Final Progress Report

DATE: July 31, 2015

Project: Swift fox survey along Heartland Expressway Corridor

Title: Swift Fox Abundance along the Heartland Expressway Corridor in Nebraska

Starting Date: July 1, 2013

Completion Date: May 31, 2015

Principal Investigator: Marc Albrecht

Progress:

Task	% completed
1. Placing scent bait stations, cameras	100%
2. Trapping foxes for GPS collar fitting	100%
3. Radio tracking for GPS data download	100%
4. Data analysis and writing	100%
5. Final reports and Presentation	80%

Activity This Quarter:

SUMMARY

The swift fox (*Vulpes velox*) is a small canid classified as endangered within the state of Nebraska. Future construction of the Heartland Expressway Corridor (HEC), a 300 km road expansion project in the panhandle of the state, may impact the resident swift fox population.

A scent-bait survey of the HEC was carried out in the summer of 2014 and a smaller survey was completed in February 2015. Swift foxes were documented in Dawes County and northern Kimball County. The areas immediately surrounding these locations show significantly higher amounts of grassland and lower amounts of agriculture than expected. Swift fox predators were found in larger numbers along HEC sections that have already been expanded to 4-lane divided highway than expected.

Three swift fox were also live trapped and collared with Global Positioning System (GPS) tracking collars in the fall and winter of 2014. Location data from one swift fox collar was retrieved. The home range for this individual was 25.70 km^2 in size and made up of 97% grassland and 2% developed land. This male traveled an average of 3.03 km a night and 42.6% of the documented movement was from one side of the HEC to the other over the course of 113 nights.

The data from the camera surveys and GPS collar give a basis for tentative conclusions about swift fox in Nebraska. Swift fox were not common on the Heartland Corridor Expressway. They occurred at the north and south portions of the panhandle. Swift fox appear to have about the same home range as reported in studies from

surrounding states about 4 square miles, and the collared animal did spend more time along roads than anywhere else but around its presumed den. Swift fox did occur most often in low grasslands in this study, compared to other types of land cover.

Additional mammal species documented by camera survey included raccoon (*Procyon lotor)*, mule and white-tailed deer (*Odocoileus hemionus* and *Odocoileus virginianus*), striped skunk (*Mephitis mephitis)*, coyote (*Canis latrans*), feral cat (*Felis catus*) and American badger (*Taxidea taxus*), and less frequent species. Species presence appears to be influenced by vegetation composition and human population density.

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Chapter One: Swift Fox (*Vulpes velox)* History and Population Monitoring in the Great Plains

Introduction to the Swift Fox

The swift fox (*Vulpes velox)* is a small canid species found throughout the Great Plains region of North America. Physically, the swift fox is slightly larger than its close relative the kit fox (*Vulpes macrotis*) with adults weighing about 2-3 kg when fully grown and little difference in size between males and females (Kahn et al. 1997). The swift fox has a slightly wider head, and shorter tail and ears than the kit fox. The primary coloration of the coat is a light cream or tan and the most distinctive marking is the black tipped tail (Kahn et al. 1997).

Swift foxes are known to mainly inhabit short and mixed-grass prairies within its distributional range. Short to mixed-grass prairies are composed of such species as blue gama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), and rabbitbrush (*Chrysothamnus nauseosa*) (Stratman 2012). Short grass prairies support a wide variety of fauna, ranging in size from tiny invertebrates and rodent herbivores to grazing bison and carnivorous mountain lions (Helzer 2010). These prairies contain vegetation less than 60 cm in height and rolling hills which may be crucial to the swift fox's ability to maintain maximum visibility of prey and incoming predators, particularly coyotes (*Canis latrans*) (Cushman 1988). However, short-grass prairie has declined in the central United States to only 20-40% of its pre-European settlement area and Sovada (2009) suggests that swift fox habitat range has shrunk to less than 50% of its original size due to habitat loss and population decline (Wohl 2009).

Historically, swift foxes were found from northern Texas to southern Canada, including large areas of Colorado, Kansas, Wyoming, Nebraska, Montana and the Dakotas (Sovada et al. 2009). The arrival of the fur trade resulted in a severe toll on the species with more than 100,000 swift fox pelts sold during a 25 year period in the late 1800's (Sovada et al. 2009). Numbers continued to fall through the first half of the 20th century due to consumption of poisoned carcasses meant to target larger predators such as gray wolves (*Canis lupus*) and coyotes (Dunlap 2012; Sovada et al. 2009). They were extirpated from large portions of their range by the early part of the last century including the states of Kansas, Oklahoma, Montana, North Dakota, Nebraska and the entire country of Canada (Sovada et al. 2009).

This marked decline in habitat and loss of the species from much of its former range during the past 150 years led to a petition in1992 to the US Fish and Wildlife Service to list it as threatened (Kahn et al. 1997). The population size of the swift fox is not well understood due to the fact that not all states within its range have been surveyed (Dowd Stukel 2011). Historic population declines have been estimated in part from sighting and trapping data changing from "extremely abundant" to less abundant and "very rare" in many portions of their range (Allardyce and Sovada 2003). Since their population decline, efforts have been made towards species recovery and stability through the joint efforts of wildlife agencies throughout the states comprising their range. An understanding of the current population size and distribution of the swift fox is crucial to long-term conservation efforts.

Swift fox populations declined sharply with loss of short grass prairie in the nineteenth and the first half of the twentieth century suggesting that swift foxes may be classified as specialists when considering habitat use (Allardyce and Sovada 2003; Kamler et al. 2003a; Prugh et al. 2009). An occupancy study, conducted in Colorado by Stratman (2012), only detected swift foxes within short-grass prairie or adjacent to its edge. However studies done throughout the current range show that, while swift foxes tend to favor short- and mixed- grass prairie, they are able to adapt to various habitat types when necessary such as stubble and fallow crop fields (Kamler et al. 2003a).

Of greater impact on swift fox decline than habitat loss may be the rise of intermediate sized predators known as mesopredators, whose populations increase with the removal of apex predators such as wolves. Mesopredators includes species such as coyotes. Evidence suggests that wolves help to decrease and maintain lower coyote population levels but do not appear to predate on swift foxes (Sovada et al. 1998). With removal of apex predators, mesopredator populations have increased. Coyotes, for example, have expanded in range size by approximately 40% from historic levels, taking advantage of food sources present in fragmented habitats, such as human garbage and prey animals attracted to crops (Prugh et al. 2009). Coyotes are responsible for a large portion of swift fox deaths, with studies finding coyotes responsible for 45- 85% of swift fox yearly mortality (Anderson et al. 2003; Meyer 2009). Maintained coyote suppression has been shown to benefit local swift fox populations (Karki et al. 2007).

Swift foxes are highly den dependent and spend almost all daylight hours inside their burrows with most animals averaging only 6-9 hours out of the den per day (Hines

1980). The small amounts of daylight movement that occur increase in the summer and usually remain in close proximity to their dens (Meyer 2009). Swift foxes prefer den locations with a slight slope and soil type for dens is best when firm but slightly crumbling to allow for easy digging (Dowd Stukel 2011). Swift foxes will also take advantage of pre-existing dens from badgers (*Taxidea taxus*), prairie dogs (*Cynomys ludovicianus)* and ground squirrels (*Sciuridae spp.*) when available, but are fully capable of digging their own burrows (Tannerfeldt 2003). Swift foxes will make use of multiple dens within a given area and they show some specialization of use. Dens used in pup rearing will often have multiple entrances and exits, while dens whose primary use is predator escape will more often have only one entrance (Marks 2005).

Swift fox primarily live in monogamous pairs for pup-rearing, but observations have revealed instances of polygamous behavior, with multiple males or females present in the natal den (Tannerfeldt 2003). The species is monoestrous, with breeding occurring in late winter or early spring, varying slightly according to latitude (Kahn et al. 1997). Pups are born in the spring and early summer, and by early fall are ready to disperse (Kahn et al. 1997). Studies in the southern portion of their range show swift foxes exhibiting two peak times of dispersal, one in the fall and one in early winter, and the timing of these dispersals may coincide with times of higher familial aggression (Kamler et al. 2004). Average dispersal distances are just over 10 km (Ausband and Foresman 2007). Typical home range sizes are between 2 km^2 to 32 km^2 depending on such factors as seasonal changes, current habitat resources and the geographic location of the individual animal within the geographic range (Allardyce and Sovada 2003).

Home range sizes vary across the extent of the species range. Swift foxes in Nebraska have home ranges between 15.2- 32.3 km^2, while the states bordering Nebraska range from 7.6 km^2 in Colorado to 11.7 km^2 in Wyoming, (Hines 1980; Hines and Case 1991; Kamler et al. 2003a). There appears to be considerable variation in home range size across species range and amongst individuals (Meyer 2009). Mated pairs share similar home ranges and there is some overlap between the home ranges of neighboring pairs (Darden et al. 2008). This overlap can be as large as 50% of the home range size of an individual; however, the core activity areas of same-sex individuals in adjacent territories are exclusive of each other indicating that swift foxes do show some territoriality (Andersen et al. 2003; Darden et al. 2008).

While swift foxes consume mostly insects and small rodents they are opportunistic feeders with a wide dietary range also including some birds and plants. They also make use of carrion throughout the year and Kamler et al. (2007) found evidence that swift foxes show prey switching behavior (Allardyce and Sovada 2003). A study in Texas revealed that a larger portion of the diet of swift foxes living in un-fragmented prairie habitat was composed of insects than those living in fragmented areas where leporids, such as hares and rabbits, were more plentiful and made up a larger portion of their diet (Kamler et al. 2007).

Conservation History

The swift fox was petitioned to be listed as a threatened species in 1992 under the Endangered Species Act (Kahn et al. 1997). In 1994 the United States Fish and Wildlife Service deemed the species as warranting listing, but precluded by species of more immediate need (Kahn et al.1997). The Swift Fox Conservation Team (SFCT) was created in 1994 and its membership is comprised of United States state wildlife agency representatives, and members of United States and Canadian federal wildlife organizations (Stratman 2012).

The purpose of the SFCT's formation was to develop a conservation strategy to give direction to swift fox recovery efforts. Paramount to these efforts is finding reliable methods to monitor the population and to accurately describe swift fox habitat so that populations and land can be successfully managed. Wildlife organizations throughout the swift fox range periodically implement distribution and habitat surveys to maintain up to date information on the population status. The Association of Zoos and Aquariums (AZA) maintains a breeding program throughout accredited North American zoos to preserve a captive population with high genetic diversity (Stratman 2013). Additionally the SFCT continues to work with land owners, public and private, to maintain habitat for the species, to increase protections for the swift fox throughout its range and to work towards a healthy population that is genetically connected (Kahn et al. 1997).

Swift foxes currently hold a variety of conservation statuses throughout their range. Colorado, Kansas, New Mexico, Texas and Montana all list the species as a furbearer and allow limited take of the species during seasonal hunting. Although present in North Dakota historically, swift fox are currently rare and the state is working on documenting any presence of the species. The states of Wyoming and Oklahoma list the swift fox as a Species of Greatest Conservation Need while South Dakota lists them as a state threatened species. Nebraska is the only state which classifies the swift fox as a state endangered species where no hunting is allowed (Dowd Stukel 2011, Stratman 2012).

Population Monitoring

To determine current population size and range, the SFCT urged all states within the known habitat range to implement periodic surveys to ascertain and monitor the status of the swift fox population within their prospective borders (Kahn et al. 1997). This information would then be combined to give a view of the overall trend in population movement and range for the species. It is up to the individual states to monitor their own populations and the frequency with which surveys are conducted varies (Dowd Stukel 2011).

A variety of techniques for these surveys are used across the population range, each with varying success. Techniques include track stations and camera traps coupled with scent lures, spot lighting, scat surveys, mark-recapture of foxes and radio collaring of animals to determine land usage. Track stations typically consist of either a large metal plate covered with chalk or dust, or a cleared area covered with a fine layer of sand and oil. A scent lure or edible bait is placed at the center of the station to draw the animal across the media to procure prints (Sargeant et al. 2003; Shaughnessy 2003). Both station designs allow animal track impressions to be left visible after the animal walks across it from which the species can then be identified.

Camera traps employ the use of trail cameras to capture photographic evidence of animal presence when approaching a scent lure. A scent lure or bait is placed at a set distance from the camera. When the animal approaches the scent lure the camera is triggered (Figure 1.1) (Harrison et al. 2002). Trail cameras have many setting options and can be adjusted to be the most efficient for the species of interest.

Spotlighting consists of attempting to locate swift foxes by transect surveys within their home ranges using a high powered spot light, typically from the back of a vehicle. Recorded calls may be used to attract the animals closer and increase detection rates. Positive visual identification of individuals and direct counting of animals is possible with this technique; however the need for multiple researchers, limitation of line of sight, bad weather, and the need for open driving conditions decrease the effectiveness of this method (Schauster 2002). Overall, spotlighting to detect swift fox appears to be inefficient when compared to other techniques (Shaughnessy 2003).

Scat surveys tend to be done by means of transect surveys. Transects are originally cleared of all scat and then reevaluated after a set time. All scat present is documented and identified. The scat is often collected and the species and number of individuals determined by analyzing the mitochondrial and microsatellite DNA of the sample (Harrison et al. 2002). This method has the additional possibility of gaining dietary information through analysis of the scat content.

Mark-recapture and re-sighting are more invasive procedures because they require the researcher to physically capture and handle the animal. Target animals are caught using live traps and marked. This marking may be a radio collar, ear tag or some other visible means. Radio collars are often used after trapping, not only to identify the individual later in the study, but also to collect data on general area and habitat use between detection surveys (Schauster et al. 2002).

A study done in 2002 in Las Animas County, Colorado examined and compared these methods and their efficiency of detecting swift foxes (Schauster et al. 2002). All of the examined methods, with the exception of spotlight counts, were found to be relatively reliable in detecting swift foxes within a designated area. Detection probabilities increased significantly when multiple techniques were used to complement each other. The most successful combination was found to be mark-recapture estimates along with scent-stations when looking at swift fox density. Schauster et al. (2002) also recommended this combination of techniques in terms of cost effectiveness.

Survey techniques used to study swift fox populations vary across states. Colorado has utilized mark recapture methods and camera trap stations (Finley et al. 2005; Martin et al. 2007). Wyoming has conducted work with camera trap and track stations where as South Dakota has employed track stations and radio collars (Stratman 2013; Grenier 2011; Luce et al. 2009). New Mexico has performed scat collection, track stations and live trapping and performed a comparative analysis of the different methods (Harrison et al. 2002). Track surveys have been carried out in Kansas, North Dakota and Oklahoma (Stratman 2013; Sargeant et al. 2005). Texas has previously made use of scat transects and live trapping and Montana has utilized live trapping and camera stations (Schwalm et al. 2012; Stratman 2013). The state of Nebraska has used a combination of camera trap surveys, track stations and public observations as a means to determine current swift fox populations (Corral et al. 2013; Stratman 2013)

Study Area

The Heartland Expressway Corridor (HEC), along with the Ports-to-Plains Trade Corridor and the Theodore Roosevelt Expressway, make up the larger Great Plains International Trade corridor which is a proposed transportation improvement project to create a four-lane divided highway system stretching from Mexico to Canada (HEA n.d.). The highway expansion is designed to relieve east-west traffic congestion, enhance mobility of military forces, increase the trade of goods and increase tourism (HEA n.d). The road construction is funded primarily by the states through which the route runs, with some additional funding from federal sources (NDOR 2014).

The study area for this research is the portion of the HEC found within the state of Nebraska (Figures 1.2 and 1.3). This section runs approximately 300 km north to south, along the entire length of the panhandle. It follows US 385 south from the South Dakota border, through Chadron, past Alliance, then west along L62A and U.S. Highway 26 through Scottsbluff to the Wyoming border and south via Nebraska Highway 71 through Kimball to the Colorado border. The route runs through six Nebraska counties: Dawes, Box Butte, Morrill, Scotts Bluff, Banner and Kimball. As of 2014, approximately one third of the HEC in Nebraska has been expanded to 4-lane divided highway, with feasibility studies projecting that the remaining construction will cost just over $500 million dollars over the next twenty years (HECDMP 2012; NDOR 2014).

The panhandle of Nebraska consists of Box Butte, Dawes, Sioux, Morrill, Kimball, Banner, Cheyenne, Sheridan, Garden, Deuel and Scotts Bluff counties. The habitat is dry, with precipitation averaging less than 51 cm of rain per year. Temperatures vary widely with averages in the winter and in the summer of -10° C and 30°C respectively (Climate-Nebraska 2014). Temperatures can reach extremes with lows below -29° C and highs over 38° C and thunderstorms, tornadoes, and blizzards occur seasonally (Nebraska-climate 2010). The primary vegetation coverage in this area is short- and mixed- grass prairie as well as agricultural cropland (Henebry et al. 2005). A small percentage of the study site also falls within the Pine Ridge region of the state, an area of rock outcrops covered with ponderosa pine forests in the northwestern corner of Nebraska (Schneider et al. 2011). These forests are represented by dark green in the Nebraska Gap Analysis Program (GAP) (Figure 1.4) (Henebry et al. 2005). The Pine Ridge region harbors several threatened species in Nebraska including Rocky Mountain Bighorn Sheep (*Ovis canadensis canadensis*) and Pierre Northern Pocket Gopher (*Thomomys talpoides pierreicolus*) (Schneider et al. 2011).

The Nebraska panhandle saw increases of grassland conversion to agriculture from the early 1970's to the mid 1980's and then a decrease of conversion through the year 2000 (Drummond et al. 2012). Low gas prices and the presence of the Ogallala aquifer spurred the installation of central pivots for irrigation in the area, however changing economic conditions, natural events like droughts and land conversion projects such as the Conservation Reserve Program (CRP) have since caused fluctuations in the rate of habitat conversion and resulted in lower overall levels of change (Drummond et al. 2012). The CRP has returned millions of acres of land in the United States to grassland; however the majority of replanting has consisted of tall grass prairie species which can form dense assemblages of vegetation not easily used by swift foxes (Dowd Stukel 2011).

Historically swift foxes likely occurred throughout the western two-thirds of Nebraska where short-grass prairie occurred (Sovada et al. 2009). The species is thought to have been nearly or completely absent from Nebraska during the first half of the 20th century (Stratman 2013). Surveys since 2001 have documented swift fox presence in the majority of counties in the panhandle including Kimball, Banner, Morrill, Scottsbluff, Dawes, Box Butte and Sioux (Figure 1.5) (Sovada et al. 2009, Stratman 2013).

Due to the swift fox's ranking as a state-endangered species, the Nebraska Department of Roads (NDOR) must survey areas of future road projects to evaluate potential effects from increased road density and construction on swift fox populations. Swift foxes are also classified as a Tier I Legacy species in the Nebraska Natural Legacy Project (NNLP) along with such species as Burrowing Owls (*Athene cunicularia*) and Blanding's Turtle (*Emydoidea blandingii*) (Schneider et al. 2011). One of the primary goals of the NNLP is to enhance conservation efforts to prevent species from warranting federally endangered or threatened status. In addition it strives to assist currently listed species to no longer be in need of listing (Schneider et al. 2011).

Swift Foxes and Roads

There is evidence that swift foxes may be drawn to roads. In the Nebraska panhandle, Hines (1980) observed that two thirds of dens were within 200 m of a roadway and two thirds of all telemetry locations were less than 1 km from a road. Swift fox dens tend to be closer in proximity to roads than to random points and there do not appear to be any studies that find swift foxes to avoid roads (Harrison and Whitaker-Hoagland 2003). Roads may be movement corridors, allowing swift foxes to cover more distance in less time. They may choose roadways to avoid contact with their predator species, particularly coyotes, which tend to avoid roads (Kamler et al. 2003b). There is also evidence that road right of ways may harbor higher density and diversity of rodents, one of their primary prey items, than surrounding areas (DOT 1981). Swift foxes have also been known to scavenge carrion, which highways routinely supply (Hines and Case 1991). While this available resource is beneficial to the swift fox, the time spent in close proximity to the road increases the chance of the animal being killed by vehicle collision.

There are four primary ways in which roads can negatively affect wildlife populations: loss of habitat, increased death through vehicle mortality, loss of access to resources, and isolation of subpopulations (Jaeger et al. 2005). Those interested in preserving the species are concerned with these potential effects.

While swift foxes are primarily associated with short grass prairie, they have also been documented making use of such habitats as dry-land agricultural fields and road embankments. Research performed in north western Texas indicates irrigated cropland and CRP land are almost entirely avoided by swift foxes and those foxes found in dry-land agriculture appeared less fit than their short-grass prairie counterparts (Kamler et al. 2003a). Increases in road density fragment areas into smaller pockets of usable habitat.

Vehicle strikes remain a substantial source of mortality for swift foxes throughout their range (Allardyce and Sovada 2003). It is estimated that by 2035 traffic in Nebraska will increase by approximately 20% and traffic in the four-state surrounding area by up to

90% (NDOR 2014). Wider highways are correlated with increases in automobile speed and with these increases come a decrease in available time to avoid vehicle-animal collisions (WDOT 2004; DOT 2007). Researchers documenting road kill during one swift fox study found that pups were particularly vulnerable to vehicle mortality as they become more independent of their parents (Cypher et al. 2009). There is evidence that swift fox mortality may rise with increases in road density (CDOT 2010).

Swift foxes may not suffer resource loss as road construction and road width increase since one of their primary prey resources, small rodents, have been observed in greater density in interstate right of way habitat than in surrounding areas (DOT 1981). Completion of the HEC will create a system similar to a rural interstate through swift fox habitat and may therefore increase prey densities along the road edge.

Road width and traffic volume have been shown to have an effect on crossing frequency in some species like brown bears (*Ursus arctos*) (Graham et al. 2010; Graves et al. 2006). However studies carried out in Colorado and South Dakota showed that four-lane divided highways are not barriers to swift fox movement and that they will occasionally use underpasses and culverts to pass from one side of the roadway to the other (CDOT 2010).

Increases in human infrastructure affect a variety of species. A meta-analysis of mammal and bird populations documented an average decrease in density of a population in areas closer to infrastructure (Benitez-Lopez et al. 2010). They also determined that these animals tended to avoid infrastructure at higher rates when surrounding habitat was open, providing a longer line of sight, such as is found on open prairie (Benitez-Lopez et al. 2010). Swift fox populations may not see immediate negative effects from increased road construction, road density and habitat fragmentation, but long term effects may still pose a significant threat. Therefore frequent population monitoring is recommended (Findlay and Bourdages 2000).

Swift fox mitigation techniques used in other locations include installation of culverts that span the width of the roadway, median barriers that are not solid allowing passage of animals that do attempt to cross the road, and fencing along the length of the roadway to funnel animals to safe crossing points such as culverts (CDOT 2010).

Objectives

The objectives of the project are to 1) document current locations of swift fox presence along the current and proposed Heartland Expressway Corridor, identifying associations between swift foxes, landscape characteristics and other species presence, 2) to track swift fox movement on a fine spatial and temporal scale and to look for habitat use and associations with roads and other landscape features, and 3) to examine mammal composition as a whole around the Heartland Expressway Corridor and identify associations with habitat type and other characteristics.

FIGURES

Figure 1.1: Image of a swift fox documented in Kimball County, Nebraska by trail camera on 11 June 2014.

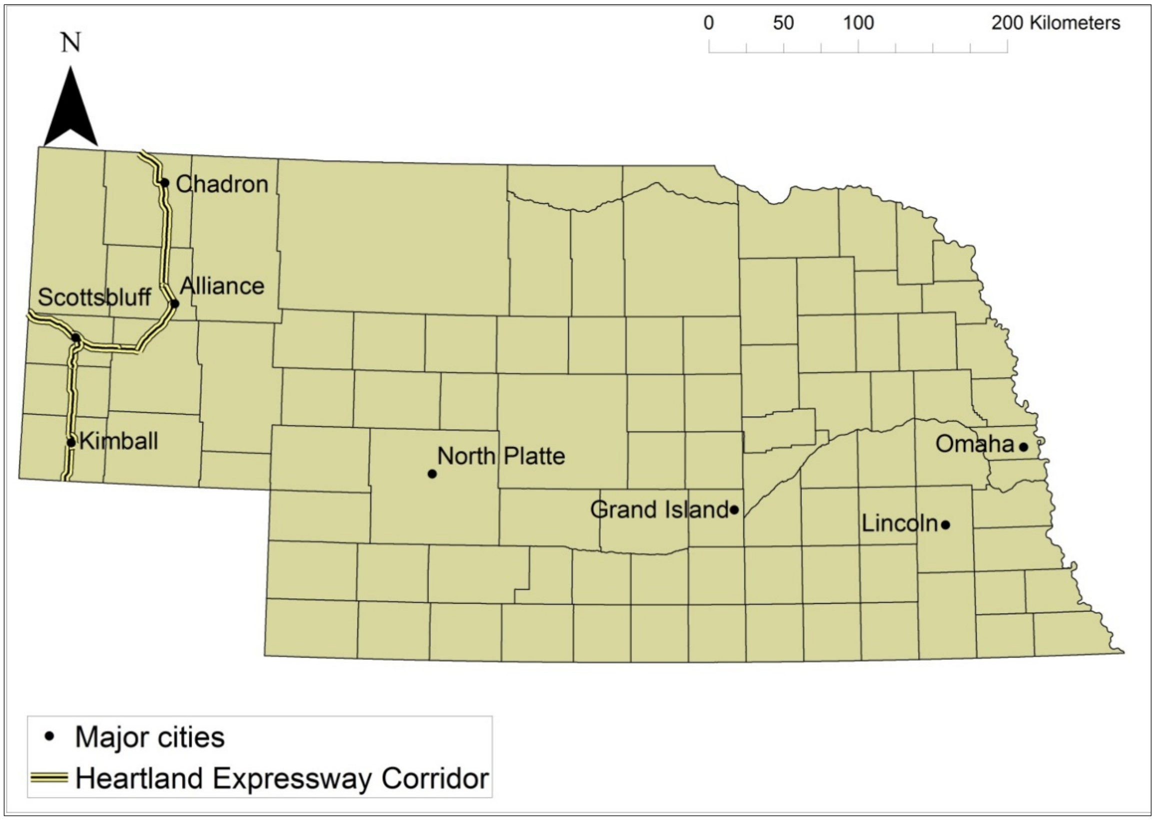

Figure 1.2: The Heartland Expressway Corridor located within the state of Nebraska (ESRI 2014).

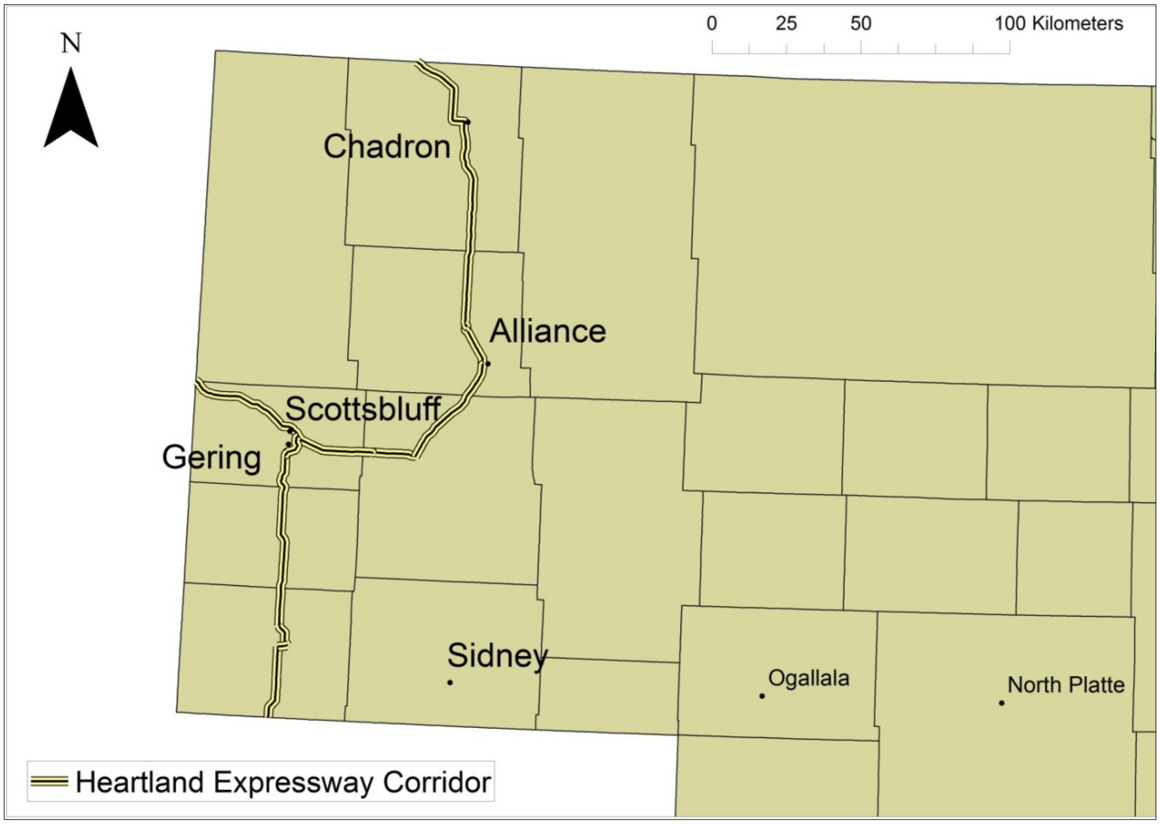

Figure 1.3: Nebraska Panhandle with Heartland Expressway Corridor indicated (ESRI 2014).

