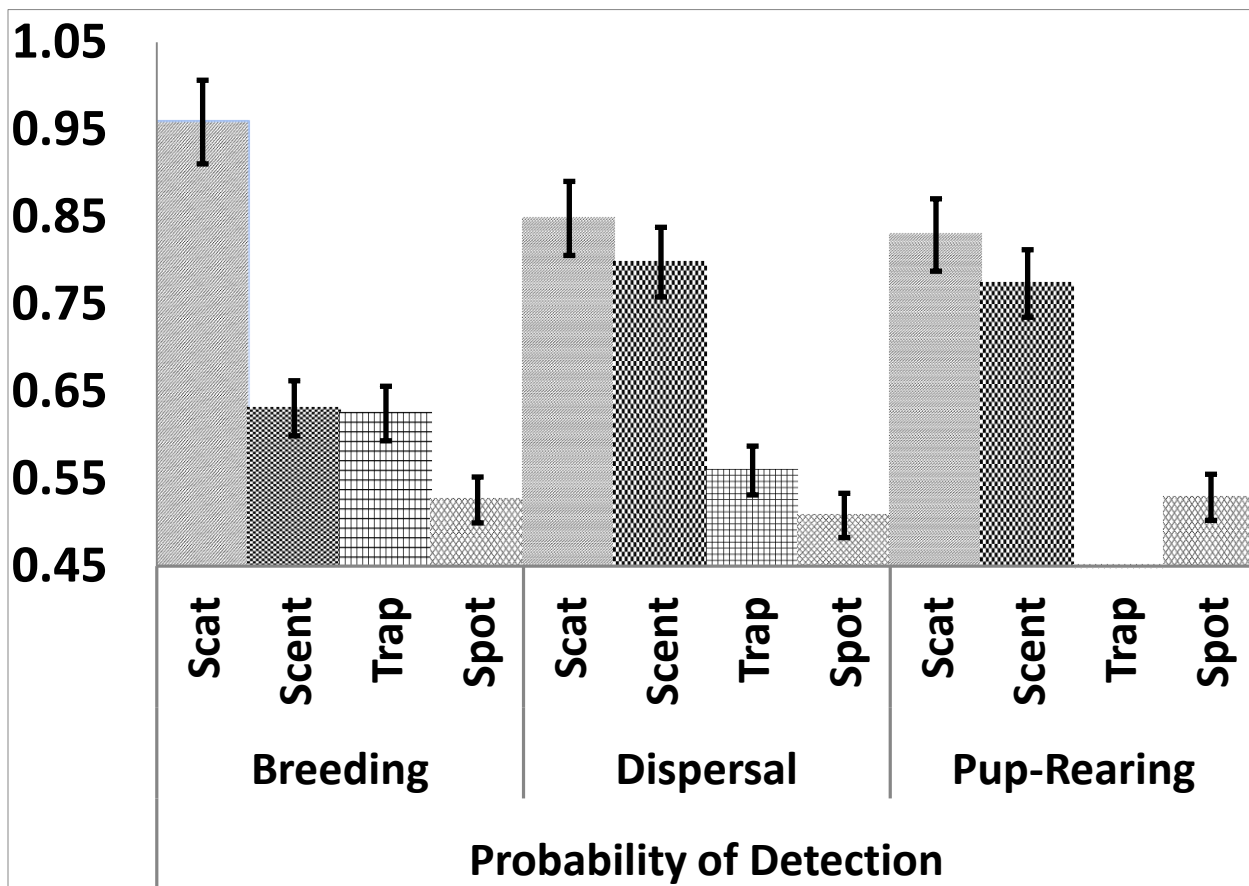


Figure 2-2. Detection probabilities for scat deposition (Scat), scent station (Scent), trapping (Trap), and spotlight (Spot) surveys during 3 biological seasons for kit foxes on the Dugway Proving Grounds, Utah. Standard error bars included for each method.

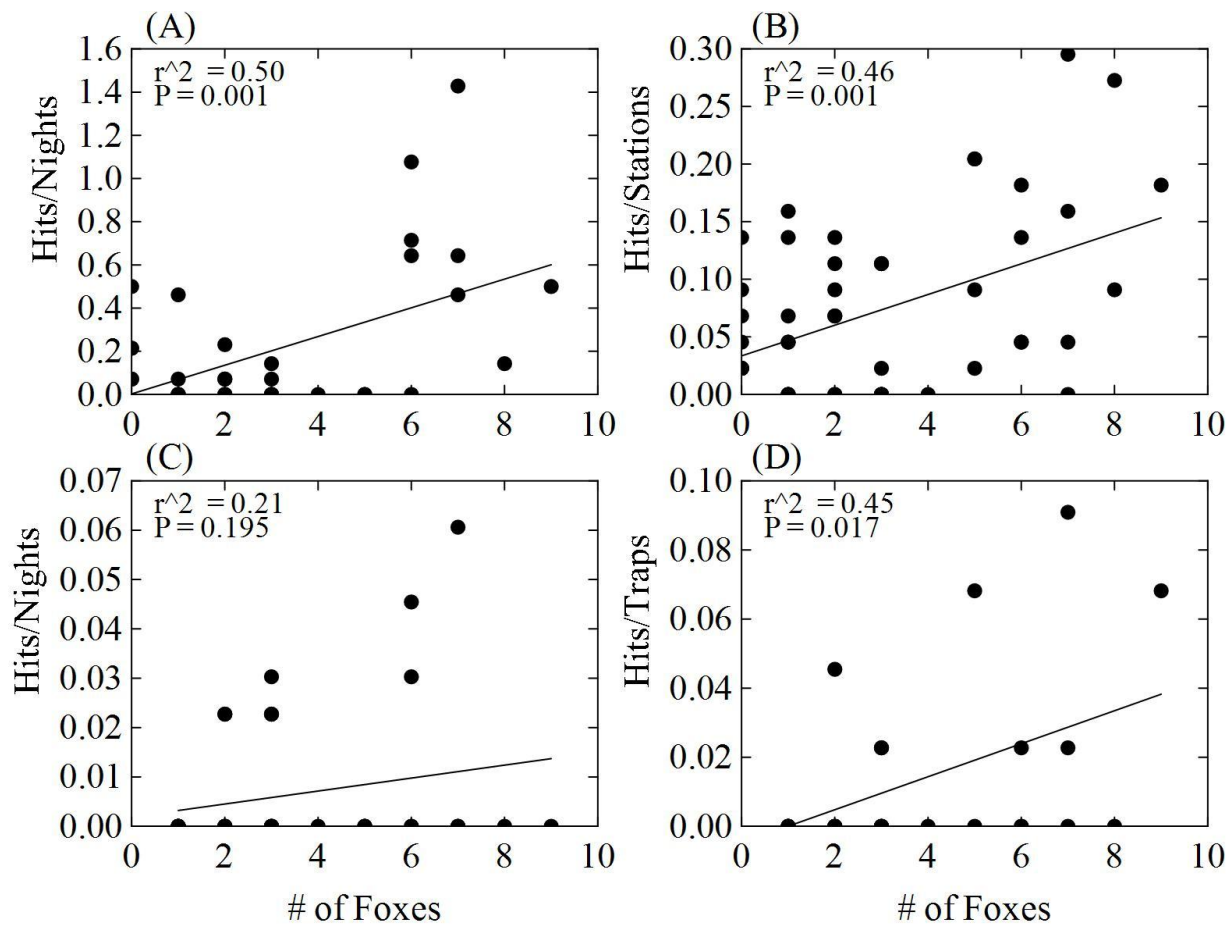


Figure 2-3. Relationship between the minimum number of known available foxes along the transects and indices of relative abundance for (A) scat deposition transects, (B) scent station surveys, (C) spotlight counts, and (D) trapping index, U.S. Army Dugway Proving Grounds, Utah, 2010-2011.

### CHAPTER 3

## DEVELOPMENT OF A SPECIES DISTRIBUTION MODEL USING RESOURCE SELECTION FUNCTIONS FOR KIT FOXES IN WESTERN UTAH

### ABSTRACT

Historically, kit foxes (*Vulpes macrotis*) once occupied the desert and semi-arid regions of southwestern North America, ranging from Idaho to central Mexico. Once the most abundant carnivore in the western desert, the species is now considered rare. In the past few decades, attempts have been made to model the environmental variables influencing kit fox space use. We modeled kit fox distribution using three popular techniques (Maxent, fixed-effects and mixed-effects general linear models) using noninvasive scat deposition surveys for determination of presence data. Models were developed using all possible combinations of elevation, slope, aspect, vegetation height, and soil type. The Maxent modeling approach had the highest area under the curve (AUC) score (AUC = 0.832) and appeared to best fit the testing data. The next best model was the fixed-effects (AUC = 0.755). The mixed-effects model over valued higher elevations and had poor model fit. Our modeling effort suggested that both the Maxent and fixed-effects models performed to an acceptable level. Both of these models showed that elevation was a large contributor to kit fox occurrence. What is equally important from this study is we demonstrated that it was possible to create valid and informative predictive maps of a species distribution using a noninvasive survey method for detecting a carnivore existing at low density. By demonstrating the application of noninvasive surveying to model habitat quality wildlife managers can develop predictive distribution

maps for species of interest providing more knowledge in guiding future management decisions.

## INTRODUCTION

Historically, kit foxes (*Vulpes macrotis*) occupied the desert and semi-arid regions of southwestern North America ranging from Idaho to central Mexico (McGrew 1976). Their range-wide decline has warranted the kit fox to be listed as endangered in Colorado, threatened in California and Oregon, and designated as a state sensitive species in Idaho and Utah (Meaney et al. 2006). Although listed and protected in several states, a comprehensive study of kit fox distribution is lacking, with the majority of studies focused on the endangered subspecies, the San Joaquin kit fox (*V. macrotis mutica*), leaving a need for greater knowledge of monitoring methods for the species across its entire range. Once considered the most abundant carnivore in western Utah (Egoscue 1956, 1962), the kit fox has been in steep decline over the past couple decades (Thacker et al. 1995, Arjo et al. 2007, Utah Department of Natural Resources 2011).

Habitat use by kit foxes has been previously studied. In early reports on the kit fox population in western Utah, Egoscue (1962) described the kit fox as using areas that were predominately flat and featureless with sparse vegetation. He also described kit foxes as selecting areas with silt and clay soils or sandy dunes and their den sites being mostly found in greasewood. In a later study on the same geographic area, Arjo et al. (2003) found that most kit fox dens (54.4%,  $n = 88$ ) were now found in grasslands, with a surrounding vegetation height of ~26 cm.

Amongst all populations, multiple studies have reported the environmental variables important for kit fox distribution and ecology. Fitzgerald (1996) found kit foxes existed at elevations between 1,463 to 1,829 m and in areas with high clay to clay-loam soils. Vegetation height at capture sites averaged 43 cm, and at den sites were ~ 22 cm and vegetation was generally sparsely distributed. In addition, they found most den entrances had a southerly aspect. McGrew (1976) also found kit foxes to be present in areas with low ground cover (<20%), loamy desert soils, at elevations <1,675 m, and vegetation height at den sites was generally >22 cm.

In the past few decades, attempts have been made to model the environmental variables influencing kit fox space use. Zoellick et al. (1989) reported the geographic range of kit foxes was closely associated with open flat habitats with little vegetative cover. They also determined kit foxes spent more time in greasewood flats than riparian areas. Warrick and Cypher (1998) modeled kit fox occurrence using capture rates, and used a standardized regression approach to evaluate the influence of land development, ruggedness, fenced lands, and burned areas. They also used linear regression to compare space use of foxes with coyote and lagomorph abundance, but found no significant relationship. They determined that topographic ruggedness was the only consistent variable affecting the spatial distribution of kit foxes. Gerrard et al. (2001) provided an early attempt at GIS modeling of habitat use by kit foxes, based on landcover type and roads, in which they ranked grasslands as most important to kit foxes. We modeled kit fox distribution using three popular techniques for creation of a resource selection function (RSF). A “RSF is any model that yields values proportional to the probability of



use of a resource unit” (Boyce et al. 2002). RSF’s differ from habitat suitability models in that they are always estimated statistically from data. These RSF’s can vary greatly depending on which techniques are used to build the model.

We developed RSF’s for kit foxes using two general linear model (GLM) approaches: traditional fixed effects (Boyce et al. 2002) and mixed effects models (Bolker et al. 2009). Additionally, we used the maximum entropy (Maxent) technique (Phillips and Dudik 2008). All of these methods require ‘use’ or ‘presence’ data which is often obtained through animal locations via radio telemetry or global positioning system collars. Carnivores are generally difficult to survey because they exist at low densities, are usually nocturnal and elusive, as well as wary of humans (Thacker et al. 1995, Gese 2001, 2004, Gompper et al. 2006, Long et al. 2007). The kit fox population on the Dugway Proving Grounds (DPG), Utah, is considered declining in abundance, of low density, and widely dispersed (Arjo et al. 2007, Kozlowski et al. 2008, 2012). Given these conditions, obtaining presence data from traditional radio telemetry may be difficult and there is a need for a passive technique to determine specie’s presence (Gese 2001). We used scat deposition surveys (Knowlton 1984, Schauster et al. 2002a) to determine animal presence, then created the RSF’s using environmental variables related to topography, soil, and vegetation.

## **STUDY AREA**

We conducted our research on 879 km<sup>2</sup> of the eastern portion of the DPG and the adjoining land managed by the Bureau of Land Management, located approximately 128 km southwest of Salt Lake City, in Tooele County, Utah. Elevations ranged from 1302 m

to 2137 m. The study site was in the Great Basin Desert and was characterized as a cold desert. Winters were cold, summers were hot and dry, with the majority of precipitation occurring in the spring. The study area consisted of predominately flat playa punctuated with steep mountain ranges. The lowest areas consisted of salt playa flats sparsely vegetated with pickleweed (*Allenrolfea occidentalis*). At slightly higher elevations, was less salty supporting a cold desert chenopod shrub community, consisting predominately of shadscale (*Atriplex confertifolia*) and gray molly (*Kochia America*). At similar elevations, greasewood (*Sarcobatus vermiculatus*) communities would be found with mound saltbrush (*Atriplex gardneri*) and Torrey seepweed (*Suaeda torreyana*). Higher elevations consisted of vegetated sand dunes including fourwing saltbush (*Atriplex canescens*), greasewood, rabbitbrushes (*Chrysothamnus* spp.), shadscale, and horsebrush (*Tetradymia glabrata*). Near the bases of the higher steep mountains were shrubsteppe communities of sagebrush (*Artemisia* spp.), rabbitbrush, Nevada ephedra (*Ephedra nevadensis*), greasewood, and shadscale. The highest elevation was a Utah juniper (*Juniperus osteosperma*) community including black sagebrush (*Artemisia nova*) and bluebunch wheatgrass (*Elymus spicatus*) (Arjo et al. 2007).

## **METHODS**

### *Scat deposition surveys*

Scat deposition surveys were conducted along 15 5-km established transects distributed randomly along available roads with the constraint of being linear as possible and having year-round access (limitations included military closures and low lying seasonally inundated greasewood areas). We initially walked the transect to clear any

scat from the road surface, then returned approximately 14 days later to walk and count the number of scats deposited (Warrick and Harris 2001, Schauster et al. 2002a).

Following recommendations from Schauster et al. (2002a) and Knowlton (1984), each transect was walked in both directions to reduce missing scats. Scat location and type (species) was recorded on a handheld GPS unit and the scat was collected. We conducted scat deposition surveys during each of the 3 biological kit fox seasons (breeding, pup-rearing, and dispersal). Biological seasons were defined by behavior and energetic needs of kit foxes: breeding (15 December – 14 April), pup-rearing (15 April – 14 August) and dispersal (15 August – 14 December) following seasons defined by Egoscue (Egoscue 1962), Schauster et al. (2002b), and Arjo et al. (2003). During the breeding season of 2013, a DNA capture-recapture and occupancy modeling study was initiated. This study included the addition of 5 5-km transects randomly placed within the study area; randomization was conducted using a 5 km x 5 km square extent. In addition, 69 smaller 500 m transects were randomly placed across the study area to determine fox occupancy.

### *Environmental variables*

All environmental data sets are readily available from free public access GIS databases found online. Elevation, slope, aspect and a soil layer were downloaded from the Utah Automated Geographic Reference Center (<http://gis.utah.gov/>). Soils in the study area were classified into 4 major classes; silt (SLT), fine sand (FS), blocky loam (BL\_L), and gravel (GRV) (Table 3-1). The SLT class included Playa loam, Taylorsflat loam, Pits, Saltair-Playas complex, Skumpah-Yenrab complex, Skumpah silt loam, and Timpie silt loam. The FS class included Yenrab fine sand, Medburn fine sandy loam,

Tooele fine sandy loam, Berent-Hiko Peak complex, and Yenrab-Tooele complex. The BL\_L class consisted of Kapod stony loam, Amtof rock outcrop complex, Checkett rock outcrop complex, Kapod very cobbly loam, Reywatt broad rock outcrop, dune land, and Hiko Peak very stony loam. The GRV class included Hiko Peak gravelly loam, Hiko Peak-Checkett complex, Hiko Peak-Taylorsflat complex, Cliffdown gravelly sandy loam, and Izamatch-Cliffdown complex.