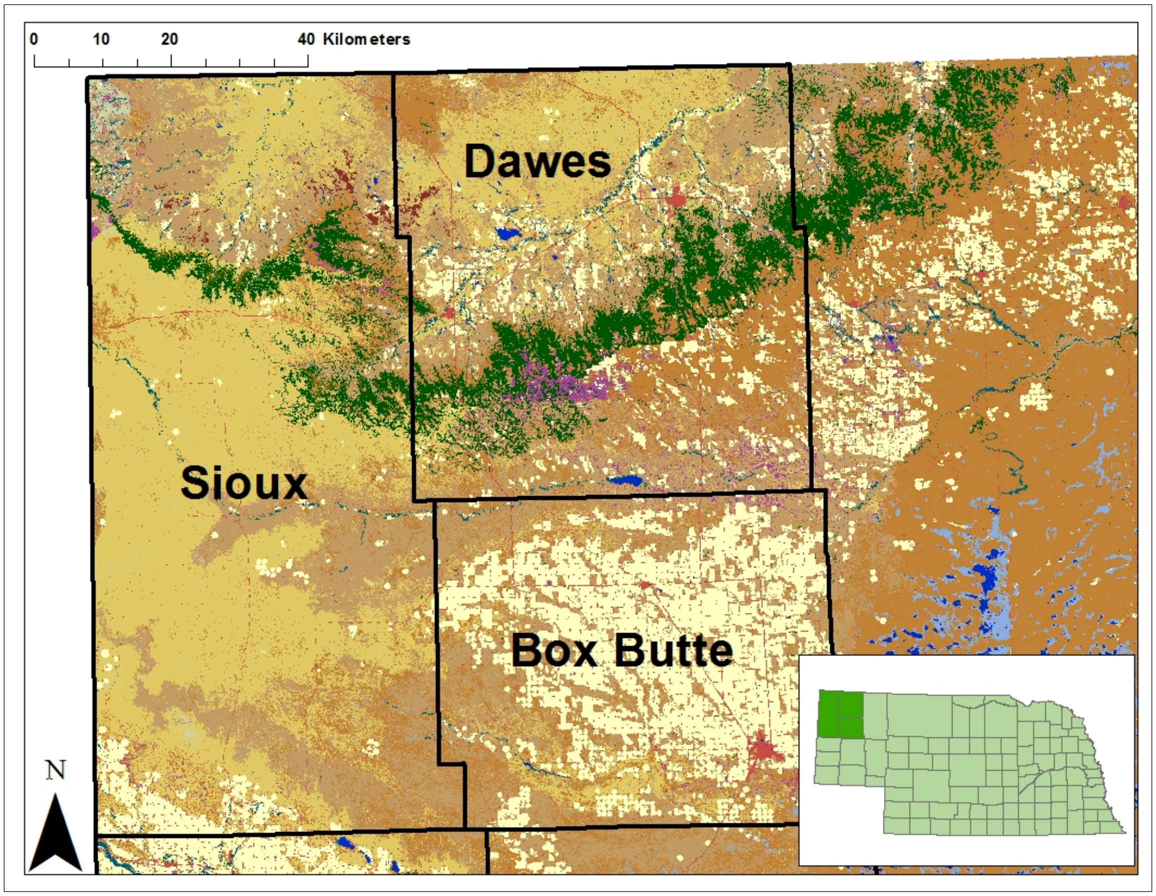

Figure 1.4: The Pine Ridge Forest in northwestern Nebraska as represented in dark green by the Nebraska GAP vegetation layer (ESRI 2014; UNL SNR 2005).

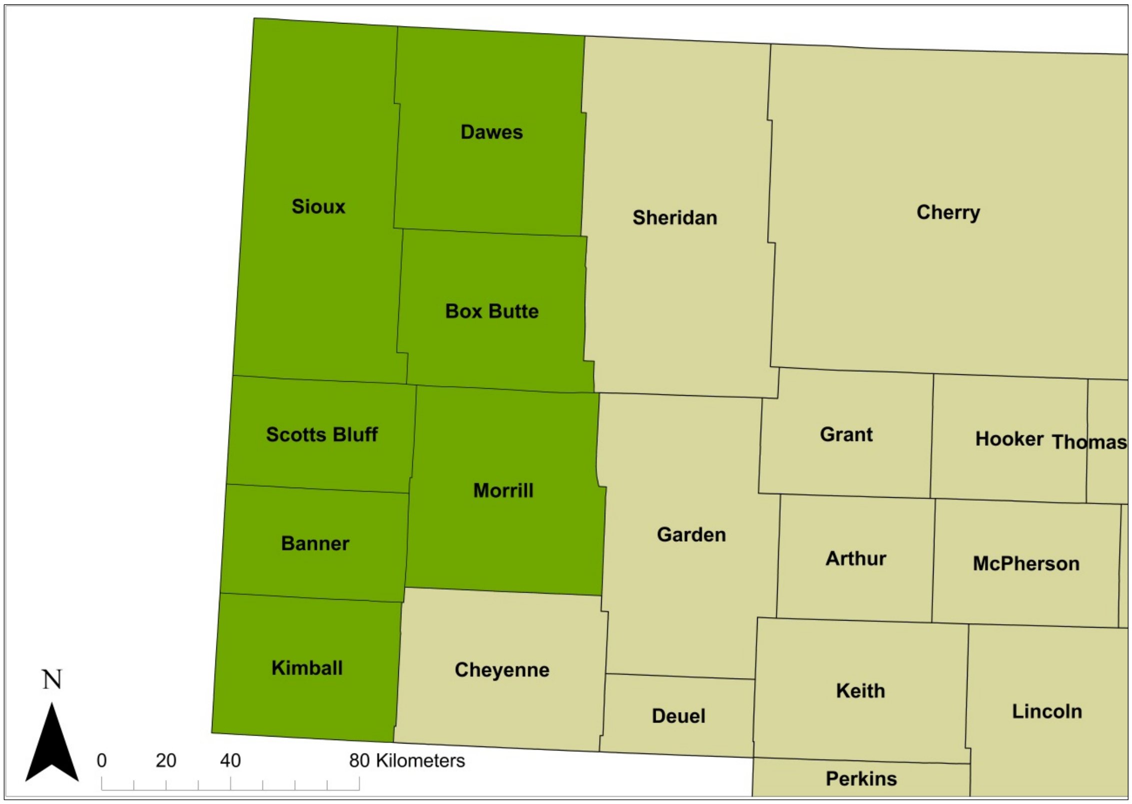

Figure 1.5: Shaded counties indicate swift fox presence documented since 2001 in the Nebraska panhandle.

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Chapter Two: Distribution of Swift Fox (*Vulpes velox*) Along the Heartland Expressway Corridor in Western Nebraska

Abstract

The swift fox (*Vulpes velox*) is a small canid currently listed as endangered in the state of Nebraska. Current and future construction of the Heartland Expressway Corridor (HEC) through the Nebraska panhandle may be a cause for concern for resident swift fox populations. Current swift fox presence along the roadway will be documented before construction continues.

We surveyed for swift foxes with trail cameras in the summer of 2014 every 1.6 km along the length of the HEC, and identified associations of foxes with vegetation, land use and road -way type.

We had four positive and three highly probable swift fox sightings in Dawes and Kimball counties with most documented observations along 2-lane roadway. Swift foxes were significantly associated with grassland vegetation compared to agricultural vegetation. Predator and major competitor presence was significantly greater along 4-lane sections of highway, potentially excluding swift foxes.

Swift foxes appear present in low densities around the HEC. The area of primary concern as construction progresses is Dawes County, as construction has already been completed at the location in Kimball County where foxes were documented.

Keywords

Vulpes velox, swift fox, Nebraska, Heartland Expressway Corridor, camera survey, roads, predators

Introduction

Historically common from Canada to Texas, the swift fox (*Vulpes velox*) experienced a severe population and habitat decline with the arrival of European settlers. Causes of decline included the transformation of prairie to cropland, predation from mesopredator increase, the fur trade and unintentional poisoning targeting larger predators (Sovada et al. 2009). The species has shown some recovery and the formation of the Swift Fox Conservation Team (SFCT) in the early 1990's brought attention to its plight (Dowd Stukel 2011).

Swift foxes show a strong affinity for short to mixed-grass prairie habitat (Allardyce and Sovada 2003). Vegetation height of less than 60 cm may be important in allowing the swift foxes to view both their predators and their prey (Cushman 1988). However, with the loss of more than half of the historical short grass prairie habitat in the United States, populations of swift foxes have made use of less desirable habitats such as highway embankments and dry agricultural fields (Kamler et al. 2003a). Evidence suggests that though some foxes use these environments they are not as fit as those present in short-grass prairie (Kamler et al. 2003a).

Currently the swift fox occurs throughout 40-50% of its historical range and uses only about 50% of quality short grass prairie habitat now available (Kamler et al. 2003a; Sovada et al. 2009). The swift fox holds a variety of conservation statuses across its range and the state of Nebraska currently lists the swift fox as endangered and as a Tier I Legacy species (Schneider et al. 2011). Although there is evidence that the swift fox may have historically been present in the western two-thirds of the state, current presence has been established only in counties of the panhandle (Sovada et al. 2009; Stratman 2013).

The Nebraska Department of Roads (NDOR) currently is involved in the construction and expansion of the Heartland Expressway Corridor. This roadway is part of a larger international construction project that will connect Canada, the United States and Mexico with a continuous north-south running 4-lane divided highway. The portion of this Great Plains International Trade Corridor that runs through Nebraska is located in the panhandle and the six counties through which the roadway will run are all considered to be within potential swift fox habitat (NNHP 2011).

Vehicle impact is a significant source of mortality for swift foxes, particularly for juveniles (Allardyce and Sovada 2003). Infrastructure has been shown to negatively affect mammal density and abundance, particularly in open areas without visual obstruction, such as short-grass prairie (Benítez-López et al. 2010). Increased road density, road width, vehicle speed and vehicle frequency could potentially have negative effects on swift fox populations in the area.

Fragmentation of habitat by roads and the removal of apex predator such as gray wolves (*Canis lupus*) have provided favorable circumstances for the increase of mesopredators like coyotes (*Canis latrans*) (Prugh et al. 2009). Coyote predation is consistently the largest source of mortality for radio-collared swift foxes throughout their range (Herrero 2003). Nearly 85% of swift fox mortality documented in a study from southern Colorado resulted from coyote predation (Sovada et al. 1998). Although coyotes do kill swift foxes, they often do not consume the carcasses, suggesting that they may be driven more by resource competition than by predation (Kamler et al. 2003b).

Evidence suggests that swift foxes make use of roads and roadsides. They are used as transportation corridors, for foraging, and dens are often found in close proximity to roadways (Allardyce and Sovada 2003). A study in Wyoming observed that swift fox telemetry locations were much closer to roads on average than randomly generated points (Harrison and Whitaker-Hoagland 2003). A study in the Nebraska panhandle by Hines and Case (1991) documented 68% of dens to be within 230 m of a roadway. Roads may also be important sources of food providing road kill carrion and harboring higher rodent density and diversity in adjacent ditches and fencerows than do surrounding areas (Hines and Case 1991; Kaufman and Kaufman 1989; Kirsch 1997). Roads can have negative effects on fox populations however, as Cypher (2009) noted that kit foxes (*Vulpes macrotis mutica*) in urban areas of California suffered vehicle strikes more often on roadways with more lanes, higher vehicle volume and higher vehicle speed.

We conducted a survey for swift foxes along the length of the Heartland Expressway Corridor in Nebraska. We examined patterns between swift fox presence, vegetation type, landscape characteristics and predator/competitor presence.

Materials and Methods

Study Area

A camera survey of the Nebraska portion of the Heartland Expressway Corridor was carried out from 14 May to 3 July 2014. This route runs along the length of the panhandle for approximately 300 kilometers north to south. The route passes through six Nebraska counties: Dawes, Box Butte, Morrill, Scotts Bluff, Banner and Kimball. It follows US Hwy 385 south from the South Dakota border, through Chadron, past Alliance, then west along L62A and US Hwy 26 through Scottsbluff to the Wyoming border and south via Nebraska Highway 71 through Kimball to the Colorado border (Figure 2.1). Approximately a third of the route has already been expanded from two-lane highway to four-lane divided highway. The 4-lane portion runs approximately from Kimball to Scottsbluff, east from Scottsbluff to Minatare and west from Scottsbluff to Mitchell (Heartland Expressway 2012).

The Heartland Expressway study site lies within the Great Plains geographic region. This area tends to be dry and precipitation averages less than 50 cm of rain yearly. Average temperatures in winter and summer are -10° C and 32°C respectively with low humidity (Schneider et al 2011). Severe weather can be common due to temperature fluctuations, bringing blizzards, thunderstorms and tornadoes (Hickey et al. 2007). The primary vegetation cover is short and mixed grass prairie made of species such as blue gama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), and rabbitbrush (*Chrysothamnus nauseosa*) (Stratman 2012). A substantial proportion of this land has been converted from grassland to agriculture (Henebry et al. 2005).

The camera survey began at the northern end of the route, at the border between Nebraska and South Dakota. It proceeded south through Dawes County and into Box Butte County. From there it moved south to the border between Nebraska and Colorado and proceeded north to the city of Scottsbluff. The survey was completed between

Scottsbluff and Wyoming and then continued east along US Hwy 26 and L62A, then north on US Hwy 385 to complete the survey. This route was followed in an attempt to first survey those areas where previous studies and anecdotal evidence indicated the highest probability of swift fox detection, i.e. Dawes and Kimball counties.

Land parcels along the study route are largely privately owned, with a small percentage owned by federal, state or local organizations. The area is primarily rural farm and pasture land. Urban areas, with high densities of human population and infrastructure, are restricted to the towns of Kimball, Alliance, Chadron, Mitchell, Morrill, Minatare and the larger cities of Gering and Scottsbluff.

Survey Design

To determine station placements, permission for access to private land was sought. Shapefiles containing parcel data and contact information were provided by GIS Workshop of Lincoln, NE as well as directly from the county of Scotts Bluff. These layers were combined using ArcGIS 10.2.2 GIS software (ESRI 2014) and all parcels within 1.2 km (0.75 mi) on either side of the HEC were selected and ranked according to desirability for camera placement. Aerial photography and the program Google Earth were used to examine vegetation cover and infrastructure proximity (Digital Imagery 1993-2012 1&2-meter 2015; Google 2013). Rankings from 1 to 5 were assigned, with 1 indicating highest desirability, 2 indicating very good habitat but with potential placement conflict and 3 indicating that the parcel would be usable if no other land was available but that there may more desirable habitat in the area. A desirability of 4 indicated that the parcel could potentially be used if no other options were available but that it was not desirable habitat and 5 indicated that the parcel was unusable even if permission was obtained, such as land within a dense urban area. The addresses for all parcels ranked 1-4 were extracted and compiled for a preliminary mailing providing basic information about the project and requesting permission for parcel access from the land owners.

Community meetings at the public libraries of Kimball, Scottsbluff, Alliance and Chadron, NE were conducted during the winter and spring of 2014. A second brochure was mailed in May 2014 to land owners who had not yet responded. An attribute column was added to the shapefile of parcel data indicating whether land owner permission had been given. From these data, a new layer was created containing only parcels for which permission had been given. This layer was used to plan camera placement.

Theoretical camera placement was plotted using MapWindow 4.8.8 (MapWindow 2013). Following standardized guidelines, we created a point shapefile, marking desired camera locations every 1.6 km (1 mile) and on either side of the HEC. Placement was based on land permission in the area, proximity to infrastructure and potentially good swift fox habitat. Upwind locations were considered to be those locations on the western side of the HEC when running north and south and locations on the southern side of the HEC when running east and west. Upwind stations were placed from 0.4 km to 0.8 km (0.25-0.5 mi) from the road. Downwind stations were those on the eastern side of the HEC when running north and south and on the northern side of the HEC when running east and west. Downwind stations were placed within 0.8 km (0.5 mi) of the road. This design was based on typical wind directions for the summer months in the panhandle and was used to avoid attracting foxes across the road where they could be hit by vehicles. In locations where there was no access to place an upwind station, only one downwind station was placed for that 1.6 km division. In rare instances of high urban density, such as where the HEC passes through Scottsbluff, no station would be placed for that 1.6 km division.

The chosen survey method was a trail camera station paired with scented bait. Additional survey methods for swift foxes include mark/recapture, track stations, scat surveys and spot light surveys. A comparative study examining these methods found scent stations and mark/recapture to be the most efficient methods (Schauster et al. 2002). A recent study conducted in western Nebraska showed that camera traps were more efficient at documenting swift fox presence than were track stations due to their ability to document an animal's presence even when they did not approach the scent stake closely enough to leave tracks at the station (Corral et al. 2013). Camera traps were also chosen for their ability to run for multiple nights without needing to be checked and reset daily, the low manpower needed for set up and retrieval and for their ability to work in poor weather conditions.

Bushnell Trophy Cam HD Model 119537C trail cameras (Figure 2.2) and Moultrie D55IR GameSpy digital cameras were placed every mile, on both sides of the highway. For each camera station, the set and retrieval dates were recorded, as well as the station's identification number indicating the mile of the study site and its upwind or downwind orientation. The number of the individual camera, the county where the station was located and the degree angle from the camera to the scent stake were recorded.

Universal Transverse Mercator geographic coordinates were determined using a hand held GPS device (Magellan Explorist 600). Road type (2-lane or 4-lane), general habitat type and land type (public, private, right of way or county road) were also recorded.

Station categories are as follows. Right of way (ROW) indicates stations that were placed within the area between the paved road and the NDOR right of way markers along the HEC. County roads indicate roads maintained by the county government, primarily dirt roads running perpendicular to the HEC. Public land stations are state funded areas, including the Wildcat Hills State recreation area and Chadron State Park. Private land is any station for which permission was received from private land owners to place stations on their property for this survey.

Previous swift fox studies have used various scent lures to draw target animals to the stations including beef scraps, road kill and turkey chicks (Finley et al. 2005; Harrison et al. 2002; Kamler et al. 2002) The most common baits have been raw chicken and jack mackerel fish (Sargeant et al. 2003; Schauster et al. 2002). After examination of several studies we used a lure made of skunk essence suspended in petroleum jelly used with success in both Wyoming and Colorado (Stratman 2012; Stratman 2013). A Wyoming study in 2010 utilized the skunk essence mixture and, examining their data, determined that their method was efficient in detecting swift foxes as well as in identifying suitable habitat characteristics for the species (Stratman 2013). An additional study by Stratman (2012) also made use of the skunk based lure. It boasted a significantly higher detection rate and occupancy calculation when compared to results from previous similar swift fox occupancy studies in Colorado. Stratman (2012) attributes this partly to his use of the skunk essence lure. The pungency of the lure has the potential to diffuse farther than other baits, increasing the radius of detection around each scent station (Stratman 2012).

Field Work

Actual placement of camera stations in the field took into account land access, topography and area features. Stations were set along high ridges where possible as scent tends to travel downhill as the temperature drops overnight (G. Schroeder, personal communication 21 May 2014). Worn pathways including fence lines, trails, approaches, power pole lines and flattened areas around water troughs in fields were used where available. Best placements were considered to be locations where more than one of these characteristics converged (G. Schroeder personal communication May 21, 2014). Ditches containing high, unmown grass were avoided whenever possible and open areas of shorter grass were favored.

Trail cameras were often mounted on existing infrastructure, such as fence posts and telephone poles (Figure 2.3). Where no infrastructure was present, a t-bar was sunk into the ground and the camera was mounted using coated wire. Camera stations located in the ROW were mounted inside a camera cover manufactured before the survey began (Figure 2.4). They were constructed from 12.7 cm x12.7 cm (5”x5”) vinyl fence posts that had been cut in half and had bolts drilled through from side to side to provide a mounting surface for the camera. A hole was cut out of the side to accommodate the lens and LED lights and vinyl decals were added to the side of the cover to roughly resemble “buried cable” indicator posts already found in the ROW of the HEC (M. Peek, personal communication 21 April 2014).

When locations had been chosen the camera stake was set to face away from traffic whenever possible to avoid excessive triggering of the camera. Camera were set with the lens between 45 and 60 cm (18-24 inches) from the ground. The scent stake was set 2.5 meters from the camera and aligned with the lens. The stakes were marked with lines at 15.2 cm, 30.5 cm and 45.7 cm (6, 12, 18 inches) from the top of the stake. It was sunk, as consistently as possible, so that the lowest line was even with the ground, providing a size reference for the animals in the photographs.

The scent lure was created by melting unscented petroleum jelly and adding skunk essence at a ratio of 15 ml of skunk essence to 385 ml of jelly (Figure 2.5). The lure was mixed thoroughly and allowed to cool. Scent stakes were baited with 15-30 ml of skunk essence petroleum jelly. This was spread evenly over the middle portion of the stake between the middle two height markers. Three to four sprays of fish oil mixture from canned chub mackerel were applied around the base of the stake.

Stations were set and run for 120 hours (5 consecutive nights). Cameras were originally set to take individual photos when triggered. However due to trigger delays and the difficulty of identifying animals in the photographs, cameras were reset to record 3-photo bursts when triggered and the night vision shutter speed was adjusted to the highest setting to sharpen photos. Additionally, tall grasses within the frame of the camera were cut back or flattened to decrease extraneous triggers.

Approximately two weeks into the camera survey it became obvious that the 10 Moultrie GameSpy cameras being used were not sufficiently sensitive to record animal movement after dark. These cameras were removed from the camera rotation and all stations that had previously been completed with Moultrie cameras were rerun using Bushnell Trophy cams. All stations were therefore run with Bushnell Trophy cam trail cameras. Additional stations were rerun based on issues with battery or camera malfunction, large numbers of false positives from brush that was blown in front of the camera lens, large numbers of overexposed photos or excessively rainy weather conditions. A total of 28 stations were repeated in an attempt to correct for these issues.

All camera station photos were downloaded immediately after retrieval onto an external hard drive. All animal presence was documented separately on physical data sheets as well as into a digital spreadsheet. Station identification and station location information were added to the spreadsheet data. This file was then converted into a shapefile using the GIS mapping program MapWindow 4.8.8 (MapWindow 2013) and plotted in the mapping software.

The vegetation makeup at swift fox stations was compared with the makeup of vegetation in buffers of various sizes around the HEC. Each swift fox location was buffered by 1.56 km. This resulted in an area equal to half of the average home range size of swift foxes in Nebraska, estimated to be 15.2 km^2 (Hines 1980). The HEC was buffered on either side by 1.56 km as well as twice this distance (3.12 km). Additionally, 50 random points were generated within the HEC buffer and buffered with the same area as the swift fox locations. These areas were used to compare vegetation composition.

The vegetation classifications used came from the Nebraska Gap Analysis Project (GAP) (UNL SNR 2005). This project uses various types of imagery to produce a map representing vegetation types and their presence in the state by colored pixels, each representing an area of 30m by 30m. This research is in conjunction with the United States Geological Survey's (USGS) National Land Cover Dataset (NLCD) and its purpose is to reveal gaps in knowledge and stewardship for resident species (Henebry et al. 2005). Using the program ArcGIS 10.2.2 (ESRI 2014), the Nebraska GAP raster layer (UNL SNR 2005) was clipped to each of these buffers separately (Figure 2.6). Vegetation was divided into six categories using Nebraska GAP NVC classification divisions (UNL SNR 2005): Forest/ Woodland, Shrub/ Grassland, Agricultural Vegetation, Recently Disturbed/Developed, Open Water, and Miscellaneous. Miscellaneous included semi-desert, introduced, and semi-natural vegetation categories.

Pixel counts for each vegetation category represented in the clipped layers were used to calculate expected values. The percentage of each HEC buffer that was composed of a specific vegetation category was multiplied by the total number of pixels in the buffer layer surrounding the swift fox stations, giving the expected pixel count for that vegetation category within the swift fox buffer if that area possessed the same vegetation composition as that which surrounds the HEC. This was carried out for each comparison: the 1.56 km buffer, the 3.12 km buffer and the 50 random points along the HEC that were each buffered to 1.56 km.

Chi-squared goodness-of-fit tests examined predator/competitor distribution and coyote presence specifically compared to road type. Expected values were generated by multiplying the percentage of camera stations adjacent to 2-lane versus 4-lane road by the total number of stations documenting each species or group of species. This gave an expected value of how many animals should be detected along each type of roadway if distribution is random. Vegetation composition around stations documenting coyote presence was compared to available vegetation composition. Similar methods for generating expected values for vegetation pixel counts for swift foxes were used for coyotes. The coyote home range estimate was averaged from two studies conducted in northern Texas and southeastern Colorado (Gese et al. 1990; Kamler et al. 2005).

Additionally an abbreviated camera survey was conducted in February 2015 focusing on locations that yielded swift fox presence in the survey of 2014. Eighteen stations were run for 10 nights for a total of 180 trap nights, following station protocols similar to the survey in the summer of 2014.

Results

Camera Survey

The camera survey was completed between 14 May 2014 and 3 July 2014. The route was approximately 307 km (191 mi) in length, consisted of 278 camera stations and ran for a total of 1390 camera nights (Figure 2.7). Approximately 545 mailers were sent out to private land owners with a response rate close to 28%, with 150 responses, both positive and negative. This yielded 69 stations on private land. Of the remaining stations, 95 were placed on county roads, 2 were in public parks and 112 were on NDOR right of ways. One hundred and eighty stations were adjacent to 2-lane sections of highway and

98 stations were adjacent to the already completed 4-lane sections of the highway. The major types of land seen adjacent to the stations were agricultural land, grazing pasture, and rangeland. Agricultural land was present at 157 stations and some combination of pasture or rangeland was present at 230 stations. A small portion of stations were near urban areas, woodlands, or bodies of water.

There were 250 records of animals documented during the survey. Each documentation was considered as a presence indication of the species, not a count of the number of animals present at the station. Some stations documented numerous photos of a species and it is unknown if there were multiple unique individuals.

Swift Fox Locations

Confirmed swift fox sightings occurred at 4 stations with 3 additional locations highly suspected to be swift foxes (Figure 2.8). Of these, 6 were located in Dawes County and 1 in Kimball County. The Kimball County location documented what appeared to be a family of 4 swift foxes in the background of a single photo, followed 15 seconds later by a detailed photo of a single swift fox next to the scent stake (Figure 2.9 and 2.10). Swift fox detection for the first survey over 1390 camera nights was 0.0065. Detection across both surveys was 0.0057 for a total of 1570 camera nights.

Of the 7 swift fox locations, 6 did not document the fox until the 4th or 5th night of the 5-night run. Only 1 station was visited on the 1st night of operation and only 1 station was visited twice in the 5 night run. No station was visited more than twice and the station that was visited twice was visited on the last 2 nights of the run.

Of the 7 swift fox locations documented, 6 had some kind of grazed pasture present adjacent to the station location and only one was surrounded entirely by agricultural fields. This location was the single station in Kimball County. However, there was pasture approximately 0.4 kilometers (0.25 mile) to the north of the camera location. Six of the seven swift fox sightings were along 2-lane sections of the Heartland Expressway route. The only location that occurred along a 4-lane section of the expressway was the station in Kimball County which was surrounded by crop fields that had recently been plowed at the time of the survey. Swift fox station locations were primarily located on county roads or ROW areas (Figure 2.11).

While 65% of the HEC is composed of 2-lane road, 86% of swift fox stations were found along 2-lane sections of highway. Four-lane road makes up 35% of the HEC but only accounts for 14% of swift fox stations. While these numbers may show a decrease of swift foxes along wider, busier highways, the sample size is too small to run statistical tests and additional swift fox documentation would be needed to draw habitat preference conclusions based on road type. These data could also be used as a baseline of comparison for future study results to identify effects on resident swift fox populations in the area after the completion of the HEC expansion.

Chi-squared goodness-of-fit tests revealed a significant difference between swift fox station vegetation makeup and vegetation availability in both 1.56 km and 3.12 km buffers around the HEC, as well as around the 50 random points generated along the HEC (Tables 2.1, 2.2 and 2.3). Vegetation categories were examined individually and compared with the remaining vegetation categories grouped together. Using the

Bonferroni correction technique, significance values were set at $p<0.008$ to account for the 6 vegetation categories used in this comparison. All 3 buffer comparisons showed that shrub and grass land were present in significantly higher amounts than expected and agricultural land was present in significantly lower amounts than expected (Tables 2.4, 2.5 and 2.6). Recently disturbed areas, open water and miscellaneous vegetation were found in lower amounts than expected. Forests were present more often than predicted, which is unexpected due to the dependence of the swift fox on short grass prairie. It is likely that the station that was located along the southern edge of the Pine Ridge Forest is responsible for the higher proportion of woodlands.