A vegetation height layer was downloaded from the national Landfire database (<http://landfire.cr.usgs.gov/>). This layer was generated separately for tree, shrub, and herbaceous cover life forms and determined by the average height (m) weighted by species cover based off of existing vegetation type. All layers were reprojected using Project Raster tool (Data Management) to 30 m x 30 m cells (the largest cell extent of any layer) and confined to the same spatial extent as the study area. After reprojection, each layer consisted of 977,122 cells. All spatial processing was completed using ArcGIS 10 (ESRI, Redlands, CA, USA).

### *General linear models*

Fixed and mixed-effects generalized linear models (GLM) were created using the scat location data. We followed a use – available design using all scats detected during our surveys and 10,000 random locations from within the study area. This was the same number of background locations used in the Maxent model. Environmental values were attached to the use/available locations using the Extract Multi-Values to Points tool (Spatial Analyst). We created GLM's using all possible combinations of the environmental layers, following guidelines described by Bolker et al. (2009). Elevation,

slope, aspect, and vegetation height were continuous variables and soil type was the only categorical variable. To limit the number of parameters and improve model fit, we reclassified soil type into four broad classes (Table 3-1). In the mixed models, the survey transect was assigned as a random intercept to help improve model fit (Gillies et al. 2006). Both fixed and mixed-effects models were created using R (Version 2.12.1, <http://www.r-project.org/>). Fixed-effects models created using the GLM function and the mixed-effects models with function glmer (lme4 Package Version 0.999375-37). Models were ranked by Akaike information criterion corrected for small sample sizes (AICc; Akaike 1973, Boyce et al. 2002, Burnham and Anderson 2002, Bolker et al. 2009). The global fixed effects GLM was: Use ~ Elevation + Slope + Aspect + Vegetation Height + BL\_L + FS + GRV + SLT. The mixed effects GLM was similar with the addition of a random intercept: Use ~ Elevation + Slope + Aspect + Vegetation Height + BL\_L + FS + GRV + SLT + (1|Transect).

### *Maxent*

The same environmental variables (elevation, slope, aspect, soil, and vegetation height) were included in Maxent modeling. As the predictor, Maxent uses only presence data (scat locations) and does not require random creation of available data; see Elith et al. (2011) for an explanation of the Maxent modeling process. We kept the default tuning parameters in Maxent (Phillips et al. 2004, Elith et al. 2011, Cao et al. 2013) and selected a random seed for 100 replicates with cross-validation.

### *Telemetry*

To evaluate the use of scat transect surveys to develop a predictive map, we followed the same protocol as the Maxent scat model to develop a model from all the telemetry locations collected on kit foxes (Chapter 2). Animal locations were collected >3 times per week using a portable receiver (Communications Specialists, Inc., Orange, CA) and a handheld 3-element Yagi antenna. We triangulated an animal's location using  $\geq 2$  compass bearings, each  $>20^\circ$  but  $<160^\circ$  apart, for each animal within 20 minutes (Arjo et al. 2007, Kozłowski et al. 2008). Positions were then calculated using program Locate III (Pacer Computing, Tatamagouche, Nova Scotia). For each week, we temporally distributed telemetry sampling by collecting two crepuscular (hunting) locations and one den (resting) location. To reduce auto-correlation and retain temporal independence between locations each crepuscular sample was separated by >12 hours and a difference of >2 hours in the time of day of each location (Swihart and Slade 1985a, b, Gese et al. 1990). We collected one weekly den location for each animal by homing in on the signal during daylight hours.

### *Model evaluation*

To test the performance of the models, two techniques were examined: area under the receiver operating curve (AUC) and AICc. Similar to the Wilcoxon test of ranks, AUC can be interpreted as a probability of a correct classification or prediction (Baasch et al. 2010). Using AUC has been generally found best at evaluating model performance (Peterson et al. 2007) and considered highly effective (Allouche et al. 2006) while not being dependent on thresholds (Fielding and Bell 1997, Allouche et al. 2006).

We followed the general thresholds of ranking model accuracy in AUC scores; 0.5-0.7 = low accuracy, 0.7-0.9 = useful application, and  $>0.9$  = high accuracy (Swets 1988, Boyce et al. 2002, Manel et al. 2002). The fixed effects model AUC score was calculated using the ROCR function (ROCR Package Version 1.0-4) in R (Version 2.12.1, <http://www.r-project.org>). Maxent provides the AUC scores by default. The random term in the mixed effects GLM precludes the use of AUC to evaluate model performance. AICc has been shown appropriate for GLM's (Boyce et al. 2002, Burnham and Anderson 2002, Bolker et al. 2009) and is generally considered a good test of model fit. AICc scores were calculated for both the mixed and fixed-effects models. Recently, Cao et al. (2013) demonstrated that AICc does not improve modeling in Maxent and suggested it should not be used.

Additionally, models were visually assessed using a test dataset withheld from the training dataset (Fielding and Bell 1997, Anderson et al. 2003, Elith et al. 2006, Phillips et al. 2006). We withheld the third year of sampling along the 5 km transects to provide a test if the models were predicting where fox locations would occur. The withheld scats were overlaid on the predictive maps to see if they were accurately predicting where fox detections should occur. Habitat values were divided into 10 bins using the quantile method in ArcGIS 10. The quantile method divides the bins into equal sizes by the number of pixels. Then the number of test scats that fell into each bin size was calculated.

### *Resource selection function*

Resource selection functions (RSF's) for the GLM's were created using the Raster Calculator tool (Spatial Analyst) in ArcGIS 10 using the exponential RSF developed by Manly et al. (2002). The  $\beta$  coefficient values were calculated from a model average of all reasonable models which considered all model's within  $<10 \Delta AICc$ .

## **RESULTS**

### *Scat depositions surveys*

We conducted scat deposition surveys from December 2009 through March 2013. The training dataset consists of 95 5-km transects were surveyed with 212 scat detections and 69 500-m transects were conducted with 14 scat detections. The test dataset consisted of 90 scats collected during the third year of sampling along the 5 km transects. A total of 584.5 km were surveyed and 316 kit fox scats detected that were considered kit fox 'presence' for our RSF models. Sampling effort during biological seasons varied from 3 surveys during the breeding season (2011, 2012, 2013), 2 surveys during the dispersal season (2010, 2011) and 1 survey during the pup-rearing season (2011).

### *Model fit*

The Maxent model had the best performance of the four types of models developed (AUC = 0.832). The AUC was calculated for the top-ranked fixed-effects model (use  $\sim -0.002\text{elevation} - 0.202\text{slope} + 0.001\text{height} - 1.066\text{BL\_L}$ ; AUC = 0.755, AICc = 1961.43) and was slightly less than the Maxent model. The telemetry model had a lower fit than both the Maxent and fixed-effects models (AUC = 0.713). All three



models, the Maxent, fixed-effects, and telemetry models fall within the criteria (0.7-0.9) of having useful application. All these models showed the most important variables to be elevation, slope, height, and BL\_L soil type.

The top-ranked mixed-effects model (use  $\sim 0.001\text{elevation} - 0.310\text{BL\_L} - 0.089\text{GRV}$ ; AICc = 330.36) outperformed the fixed-effects model based on AICc scored. Although the mixed-effects model had a much better model fit, the top model's weight (0.063) suggested that it was not very informative. Therefore, RSF models were created with the model averaged  $\beta$  coefficient of all reasonable models. The top-ranked fixed-effects model had relatively high model weight (0.465) which is expected with only 7 models.

Resource selection functions were created for each model type which produced different resulting maps (Figs. 3-1, 3-2, 3-3, 3-4). Although the mixed-effects model had a lower AICc score than the fixed effects, it appears to be overly smoothed and does not provide much inference to kit fox resource selection. The fixed-effects model was an improvement over the mixed model, and showed the low elevation flat areas in the central portion of the study area to be of higher value. The Maxent model produced a much coarser prediction showing large differences in high and low value areas. The telemetry model appeared to combine aspects of the Maxent and fixed-effects models. The fixed-effect, Maxent, and telemetry models were coarse enough to distinguish the "ripple marks" (Egoscue 1962) common on shadscale flats.

### *Assessment of model prediction*

When the testing data is overlaid on the maps it is apparent that the Maxent model most accurately predicted kit fox scat detections (Figs. 3-1, 3-5). Nearly all locations where the test scat occur are considered to be good to high value habitat (>5). The fixed-effects model and telemetry also appeared to perform well, with most of the test scats occurring in the higher habitat values (Figs. 3-2, 3-4, 3-5). The mixed-effects model appeared to have over-predicted the habitat quality of the eastern portion of the study area, suggesting that a large area was of high value, yet only few scat's were detected in that area in the subsequent test survey. In contrast, in the central portion of the study area that was modeled to be of moderate habitat for kit foxes, 40% ( $n=36$ ) of the testing scats were found in the subsequent test survey (Fig. 3-3).

### *Variable contribution*

Depending on the model constructed, each environmental variable had a different contribution to the models (GLM's, Table 3-2). In the Maxent model, elevation had 45% of the model contribution followed by slope, height, and soil type with similar contributions of 18%, 17%, and 15%, respectively. Aspect had a very small contribution of 5%. In all models, elevation was very important and contributed to nearly half the Maxent model and was included in almost all the GLM's that were considered reasonable. Also, in all models, aspect had a very low contribution. In both GLM's, the blocky loam soil type was included with high weights and had much lower probability of presence than the other soil types in the Maxent model. For the fixed-effects models, the only other soil type that was included was gravel, but with low weight. In the mixed-

effects model, all soil types were used, but again only the blocky loam soil type had much weight. A jackknife test performed in Maxent showed the individual contribution of the variables when ran alone, and then when individually omitted. The jackknife test demonstrated the variable's individual contribution to the model (Fig. 3-6) and showed that elevation alone provided most of the AUC score.

Logistic response curves showed the variable effects to the Maxent prediction and provided the range of probability for detecting a kit fox. The probability of detecting a kit fox gradually increased as vegetation height increased with a sharp rise at heights between 100 and 110 cm (Fig. 3-7A). The probability of detecting a kit fox occurred more frequently on areas with elevations <1600 m (Fig. 3-7B), areas with southerly aspects (Fig. 3-7C), and was higher in flat areas with little slope (Fig. 3-7D).

## **DISCUSSION**

For many carnivore species, obtaining sufficient data on species presence can be difficult and expensive, limiting the development of informative models of resource selection functions. In this study, we were able to create a suitable RSF using data that was readily collected from scat deposition surveys. We applied a survey technique that has been shown to be one of the best methods for detecting occurrence of carnivores (Harrison et al. 2002, Long et al. 2007), and was relatively low in cost, resilient to weather, had low labor requirements, and posed no risk to the study animals (i.e., a noninvasive technique; Schauster et al. 2002a). In addition, we used readily available spatial layers for topographic features, soil types, and vegetation height. With a sufficient amount of scat data, we were able to create a fixed-effects model that performed well

enough (based on AUC score) to be considered a useful application (Swets 1988, Boyce et al. 2002, Manel et al. 2002) and a Maxent model that performed better than the fixed-effects model based on inspection of the testing dataset.

The more traditional model built using telemetry locations instead of scats, produced a model that appears to be a synthesis of the Maxent and fixed-effects models. This should be more robust to kit fox spatial movements, as it is “true” animal locations, was created from ~4,500 locations, and is not restricted or biased by our method of collecting scat “use” data only along roadways.

The mixed-effects model vastly outperformed the fixed-effects model by AICc ranking. This model included a random intercept to help account for variables of importance that were not included in the model, unbalanced sampling, variance among regions, and time (Gillies et al. 2006, Bolker et al. 2009). Additionally, the random effect allowed for extrapolation of the model (Bolker et al. 2009) into new areas, allowing for application of the model outside the area studied. Unfortunately in this study, this method proved to be over-smoothed and did not provide much insight into where kit foxes may occur. When plotting the testing data it became apparent that this model was inaccurate. The primary difference in this model appeared to be that it selected a slightly higher elevation as the most high value habitat than both the Maxent model and the fixed-effects model.

Gerrard et al. (2001) suggested that vegetative cover was the single most important environmental variable for modeling kit fox habitat using their available data. They noted that soil type was most likely of high importance and possibly other

environmental variables. Today, with the wide variety and easy access to extensive spatial data, more complex models can be constructed. In this study, our results suggested that in this ecosystem, elevation was highly important to kit fox space use, followed by slope, vegetation height, and soil type. Elevation's contribution to the model may be from its relationship to many other environmental variables in this system including, soil type, ruggedness, vegetation type, and even climatic factors. Similar to results reported by McGrew (1976), in our study area kit foxes appeared to occur in areas with elevations <1600 m.

Kit foxes were found to occur more frequently in areas with taller vegetation height, although this was only a moderate contribution to the model. It was difficult to determine how vegetation height was influencing kit fox presence. Vegetation height was related to many variables that may affect kit fox presence. Vegetation height was related to the vegetation type, which may also influence the level of prey available in those areas. Vegetation height was also related to the amount of visibility for detection of prey and avoidance of predators, but this was likely confounded by vegetation density. More inference may be made by including those variables to help determine how vegetation height influenced kit fox occurrence. Of particular interest would be investigating the effects of vegetation heights between 100 and 110 cm, to determine the cause of the sharp spike at that height. With more detailed use data, more complex models could be constructed to explore some of these additional variables.

The response to soil type appeared to be driven by the importance of den sites to kit foxes. Kit foxes rarely occur in areas with large rocky soils which would be difficult

for den excavation. Den sites are considered to be important to kit foxes as they “provide shelter from temperature extreme, moist microclimate, escape from predators, and a place to rear young” (Arjo et al. 2003) and are a critical part of the survival strategy of kit fox (Gerrard et al. 2001). Therefore the proper conditions (i.e., denning substrate and surrounding habitat) may be required to support kit foxes. Although kit foxes are highly mobile and capable of traveling away from denning areas to forage, they still tend to occur on soils where dens are easily dug. This may suggest kit fox stay within ‘den friendly’ soils because of the use of dens for refuge from predation (White et al. 1994, Koopman et al. 2000, Arjo et al. 2003).

The effect of slope was as expected from prior knowledge that kit foxes occur on mostly flat terrain (Egoscue 1962, Zoellick et al. 1989). The contribution of slope maybe greater in more rugged areas, but the study area was mostly flat reducing the importance of slope in this model. Aspect was included due to results reported by Fitzgerald (1996) that kit foxes often select dens with southern den entrances, which was hypothesized to provide thermal and microclimate advantages (Arjo et al. 2003). The low model contribution of aspect, which showed higher use of southern facing areas may be due to foxes using southern aspects for increased warmth from the sun.

Our study demonstrated the importance of model selection for development of resource selection functions and creating inference on the importance of environmental variables on species distribution. All models we examined did show a large effect of elevation on kit fox presence. But had we only used the fixed-effect model, it would appear that elevation, slope, and vegetation height had nearly equal influence on kit fox

occurrence. AUC score and visual inspection of testing data suggested the Maxent model performed best, with elevation as a primary contributor, with smaller effects from slope, vegetation height, and soil type.

Our modeling effort suggested that both the Maxent and fixed-effects models performed to an acceptable level. Both of these models showed that elevation was a large contributor to kit fox scat detection and occurrence. Both models showed their top ranked three habitat values had mean elevations under 1400 m, while the mixed model ranked mean elevations of 1519 m and 1488 m as the top two habitat values. The difference in mean elevation of the mixed model was the primary distinction from the fixed and Maxent models. All three models suggested that foxes occurred on areas with soils in which dens could easily be dug and avoided large rocky soil types. These results are similar to the expert opinions as noted above. What is equally important from this study is we demonstrated that it was possible to create valid and informative predictive maps of a species distribution using a noninvasive survey method for detecting a carnivore existing at low density. Hopefully by demonstrating the application of noninvasive surveying to model habitat quality more managers will be able to develop maps for species of interest and provide more knowledge to help guide future management decisions.

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Table 3-1. Soil types found on our study area in the western desert of Utah with our reclassification into 4 general soil classes (soil types provided by Utah Automated Geographic Reference Center (AGRC, <http://gis.utah.gov/>)).