Swift Fox Predators and Competitors

Swift fox predators and competitors were documented 46 times along the HEC, with coyotes (*Canis latrans*) being present at 26 stations, American badgers (*Taxidea taxus*) at 15 and red foxes (*Vulpes vulpes*) at 5 (Figure 2.12). Three stations documented more than one predator or competitor during the station's run. One red fox was documented visually when setting up a camera station along a county road and its presence was documented for that station. Only one swift fox location also documented a known swift fox predator. This location was located in Kimball County and documented a badger.

A chi-squared goodness-of-fit test was performed comparing predator presence along 2-lane and 4-lane highway versus the amount of 2-lane and 4-lane highway available. The result showed a statistically higher number of predators along 4-lane highway as opposed to 2-lane highway ($p<0.05$) (Table 2.7).

Expected values of coyotes along 2-lane and 4-lane highway were calculated in the same way, by multiplying percentage of road type by the total number of coyotes detected. This chi-squared goodness-of-fit test did not reveal a significant pattern in their distribution along 2-lane or 4-lane highway (Table 2.8).

Badger presence was also examined using a chi-squared goodness-of-fit test. Expected values were calculated in the same way as for predators and coyotes. The test found that badgers were present in greater numbers along 4-lane highway than would be expected, with $p<0.05$ (Table 2.9).

A home range of 11.18 km^2 for resident coyotes was calculated from an average of two separate studies conducted in habitat roughly similar to that of Nebraska, northern Texas and southeastern Colorado (Gese et al. 1990; Kamler et al. 2005). This value was used to buffer each coyote location with an area half the size of the average home range and vegetation pixel proportions within these buffers were recorded. This vegetation composition was compared to a similar buffer around 50 randomly generated points within a 1.56 km buffer of the HEC using a chi-squared goodness -of-fit test. The results were statistically different than expected values (Table 2.10). Chi-squared goodness-of-fit tests of individual vegetation categories show a significantly higher amount of agricultural vegetation and lower amounts of forest/woodlands, recently disturbed land, open water and miscellaneous vegetation than expected (Table 2.11). Grassland was present in amounts similar to what would be expected.

Additional Species

The most highly documented animals during the survey were raccoons (*Procyon lotor)* with 47 stations, followed by mule and white-tailed deer (*Odocoileus hemionus* and *Odocoileus virginianus*) at 37 and striped skunks (*Mephitis mephitis)* at 32. Skunks were documented at 3 of the 7 locations that also documented swift foxes. Feral cats (*Felis catus*) were documented at 25 stations and 15 of those stations were in Scotts Bluff County. Cottontails and jackrabbits (*Sylvilagus ssp*. and *Lepus spp.*) were seen at 15 stations, Virginia opossum (*Didelphis virginiana*) at 3, pronghorn (*Antilocapra americana*) at 3 and North American porcupine (*Erethizon dorsatum*) at 1 (Figure 2.13).

Second Camera Survey

The abbreviated camera survey conducted in February 2015 ran for a total of 180 camera nights. Stations were placed along portions of the HEC where swift fox presence had been documented in the first survey and yielded 11 animal documentations in three species categories: striped skunk, cottontail rabbit, and various small rodents. No swift foxes were documented during this spring survey.

Public Observations

At least one den with two visible swift foxes was sighted approximately 50 meters or less from the HEC, north of Chadron in the spring of 2014 by local students (B. Werner personal communication Jan. 30, 2015). A male swift fox was killed by vehicle strike in the same vicinity as the den in late August 2014.

Discussion

Swift Fox Presence

Swift foxes appear to be present in low densities along the HEC in Kimball and Dawes counties. Previous studies also documented swift fox presence in the panhandle counties of Sioux, Box Butte, Morrill and Banner (Stratman 2013; Kahn et al. 1997). Additional swift foxes may not have been detected due to the restraint in camera placement for this survey. Cameras were never placed further than 0.8 km (0.5 mi) from the HEC. While the exact dispersal distance of the skunk lure is unknown, it is unlikely that it would attract animals whose home ranges do not already overlap the HEC. It is also unclear how often swift foxes patrol their entire home range. A camera study conducted in western Nebraska showed that the probability of swift fox detection at a camera station only rose to 70% by the end of five nights and required a survey length of ten nights to raise the probability to 90% (Corral et al. 2013). Although placement of stations every 1.6 km on either side of the HEC was designed to maximize detection of animals that include the HEC in their home range, animals that live in close proximity, but not directly bordering the roadway may have been missed. Although the total number of undetected animals is likely low these swift foxes could still be affected by future road construction in the area.

The majority of swift fox stations, 6 out of 7, were not visited until the fourth or fifth nights of the 5-night run. This supports findings from a study by Corral et al. (2013) where 5 nights were needed to raise the probability of detection to 70%. While the second survey did not document any swift foxes in the month of February, it is logical that surveys performed in the summer months when detections did occur may benefit from a longer run, increasing the probability of detection. Swift foxes rarely visited a station more than once during the 5-night run. This only occurred at one station and occurred on the fourth and fifth nights. There is little literature on the frequency with which swift foxes patrol their entire home range and it is possible that it requires a minimum of 5 nights for the animal to cover the entire area. This would support a longer station run in order to increase the probability of documenting a swift fox if their home range overlaps with the camera location.

Statistical analysis showed significantly higher amounts of grassland and lower amounts of agricultural vegetation surrounding swift fox locations than what was expected based on available vegetation along the HEC. Kamler (2003a) found that short grass prairie was highly preferred over dryland and irrigated fields and agricultural land was only used when other suitable habitat was not available. However Sovada et al. (1998) found that the substantial swift fox populations inhabiting agricultural areas of Kansas did not exhibit higher mortality rates than those living in short grass prairie. While they appear to be able to utilize many different habitat types they are found primarily in short to mixed grass prairie (Harrison and Whitaker-Hoagland 2003).

Predator patterns

Swift foxes are known to be predated on by coyotes and badgers and have been shown to be in competition with red foxes (Harrison and Schmitt 2003; Kahn et al. 1997). These swift fox predators and competitors were located at 43 stations and were shown to be present significantly more often along 4-lane highway than along 2-lane highway. Badgers, in particular, were concentrated along 4-lane highway.

Habitat use patterns for badgers are complicated as some studies have documented badgers avoiding roads, while others have found patterns of association with linear disturbances like roads (Duquette et al. 2014). Badgers also select for cropland, potentially for its beneficial burrowing conditions and prey base (Duquette et al. 2014). While badgers were found to be present significantly more often along 4-lane highway stations than expected, all but one of these 4-lane stations were on county roads or private land, which experience less traffic than do stations in the right of way of 4-lane highway. Large amounts of agricultural land along the 4-lane sections of the HEC may be a primary reason for the species' presence.

All documentations of red foxes were along Hwy 71, south of Scottsbluff, NE and 3 out of 5 of these stations were along 4-lane roadways. Red foxes tend to select for areas of human activity and will make use of croplands, to exploit resources as well as potentially avoid larger predators such as coyotes (Gosselink et al. 2003). While the areas along the HEC where red foxes were documented were not high in human density, farm houses that are present in the area tend to be located close to the main road. This, coupled with the plentiful agriculture to provide rodent prey, may account for red fox presence in this area.

More than half of predator and competitor locations, 54%, were found within Kimball and Banner counties, which themselves make up 55% of all 4-lane highway for this study. Only one swift fox station also documented a known swift fox predator and it was also along this 4-lane section of road. The presence of higher numbers of swift fox predators as well as a major swift fox competitor species along this 4-lane highway may be partly responsible for the lower swift fox detection there and may signal that the area is a population sink for swift foxes.

Visual examination of the Nebraska GAP vegetation data (UNL SNR 2005) in ArcGIS 10.2.2 (ESRI 2014) shows a higher proportion of agricultural and developed land in the central and southern counties of the study area than in the most northern county of Dawes, where the majority of swift foxes were documented. Swift foxes select for short to mixed grass prairie and, while some populations will utilize cropland, characteristics such as frequent plowing, herbicide applications, high vegetation height and frequent prey disturbance decrease the frequency of its usage (Harrison and Whitaker-Hoagland 2003). The high densities of row crop and irrigational pivots in the central and southern counties of the panhandle may be providing lower quality habitat for swift foxes and may be partly responsible for their low detection numbers.

Coyotes are considered to be the greatest source of swift fox mortality (Allardyce and Sovada 2003; Sovada et al. 1998). Although the two species coexist in similar habitat, swift foxes have been shown to occupy home ranges on the periphery of coyote home range, often making use of roadways which coyotes avoid (Kamler et al. 2003c). Our survey results did not show a significant difference in coyote presence by lane type but did show coyotes to have significantly more agricultural vegetation present at their documented stations than expected. As this area south of Scottsbluff has higher amounts of agricultural land than does the northern portion of the study area it is possible that additional coyotes were present but not documented are they tend to be suspicious of camera and track stations and may actively avoid human scent (Corral et al. 2013).

Second survey

The second camera survey that was completed in February 2015 did not document any swift foxes at the locations where they had been previously documented. The stations did document striped skunk, rabbit species and various rodents, indicating that the cameras were functioning sufficiently to detect small to medium sized mammals. There are many reasons that may have prevented detection during this survey.

The survey took place during winter when temperatures are much colder than during the previous survey. Specific weather conditions in the Nebraska panhandle during this 10 night survey included periods of negative degree wind chills, high winds and snowfall. Snow and ice were also covering the lenses of several cameras when retrieved at the end of the second survey. These stations may not only have missed swift fox presence because the lenses were obscured but this may have caused the cameras to drain their batteries through many false triggers. Routine checks of the cameras during station runs to ensure clear lenses and sufficient battery life may be necessary for future studies carried out at this time of year.

Ruzicka and Conover (2012) documented that temperature, humidity and wind speed all affect the time of persistence before wildlife will detect and approach bait. The high winds present during the second survey may have dispelled the odor plume of the skunk bait. While Ruzicka and Conover (2012) found that lower temperatures actually decreased the time until detection, their study does not record temperatures below 11°C.

The temperatures in the panhandle averaged -10°C during the second survey run (TWC 2015). These colder temperatures coupled with high winds averaging 4.5 m/s, likely decreased detection probabilities (TWC 2015).

There is evidence that swift fox home range size increases in the winter months, potentially in the search for prey (Hines and Case 1991). This overall increase in home range size may decrease detection probabilities as the possible locations where swift fox may be present during the station run are much greater and may be less likely to intersect with the camera station.

Repeated exposure to bait has been shown to cause habituation in wild swift foxes (Sargeant et al. 2003). Skunk essence petroleum jelly was used as the scent bait for the summer camera survey, the February 2015 survey, and as additional lure during live trapping attempts. As the trapping attempts and the second camera survey were both focused on those areas where swift fox had previously been documented, it is possible that animals in that area had been exposed to the scent sufficiently by that time to make it undesirable. Swift foxes may have approached close enough to see the stake but not moved within the range of the camera once the stake had been visually identified.

February is part of breeding season for swift foxes in the northern portion of their range (Kahn et al. 1997). Prior to pupping, mated pairs move together frequently, however with the birth of the litter coordinated movements decrease as both male and female parents help to care for the young (Allardyce and Sovada 2003; Hines and Case 1991). Pups remain with their parents through the summer months before dispersing in the fall (Allardyce and Sovada 2003). The first camera survey occurred during the summer months when the mated foxes would be spending more time apart, females focusing on their core territory and the males spending more time at the periphery of their territory (Kitchen et al. 2005). This increases the potential of swift fox documentation as males and females are in multiple parts of their ranges on the same night. The second survey was conducted during the breeding season, when foxes spend much more time in close proximity, potentially decreasing the chance of encountering the camera station (Kitchen et al. 2005).

Populations of swift foxes are noted to be low in Nebraska, making population assessments difficult (Kahn et al 1997). While juvenile swift foxes have two peaks of dispersal, in fall and winter, adults may disperse at any time of the year, particularly after the death of a mate (Kamler et al. 2004) With a small population present along the HEC, animals that were documented during the summer survey may have dispersed to new territories in the fall and winter months before the February survey was conducted (Kamler et al. 2004).

Future directions and Management

Vegetation surrounding swift fox stations showed significantly more grassland and less agricultural vegetation than expected compared to availability along the HEC. As construction moves forward along the route, additional scrutiny should be applied in areas showing similar vegetation composition to that surrounding swift fox stations, as these areas will have higher probability of swift fox presence. Additionally, conducting future surveys yearly as well as in various seasons of the year would provide more precision in identifying areas of higher swift fox density along the roadway. With such low presence numbers as documented here, the simple act of dispersal of young, which occurs yearly in the fall and winter, could significantly alter the population density around the HEC from season to season and from year to year (Kamler et al. 2004).

A swift fox survey of the HEC route was not completed before original construction began. It is therefore unknown if swift foxes were previously present in greater numbers along the southern portion of the route and left following construction, or if presence was always low. Future surveys of the HEC can be used to document swift fox presence or absence along the north portion of the route after construction is complete to evaluate the effect of construction on the local population and to document if species numbers persist.

Noting that the majority of swift foxes were not recorded until the fourth or fifth night of the camera survey, it is recommended that future surveys carried out in the late spring and early summer increase the length of individual camera runs to 7-10 nights which may increase detection probability to as much as 90% (Corral et al. 2013). This would ensure fewer animals are missed by the survey, giving researchers more accurate data of where animals are present across the study area.

This study did not survey for swift foxes further than 0.8 km on either side of the HEC. It is unknown how often a swift fox will patrol the full extent of its territory. If this timing is longer than 5 nights then there is the possibility that some resident swift foxes along the HEC were not documented during this survey. The first attempt at aerial telemetry briefly located a collar signal approximately 1.6 km northeast of the SWANN landfill (Chadron, NE) which is itself approximately 2.4 km from the HEC where two female foxes were trapped and collared. If this area is the primary den location for the collared animals then they may be located further from the HEC than originally thought and may only visit the road periodically.

Potential management usage of these data includes adjustment of road construction practices and mitigation techniques to lessen negative impact to the species. Mitigation techniques may include fencing to direct wildlife to safer crossing locations, culverts that span the width of the roadway to offer a safe passageway, and medians without solid barriers so that they are passable to wildlife attempting to cross the roadway (CDOT 2010). Mitigation techniques implemented in Nebraska can also be applied to the construction practices of other states.

FIGURES

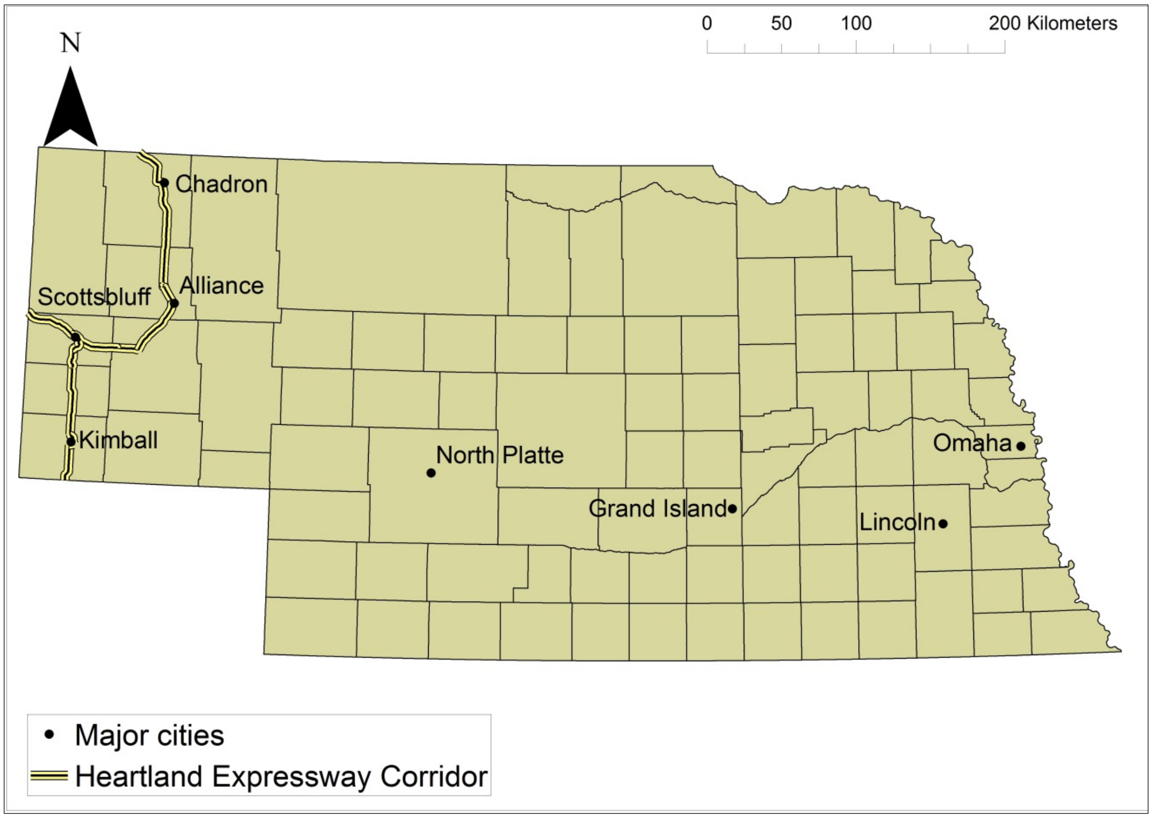


Figure 2.1: The Heartland Expressway Corridor located within the state of Nebraska (ESRI 2014).

Figure 2.2: Bushnell Trophy Cam trail camera, Model 119537C, used in swift fox (*Vulpes velox*) camera survey in western Nebraska during the summer of 2014.

Figure 2.3: Example of camera mounting and station design on private property, utilizing existing fence post.

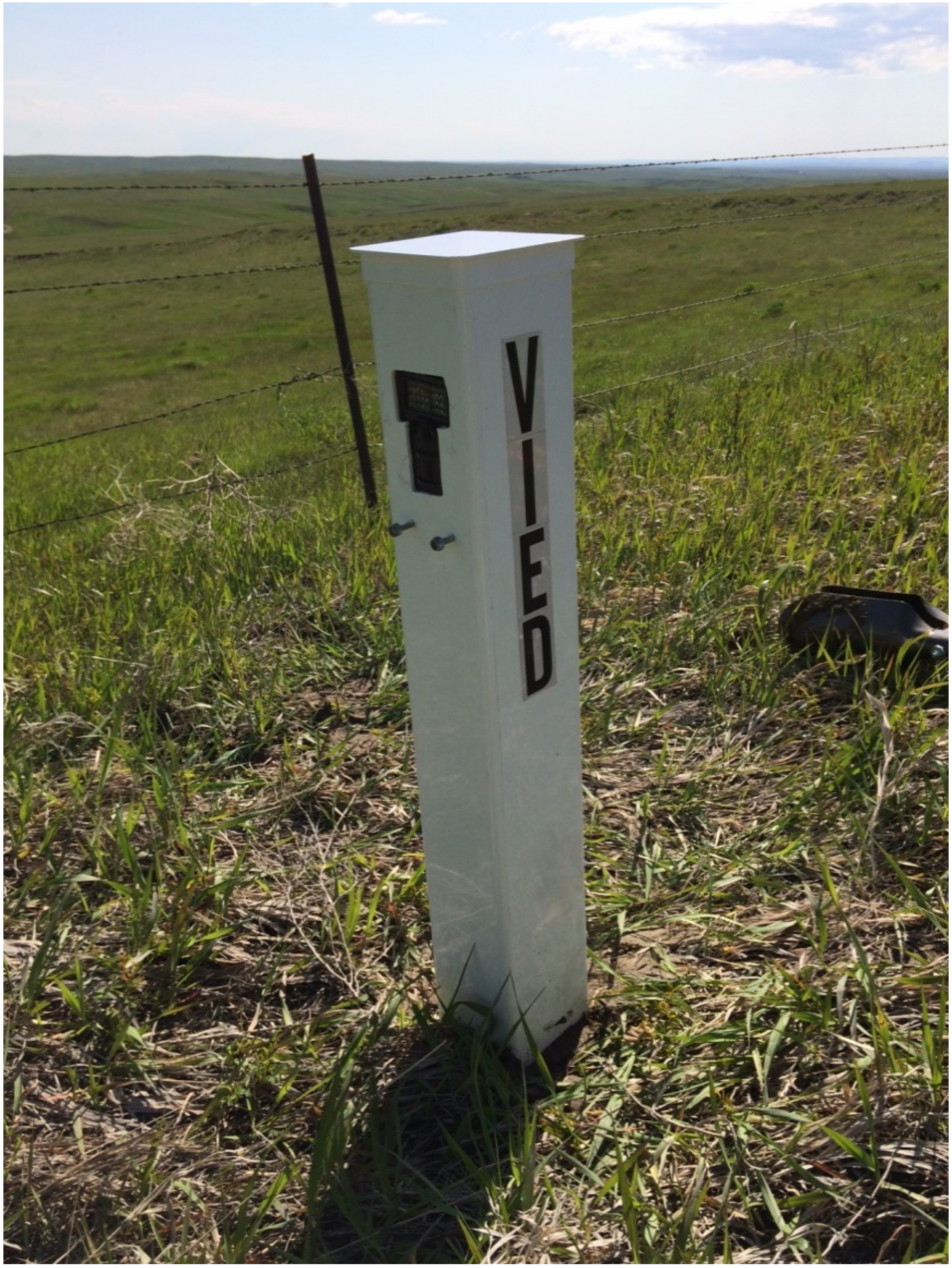


Figure 2.4: Example of “buried cable box” camera cover constructed to house trail cameras placed in HEC right of ways.

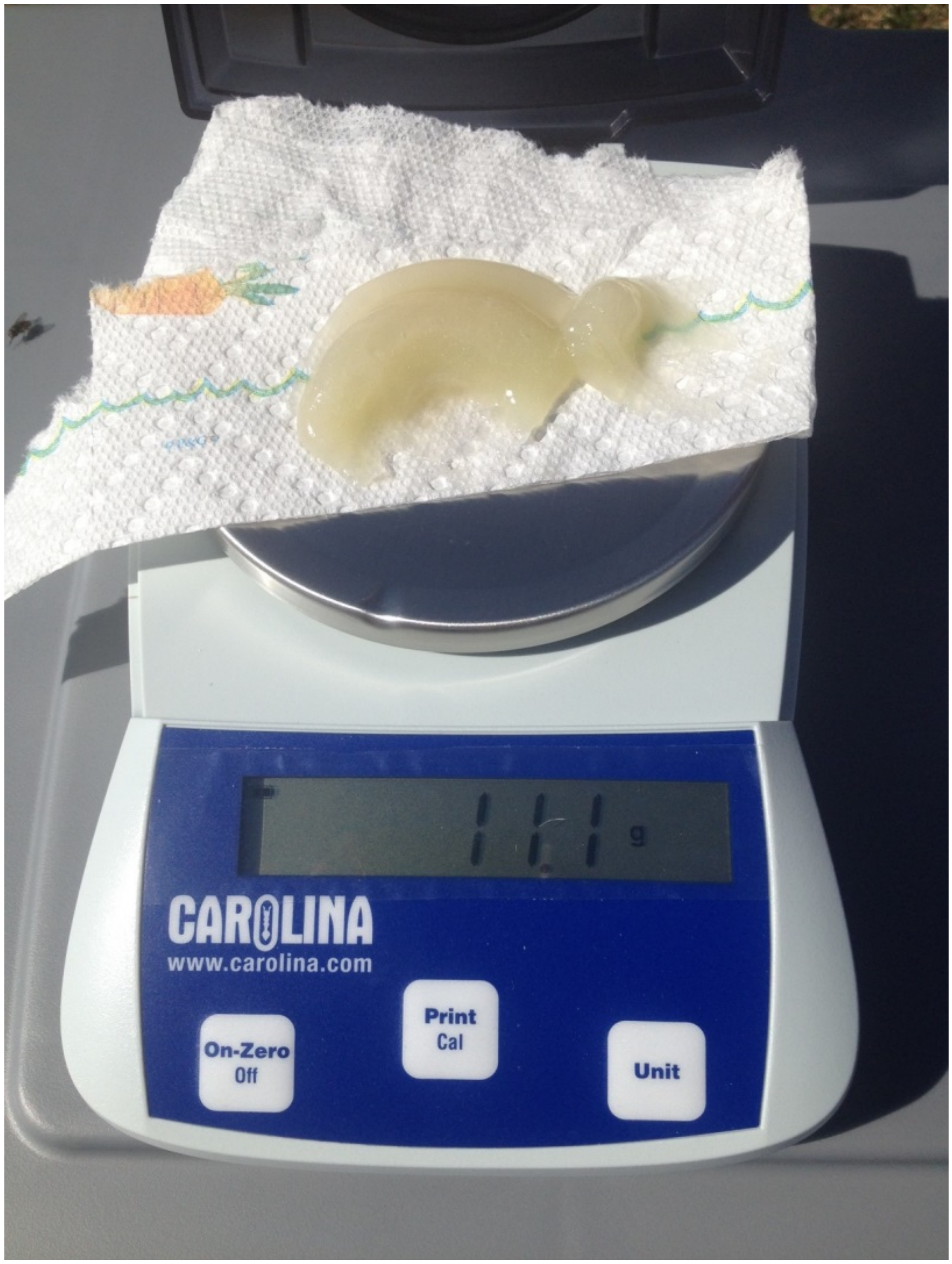
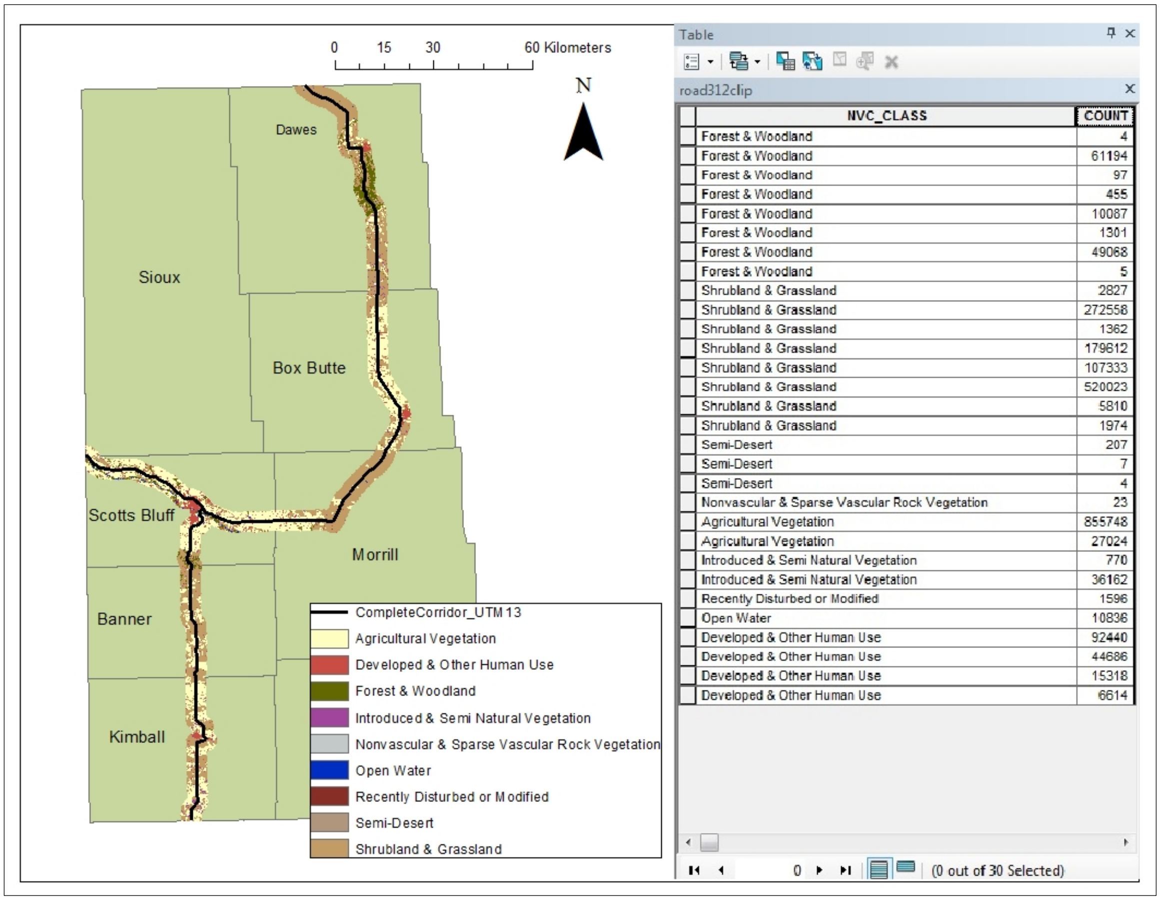


Figure 2.5: Scent lure consisting of 15 ml skunk essence mixed with 385 ml of petroleum jelly. Each station was baited with 15-30 ml of bait



NVC_CLASS	COUNT
Forest & Woodland	4
Forest & Woodland	61194
Forest & Woodland	97
Forest & Woodland	455
Forest & Woodland	10087
Forest & Woodland	1301
Forest & Woodland	49068
Forest & Woodland	5
Shrubland & Grassland	2827
Shrubland & Grassland	272558
Shrubland & Grassland	1362
Shrubland & Grassland	179612
Shrubland & Grassland	107333
Shrubland & Grassland	520023
Shrubland & Grassland	5810
Shrubland & Grassland	1974
Semi-Desert	207
Semi-Desert	7
Semi-Desert	4
Nonvascular & Sparse Vascular Rock Vegetation	23
Agricultural Vegetation	855748
Agricultural Vegetation	27024
Introduced & Semi Natural Vegetation	770
Introduced & Semi Natural Vegetation	36162
Recently Disturbed or Modified	1596
Open Water	10836
Developed & Other Human Use	92440
Developed & Other Human Use	44686
Developed & Other Human Use	15318
Developed & Other Human Use	6614

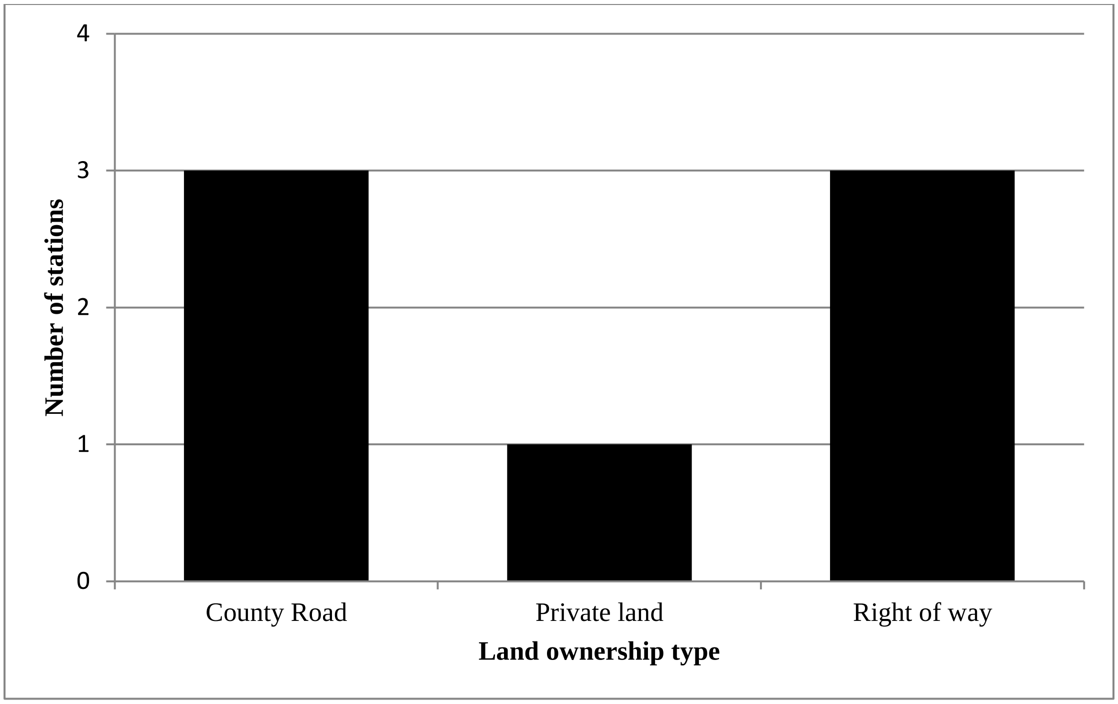
Figure 2.6: Example of pixel selection within a buffer of the HEC from GAP vegetation layer (ESRI 2014; UNL SNR 2005).