<b>Tex_Deft</b>	<b>Composition</b>	<b>Reclassification</b>	<b>Code</b>
Fine Sand	Yenrab fine sand	Fine Sand	FS
Fine Sandy Loam	Medburn & Tooele fine sandy loam	Fine Sand	FS
Gravelly Loam	Hiko Peak gravelly loam; Hiko Peak-Checkett & Hiko Peak-Taylorsflat complex	Gravelly	GRV
Gravelly Sandy Loam	Cliffdown gravelly sandy loam; Izamatch-Cliffdown complex	Gravelly	GRV
Loam	Playa & Taylorsfalt loam	Silt	SLT
Loamy Fine Sand	Berent-Hiko Peak & Yenrab-Tooele complex	Fine Sand	FS
Silt Loam	Pits; Saltair-Playas & Skumpah-Yenrab Complex; Skumpah & Timpie silt loam	Silt	SLT
Stony Loam	Kapod stony loam	Blocky Loam	BL_L
Very Cobbly Loam	Amtof & Checkett rock outcrop complex; Kapod very cobbly loam; Reywat broad rock outcrop	Blocky Loam	BL_L
Very Gravelly Loam	Dune land	Blocky Loam	BL_L
Very Stone Loam	Hiko Peak very stony loam	Blocky Loam	BL_L

Table 3-2. Results of the fixed and mixed-effect models for the environmental variables examining kit fox detections from scat deposition surveys, Dugway Proving Ground, Utah, 2011-2013.

Variable	$\beta$ Coefficient		SE		Weight	
	<u>Fixed</u>	<u>Mixed</u>	<u>Fixed</u>	<u>Mixed</u>	<u>Fixed</u>	<u>Mixed</u>
Aspect	0.0002	0.0005	0.0004	0.0012	0.32	0.31
Elevation	-0.0030	0.0077	0.0025	0.0082	0.96	0.84
Slope	-0.4368	-0.1115	0.3184	0.1493	1.00	0.36
Height	0.0012	0.0001	0.0009	0.0002	1.00	0.28
BL_L	-2.2915	-2.6318	1.8908	3.1205	1.00	0.69
FS	0.0000	0.4679	0.0000	3.1783	0.00	0.29
GRV	-0.0484	-0.3587	0.1475	0.6485	0.31	0.50
SLT	0.0000	0.3919	0.0000	0.7049	0.00	0.25



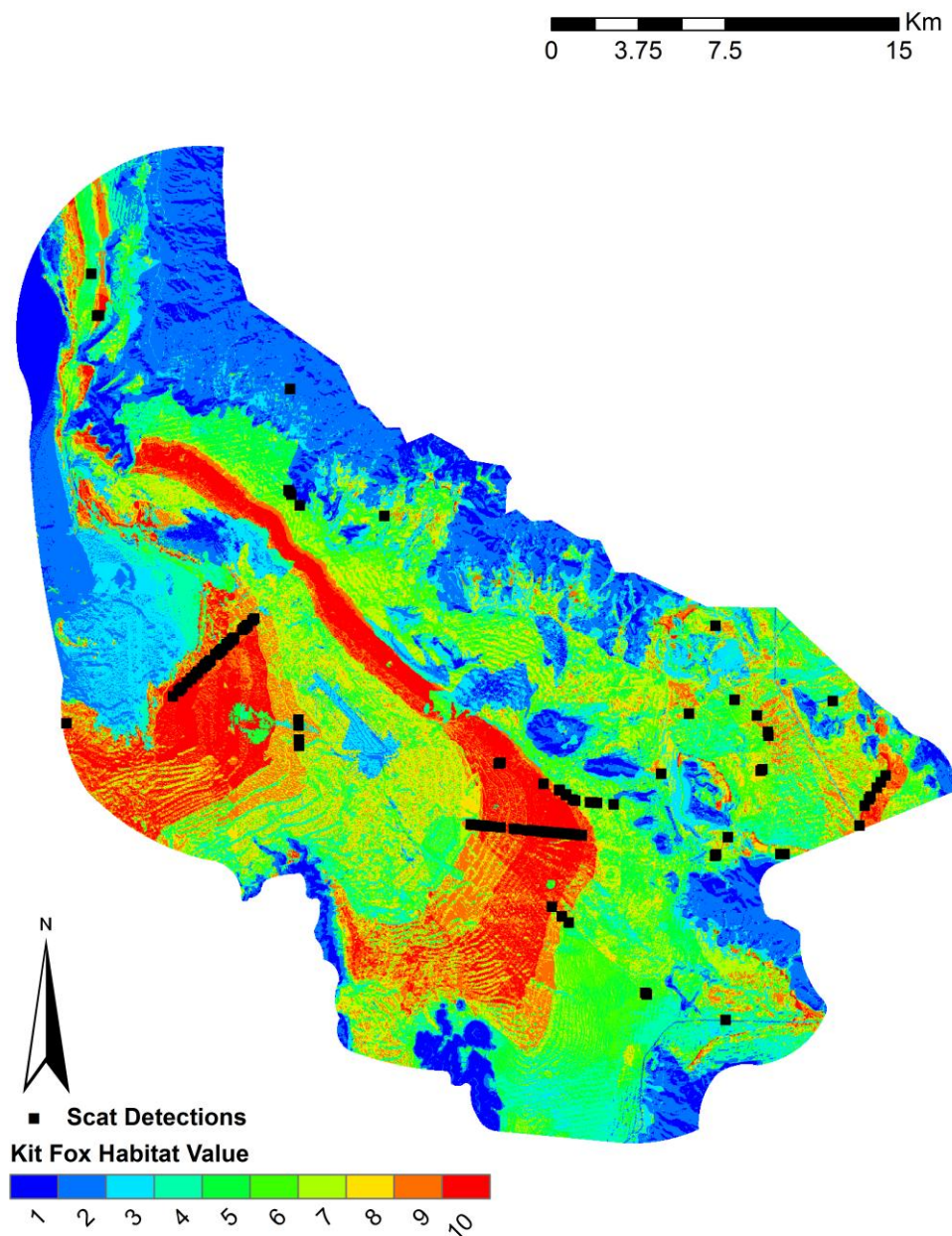


Figure 3-1. Resource selection function generated by Maxent using scat deposition transects for kit foxes, Dugway Proving Ground, Utah. Kit fox habitat quality is shown in quantile ranked categories from 1 (low quality) to 10 (high quality). Locations of kit fox scats from the subsequent test survey are plotted.

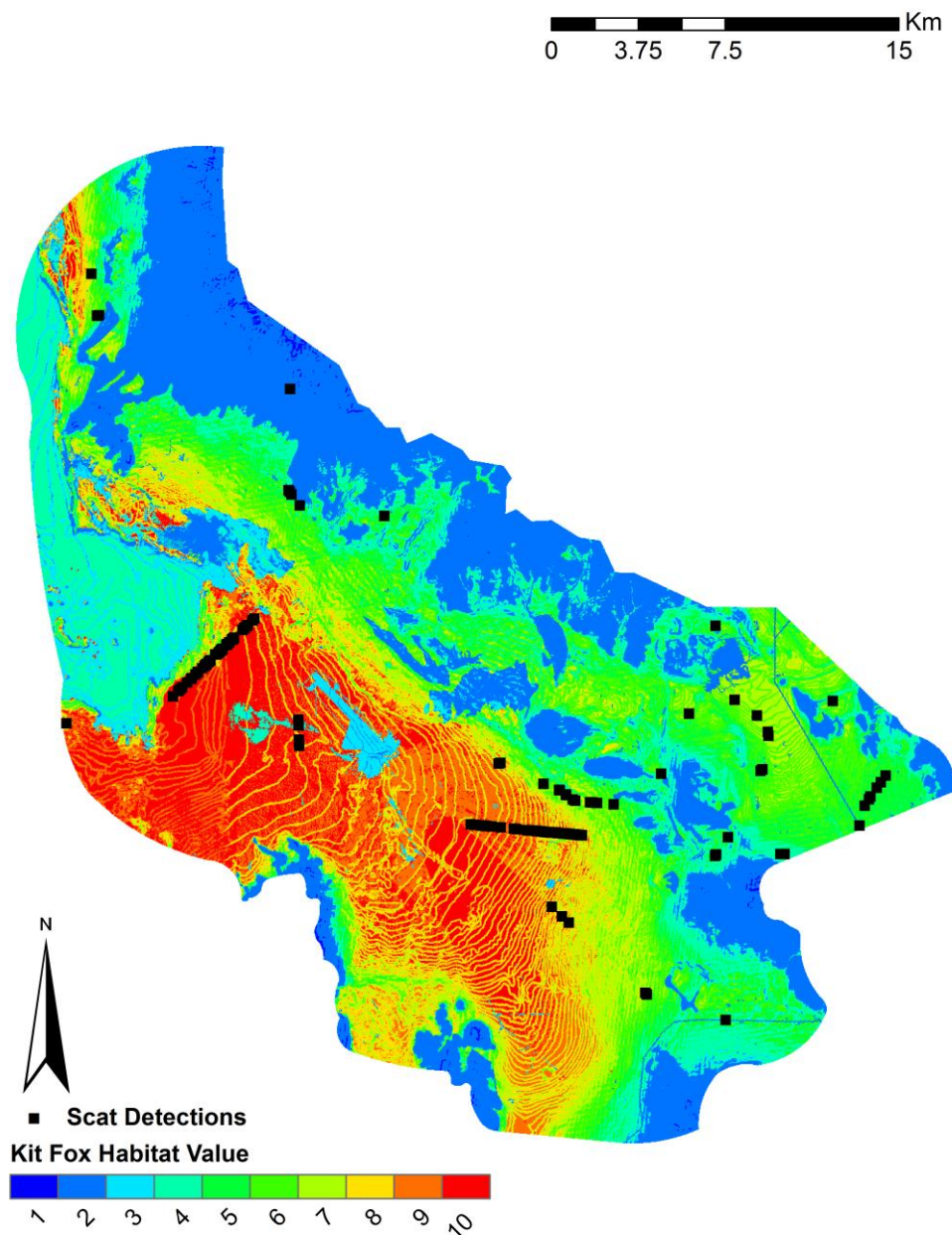


Figure 3-2. Resource selection function for kit foxes as generated by fixed-effect model (elevation + slope + aspect + vegetation height + BL\_L + FS + GRV + SLT) using scat deposition transects for kit foxes, Dugway Proving Ground, Utah. Kit fox habitat quality is show in quantile ranked categories from 1 (low quality) to 10 (high quality). Locations of kit fox scats from the subsequent test survey are plotted.

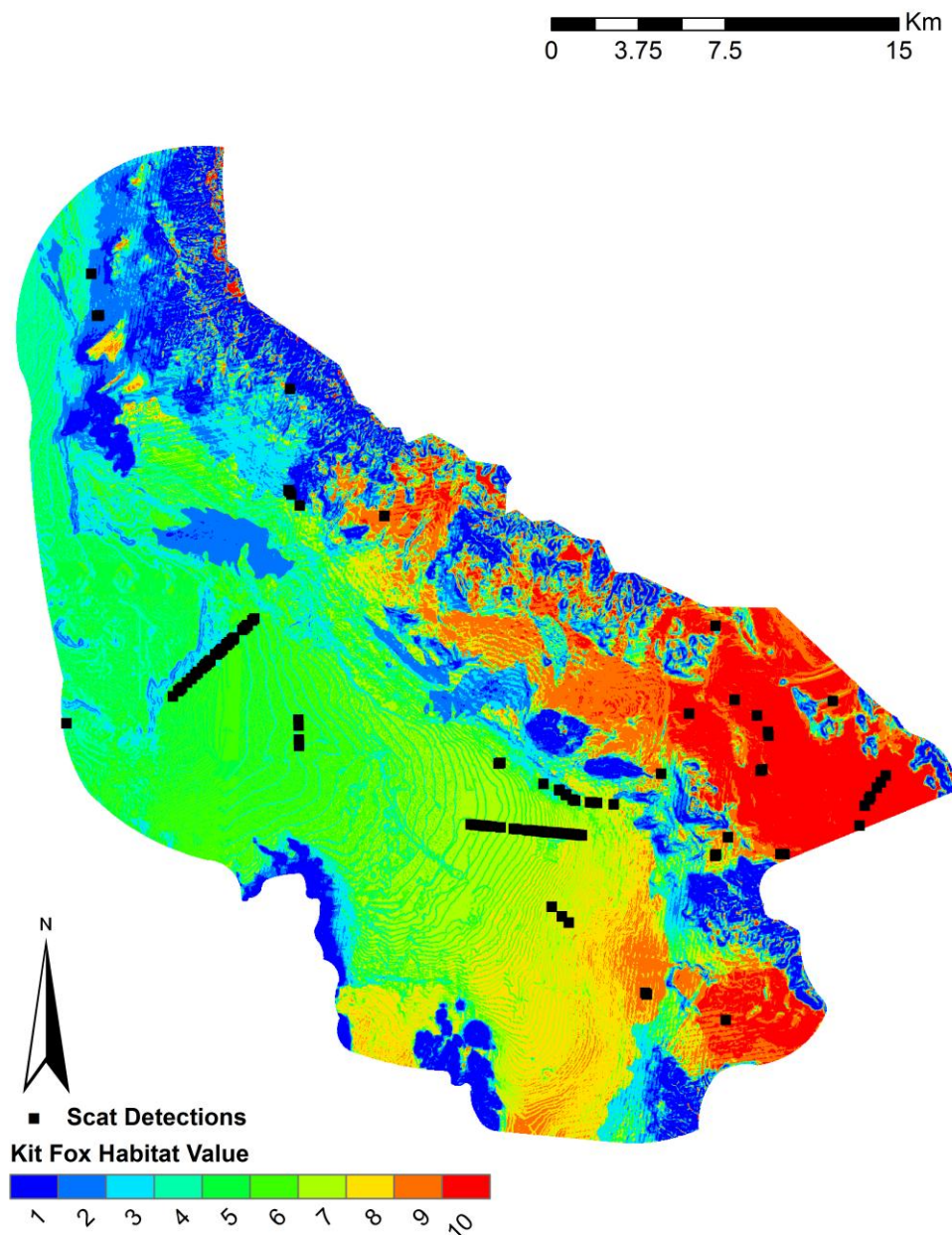


Figure 3-3. Resource selection function for kit foxes as generated by the mixed-effect model: (elevation + slope + aspect + vegetation height + BL\_L + FS + GRV + SLT) using scat deposition transects for kit foxes, Dugway Proving Ground, Utah. Kit fox habitat quality is shown in quantile ranked categories from 1 (low quality) to 10 (high quality). Locations of kit fox scats from the subsequent test survey are plotted.