Figure 2.7: Locations of camera stations for swift fox survey of the HEC in western Nebraska, summer of 2014 (ESRI 2014).

Figure 2.8: Stations documenting confirmed or highly suspected swift fox presence during camera survey, summer of 2014 (ESRI 2014).

Figure 2.9: Photo documenting what is suspected to be a family of 4 swift foxes (*Vulpes velox*) at the station located at the border between Banner and Kimball counties on 11 June 2014.

Figure 2.10: Swift fox (*Vulpes velox*) documentation in Kimball County, Nebraska on 11 June 2014.



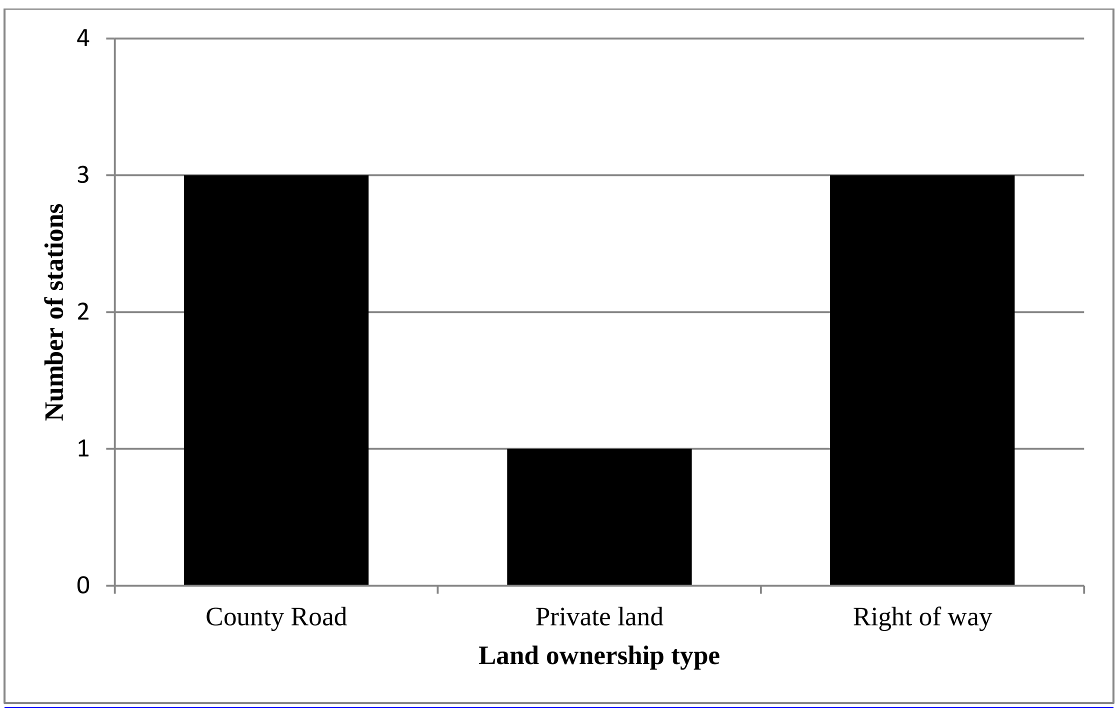


Figure 2.11: Land ownership categories at positive swift fox camera stations.

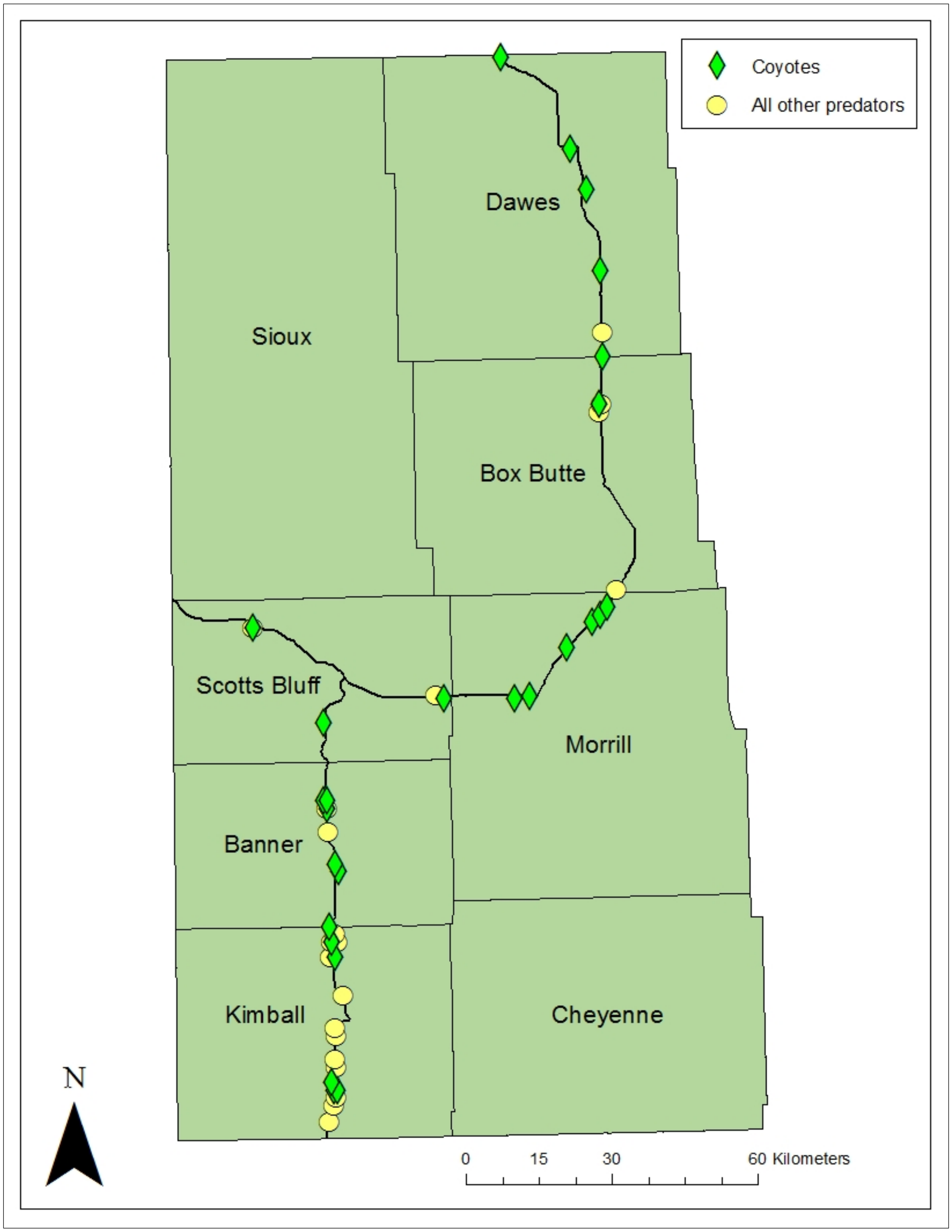
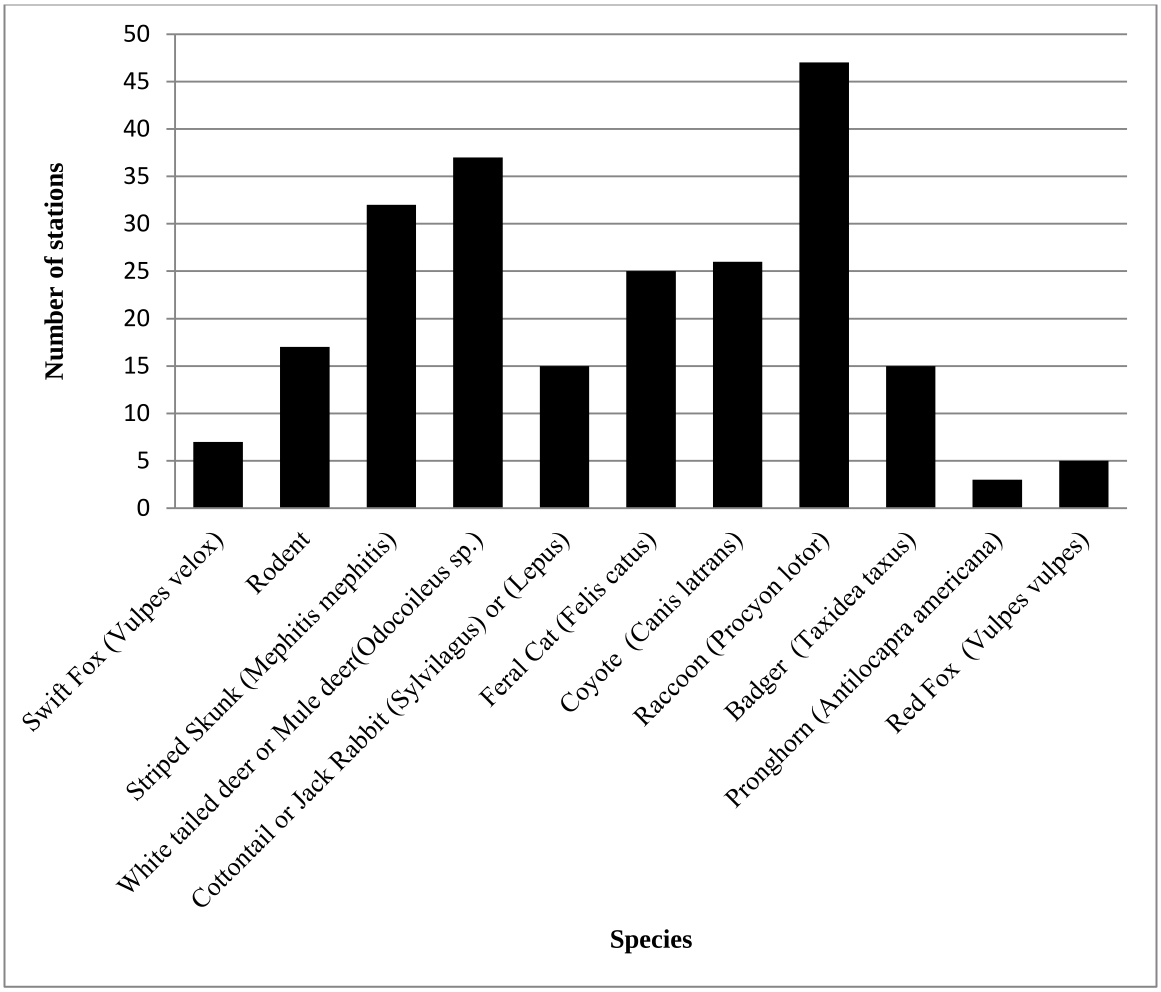


Figure 2.12: Camera stations documenting predators and competitors with coyote locations highlighted (ESRI 2014).



Number of stations
50
45
40
35
30
25
20
15
10
5
0
Swift Fox (Vulpes velox)
Rodent
Striped Skunk (Mephitis mephitis)
White tailed deer or Mule deer(Odocoileus sp.)
Cottontail or Jack Rabbit (Sylvilagus) or (Lepus)
Feral Cat (Felis catus)
Coyote (Canis latrans)
Raccoon (Procyon lotor)
Badger (Taxidea taxus)
Pronghorn (Antilocapra americana)
Red Fox (Vulpes vulpes)
Species

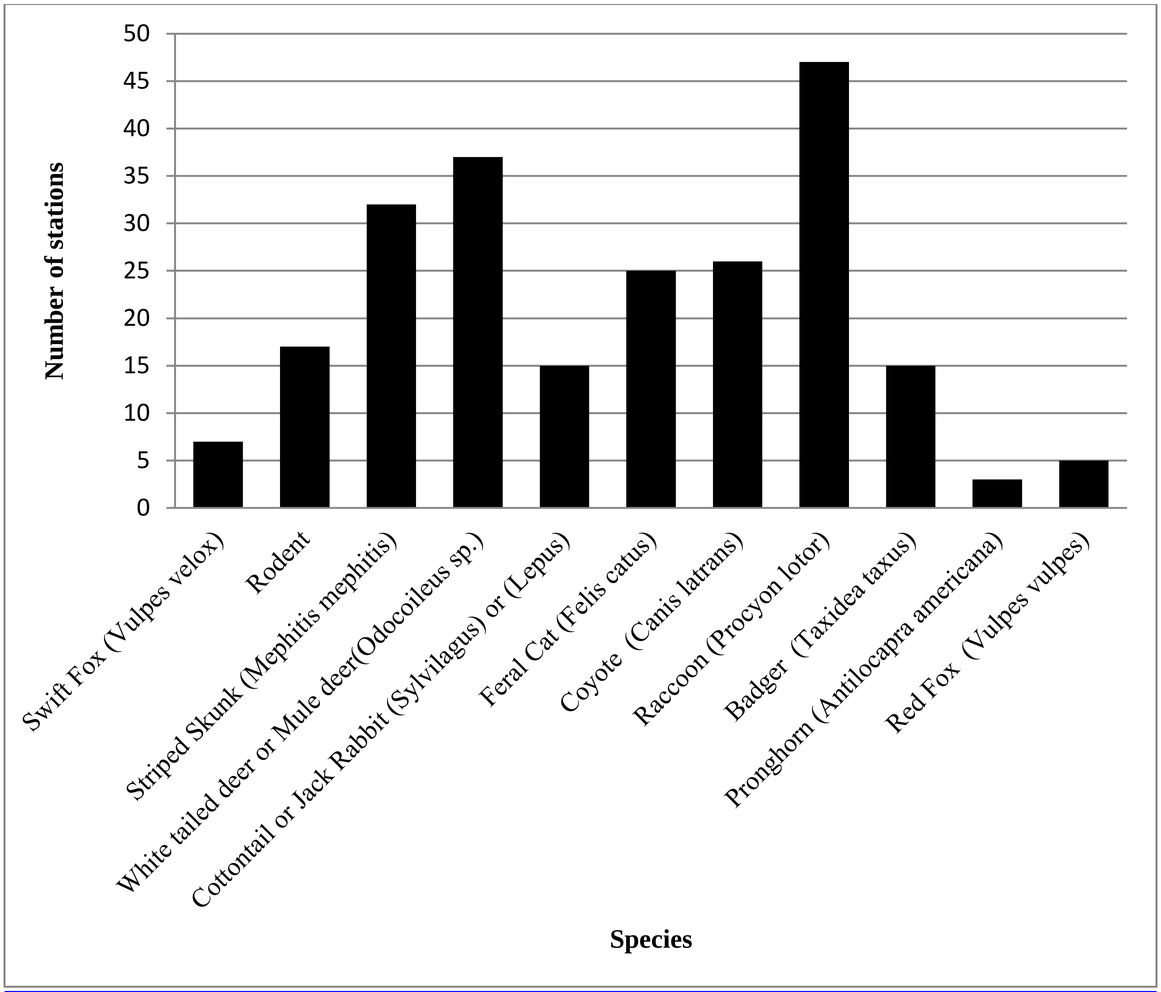


Figure 2.13: Species presence across entire camera survey of the Heartland Expressway Corridor during the summer of 2014.

TABLES

Table 2.1: Chi-Squared goodness-of-fit test for swift fox habitat preference (number of pixels) versus available habitat along a 1.56 km buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship (p<0.001).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	7959	2848.08	9171.64
Shrub / Grassland	35158	23074.47	6327.85
Agricultural vegetation	6002	20691.61	10428.61
Recently disturbed/ Developed	2875	4625.86	662.69
Open Water	122	265.88	77.86
Miscellaneous	284	894.11	416.32
Totals	52400	52400	**27084.97*** **

Table 2.2: Chi-Squared goodness-of-fit test for swift fox habitat preference (number of pixels) versus available habitat along a 3.12 km buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship (p<0.001).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	7959	2778.07	9662.11
Shrub/Grassland	35158	24811.69	4314.34
Agricultural vegetation	6002	20066.96	9858.15
Recently disturbed/ Developed	2875	3651.95	165.30
Open Water	122	246.32	62.75
Miscellaneous	284	845.01	372.46
Totals	52400	52400	**24,435.10*** **

Table 2.3: Chi-Squared goodness-of-fit test for swift fox habitat preference (number of pixels) versus available habitat at 50 randomly generated points within a buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship ($p<0.001$).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	7959	2475.10	12150.280
Shrub/ Grassland	35158	27170.70	2348.01
Agricultural vegetation	6002	18112.10	8097.05
Recently disturbed/ Developed	2875	3577.57	137.97
Open Water	122	190.55	24.66
Miscellaneous	284	873.98	398.26
Totals	52400	52400	**23,156.23*** **

Table 2.4: Chi-squared goodness-of-fit results for each vegetation category compared to all other available habitat when comparing swift fox locations to available vegetation in a 1.56 km buffer of the Heartland Expressway corridor. Asterisks denote a significant relationship (p<0.001).Directionality of significance is indicated in last column.

Vegetation category	χ^2 value	Higher (+) or lower (-) than expected frequency
Forests and Woodlands vs. other habitat	9698.80***	+
Shrub and grassland vs other habitat	11306.84***	+
Agricultural land vs other habitat	17233.89***	-
Recently disturbed vs. other habitat	726.86***	-
Open water vs. other habitat	78.26***	-
Misc. vegetation vs. other habitat	423.55***	-

Table 2.5: Chi-squared goodness-of-fit results for each vegetation category compared to all other available habitat when comparing swift fox locations to available vegetation in a 3.12 km buffer of the Heartland Expressway corridor. Asterisks denote a significant relationship ($p<0.001$). Directionality of significance is indicated in last column.

Vegetation category	χ^2 value	Higher (+) or lower (-) than expected frequency
Forests and Woodlands vs. other habitat	10203.04***	+
Shrub and grassland vs other habitat	8194.47***	+
Agricultural land vs other habitat	15976.45***	-
Recently disturbed vs. other habitat	177.68***	-
Open water vs. other habitat	63.04***	-
Misc. vegetation vs. other habitat	378.56***	-

Table 2.6: Chi-squared goodness-of-fit results for each vegetation category compared to all other available habitat when comparing swift fox locations to available vegetation at 50 randomly generated points within a 1.56 km buffer of the Heartland Expressway corridor. Asterisks denote a significant relationship (p<0.001). Directionality of significance is indicated in last column.

Vegetation category	χ^2 value	Higher (+) or lower (-) than expected frequency
Forests and Woodlands vs. other habitat	12752.65***	+
Shrub and grassland vs other habitat	4876.70***	+
Agricultural land vs other habitat	12374.20***	-
Recently disturbed vs. other habitat	148.08***	-
Open water vs. other habitat	24.75***	-
Misc. vegetation vs. other habitat	405.02***	-

Table 2.7: Chi-Squared goodness-of-fit test of predator/competitor presence along 2-lane versus 4-lane highway, showing higher density along 4-lane highway. Asterisk denotes a significant relationship ($p<0.05$).

Lane type	Observed	Expected	χ^2
2-lane	19	27.84	2.81
4-lane	24	15.16	5.15
Totals	43	43	**7.96***

Table 2.8: Chi-Squared goodness-of-fit test of coyote presence along 2-lane versus 4-lane highway.

Lane type	Observed	Expected	χ^2
2-lane	14	16.8	0.47
4-lane	12	9.2	0.85
Totals	26	26	**1.32**

Table 2.9: Chi-Squared goodness-of-fit test of badger presence along 2-lane versus 4-lane highway, showing a higher density along 4-lane highway. Asterisk denotes a significant relationship ($p<0.05$).

Lane type	Observed	Expected	χ^2
2-lane	6	9.7	1.41
4-lane	9	5.3	2.58
Totals	15	15	**3.99***

Table 2.10: Coyotes vs. vegetation chi-squared goodness-of-fit test for coyote habitat preference (number of pixels) versus 50 randomly generated points within a 1.56 km buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship (p<0.001).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	4646	7217.18	916.01
Shrub/ Grassland	79633	79227.470	2.08
Agricultural vegetation	56526	52813.37	260.99
Recently disturbed/ Developed	9626	10431.90	62.26
Open Water	357	555.63	71.01
Miscellaneous	2006	2548.44	115.46
Totals	152794	152794	**1,427.80*** **

Table 2.11: Chi-squared goodness-of-fit results for each vegetation category compared to all other available habitat when comparing coyote locations to available vegetation at 50 randomly generated points within a 1.56 km buffer of the Heartland Expressway corridor. Asterisks indicate significant relationship ($p<0.001$). Directionality of significance is indicated in last column.

Vegetation category	χ^2 value	Higher (+) or lower (-) than expected frequency
Forests and Woodlands vs. other habitat	961.42***	-
Shrub and grassland vs other habitat	4.31	same
Agricultural land vs other habitat	398.85***	+
Recently disturbed vs. other habitat	66.82***	-
Open water vs. other habitat	71.27***	-
Misc. vegetation vs. other habitat	117.42***	-

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Chapter Three: Fine Scale Movement of Swift Foxes (*Vulpes velox*) and their Interaction with Roadway Systems

Abstract

The swift fox shows no aversion to roadways, utilizing them for movement, food resources and den locations. Vehicle strike is a significant source of mortality for juveniles. The swift fox is currently listed as endangered in the state of Nebraska. The expansion of the Heartland Expressway Corridor in the panhandle of Nebraska will run through potential swift fox habitat. Movement of swift foxes around the HEC is a concern as construction moves forward.

Individual swift foxes were trapped and fitted with GPS enabled collars along the HEC in order to assess individual animal movement patterns and their relation to the road system. Data from one collar were retrieved and analyzed showing a home range of approximately 25.70 km^2 overlapping with the HEC, and nightly movement of 3.03 km. Data revealed frequent movement between the HEC and open short grass prairie.

Data from two additional swift foxes outfitted with GPS collars were not recovered despite multiple re-trapping and telemetry attempts taking place over several months.

Visitation to and crossing of the HEC by the collared fox indicates that roads are used frequently by the species and therefore mitigation protocols should be utilized when construction in the area begins.

Keywords: Swift fox, *Vulpes velox*, roads, Nebraska, Heartland Expressway Corridor, GPS collars, nightly movement

Introduction

Roads appear to be important to the swift fox (*Vulpes velox*). There is evidence that swift foxes do not avoid roadways and may even favor them as transport corridors as well as to bypass predators like coyotes that may avoid roads (Kamler et al. 2003b). Harrison and Whitaker-Hoagland (2003) found that the mean distance from collared swift foxes to roads was less than that of randomly generated points in the study area. Roads are also potential food resources as they provide carrion in the form of road kill and may harbor higher densities of rodents in the adjoining ditches than surrounding areas (Allardyce and Sovada 2003; Kirsch 1997). The effects on swift fox populations as road densities increase and road lanes expand are of conservation concern.

A study carried out in Colorado and South Dakota examined swift fox road crossings and their use of below-grade passes such as culverts to identify whether 4-lane interstate impeded swift fox movement (CDOT 2010). It was determined that while swift foxes do cross 4-lane highway and will occasionally make use of culverts and other below-grade passageways to do so, 4-lane highways do appear to be barriers for some individuals (CDOT 2010). The study made inferences for management of the endangered San Joaquin kit fox in areas where 2-lane highway was to be widened to 4-lane.

Swift fox dens are often found near roads, even high volume roadways (CDOT 2010). Hines and Case (1991) found that nearly 70% of dens located in their Nebraska study were less than 250 m from a roadway. While this may be beneficial for avoiding coyotes or utilizing roads as movement corridors, juvenile swift foxes are particularly vulnerable to vehicle mortality (Cypher et al. 2009).

While previous swift fox studies have included spatial components there have been some limitations. Previous research has focused primarily on radio collar work, where each animal location is triangulated using multiple antennae. However this technique produces low numbers of swift fox locations, sometimes only 30 to 40 over the course of the study (Kamler et al. 2004b). Often locations are only taken every few days as researchers must be present to record locations.

Previous radio collar studies on this species have focused primarily on questions of broad movement and land use. These data have been used to calculate home range sizes for swift foxes in different parts of their range, to evaluate predation and survival rates, measure dispersal distances and to analyze adult emigration patterns (Ausband and Foresman 2007a,b; Kamler et al. 2004a). However few studies have gathered location data for the swift fox on a fine time scale within a single season to study nightly movement patterns.

Minimum convex polygons (MCP) are a common method used to estimate species home range size (Kamler et al. 2003a; Sovada et al. 2003). Many studies use a minimum of 30-40 location points to estimate swift fox home range size and even more extensive radio collar studies may only gather 300 locations over 18 months (Andersen et al. 2003, Darden et al. 2008; Kamler et al. 2004b; Thompson and Gese 2012). Home range estimates from MCP calculations using less than 90 location points have been shown to underestimate actual home range size by more than 50% (Kolodzinski et al. 2010). Larger numbers of location points can increase the accuracy of MCP estimates.

Global Positioning System (GPS) technology provides larger numbers of location points over the course of the study than does radio collar work but has not yet been utilized to a great extent for this species. Technology has only recently improved in battery requirements and overall collar weight to where it can be of use in studying this small species. Many challenges still exist however.

The Heartland Expressway Corridor (HEC) is a road expansion project currently underway in the Great Plains. It forms part of a larger traffic system called the Great Plains International Trade Corridor that will consist of a 4-lane divided highway stretching from Canada to Mexico (HEA n.d.). The portion of the corridor that will run through Nebraska is just over 300 km in length and is located in the panhandle of the state. This entire area is currently considered to be potential swift fox habitat by the Nebraska Natural Legacy Project (NNHP 2011).

Effects on local swift fox populations resulting from the expansion of the HEC in western Nebraska are of concern to the Nebraska Department of Roads (NDOR) as construction prepares to continue. In depth knowledge of nightly movement will help inform future management decisions.

Objectives

Individual swift foxes were collared with GPS enabled collars during the summer and fall of 2014. The objectives of this study are to gather more detailed data on swift fox nightly movement patterns in proximity to the HEC and to make management suggestions to mitigate negative impact from future roadway construction.

Materials and Methods

Two types of GPS collars were used during this study (Figure 3.1). The first was a prototype GSM-GPS collar manufactured by Skorpa telemetry and Utrackit based in Scotland and South Africa (Skorpa 2013). The remaining collars were VHF/UHF GPS W500 Wildlink collars from Advanced Telemetry Solutions (ATS) which were used when the prototype GSM collars failed to work properly.

Efforts were made to work with Skorpa and Utrackit to modify their GSM technology to function with the United States wireless networks and to house this hardware in a collar light enough for use with swift foxes. Biotelemetry guidelines highly recommend keeping collar weights below 5% of the animal's total weight (USGS 2002). With swift foxes averaging only 2-3 kg this places the limit of collar weight around 150 g (Kahn et al. 1997). The GSM-GPS collars used averaged 155 g and the VHF/UHF collars averaged 88 g each.

Trapping occurred from 12 August 2014 to 28 January 2015 for a total of 202 trap nights. Trap sites were initially based on camera stations that documented swift fox presence during the survey in the summer of 2014. Locations were adjusted when a location had not yielded any animals for several nights. Eight trap nights were carried out at the single location documenting swift foxes in Kimball County. However with no immediate results, efforts were directed to the additional six swift fox locations in Dawes County, where animal density appeared to be higher. All locations in Dawes County were at least 25 km north of the border with Box Butte County and primary trapping attempts occurred within 15-20 km of the South Dakota border, where the majority of positive swift fox camera locations had been located.

Trapping attempts used baited Tomahawk single door live traps, model 108.1, set in highway right of ways, along county roads and along fence lines on private property where permission was available (Figure 3.2). Traps were baited with ground beef, chicken or turkey breast, and/or canned mackerel fish. Chicken or turkey strips were tied with twine to hang near the back of the trap to increase the movement of the bait (Finley et al. 2005). Plastic floor mats were secured along the top of each trap to provide shelter in case of inclement weather. When set in public areas, traps were secured via cable to fence posts or other fixtures present. Most traps were placed along fence lines to correspond with animal movement corridors. Cut grass was added as bedding during the trapping that took place in November and December to give animals opportunity for warmth if in the trap overnight (Figure 3.3). Based on protocols used in a study in Colorado, no trapping occurred on nights when temperatures were expected to dip below -9 °C (Schauster et al. 2002). Additionally traps were not set when snow or high winds coupled with cold temperatures were expected (Lebsock et al. 2012; Moehrenschlager et al. 2003). All traps were set before sundown and were checked by 0800 the next morning.

After trapping, swift foxes were transferred from the trap to a canvas bag in which they were weighed (Figure 3.4). They were then hand restrained while gender was assessed and neck circumference measured. Trapping location and collar identification number were also recorded (Table 3.1). The first fox was collared with a Skorpa GSM collar and data collected by this collar were routinely downloaded from the company’s website, Utrackit.com. The other two foxes were collared with ATS collars. ATS collars were scheduled to emit the VHF location beacon daily from 0800 MST to 1800 MST. Attempts to retrieve data from the VHF/UHF collars were made multiple times throughout the study using a combination of recapture attempts and ground and aerial telemetry.

ArcGIS 10.2.2 (ESRI 2014) was used to generate minimum convex polygons, run average nearest neighbor calculations and to create a kernel density plot for the retrieved collar data. The Tracklines feature of ArcGIS10.2.2 was used to connect the GPS collar locations in temporal order to show movement patterns. Weekly average temperature records were obtained from the Weather Underground website and compared to weekly distance moved (TWC 2015). Analyse-it software (2014) was used to create a scatterplot graph and to calculate a correlation coefficient between these two variables.

Results

Three swift foxes were trapped over 202 trap nights resulting in a 1.48 swift fox/ 100 trap night trap success rate. This is slightly lower than the 1.75 individuals/ 100 trap nights documented by Matlack (2000) in western Kansas. One male swift fox was collared in mid-August 2014 using a Skorpa GSM-GPS collar (Figure 3.5). This collar took fixes every four hours at night. Two females were collared in November 2014 using VHF/UHF collars from ATS. These two collars were scheduled to take GPS fixes every 30 minutes from 1900 to 0630 nightly.

GSM-GPS Collar Data

The location data gathered from the Skorpa GSM-GPS collar (collar 1625862D) consisted of 210 GPS locations taken over the course of 113 nights from August 15 to December 6, 2014 (Figure 3.6). Between 0 and 3 locations were recorded nightly, with an average of 1.85 locations a night. Nightly distance moved averaged 3.03 km and the average speed was 0.43 km/hour.

The habitat makeup of the minimum convex polygon was heavily weighted towards shrub and grassland vegetation. The Nebraska GAP vegetation layer showed that more than 97% of the area was classified as shrub or grassland, with the remainder composed of 2% developed land and less than 1% each of forest and open water (Figure 6) (UNL SNR 2005). No agricultural land was present in this animal's home range.

A minimum convex polygon was created from the GPS locations, using ArcGIS 10.2.2 (ESRI 2014). This gave an estimated home range for this animal of 25.70 km^2. The mean center was identified and areas of standard distance plus 1 and 2 standard deviations were calculated, also using ArcGIS 10.2.2 (ESRI 2014). The area of standard distance plus 1 standard deviation included approximately 68% of the GPS points around the geometric mean center and was 6.80 km^2 in size. The area of standard distance plus 2 standard deviations included approximately 95% of the GPS points and was 27.21 km^2 in size (Figure 3.7).

An average nearest neighbor calculation was performed in ArcGIS 10.2.2 (ESRI 2014) resulting in a z-score of -10.351. This indicates that the GPS locations show a statistically significant pattern of high clustering ($p<0.01$).

A kernel density plot was created using ArcGIS10.2.2 (ESRI 2014). The resulting figure shows 2 primary areas of activity. One area of high point density stretches along the HEC and the other lies to the south, in an area of open short grass prairie (Figure 3.8).

Nearly a quarter of all locations, 24.29%, were within 100 m of the HEC. More than half of the points, 59.52%, were within 1500 m of the roadway and there were no locations recorded further than 5000 m from the HEC.

Examination of monthly movement patterns shows a high percentage of GPS locations, 82.6%, were within 250 m of the HEC in August 2014. September, October and November show frequent movement within the heavily utilized area south of the HEC, as seen in the kernel density plot (Figure 3.8), with 2-3 locations monthly that extended to the furthest edges of the home range. All months show regular movement back and forth, from the roadway to the more open short grass prairie south of the HEC. Nearly all GPS locations were along or south of the HEC. Only 29% of locations were located on or north of the HEC (Figures 3.9-3.13).

Analyse-it (2014) was used to compare weekly average temperatures with weekly distance moved for all GPS locations. A scatterplot was constructed and a correlation coefficient of -0.082 was calculated (Figure 3.14). A Pearson test examining a hypothesis of no correlation resulted in a p-value of 0.7633.

GSM-GPS Collar Challenges

Several difficulties arose in the attempt to use Skorpa's GSM-GPS collars. Miscommunication led to the manufacture of the first set of collars with a weight and neck diameter far larger than was needed (Figure 3.15).A second set of collars at the correct size and weight were sent but after collaring the first swift fox of the study it was discovered that the collar was only able to send location fixes through an SMS (voice) link rather than via a data link. As such, the GPS fix frequency schedule could not be increased to take fixes every 30 minutes of nightly movement, as originally intended, without depleting the battery life in a matter of days. This collar, therefore, continued to take fixes every four hours of nightly movement.

Skorpa and Utrackit began construction of a third set of collars, taking into account the issues the current collars were experiencing. However there was a delay in manufacture of the vacuum cover through a third party company and collaring had to continue with the ATS collars before they could be shipped. ATS collars were used throughout the remainder of the trapping.

VHF/UHF Relocation Attempts

Attempts were made from November 2014 to February 2015 to relocate the two female foxes collared with the ATS W500 Wildlink collars. Ground telemetry was attempted on multiple trips to Chadron, NE and focused on available NDOR ROW close to where the foxes had been collared as well as along the approximately 2.0 km entrance to the SWANN landfill north of Chadron for which permission had been obtained. Additional trapping and recapture attempts continued for 148 trap nights after the collaring of the two female foxes. Two skunks and one raccoon were trapped as bycatch when recapture attempts occurred along the fence line of the SWANN landfill. All bycatch animals were safely released. Six aerial telemetry flights were conducted from 27 January 2015 to 19 February 2015 for a total of approximately 12 hours of flight time over the study area. Additional ground telemetry attempts were conducted immediately following the last two flights on 18 and 19 February 2015 to attempt to locate the signals that had been heard from the air.

Very weak collar signals for both collar 033317 and 033345 were heard during the flights on 27 and 29 January respectively. The signal of collar 033317 appeared to be coming from an area of open short grass prairie on private property approximately 3 km north of the HEC. Strong signals from collar 033317were heard on 18 and 19 February 2015 and were the strongest signals heard during telemetry attempts. These signals were emitting from a parcel of private land bounded on the south by the HEC and on the east by the SWANN landfill drive. Attempts were made to download the location data from the collars during the aerial telemetry flights, as well as from the ground after flights were completed. However, the signal was too weak to download the data in the aircraft and the signal could not be picked up from the ground. The computer program never successfully downloaded any of the location data. Multiple discussions with ATS IT support were held to ensure that download procedures were correct and that all possibilities were pursued.

Attempts were made to contact the owners of the parcels along the HEC where collar signal 033317 was heard as well as the surrounding areas. Contact was attempted through mail and telephone. Voicemail messages were left for one landowner but not returned. The second landowner was contacted by phone but refused to give permission to access their property.

Discussion

Home Range

Although only one sample set of data was retrieved from the collars during this study some patterns can be seen in the animal's movement.

The home range size calculation for collar 1625862D, using a MCP, was 25.70 km^2. This lies between two previous estimates for swift foxes in Nebraska of 15.2 km^2 and 32.3 km^2 (Hines 1980; Hines and Case 1991). This estimate is also larger than those found in states bordering Nebraska. Olson and Lindzey (2002) in Wyoming found home ranges to average around 18.6 km^2, while Colorado and Kansas estimated 9.39 km^2 and 15.9 km^2 respectively (Schauster 2002; Sovada et al. 2003). It has been suggested that the size of a swift fox home range may be dependent on such factors as the species density in the area and the physical features of the landscape that can divide territory and it has been shown to be so in red foxes (Hines and Case 1991; Sargeant 1972). The study area where the collared foxes reside appears to have fairly low swift fox density, based on the results from the HEC camera survey in the summer of 2014. The landscape is also primarily short grass prairie with few roads, waterways or large geologic features dividing the area. Therefore the animals present here, including the collared foxes, may have few limiting factors which would restrict their home range size. It is interesting to note that though collar 1625862D did have a larger home range area than surrounding studies found, the majority of GPS locations were located in a concentrated area overlapping with the HEC. When the five furthest outlying points are removed and a MCP is calculated for the remaining locations, the home range estimate drops to 11.92 km^2, which is closer to what was found in other parts of the species' range (Figure 3.16).

While other home range estimates use 6 months to 2 years of data points, the numbers of individual locations across the studies are low compared to those gathered from the Skorpa GSM collar, which logged 210 locations in just under 4 months. Thompson and Gese (2012) and Olson and Lindzey (2002) used an average of 63 and 69 locations respectively for their calculations of annual home range and Schauster et al. (2002) used a minimum of just 15. The 5 furthest outlying points for collar 1625862D occurred on average 13 days apart and substantially increase home range estimations. Outlying points like these may be missed when using low numbers of GPS locations for home range size calculations resulting in lower estimates.

Monthly home range size increased two fold from the month of September to the month of October and remained similarly large in November. August and December did not contain full months of data and therefore their monthly home ranges are not compared. Hines (1980) also saw variation in monthly home range sizes in collared swift foxes in Nebraska but did not find any consistent variations. Changes seen for collar 1625862D may be due to low sample size as well as changes in seasonal prey availability that accompanies the falling temperatures, requiring an enlargement of territory.

Nightly Movement

Swift foxes in Nebraska have previously been found to average nightly speeds of 0.87 km/h and distances of 13.1 km (Hines 1980; Hines and Case 1991). Both of these measurements are much higher than those calculated from collar 1625862D. The single data set is likely the reason for this difference. Hines (1980) broke movement down hourly and found that swift foxes are most active between the hours of 8pm and 4 am. Collars took fixes every 4 hours at night and only when movement triggered them. Actual distance moved may be higher as the current estimate does not account for non-linear movement between each GPS fix.

Collar 1625862D exhibited high levels of movement around the HEC. Although home range size estimates for this male are large, nightly distance moved and speed are lower than in previous studies (Hines 1980; Hines and Case 1991). The HEC may be providing food resources in the form of carrion and rodents living in the road ditches which would account for lower levels of movement needed on a nightly basis. Conversely the low density of swift foxes in the area may partially account for the higher home range estimate over all (Hines and Case 1991).

The statistically significant results from the nearest neighbor calculation suggests that this swift fox is showing a degree of territoriality, favoring core areas of its range, rather than regularly patrolling all portions of the available habitat. Studies by Lebsock et al (2012) and Andersen et al. (2003) showed little overlap of core use areas of neighboring swift fox pairs suggesting territoriality. Males in particular had very low levels of overlap with neighboring males (Lebsock et al. 2012). Additional samples from neighboring foxes would show if similar territoriality exists here.

Habitat Use

The habitat being used by the three collared animals lines up well with traditional understanding of swift fox preference. The vegetation found within the male swift fox's minimum convex polygon is made up of 97% grassland, with the remaining 3% comprised of small amounts of developed land, forest and open water. There was no agricultural land present within the animal's home range. The vegetation present in 30 m buffers around each collar point is still highly weighted towards grasslands at 80.5%. However at this finer scale, developed land increases in proportion to 18.2 %. Forest and open water make up the remaining area at just over 1%. Even though developed land is a small percentage of the home range area, the usage of that habitat is disproportionately large.

The parcels surrounding the collaring location for the two females are similar in vegetation type and quality to that of the male. In addition the location where both females were collared is 2 km from the entrance to the SWANN landfill, which may provide an additional food resource. During aerial telemetry flights, the signal for the first female collared was picked up over a parcel that borders the HEC that had been hayed earlier in the season. Parallel strips of higher vegetation were left throughout the field potentially providing habitat for prey items like rodents (Kaufman and Kaufman 1989).

Only one swift fox predator, a coyote, was detected by the camera survey within 5 km of the mean center of the male swift fox's GPS locations. No other predators were detected for more than 19 km from the mean center. Low predator densities may allow this area to serve as one of recruitment for the species.

A study examining swift fox movement around interstates retrieved only one GPS collar during the Colorado portion of the study due to drop off malfunction and weak UHF signal(CDOT 2010). This collar was from a female that appeared not to have crossed the interstate at any point during the 90 day study. The interstate appeared to have been a barrier for her, although trail camera evidence and swift fox sign at other locations confirmed that swift fox do in fact cross the interstate through culverts and at interstate level (CDOT 2010). The data from collar 1625862 in our study indicated that the animal did cross the HEC with some regularity, but the majority of points lay either along the HEC or south of it, indicating that the home range was oriented primarily to the south of the HEC with the road forming a loose boundary to the north. Additionally, all VHF signals detected from collar 033317 during aerial telemetry appeared to be emitted from the same side of the highway as the animal had been collared. Though far from conclusive it appears that in some cases roads may form loose outer boundaries of swift fox home ranges, even when the road way shows high levels of use by the animal.

Weekly Movement

Swift fox movement was divided into individual weeks (Figure 3.17 and 3.18). The last two weeks of August show very little movement away from the HEC. However from 30 August through 6 December the fox appears to visit multiple locations within the core of their territory on a weekly basis. This is comprised primarily of trips to the HEC and back to open prairie to the south. Only during the weeks of 4 and 11 October, 1 and 29 November did the animal venture far out of this core territory. If the entire MCP is considered to be the animal's home range then it appears that the far edges of the territory are visited only rarely. However if regular use is indicative of territory then it appears that the fox visits most portions of their range on a weekly basis, with only occasional trips outside of his territory when need arises. Although average temperatures did not fall below freezing until the week of November 8 (Table 3.2) the increasingly cold temperatures and accompanying seasonal changes may be the reason for the movement to the far edges of the home range starting at the beginning of October as the animal may need to travel farther to locate resources.

Temperature Effects

A correlation coefficient of -0.082 was calculated between weekly average temperature in Chadron, NE and the weekly distance moved for the male swift fox (Figure 3.14). The p-value of the Pearson test of no correlation was 0.7633, so the null hypothesis is not rejected. Temperature changes do not appear to significantly influence nightly movement for this swift fox. More frequent GPS fixes would increase the accuracy of nightly and weekly distance measurements.

Local Sightings and Possible Den Sites

Local wildlife majors from Chadron State College (CSC) documented additional swift fox sightings in the area. A visual sighting of two individuals at the entrance to a den in a field directly bordering the HEC was made in early 2014, northwest of the male swift fox's collaring location (Figure 3.5). A male swift fox was struck and killed by a vehicle very close to this den location in late-August 2014. An additional night time sighting was made by another CSC wildlife student in the area south of the collaring location of both female swift foxes in mid-January 2015.

Examination of the earliest GPS locations documented each night reveals possible den locations for collar 1625862D. Some nights did not record positions until after midnight. This is possibly due to times when the animal moved within its den early in the evening and the collar could not locate the GPS satellites because of being underground and therefore no location was documented. Hines (1980) found that swift foxes in western Nebraska began their movement between 1700-2100 hours. The first locations documented after the animal begins to move in the evening ought to indicate the location of one of their dens. Looking at all locations for collar 1625862D recorded before midnight over the course of the study there were 3 areas of clustered points indicating possible den locations (Figure 3.19). Swift foxes tend to use multiple dens, with some used primarily for pupping and others for predator escape (Allardyce and Sovada 2003). These clustered areas may indicate the entrances to dens used by this male.

Visual sightings of two possible swift fox dens were made in mid-February 2015 during an aerial telemetry flight. One potential swift fox den was located in the HEC right of way, while the second was located within a privately owned parcel, close to where the VHF signal appeared to be emanating from. This second den showed the distinctive single dirt plume coming from the entrance, indicating that it was likely excavated by swift foxes (Kahn et al. 1997). This potential den was located in the field that showed signs of being hayed earlier in the season. This is unlike previous findings in Nebraska by Hines (1980) where all dens were located in grazed pasture and no documented dens were located in hayed or cultivated fields.

Road Crossings

The frequency and timing of road crossings of swift foxes in the area is a subject of interest as they will be directly affected by road construction in the area. The GPS locations documented by collar 1625862D were temporally connected using the

Tracklines feature of ArcGIS (ESRI 2014). Nearly half of these lines, 42.6%, crossed the HEC. Timing of these crossings is also important. There were 15 movements ending within 50 m of the HEC and the end location occurred either in the 0100 hour or the 0500 hour of the morning. There were 61 locations documented on or north of the HEC. Most activity was located south of the roadway and so locations north of the HEC indicate movement across and near to the road. Of these locations, 90% were documented in the 0100 or 0500 hour. Only 21% of GPS locations were documented before midnight each night. The early morning hours appear to be the times of highest movement for collar 1625862D and construction may wish to be avoided during these times.

GSM-GPS Collars

The GSM-GPS collars allowed routine automatic downloading of the GPS fix locations through local cell phone towers. These data could then be regularly viewed and downloaded for analysis. This guarded against data loss in the event of collar malfunction, battery depletion and animal dispersal or mortality. There was also a decrease in costs and travel time to the study site to collect data. In the case of recapturing animals to remove collars at the end of a study, GSM-GPS collars may provide researchers with locations from which to commence re-trapping attempts.

Skorpa/Utrackit indicated that there may be a bias for locations that are closer to cell phone towers. The vast majority of documented locations were found within 6 km of the nearest cell tower and all locations were within a 10 km of the tower. As the locations that were downloaded comprise an area that is already on the higher end of swift fox home range size estimates, it is unlikely that there were many additional points that the cell phone tower bias may have missed as swift foxes do not tend to move further than this distance other than at dispersal times.

The Skorpa/Utrackit Company was based in Scotland and South Africa. Slow communication and shipping times, unfamiliarity with the United States cell phone tower system and the need to outsource portions of the manufacturing process, such as the vacuum packed covers for the collars, slowed down the manufacturing process and caused delays.

VHF/UHF Collars

Difficulties with the VHF/UHF technology of the ATS collars included the limitations of signal detection and download distance. Tests conducted prior to collaring in order to determine VHF signal detection distance varied widely in their results, from 240 m down to only 60 m. The cause of the inconsistency of these results is unknown. However if the shorter distances are in fact correct under certain conditions, then even the use of aerial telemetry may not be an effective option as planes may not be able to fly at such low altitudes over private property.

Using VHF/UHF collars for species such as the swift fox which often live in large, uninterrupted plots of short grass prairie may be challenging. Study areas which follow a linear feature such as a roadway, will likely be composed of large numbers of privately owned parcels requiring high amounts of landowner participation in order to cover an appropriate amount of the total area. Shortgrass prairie is often used for grazing pasture, meaning there may be few public roads passing through the terrain which would provide researchers some level of proximity even without land owner permission.

Additionally, swift foxes are highly den dependent and nocturnal animals. As such, they will most likely be below ground during daylight hours when aerial telemetry flights could occur. Being below ground shortens the detection distance for the collar's signal beacon. Although night time telemetry detection is possible, it becomes more difficult and potentially dangerous for the researcher. For this study collar signals were scheduled to be active from early morning to late afternoon. While the intention of this scheduling was to allow the most downloading flexibility during the day, while minimizing battery loss at night, it became apparent that the signal strength was decreased while the animals were in the den to the point that day time downloading may not be possible without land permission. It is unclear whether aerial telemetry flights would have been possible at night if the collar beacon had been active during that time. Ground telemetry attempts at night may have been possible however.

Hines and Case (1991) indicated that previous studies showed highest activity for swift fox from 0.5-4 hours before sunset to an hour after sunrise. This timing does overlap with the timing schedule on the ATS collars and telemetry attempts were conducted at multiple times overlapping with portions of this activity period.

GPS collars are fairly new to swift fox studies. Their higher cost and increased battery drain offer challenges to field researchers. Similar difficulties were experienced in a study carried out over multiple seasons in both Colorado and South Dakota using GPS collars with a UHF download feature to assess swift fox movement around a 4-lane interstate (CDOT 2010). Ten swift foxes were collared along I-70 in eastern Colorado with Tellus Mini GPS/UHF collars. A malfunction in the drop off feature and an inability to locate the animals via UHF signal ended the season with data from only one collar. These data were retrieved from a re-trapping effort later in the season. Despite additional collared foxes being documented in the area by trail camera, they were not recaptured, despite re-trapping attempts.

VHF/UHF GPS collars present challenges for research of swift fox populations due to their signal detection and download limitations.

Relocation Challenges

If swift foxes are disturbed enough by the collaring process that they leave the area or if they naturally disperse after collaring occurs then the researcher may be unable to relocate them without the use of aerial telemetry. Based on VHF signals from the airplane, the first female, collar 033317, appeared to remain very close to the original trapping location. The VHF signal from the second female, collar 033345, was heard faintly over open short grass prairie, approximately 7 km to the northeast, close to the South Dakota border. The second female, collar 033345, was slightly smaller than the first and it is possible that, as they were collared in the same location, that this smaller female was an offspring of that year’s breeding season and dispersed northward in the late fall after being collared.

The swift foxes located in this study were all on or adjacent to privately owned land. Private land owner permission can be difficult to obtain and is rarely comprehensive. Large expanses of short grass prairie or pasture land that swift foxes favor are often uninterrupted by state or county roads and study areas following features like roadways may pass through large amounts of private property. In such cases when private permission is not available aerial telemetry is a good option to increase the probability of relocating the animals. The antenna designed to relocate this brand of collar has a maximum detection distance of approximately 400-500 meters. In large tracts of prairie even low hills may block direct line of sight thus decreasing detection distance of the signal. This may cause difficulties in relocating the animals and downloading the data. During aerial telemetry flights, the plane maintained an altitude of approximately 60-90 meters above the ground. This is within VHF signal range but apparently not within UHF range for successful data download. In situations such as this, aerial telemetry may be used to locate the general area in which to search for the signal on the ground. However when land owner permission for these areas is not given, data download may not be possible. One would need to be close to the entrance to the den in order to download data during the day when animals are underground. Some studies have been able to avoid these difficulties by having all dens in their radio collar studies located on public lands, providing full access to the animals (Kintigh and Andersen 2005).

Due to the fact that signals from both collars were heard from the aerial telemetry flights it appears that the primary limiting factor to download was in fact the lack of private land owner permission to access those needed parcels. Had access been obtained then it is likely that download equipment could have been moved close enough to the collars, despite their being underground, to enable successful download. Increased signal schedules would have been beneficial and would have allowed some limited download attempts at night, however it is unclear if download would have been possible from the air or the HEC while the foxes were still on private land even if they were above ground.

Management Implications

Based on the results obtained from this study as well as the challenges involved in relocation attempts it is recommended to pursue refinement of GSM-GPS collar technology for future swift fox studies.

There are many similarities in the methods and challenges of this study and that examining swift fox habitat use around interstates in Colorado and South Dakota (CDOT 2010). Management recommendations from their work included not using solid median barriers when roads were expanded from 2-lane to 4-lane as they can trap animals that attempt to cross the highway. The installation of below-grade culverts that span the width of the highway would offer wildlife an alternative means of crossing to the opposite side of the roadway without the risk of vehicle mortality. Finally the installation of road side fencing that funnels wildlife to pre-constructed crossing points, such as culverts, may decrease wildlife mortality for species like the swift fox (CDOT 2010).

The data collected here indicate that swift fox in Nebraska may have about the same size home range as in Colorado. The animal that was collared show a clear home range, which is useful to know. Animals that are relocated need to find a new home range, but if they do, they may stay in their new location. Also the animal that was collared in this study did show an affinity for road sides. This indicates that surveys on road projects are probably worthwhile. It also indicates any measures that reduce swift fox on roads could reduce swift fox fatalities from vehicles, and reduce accidents caused by impacts or attempts to miss swift fox.

FIGURES

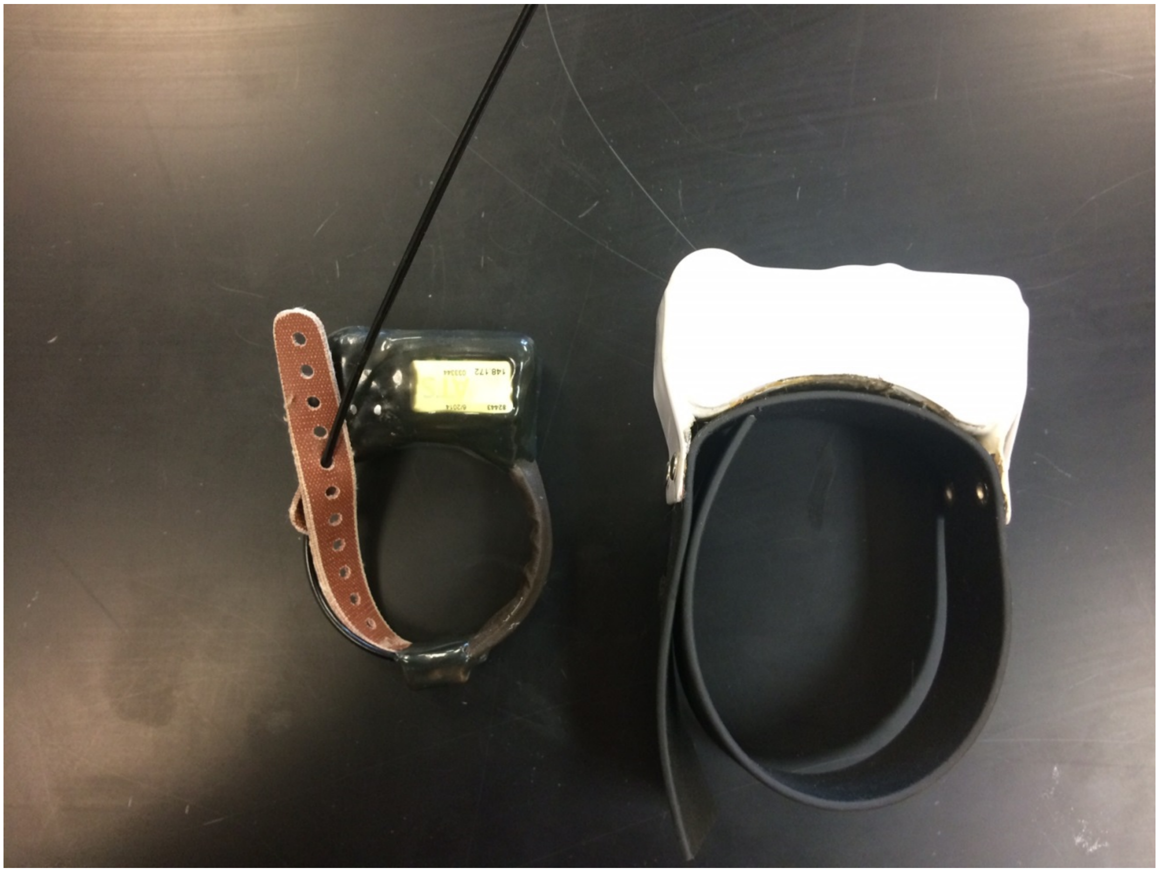


Figure 3.1: ATS Wildlink W500 collar (left) and Skorpa GSM-GPS collar (right) used in this study.