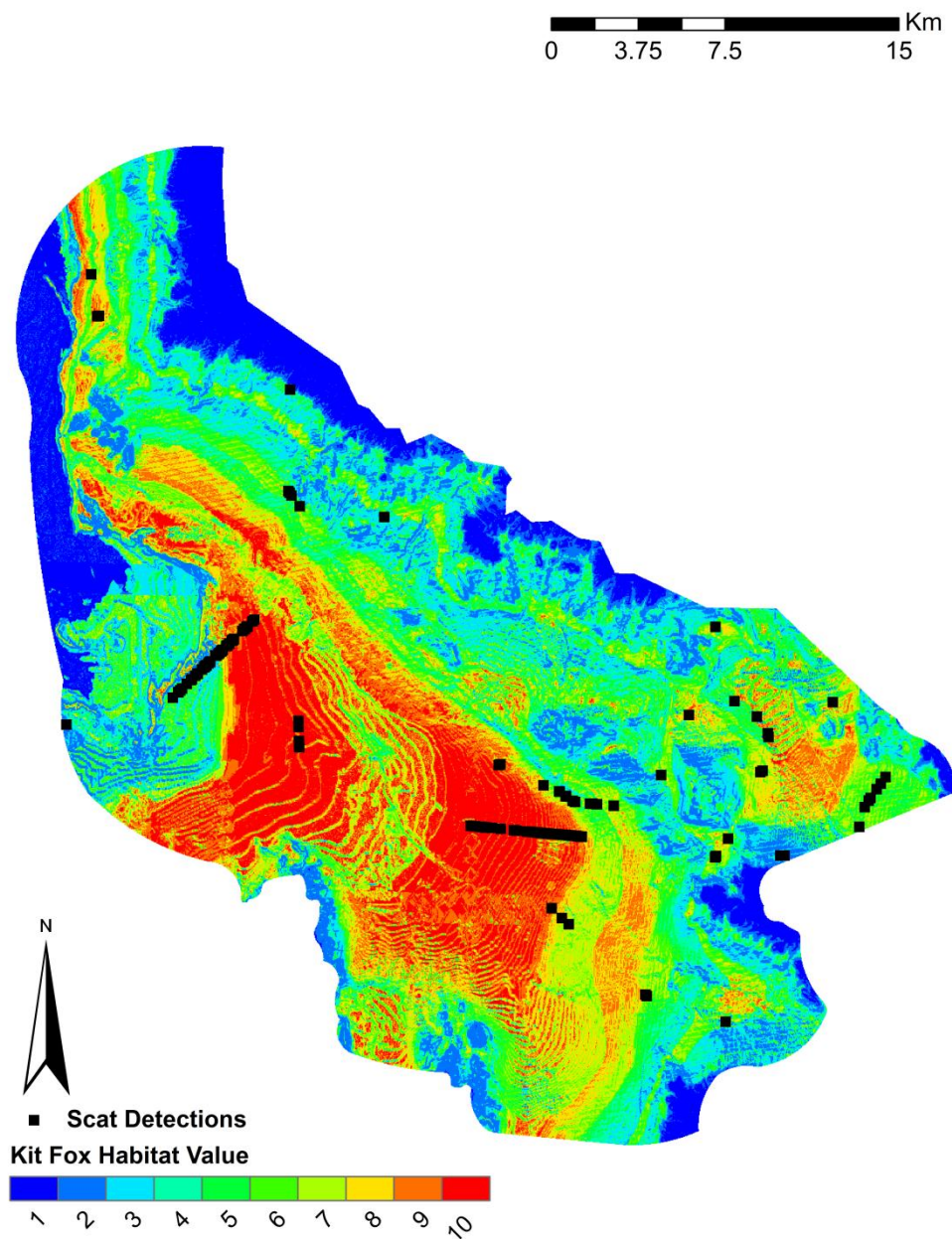


Figure 3-4. Resource selection function generated by Maxent using radio-telemetry locations of kit fox, Dugway Proving Ground, Utah. Kit fox habitat quality is shown in quantile ranked categories from 1 (low quality) to 10 (high quality). Locations of kit fox scats from the subsequent test survey are plotted.

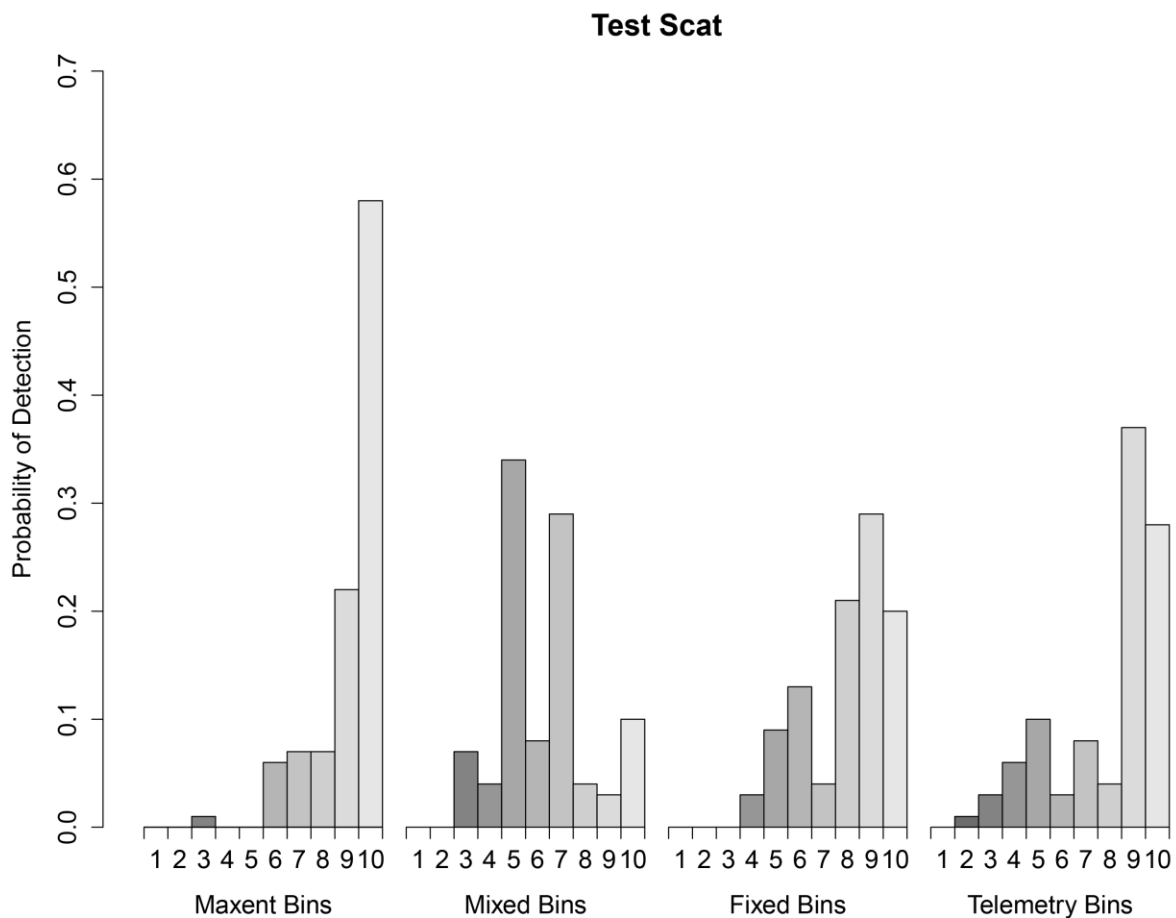


Figure 3-5. Test scat habitat values for resource selection function created with Maxent, Mixed-effects, Fixed-effects, and Telemetry for kit foxes for kit foxes, Dugway Proving Ground, Utah. Kit fox habitat quality is show in quantile ranked bins from 1 (low quality) to 10 (high quality).

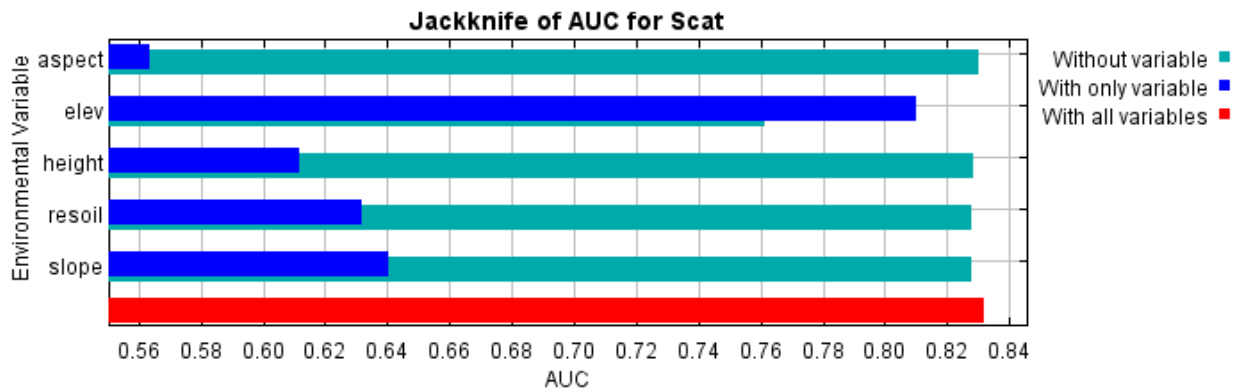


Figure 3-6. Jackknife test of variable importance on AUC score, each variable used in isolation, then omitted to complete model. Variables included aspect, elevation, vegetation height, soil type, and slope. Dark blue indicates model build with only that variable, green indicates without that variable, and red shows the global model.