Figure 3.2: Baited trap setup located along fence line of private land. Tomahawk box trap with car mat attached to top to provide shelter.

Figure 3.3: Example of baited trap with dried grass added as bedding material for cold trap nights.

Figure 3.4: Female swift fox in Tomahawk trap awaiting collaring.

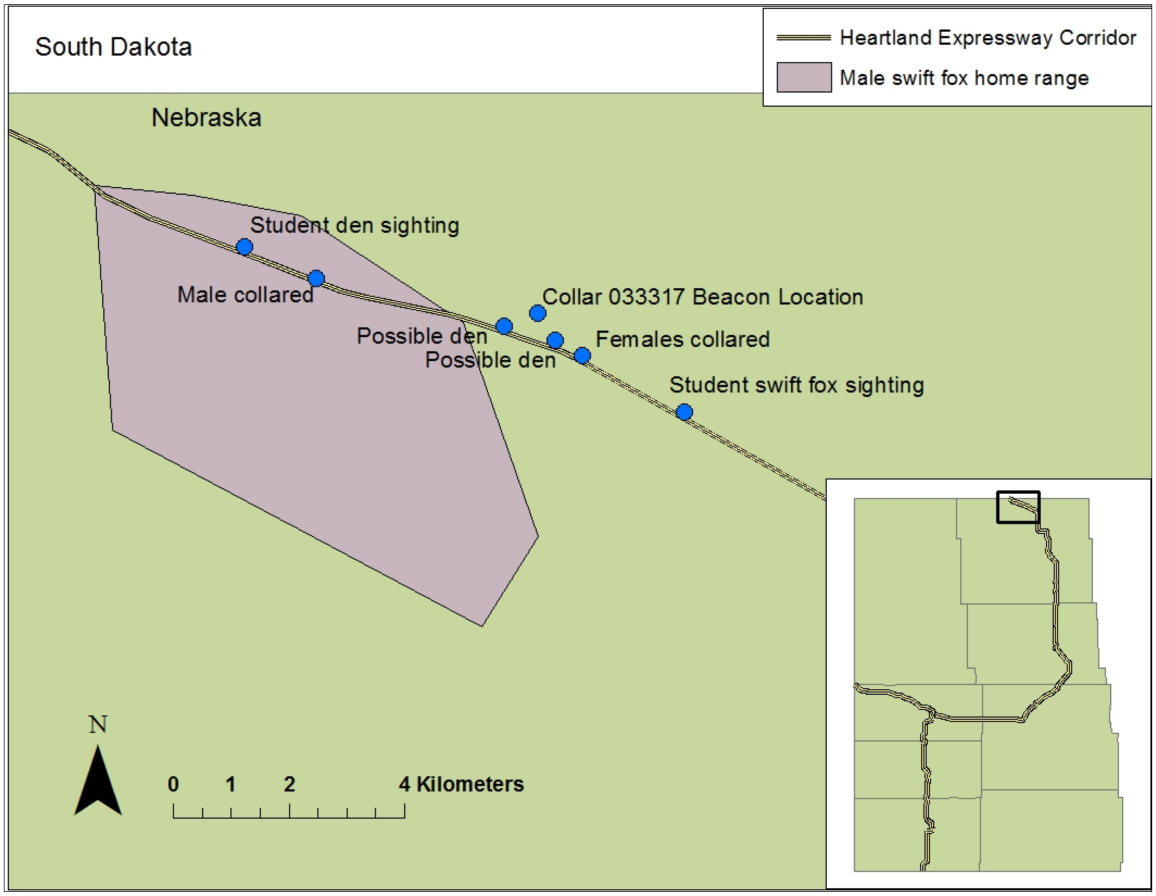


Figure 3.5: Map showing collaring locations of swift fox male and females in relation to public sightings and den sightings over the course of the study (ESRI 2014).

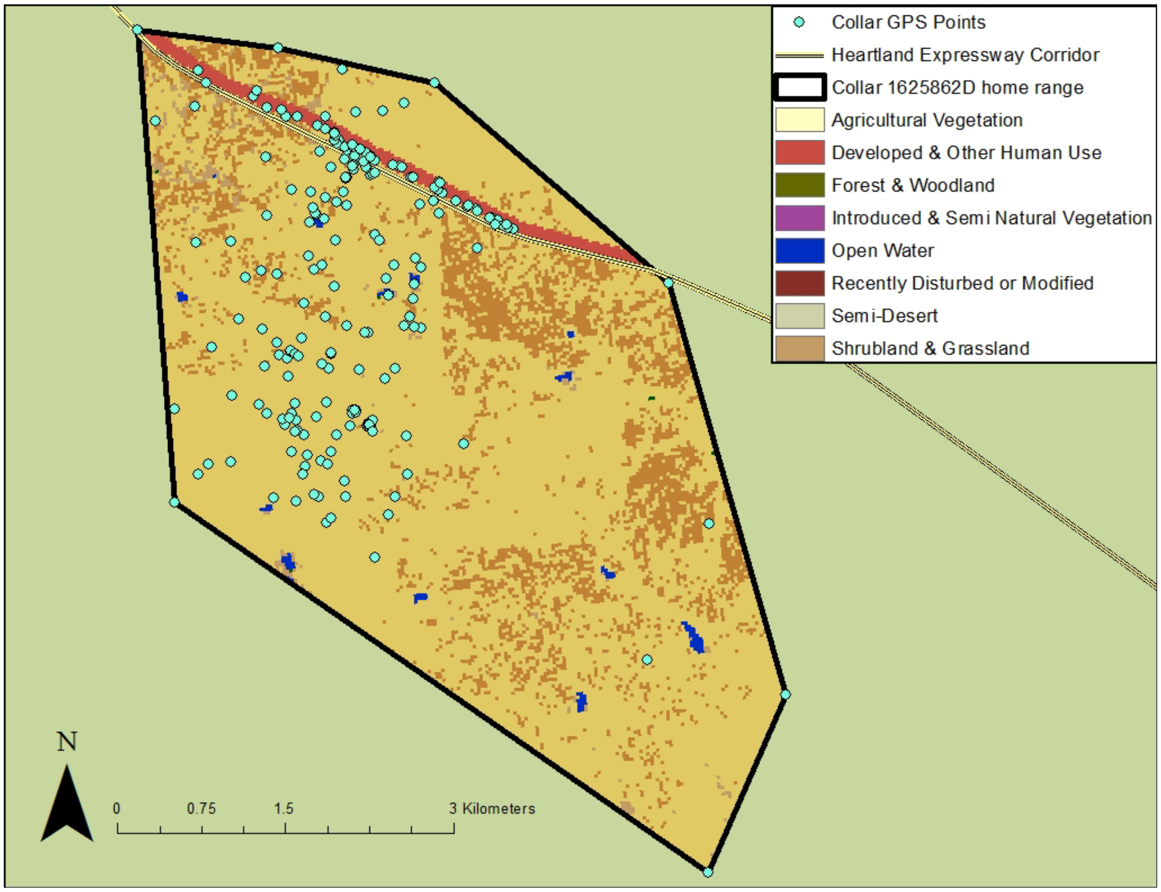


Figure 3.6: Skorpa collar 1625862D GPS locations plotted over Nebraska GAP vegetation showing 97% shrub and grassland within minimum convex polygon. Vegetation categories from Nebraska GAP land cover classification (ESRI 2014; UNL SNR 2005).

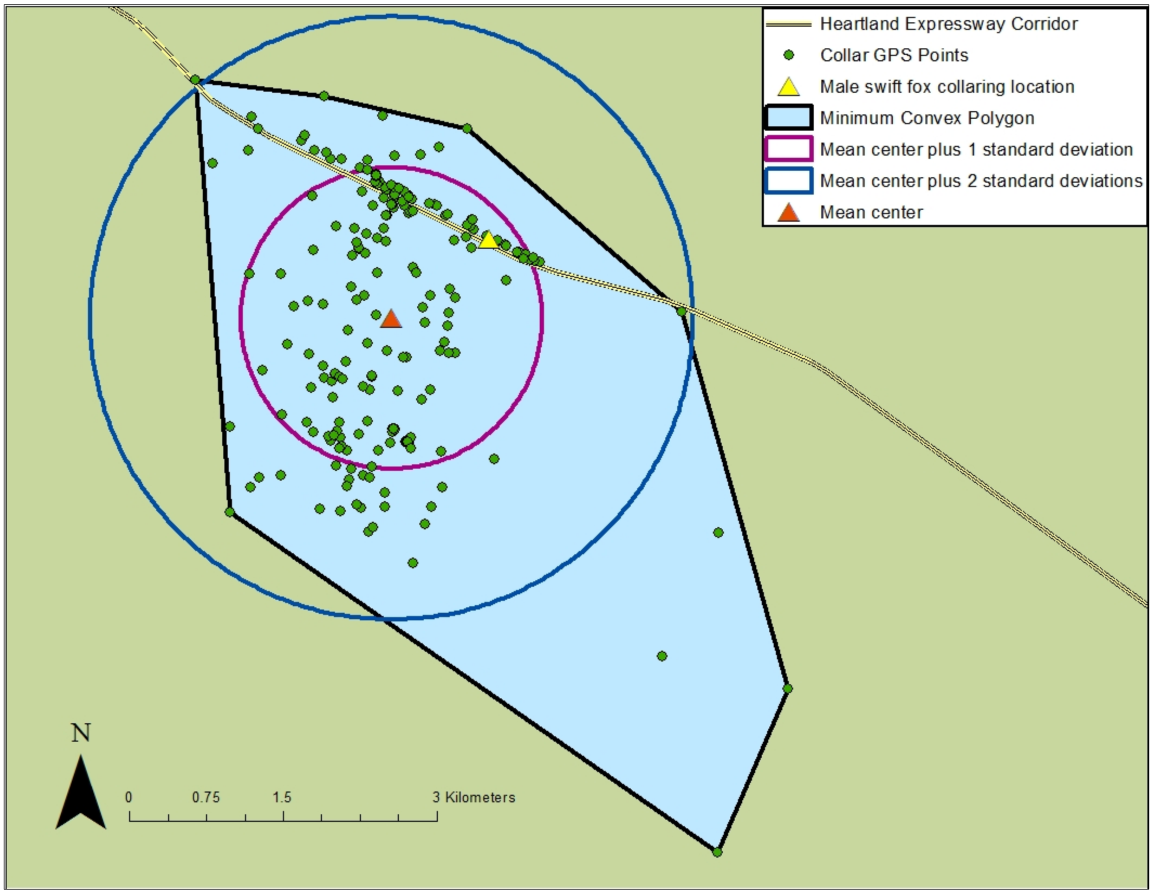


Figure 3.7: Minimum convex polygon created using locations from collar 1625862D. Geographic mean center and location of animal collaring indicated. Area of standard distance plus 1 standard deviation is 6.80 km^2 and area of standard distance plus 2 standard deviations is 27.2 km^2 (ESRI 2014).

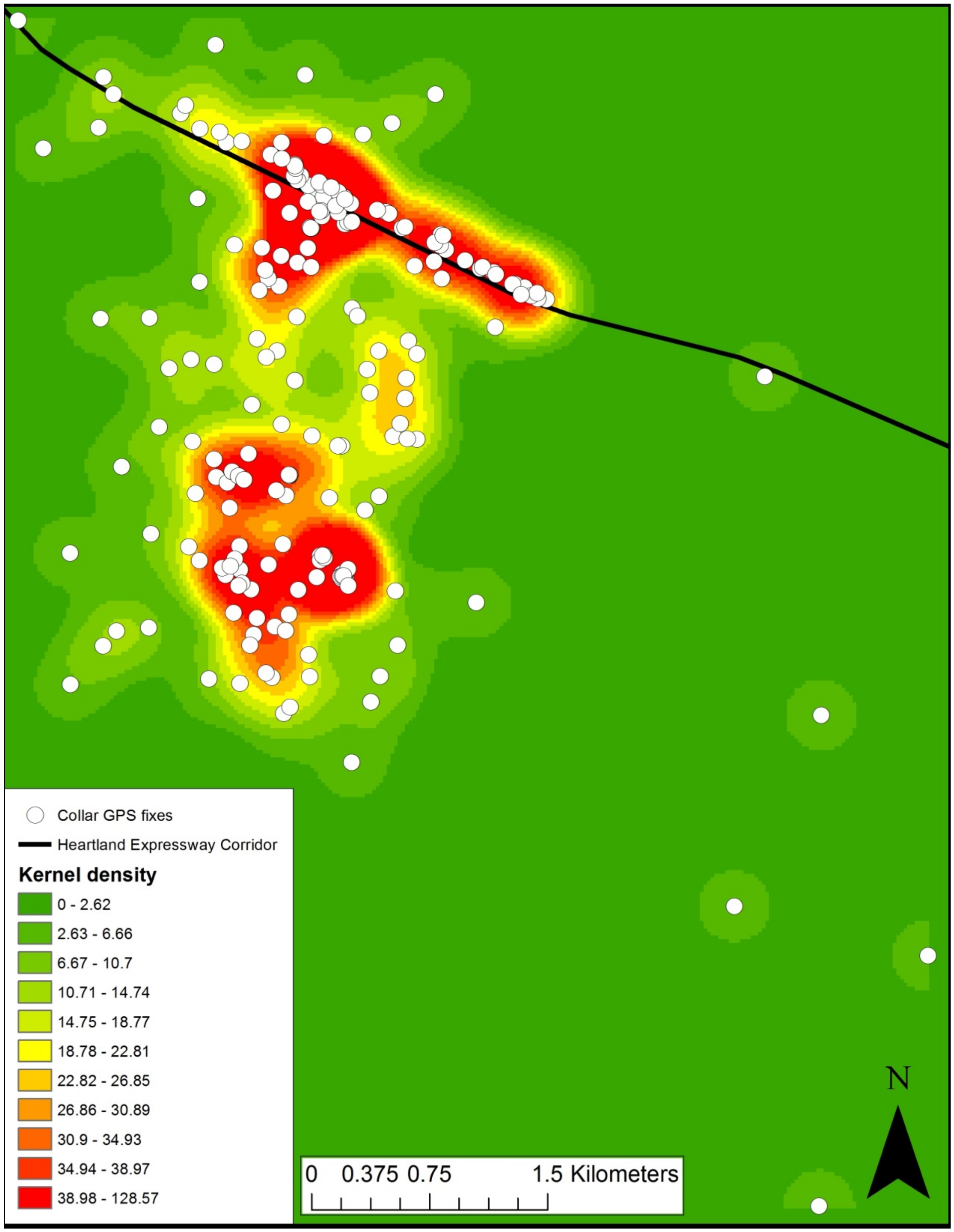


Figure 3.8: Kernel density plot of collar 1625862D GPS locations in reference to the HEC (ESRI 2014).

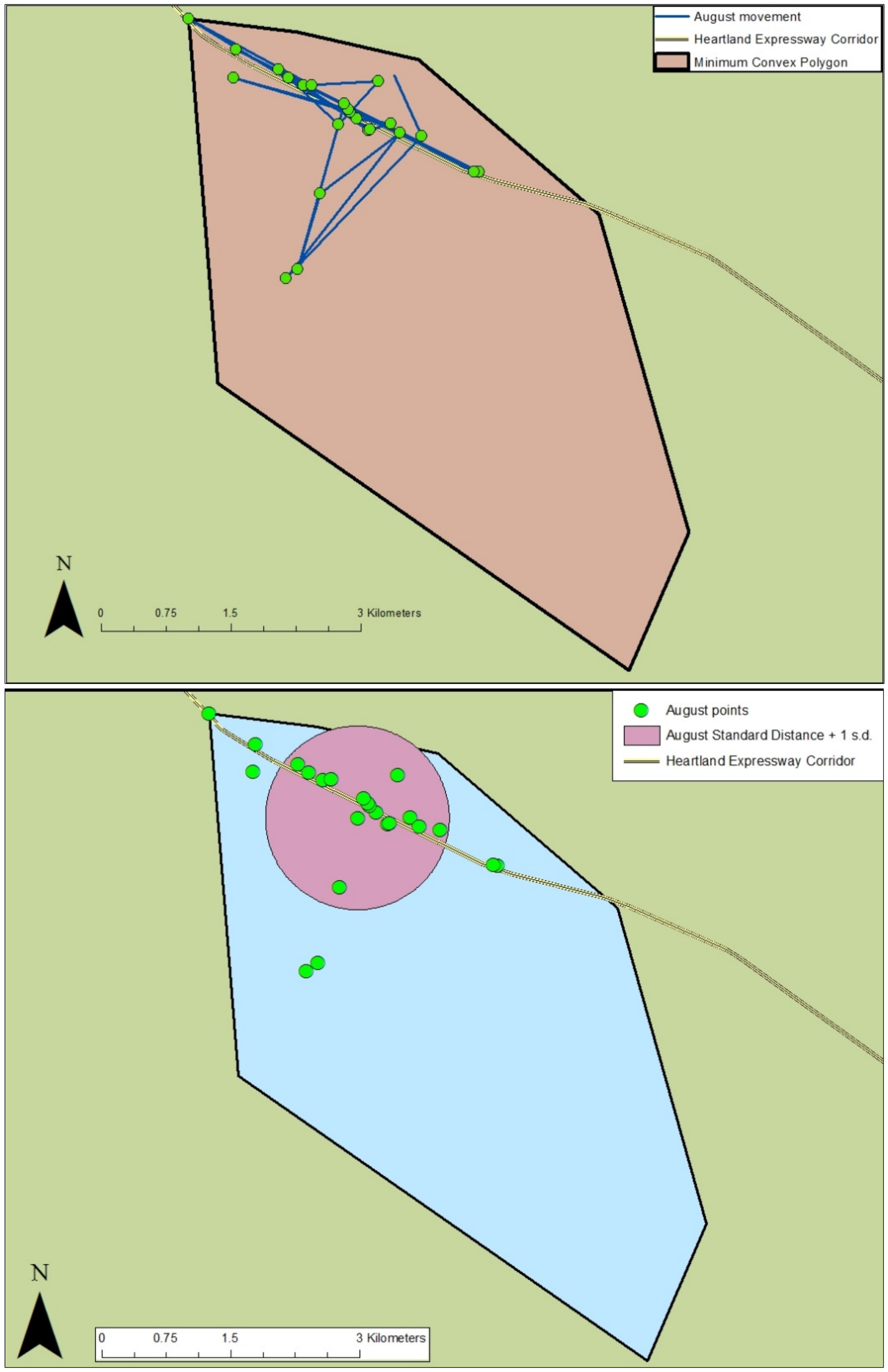


Figure 3.9: Movement lines and standard distance with 1 standard deviation for collar 1625862D for the month of August 2014 (ESRI 2014).

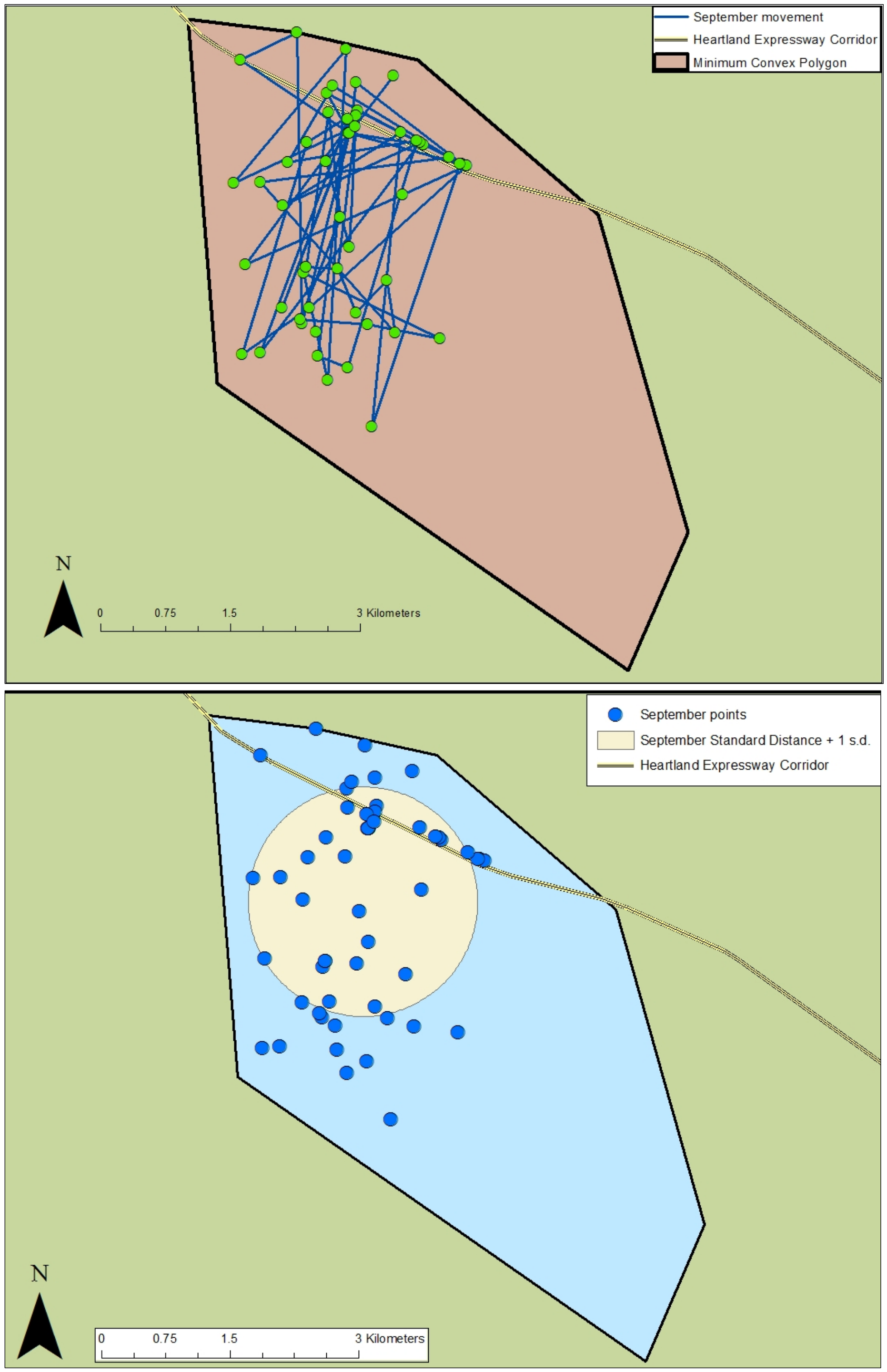


Figure 3.10: Movement lines and standard distance with 1 standard deviation for collar 1625862D for the month of September 2014 (ESRI 2014).

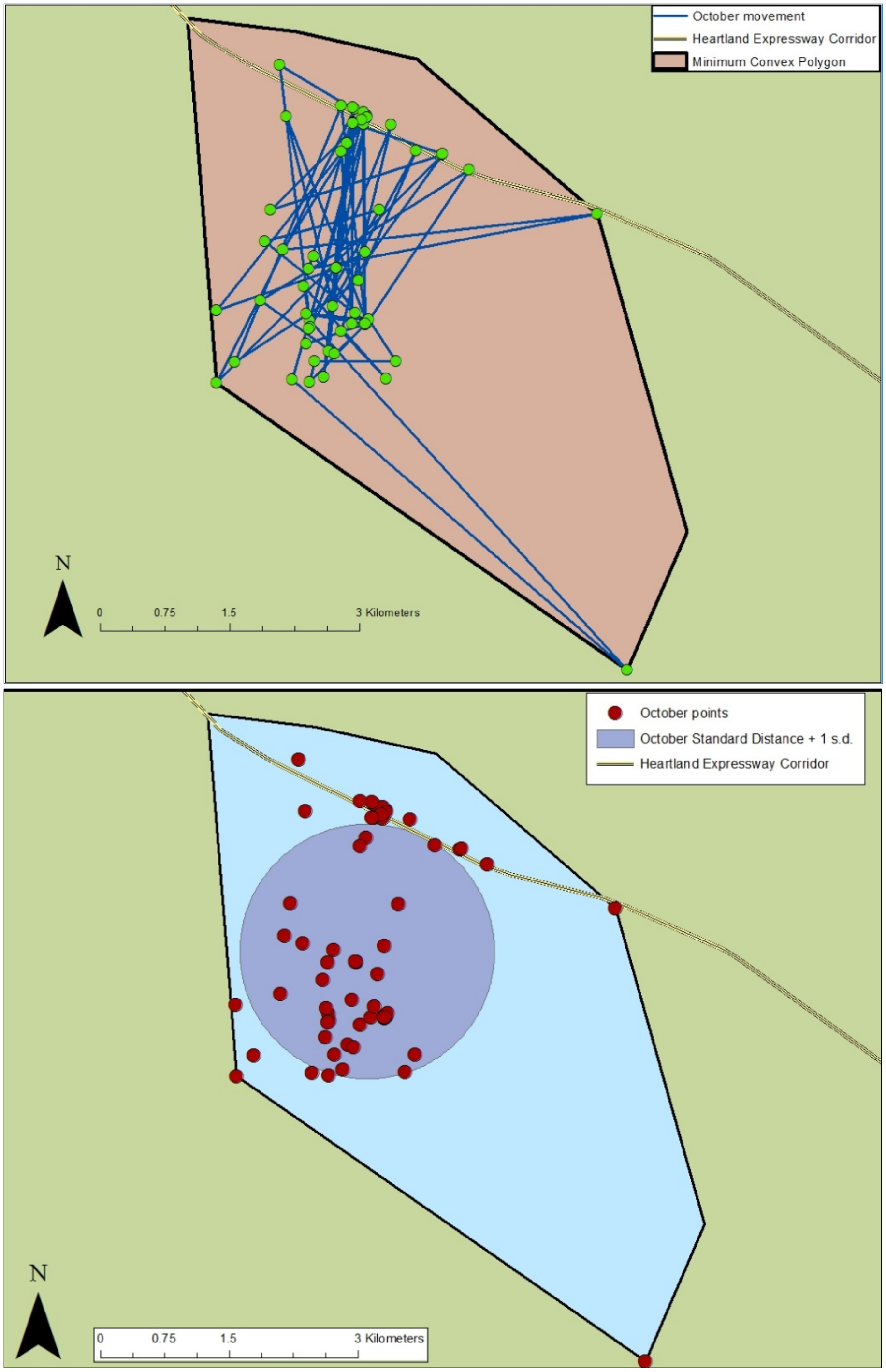


Figure 3.11: Movement lines and standard distance with 1 standard deviation for collar 1625862D for the month of October 2014 (ESRI 2014).

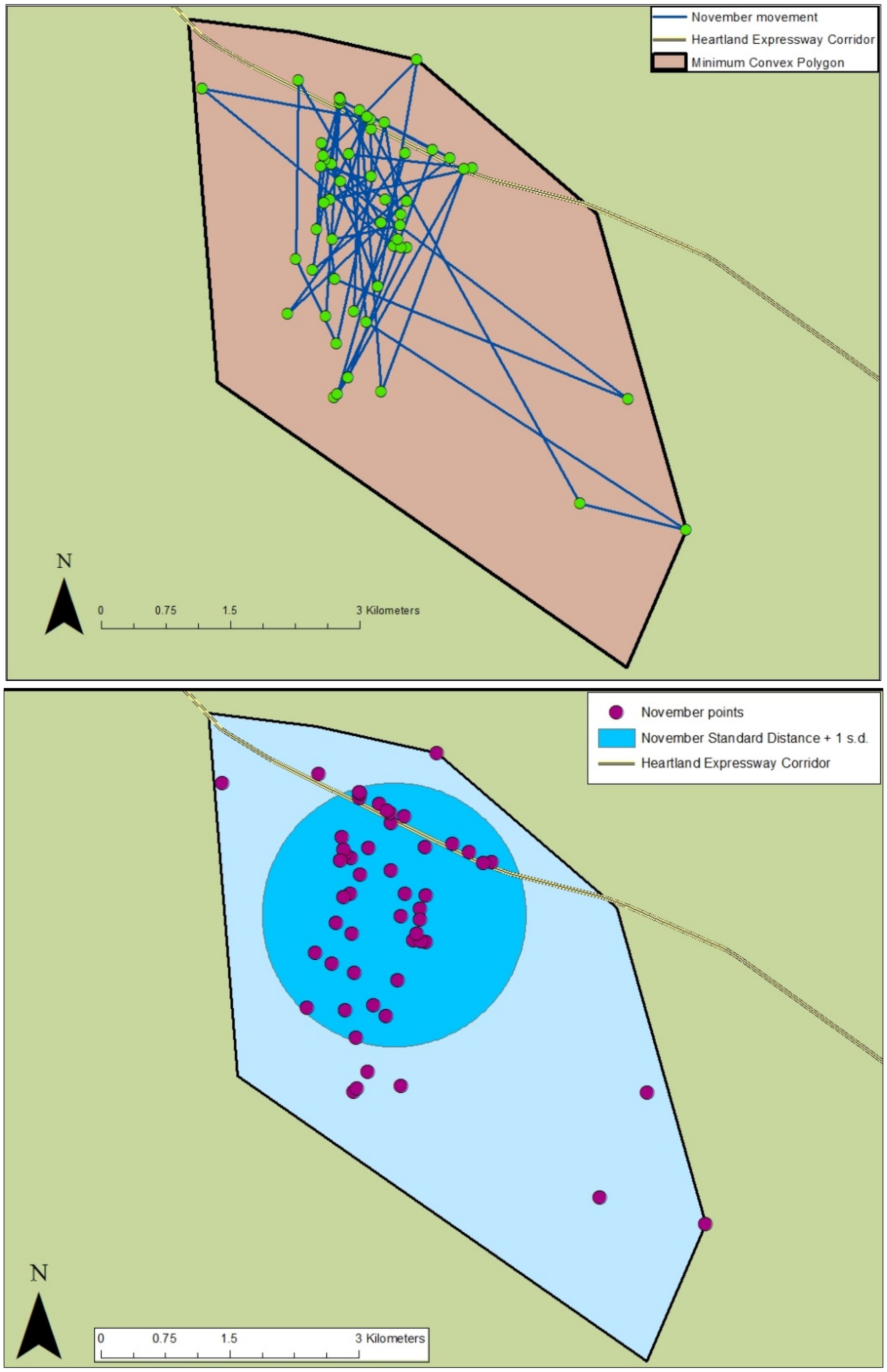


Figure 3.12: Movement lines and standard distance with 1 standard deviation for collar 1625862D for the month of November 2014 (ESRI 2014).

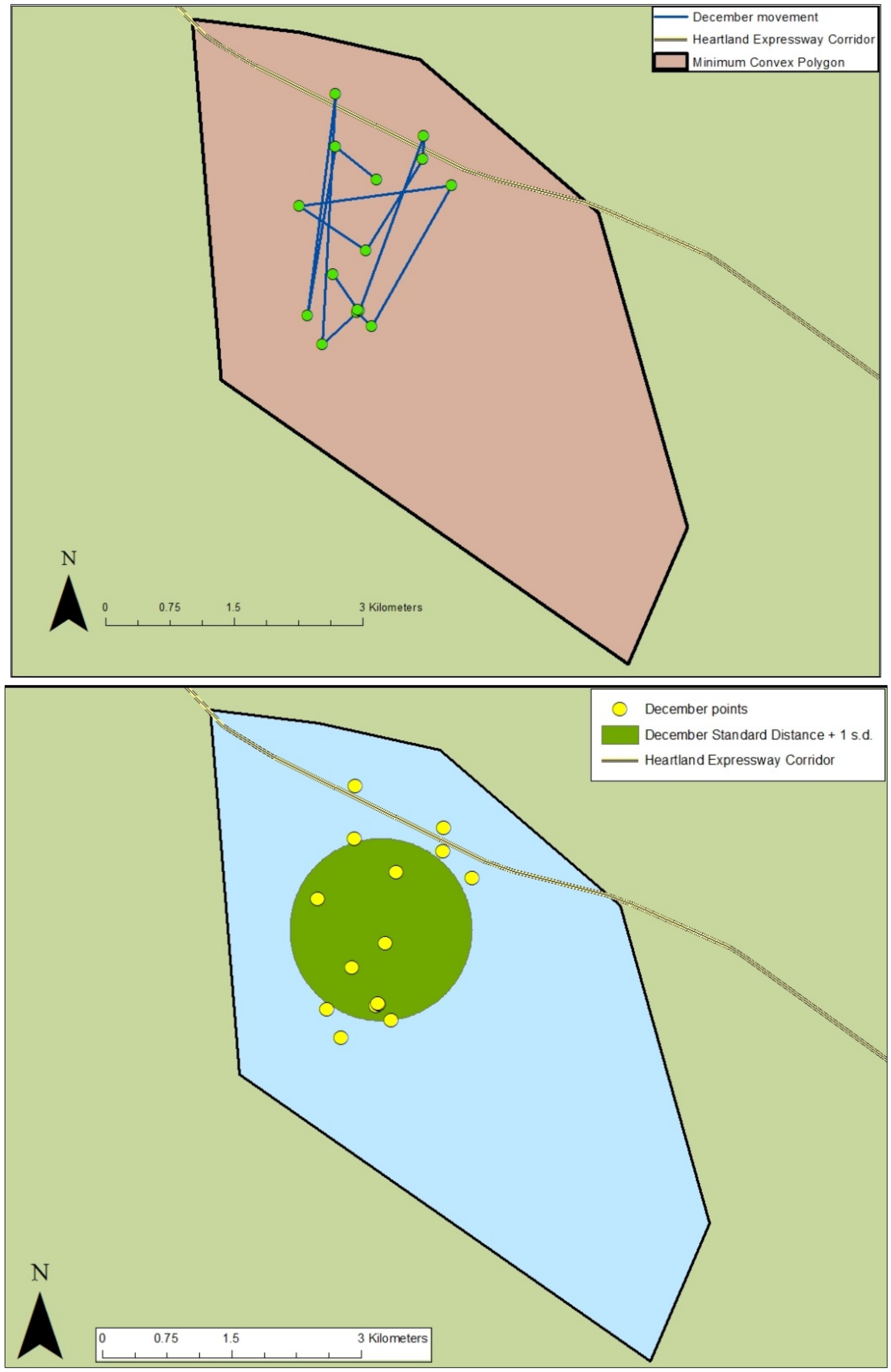
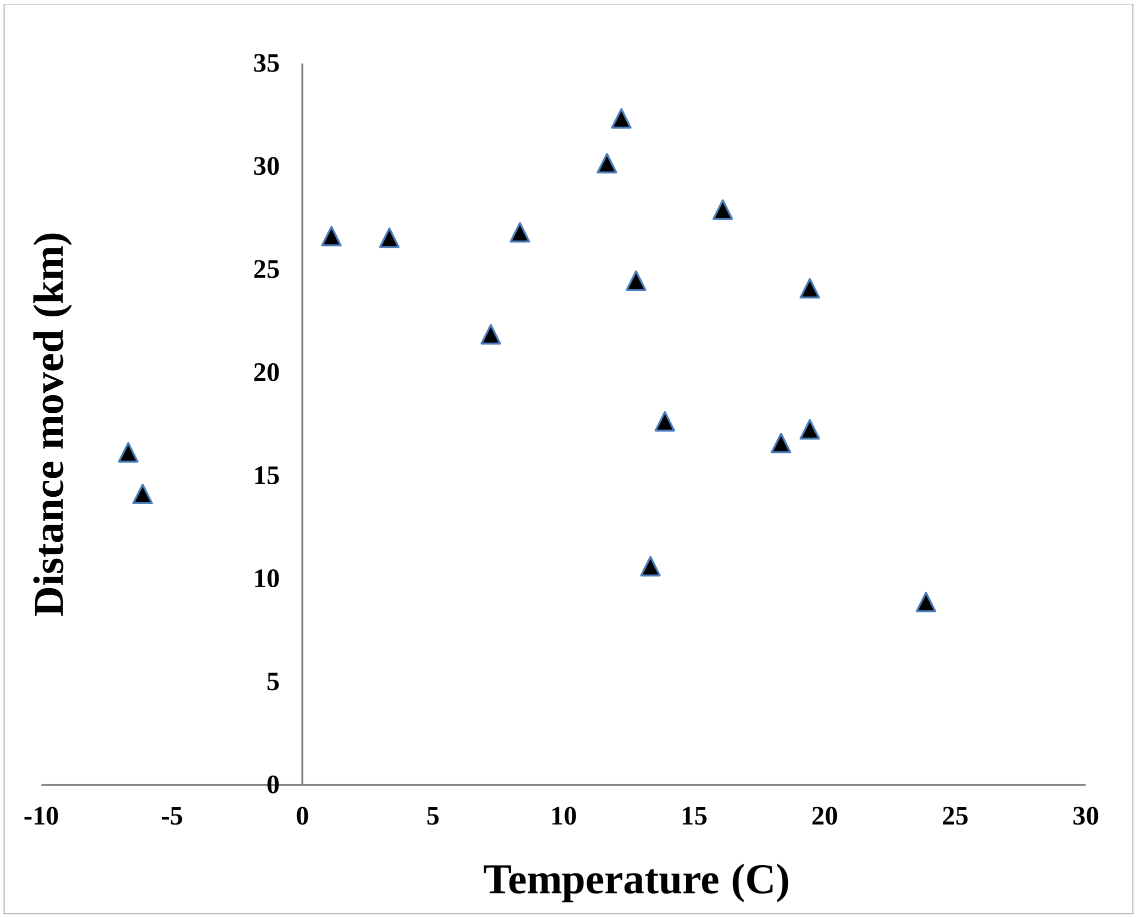


Figure 3.13: Movement lines and standard distance with 1 standard deviation for collar 1625862D for the month of December 2014 (ESRI 2014).


Distance moved (km)
35
30
25
20
15
10
5
0
-10
-5
0
5
10
15
20
25
30
Temperature (C)

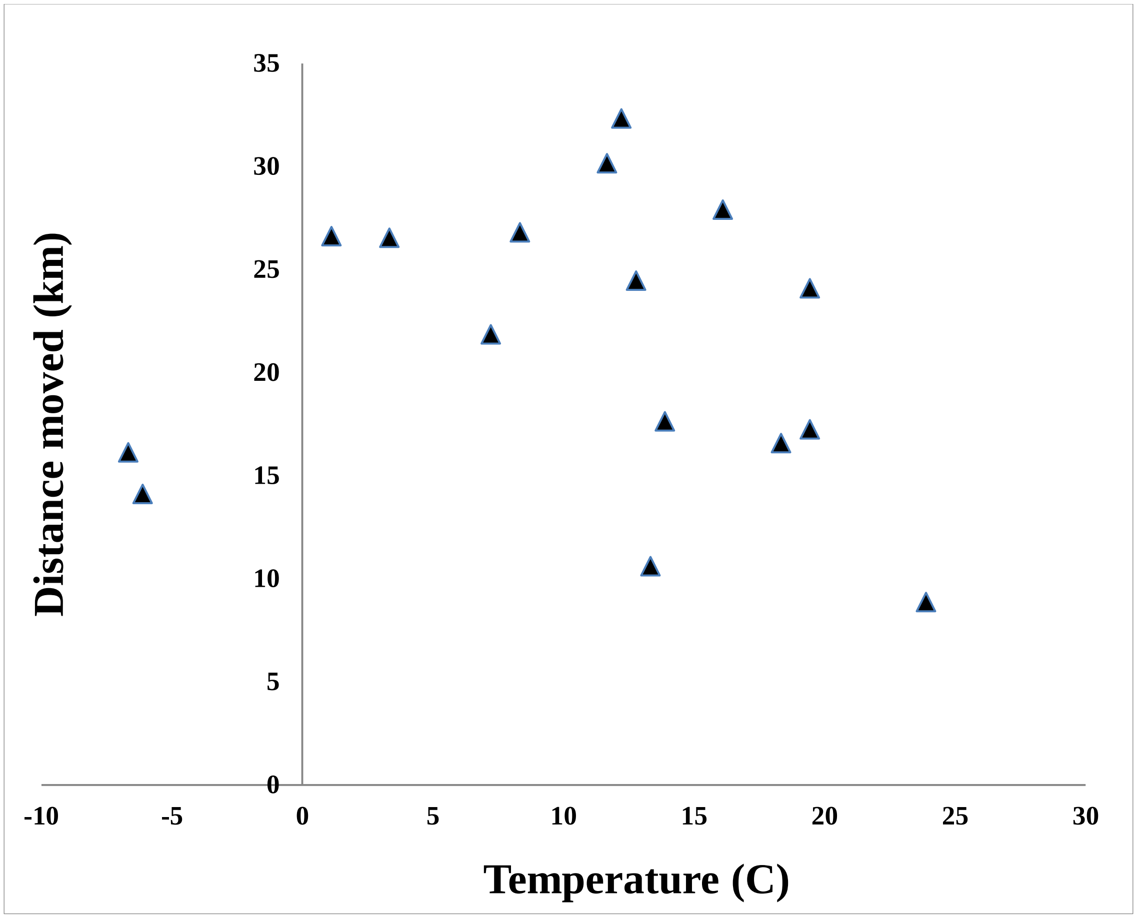


Figure 3.14: Scatterplot of weekly average temperature and weekly distance moved for collar 1625862D. Correlation coefficient of -0.082, with p>0.05.

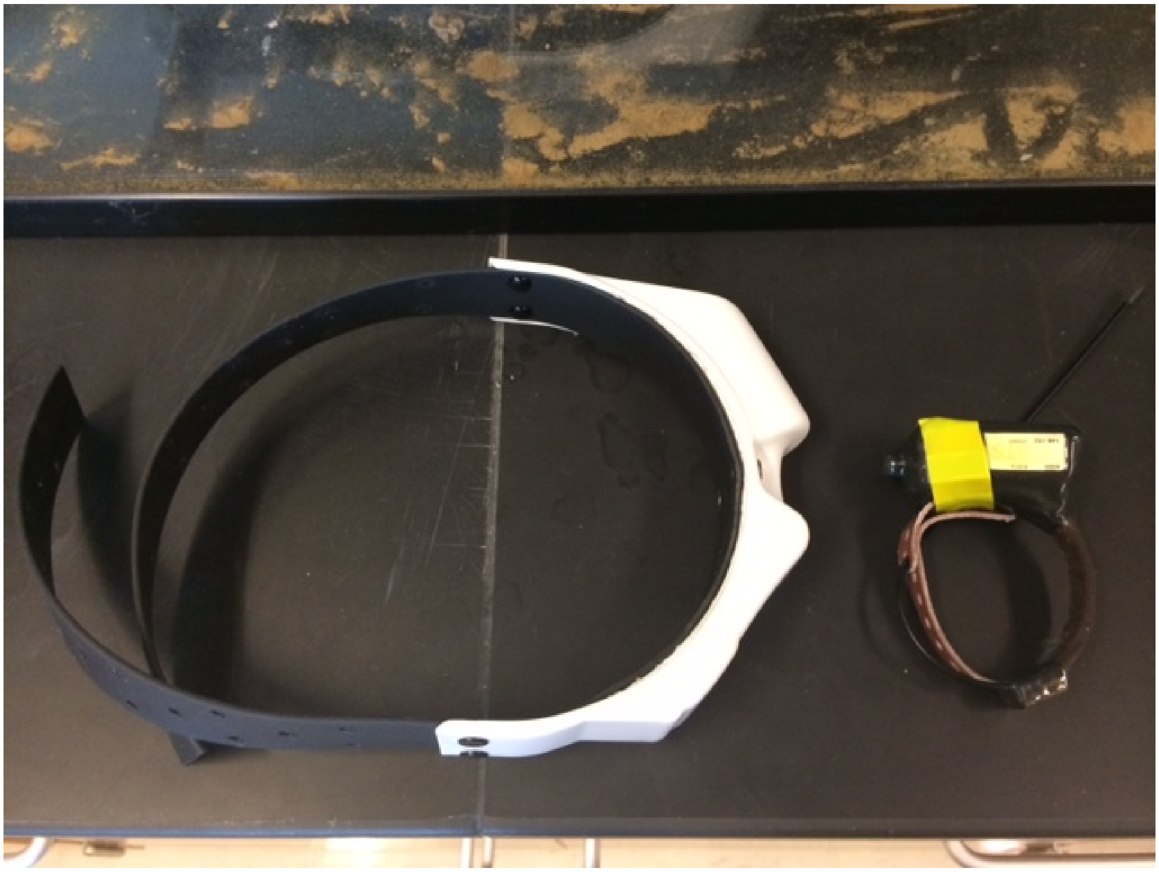


Figure 3.15: First prototype of GSM collar from Skorpa-Utrackit (left), showing immense size discrepancy when compared to ATS collar size (right).

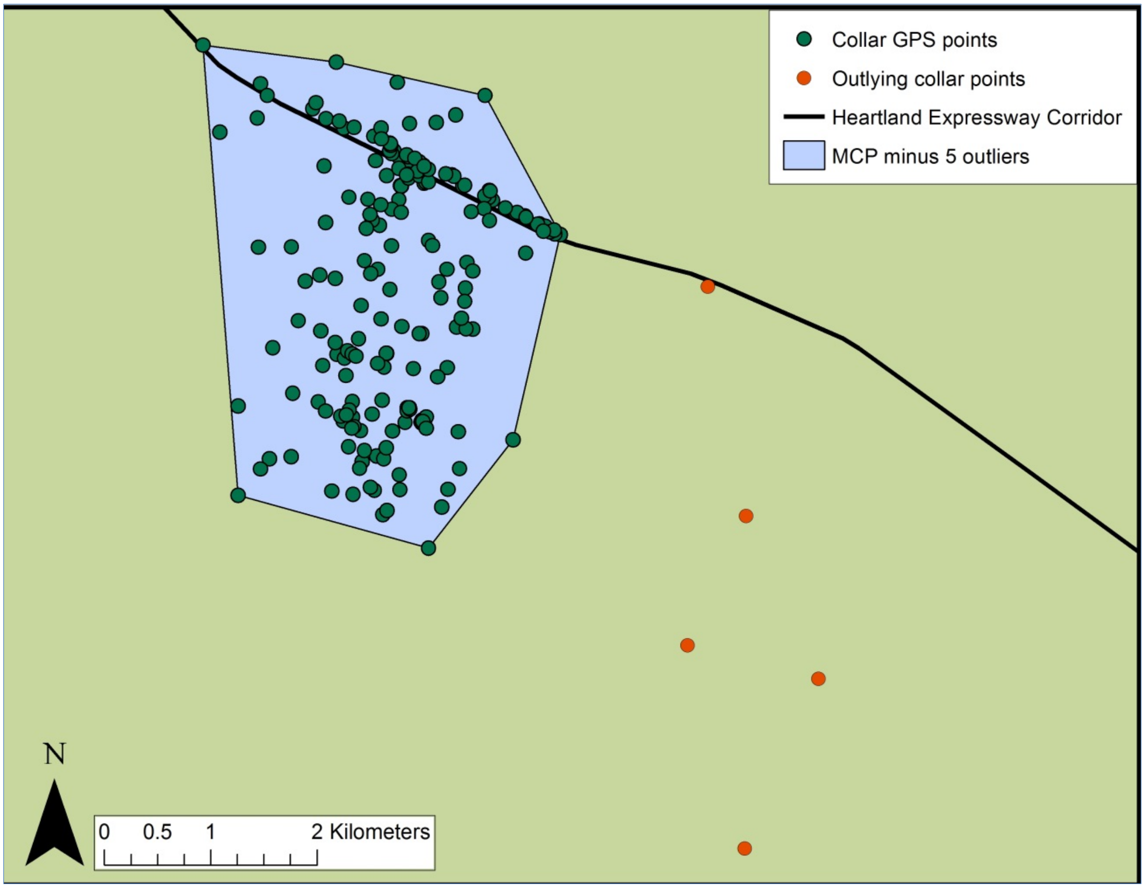


Figure 3.16: Minimum convex polygon of collar points after 5 furthest outliers are removed. Home range estimate is 11.92 km^2 (ESRI 2014).

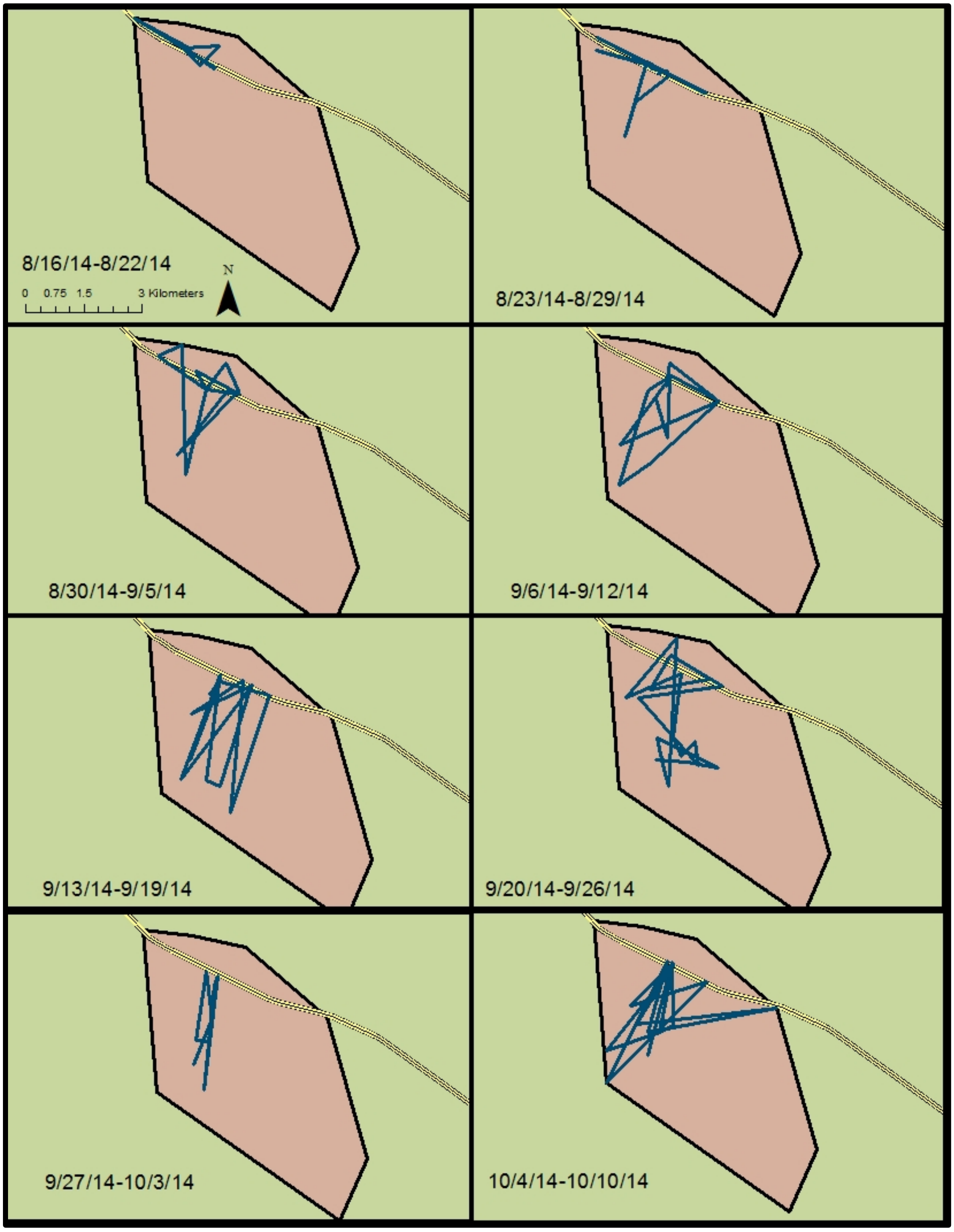


Figure 3.17: Weekly movement of collar 1625862D within animal's home range from 16 August 2014 to 10 October 2014 (ESRI 2014).

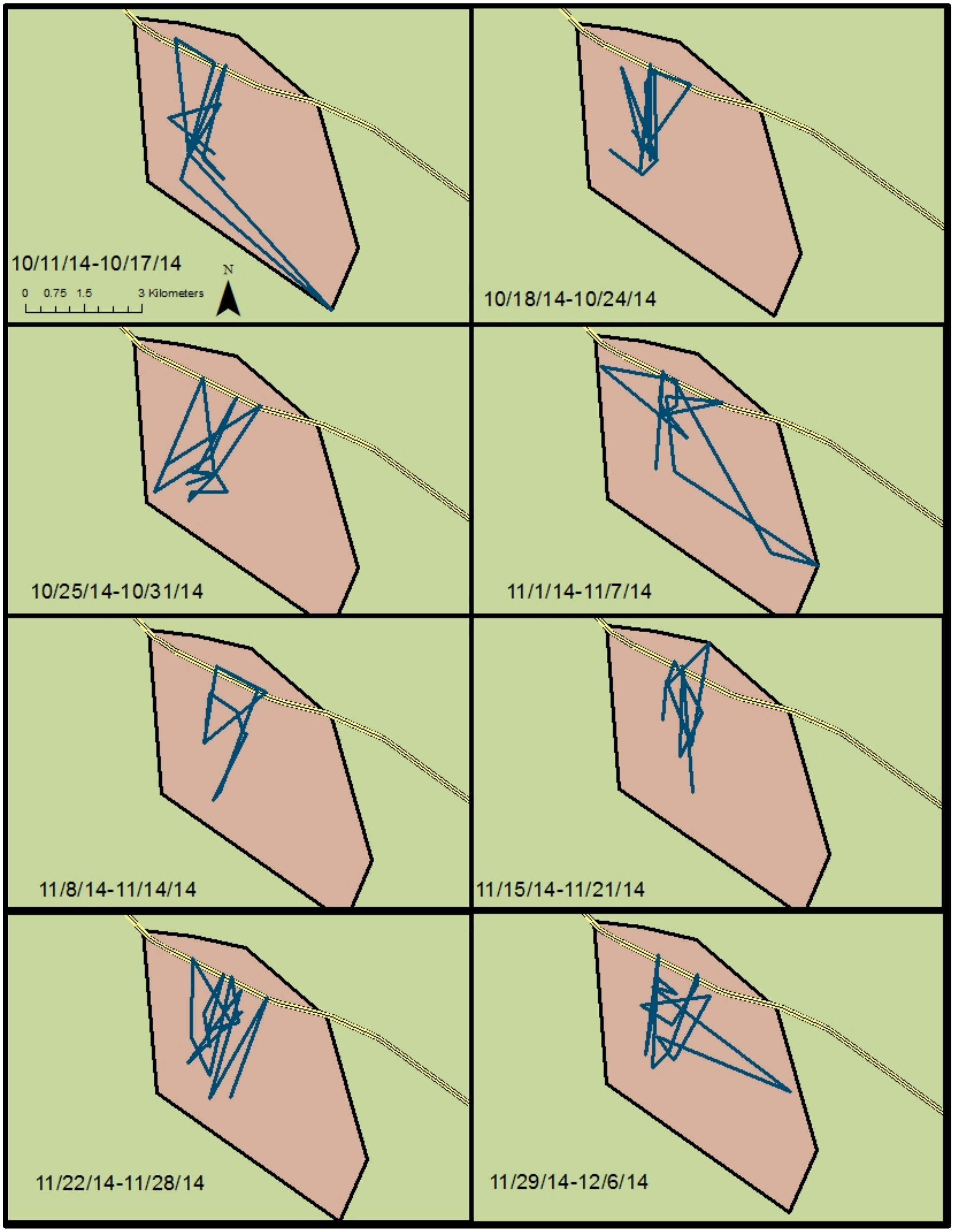


Figure 3.18: Weekly movement of collar 1625862D within animal's home range from 11 October 2014 to 6 December 2014 (ESRI 2014).