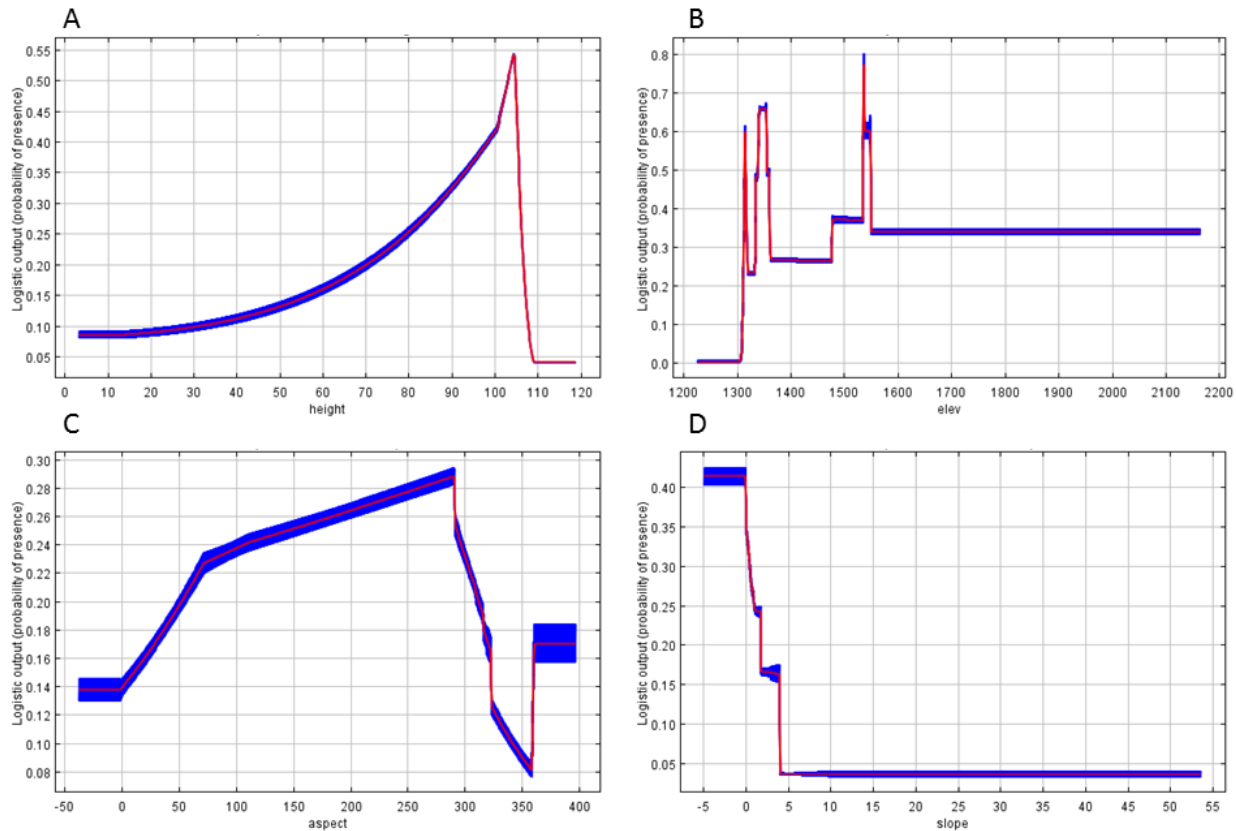


Figure 3-7. Change in detection probability for kit foxes in response to vegetation height (A), elevation (B), aspect (C), and slope (D) on the Great Basin Desert. (red = mean response, blue = +/-1 standard deviation, green = mean omission on test data).

## **CHAPTER 4**

### **CONCLUSIONS**

#### **DETECTION METHODS**

We compared four survey techniques for detecting kit fox presence. These techniques were selected because they have each been stated to be the best method for determining distribution and abundance of kit foxes. We evaluated scat deposition transects, scent station surveys, spotlight surveys, and trapping surveys within a minimum known population to determine which technique had the highest detection rates. We had a known kit fox population allowing us to test correlations of these four survey indices of relative abundance to minimum fox abundance along the survey transects. We found scat deposition and scent station surveys to have the highest detection rates and correlations to kit fox population abundance.

Both techniques provided similar detection rates and correlations to abundance so it is important to look at the positives and negatives of both techniques. Both methods are non-invasive and allow for detection when the surveyor is not present (unlike spotlight surveys). Scat deposition allowed for 2 weeks for detection while scent stations only allowed for 4 nights. Scent stations were fairly labor intensive, required the creation of level surface for the station and the transport of sand as a tracking substrate. Deposited scats were fairly resilient to most weather conditions, especially in dry desert habitats. While tracks at scent stations were the most highly susceptible to the weather; wind can blow away detections, rain washes them out, and freezing conditions make detection impossible. Although scent stations suffered more from weather and a shorter



period of detection, the technique included an attractant to draw animals in for detection (although there was evidence some animals being weary of scent stations). With proper training both methods can be used to detect multiple species. Scat deposition also allowed for the collection of genetic material for further insight into populations of interest.

Interestingly, the literature suggests that the most common technique for agencies monitoring kit fox is using spotlight surveys. In our study this technique was extremely poor at detecting fox presence, which was expected with a rare, elusive, and highly mobile species. It is possible that the low cost and ease of use of this survey method was responsible for its high prevalence as the technique of choice. Given the low detection rate of this method and its high use raises the question if our knowledge of kit fox populations may be underestimated (in particular at areas where they are rare and widely dispersed). We suggest widespread surveying using scat depositions surveys to reassess the population status of kit fox. Scat deposition surveys have much higher detection rates and higher correlation to kit fox abundance than other methods tested, while posing no risk to the animals and limited potential for the study species to modify its behavior to avoid detection. If population estimates, not just presence, is required it is possible to use this technique to obtain DNA from the scats for analysis.

Scat deposition surveys should occur during the breeding season (15 December – 14 April) when we found the highest detection probabilities. This was season was ideal because it allowed for detection of primarily resident animals. The resident animals

should be representative of a more “true” population consisting of animals that have made it through the difficult first months of life and have established territories.

## **DISTRIBUTION MODELING**

We compared three modeling approaches (maximum entropy (Maxent) and two general linear model (GLM) approaches: traditional fixed effects and mixed effects), to create predictive resource selection functions (RSF) models for kit fox occupancy. The best model for kit fox occupancy was using the Maxent approach. This open source software package was user friendly and produced easily interpretable output. We limited our inputs to datasets that were readily available online to help simplify the parameter development process of creating RSFs. It is possible that using finer resolution data, such as a LIDAR vegetation layer, to create more complex indexes of food availability, or calculating den densities; we may have been able to include parameters that are more highly related to kit fox detection. Unfortunately, these types of high resolution data do not exist in our study site and are maybe difficult to produce. But if additional environmental parameters are of interest, they can easily be added to the Maxent model and the output will show the percent contribution to help a user determine if they should include those parameters or not. This functionality may help the user develop models for kit fox in other regions or more complex models to help better determine what parameters are influencing kit fox occupancy.

Typically RSFs are created using animal use locations based off of telemetry or GPS collar data. This type of data can often be expensive to gather and can harm study species during capture. In this study we attempted to create RSFs based off non-invasive

survey data. The types of surveys conducted were limited to scat detections along roadways. At the DPG the large kit fox home range's crossed multiple transects suggesting foxes were available for detection on more than one transect. We also found due to the homogeneity of the landscape and the density of transects, we were able to sample a representative area of potential available habitat for kit foxes. The only habitat type under-represented in our surveying but available for kit fox use was the open dunes in the center of the study area. This area maybe of higher habitat value to kit foxes than our modeling suggested.

The fixed-effects model was also found to be fairly accurate at predicting kit fox detection but the process of developing these models was more difficult than the Maxent approach. Developing GLM's required the user to have a higher level of statistical understanding, outputs were not as readily interpretable, and model selection was more subjective. Subjectivity starts with the data creation. GLM's required one to develop "available" data, which was usually completed by selecting some number of random available points, but the number of random points to create was disputed in the literature. Once the user has determined how many random points to use and extracted all the environmental parameter's data, they have to pick the "best" model to use. Here the user has multiple options: use the top AICc model, model averaging using the top 2  $\Delta$ AICc, top 5  $\Delta$ AICc, top 10  $\Delta$ AICc, or all possible models, as some examples. Additional, the input of environmental data required multiple steps, typically using GIS software to extract the points. This tended to be a cumbersome process and involved a higher skill level in another software platform.

The Maxent approach involved simply loading a suite of background layers (environmental parameters) and the use locations. The software then generated the random “available” points, with the default setting (10,000 points) having been found to be as good as or better than other options. Then it built the RSF’s for the user and provided additional outputs detailing each parameters contribution to the model. The user can then determine whether or not to include those parameters. In addition, Maxent very easily allowed users to select to run replications with different random available points, complete a jackknife test of variable importance, perform cross-validation, and extract different test and training percentages.

This study demonstrated the large differences in detection rates between survey methods. Scat deposition and scent stations had much higher detections than both capture and spotlight surveys. Scat depositions have the additional benefits of relatively low costs, resilience to weather, low labor requirements, and posed no risk to the study animals. Also, the highest detection probabilities were during the breeding season, allowing for detection of the resident population. Three modeling approaches were employed to create predictive RSF models for kit fox occupancy in Great Basin habitats found within DPG and western Utah. Maxent modeling provided high prediction of kit fox occurrence, while being very user friendly. The method used to create the Maxent model was easily adaptable to other regions and environmental parameters of interest. Managers now have an increased knowledge of detection rates for kit fox in areas of low abundance and wide dispersal, with a simple method established to create predictive

maps of occurrence which should improve efforts to detect kit fox populations for future management planning and decision-making.