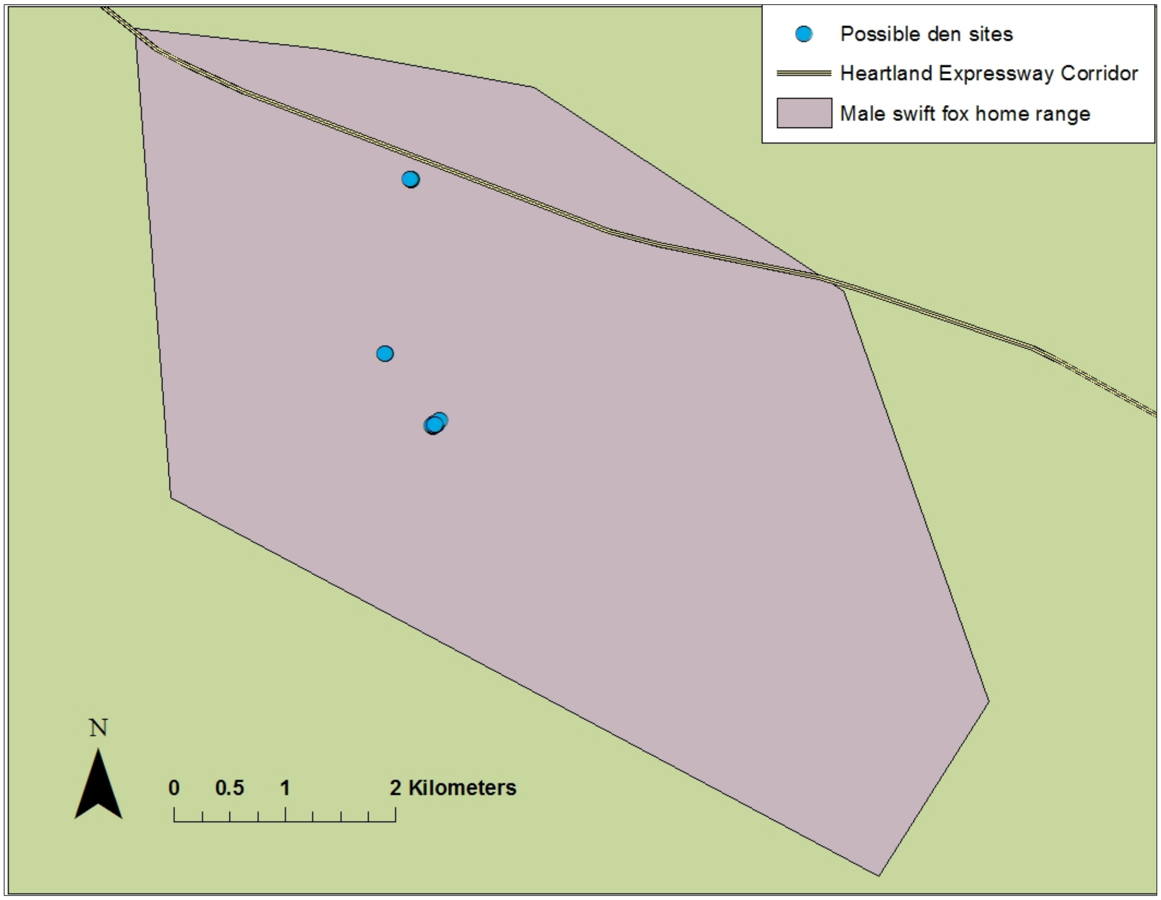


Figure 3.19: Areas of clustered GPS locations, logged within the 2100 or the 2300 hour, possibly indicating den sites for male 1625862D (ESRI 2014).

TABLES

Table 3.1: Data for individual collared swift foxes including weight, neck size, trapping location and collar identification number.

Animal	Sex	Weight (kg)	Neck circumference (cm)	Trapping location (UTM)	Collar ID
1	Male	2.48	19.5	13T 649715E 4759335N	Skorpa-1625862D
2	Female	2.44	N/A	13T 653133E 4758075N	ATS-033317
3	Female	2.40	16.7	13T 653133E 4758075N	ATS-033345

Table 3.2: Weekly distance moved by collar 1625862D and average weekly temperature in the Chadron, NE area for the same time period.

Week	Distance moved (km)	Average Temperature (°C)
8/16/14-8/22/14	8.86	23.89
8/23/14-8/29/14	17.24	19.44
8/30/14-9/5/14	16.57	18.33
9/6/14-9/12/14	17.62	13.89
9/13/14-9/19/14	27.9	16.11
9/20/14-9/26/14	24.08	19.44
9/27/14-10/3/14	10.6	13.33
10/4/14-10/10/14	32.32	12.22
10/11/14-10/17/14	30.15	11.67
10/18/14-10/24/14	24.46	12.78
10/25/14-10/31/14	21.85	7.22
11/1/14-11/7/14	26.8	8.33
11/8/14-11/14/14	14.11	-6.11
11/15/14-11/21/14	16.12	-6.67
11/22/14-11/28/14	26.53	3.33
11/29/14-12/6/14	26.61	1.11

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Chapter Four: Camera Survey Evaluation of Mammal Species Composition Along the Heartland Expressway Corridor in Western Nebraska

Abstract

Camera surveys are an important tool in wildlife monitoring that allows non-invasive documentation of species. A camera survey of the Heartland Expressway Corridor was conducted in western Nebraska in the summer of 2014, resulting in 250 animal documentations over 278 stations.

Raccoons (*Procyon lotor*) and feral cats (*Felis catus*) were found most often in areas of higher human densities, as they make use of human resources. Striped skunks (*Mephitis mephitis*) and coyotes (*Canis latrans*) appeared to avoid areas of high human density. The low numbers of coyotes documented near Scottsbluff further improves feral cat habitat as coyotes may predate on cats. American badgers (*Taxidea taxus*), while not avoiding roads, may be choosing areas of lower traffic volume and speed.

Several mammal species are present along the Heartland Expressway Corridor in western Nebraska using various vegetation and habitat types. Human population density may be a factor in the presence of some species.

Keywords

Western Nebraska, camera survey, mammal composition, Heartland Expressway Corridor, roads, habitat use, camera survey

Introduction

Trail camera surveys have become increasingly common in monitoring wildlife species for conservation purposes. Many inferences can be made from the data collected from camera surveys repeated over multiple seasons including wildlife diversity and composition, animal activity and changes in these aspects over time (Liu et al. 2013). Although population estimates require the use of species that can be identified to individuals by photograph, such as tigers (*Panthera tigris*), values such as relative abundance can be calculated for other species of interest (Linkie et al. 2013; Liu et al. 2013). While there is evidence that some wildlife can see and hear trail cameras while in operation, potentially producing a bias as to which species are documented, camera surveys consistently return valuable data covering a wide range of taxa that would otherwise not be possible (Meek et al. 2014). This survey method is one of the most effective and least invasive means of species documentation.

The Heartland Expressway Corridor (HEC) is part of a larger road construction project that will expand pre-existing 2-lane highway into 4-lane divided highway, forming a close equivalent to a north-south running interstate through a portion of the United States where no interstate exists (HEA n.d.).This larger road system is the Great Plains International Trade corridor and will stretch from Canada to Mexico, with the goal of increasing trade through the movement of goods as well as decreasing traffic congestion (HEA n.d.). Currently a third of the HEC located in the state of Nebraska has already been expanded to 4-lane divided highway. This section runs approximately from Kimball, NE to Scottsbluff, NE.

The study area through which the HEC will run is varied in habitat type and geological features, and vegetation composition changes along its north-south gradient. This area includes a combination of irrigated and dry land agriculture, grazing pasture, buttes, the Pine Ridge forest and the Platte River valley. The face of the landscape has also changed significantly over the past 40 years. From the mid-1970's to the mid-1980's land cover changed primarily from grassland to agriculture. However due to a variety of factors, there has been a positive net change from agricultural lands back to grasslands in the last 15 years of the 20th century (Drummond et al. 2012).

Objectives

A camera survey was carried out along the Heartland Expressway Corridor in the summer of 2014 to document species along the roadway and to examine patterns of species presence in relation to habitat availability, human infrastructure and other wildlife presence.

Materials and Methods

Study Area

The panhandle of Nebraska falls within the Great Plains geographic region. This area is typically dry, with low humidity and precipitation (Schneider et al. 2011). Temperatures average -10°C in the winter and 30°C in the summer (Climate-Nebraska 2014). This region has undergone fluctuations in the conversion rates of grassland to agriculture in the past 40 years (Drummond et al. 2012).

The HEC will run roughly north to south for just over 300 km along the length of the panhandle. The route will run south from the South Dakota border, through Chadron and Alliance, NE, west to Scottsbluff, NE and the Wyoming border and then south from Scottsbluff to Kimball, NE and the Colorado border.

Vegetation composition in a 1.6 km buffer of the HEC is made up primarily of shrub and grasslands (44%) and agricultural land (39%), with smaller amounts of woodlands, open water and disturbed/other human use (Figure 4.1) (UNL SNR 2005).

Field Work

Stations with Bushnell Trophy Cam HD Model 119537C trail cameras were placed on either side of the roadway, approximately every 1.6 km (1 mi). Desired camera locations were plotted prior to the beginning of field work using Map Window 4.8.8, taking into account proximity to infrastructure, land permission, and habitat preference for swift foxes (*Vulpes velox*), the target species of the survey (MapWindow 2013). Locations where permission was not available for both sides of the HEC had one only camera placed per 1.6 km division.

Stations were placed on NDOR right-of-ways (ROW), public land, county roads and private property where permission had been obtained. Cameras were mounted to existing infrastructure (fence posts, power line poles, etc.), attached to a t-bar or mounted inside a vinyl camera cover constructed to roughly resemble buried cable indicators in the ROW. Scent stakes were placed 2.5 m from the camera and baited with skunk essence petroleum jelly mixed in a ratio of 15 ml of skunk essence to 385 ml of petroleum jelly.

Stations were run for approximately 120 hours, a minimum of 5 nights, and then cameras were collected.

An index of relative abundance (IRA) was calculated for each grouping by dividing the number of stations recording the species by the total number of stations placed, multiplied by 1000. This estimate demonstrates the portion of the study area that is located within the home range of at least one individual of the species (Linhart and Knowlton 1975; Linkie et al. 2013). Liu et al. (2013) calculated an additional relative abundance index, which will be delineated as RAI-Liu, by dividing the number of stations recording the species by the total number of animal records and multiplying this by 100. This measurement shows the proportion of all wildlife documented that was comprised by the specified species.

Vegetation composition around stations documenting specific wildlife was examined by buffering each station with an area half the size of an average home range for that species. For rural raccoons (*Procyon lotor*) this was 1.27 km^2 (Prange et al. 2004). This produced a buffer radius of 0.45 km. This buffer layer was used to clip the Nebraska GAP vegetation layer in ArcGIS 10.2.2 (ESRI 2014; UNL SNR 2005). The expected values used for a chi-squared goodness-of-fit test were calculated by multiplying the percentage of pixels in each vegetation category present in a 1.6 km buffer along the HEC by the total number of pixels contained in the buffer around the stations registering the species of interest (Figure 4.2). This produced expected values for each category if vegetation composition around the stations matched the composition of the HEC as a whole. A buffer of 1.6 km was chosen because no stations were placed further than 0.8 km from the HEC and those stations placed at 0.8 km were intended to detect any wildlife between the station and the HEC. Assuming a maximum detection radius of 0.8 km, the widest detection during the survey would have been 1.6 km from the road.

This method was also used to evaluate vegetation presence around stations documenting striped skunks (*Mephitis mephitis*), coyotes (*Canis latrans*), and American badgers (*Taxidea taxus*). The home range estimate used for striped skunks was 6.69 km^2 (Doty and Dowler 2006). Home range estimates of 11.18 km^2 for resident coyotes were averaged from two studies out of Colorado and northern Texas (Gese et al. 1990; Kamler et al. 2005). The home range estimate for American badgers was 7.85 km^2 (Goodrich and Buskirk 1998).

Vegetation composition around the HEC in each county was determined by examining pixel counts within a 1.6 km buffer of the HEC in each county. Vegetation categories used came from the Nebraska GAP vegetation layer (UNL SNR 2005). They included Forest/ Woodland, Shrub/Grassland, Agricultural vegetation, Recently Disturbed/ Developed, Open Water, and Miscellaneous. Miscellaneous included semi-desert, introduced, and semi-natural vegetation categories.

Results

The camera survey documented 250 individual animals along the HEC consisting of herbivorous, carnivorous and omnivorous species (Table 4.1). Primary species included raccoon (Figures 4.3 and 4. 4), mule deer (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus virginianus*) (Figures 4.5 and 4.6), striped skunk (Figures 4.7 and 4.8), coyote (Figures 4.9 and 4.10), feral cat (*Felis catus*) (Figures 4.11 and 4.12), and American badger (Figures 4.13 and 4.14). Smaller numbers of additional species were also documented, including swift fox, Virginia opossum (*Didelphis virginiana*) and North American porcupine (*Erethizon dorsatum*). Of 278 stations, 120 (43%) recorded wildlife.

Chi-squared goodness-of-fit tests revealed a vegetation composition around stations documenting raccoons that was significantly different from the composition available along the HEC, $p<0.001$ (Table 4.2). Similar significant results were found for striped skunk, coyote and American badgers, $p<0.001$ (Tables 4.3-4.5).

Vegetation composition differs for each county within a 1.6 km buffer of the HEC (UNL SNR 2005). The buffer through Dawes County is made up of 65% shrub and grassland, while Box Butte is 60% agricultural. The Morrill County buffer contains 64% shrub and grassland and Scotts Bluff is 58% agricultural. The Banner County buffer is made up of 64% shrub and grassland and Kimball County has similar amounts of grassland and agriculture at 42% and 46% respectively.

Discussion

Raccoon Presence

The species with the highest frequency in this survey was the raccoon which was present at 47 stations (Figures 4.3 and 4.4). The IRA for the species is 170 and the RAI-Liu is 19 (Table 4.1). The average IRA value for track station surveys in the Nebraska panhandle from 1974-1981 was 23.6, lower than that found in this study (Roughton

1974-1978; Roughton and Sweeny 1979; Roughton and Bean 1980; Bean 1981). The higher abundance in the present study may be due to the ability of camera traps used in this study to document wildlife even if they do not approach the scent bait, as is necessary for track stations. Similar surveys in Minnesota by Sargeant et al. (1998) resulted in an IRA of 70.

Chamberlain et al. (2007) found that raccoons located in a prairie habitat will seek out forested areas for cover while still remaining close to cropland, such as corn fields, that provide food and water resources. Raccoons are known to utilize human refuse as food which is found in higher densities where humans are present (Gehrt et al. 2009). While no significant difference was found between raccoon presence along 2-lane roads and 4-lane roads, raccoons used significantly different amounts of habitat than what was available along a 1.6 km buffer of the HEC (Table 4.2). Agricultural land was used more often than expected while less grassland and less woodland were utilized than was available. Although raccoons tend to seek out woodlands for cover, only 5% of the entire HEC buffer was classified as woodland habitat and so croplands may be acting as a substitute for denning and cover for the species. Of the 47 stations that documented raccoons along the HEC, 20 are within the county of Scottsbluff. Scottsbluff is the county with the highest human population density in the study area, with 19.3 people per km^2 and is primarily agricultural along the HEC (US DOC 2010).

Raccoons tend to behave as a solitary and non-territorial species but there is evidence that they may aggregate together when resources are clumped rather than randomly distributed (Prange et al. 2004). A station located along the 4-lane highway running east from Scottsbluff documented two raccoons moving together. This is not unusual in summer months as raccoons may be traveling from urban to more rural habitat with juveniles that were born that spring (Prange et al 2004).

Overall the raccoon population documented in the survey appears to be adhering to previously observed patterns of habitat selection for the species. They are present in higher numbers in areas where there are more resources from human presence, including food refuse and cropland.

Mule and White-tailed Deer Presence

Mule deer and White-tailed deer were documented at 37 stations (Figures 4.5 and 4.6) and were the largest wildlife species documented during the camera survey. Not all individuals could be identified to species from the photographs. Grouping both species of deer together gives an IRA of 130 and a RAI-Liu of 15(Table 4.1).

Habitat preference differs between the two species. Mule deer tend to prefer open areas with more rugged terrain while white-tailed deer favor gentler terrain with higher amounts of wooded cover (Lingle and Wilson 2001). Deer species were seen in all 6 counties of the study area with Dawes and Scotts Bluff counties accounting for 68% of all stations. These two counties have very different habitat composition and human population densities and it may be that between the two there is sufficient preferred habitat for both mule deer and white-tailed deer available, explaining their high levels of presence there.

Striped Skunk Presence

Striped skunks were recorded at 32 stations (Figures 4.7 and 4.8). Their IRA was calculated to be 120 and their RAI-Liu is 13(Table 4.1). The average IRA value for track station surveys in the Nebraska panhandle from 1974-1981 was 41.5, lower than those found in this study (Roughton 1974-1978; Roughton and Sweeny 1979; Roughton and Bean 1980; Bean 1981). Similar indices from Minnesota for skunks (*Mephitis mephitis* and *Spilogale putorius*) give a value of 50 (Sargeant et al.1998).

Striped skunks are known to make use of various habitat types for their dens including areas of thick cover, fence rows and irrigation system ditches and they use multiple dens both above and below ground (Doty and Dowler 2006). Male and female home ranges overlap significantly, unlike many other species of mustelids (Lariviere and Messier 1998). Breeding occurs in the spring and males then disperse around June (Hansen et al. 2004).

The skunks documented in the camera survey used significantly different categories of vegetation than what is available along the HEC (Table 4.3). Woodlands were used more often than expected, most likely because of two stations that occurred within the Pine Ridge forest region in Dawes County. The category showing the second largest divergence from expected values was the miscellaneous grouping containing semi-desert, introduced and semi-natural vegetation. A visual examination of this vegetation shows that it is primarily composed of introduced and semi-natural vegetation that is scattered within larger plots of shrub and grassland.

Hansen et al. (2004) found that skunks located close to houses were often shot by land owners. This was the largest source of mortality in the study. Scotts Bluff and Box Butte counties have the highest population densities in the study area but account for only 6 out of 32 skunk stations (US DOC 2010). It is possible that human presence in these areas may be excluding skunks.

Coyote Presence

Coyotes were seen at 26 stations (Figures 4.9 and 4.10). The IRA for the species is 90 and the RAI-Liu is 10 (Table 4.1). The average IRA value for track station surveys in the Nebraska panhandle from 1974-1981 was 179.8, higher than that found in this study (Roughton 1974-1978; Roughton and Sweeny 1979; Roughton and Bean 1980; Bean 1981). Similar indices from Minnesota by Sargeant et al. (1998) give a value of 32.5.

Habitat usage by coyotes was significantly different than available vegetation in a 1.6 km buffer of the HEC (Table 4.4). More grassland was present with less agricultural, wooded and recently disturbed or developed areas than expected. Although coyotes adapt to fragmented environments, they do not appear to be attracted to areas of high human activity, but instead prefer open areas, with water access and less development (Gehrt et al. 2009). The areas of highest human population densities are in Scotts Bluff and Box Butte Counties and these two counties account for only 5 of the 26 coyote stations (US DOC 2010). The three counties with the lowest human population density, Banner, Morrill and Kimball, account for 17 of the 26stations, or 65%.

Coyotes, particularly females, have been shown to exhibit fear responses to novel stimuli (Heffernan et al. 2007). The possibility therefore exists that coyote numbers are actually higher along the HEC than seen in this survey but that the cameras failed to document additional animals due to their hesitation to approach novel items such as the scent stake and the trail camera.

Two stations documented coyotes rubbing on the scent stake, presumably to pick up the skunk scent on their fur. This behavior is consistent with documented coyote behavior when approaching some novel stimuli (Heffernan et al. 2007).

Feral Cat Presence

Feral cats were seen at 25 stations along the HEC (Figures 4.11 and 4.12). Of these 25 stations, 15 were located within Scotts Bluff County. The IRA for the species is 90 and the RAI-Liu is 10 (Table 4.1).

Feral cats are found most often in areas with higher human populations as 35% of all households in the United States own cats and the majority of cats in the country are owned as pets (Kays and DeWan 2004). Feral cats can reach density levels up to 100 times that of native carnivore predators in some areas because of the supplemental feeding provided by humans (Kays and DeWan 2004). Scotts Bluff County has the highest human density within the study area, so it is not surprising that 60% of all feral cat documentations occurred there (US DOC 2010). Track stations documented an IRA value of 6.6 across the Nebraska panhandle from 1974-1981, which may highlight the increase in human population in the panhandle since that time, as increases in human presence bring higher numbers of cats to the area (Roughton 1974-1978; Roughton and Sweeny 1979; Roughton and Bean 1980; Bean 1981).

Scotts Bluff County was also one of the two counties, along with Box Butte, that had the lowest levels of coyote presence. Coyotes have been shown to regulate populations of non-native feral cats through predation and have also been shown to actively avoid urban areas due to the higher human population density (Cove et al. 2012; Gosselink et al. 2003). It is logical that an area of high urban density coupled with low coyote presence would see higher densities of cats.

American Badger Presence

American badgers were located at 15 stations (Figures 4.13 and 4.14). The IRA for the species is 50 and the RAI-Liu is 6 (Table 4.1). The average IRA for badgers in the panhandle from 1974-1981 was 14 (Roughton 1974-1978; Roughton and Sweeny 1979; Roughton and Bean 1980; Bean 1981).

American badgers are considered to be an obligate species in prairie ecosystem, preferring croplands (Duquette et al. 2014). Their relationship with roads is complicated with some studies finding them to avoid roads while also being associated with disturbed linear landscape features like roads (Duquette et al. 2014). The species also suffers high vehicle mortality rates (Hoodicoff et al. 2009). The majority of badger stations, 73%, were located either along county roads or on private land. Only 27% were located in the HEC ROW and only one of these stations was located along 4-lane highway, which is characterized by higher traffic volume and faster vehicle speed. It is possible that while badgers may not be avoiding roads, they may prefer less travelled highways. This would lower the probability of vehicle mortality.

The chi-squared goodness of fit test examining badger habitat use showed a significant difference between observed and expected vegetation types, $p<0.001$ (Table 4.5). Examination of individual categories shows higher use of agricultural fields and less use of forest/ woodland, shrub and grassland, and recently disturbed/ developed land than expected.

Less common species

Several additional species were documented at low numbers during the survey including swift foxes, red foxes (*Vulpes vulpes*), Virginia opossums (*Didelphis virginiana*) and North American porcupine (*Erethizon dorsatum*).

Swift foxes were documented at 7 stations along the HEC, in Dawes and Kimball counties (Figure 4.15). The IRA for the species is 30 and the RAI-Liu is 3 (Table 4.1). No kit or swift foxes were positively identified by track station from 1974-1981 at any of 4 study areas in the Nebraska panhandle located along the HEC route (Roughton 1974-1978; Roughton and Sweeny 1979; Roughton and Bean 1980; Bean 1981). Studies in western Kansas and southeastern Colorado documented IRA values of 26 and 191for swift foxes respectively (Sargeant et al. 2003; Schauster et al. 2002). All stations, except for the single station located in Kimball County, documented single animals along 2-lane highway with some amount of shrub and grassland present at or near to the station. The Kimball County station documented 4 swift foxes moving along an unpaved county road.

This station was the only swift fox location adjacent to 4-lane highway and was completely surrounded by plowed agricultural fields.

There were 5 documentations of red foxes, 3 of which were found along 4-lane highway. The IRA for the species is 20 and the RAI-Liu is 2 (Table 4.1). The average IRA for red foxes in the panhandle from 1974-1981 was 8.8 (Roughton 1974-1978; Roughton and Sweeny 1979; Roughton and Bean 1980; Bean 1981). Expanded highway increases traffic volume, and potentially increases levels of development and human disturbance. Red foxes have been show to select habitat close to humans (Cove et al. 2012). Although Banner and Kimball Counties have lower population densities than some counties in the northern portion of the route, human habitations close to the HEC, coupled with plentiful agriculture which may provide higher rodent densities along this stretch of roadway may account for the presence of the foxes (US DOC 2010). The increase in IRA values in the panhandle from 1981 to the present study may be a result of increases in human population in the area during that time. These values are still lower than those from a similar survey in Minnesota, with an IRA of 140 (Sargeant et al. 1998).

Virginia opossums were documented at 4 locations, all within Scotts Bluff County (Figure 4.16). Preferred habitat usually consists of areas of woodlands in close proximity to water (Beatty et al. 2014). Scotts Bluff County has the highest percentage of open water in the 1.6 km buffer around the HEC of all counties in the study area, 1.7%, and is second only to Dawes County in percentage of the buffer that is composed of forest and woodlands. Scotts Bluff County also has the highest human population density of the study area and opossums will often live near to human populations, making use of refuse and pet food (Troyer et al. 2014).

A North American porcupine was documented at one station along the HEC (Figure 4.17). This location was located in the southern portion of the survey, 3.5 km from the Colorado border, along a county road between agricultural fields. There was almost no forest or woodlands present. While porcupines are primarily arboreal and tend to utilize woodlands for habitat, they have also been observed using dense ground vegetation for cover (Coltrane and Sinnott 2013; Marshall et al. 1962). While this location is in an area of low human population density as porcupines tend to select, it is completely surrounded by agriculture and there is evidence that porcupines avoid fields (Morin et al. 2005). This location appears to be unusual for this species and may represent an individual on the edge of their habitat range.

Conclusions

A variety of mammal species, common and threatened, was documented along the HEC in western Nebraska during the summer of 2014. The use of trail cameras allowed a noninvasive survey to examine mammal composition along a roadway in the panhandle of Nebraska. Characteristics such as vegetation type and human population density appear to be useful factors in predicting species presence.

FIGURES

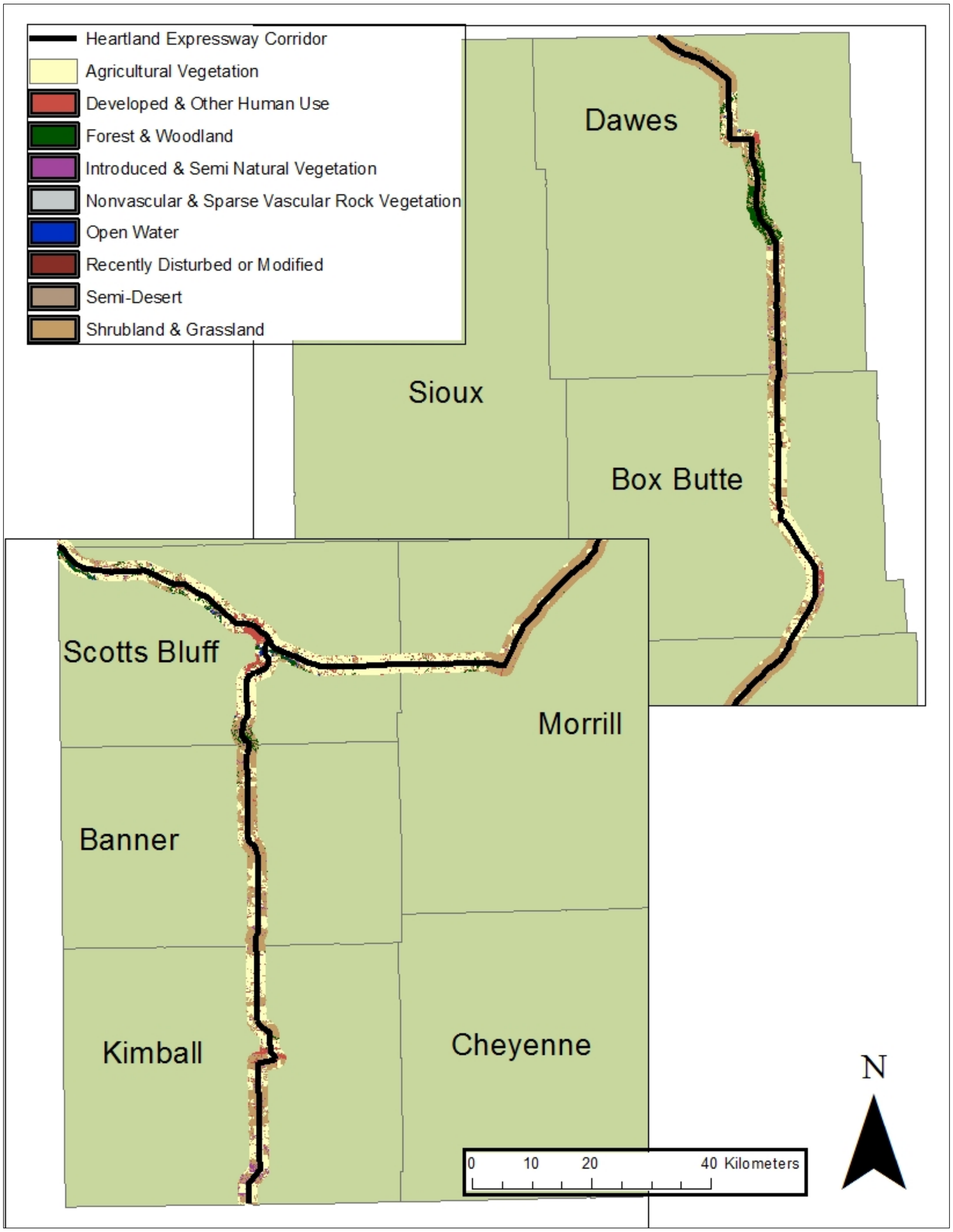

Figure 4.1: Nebraska GAP vegetation composition and categories within a 1.6 km buffer of the HEC (ESRI 2014; UNL SNR 2005).

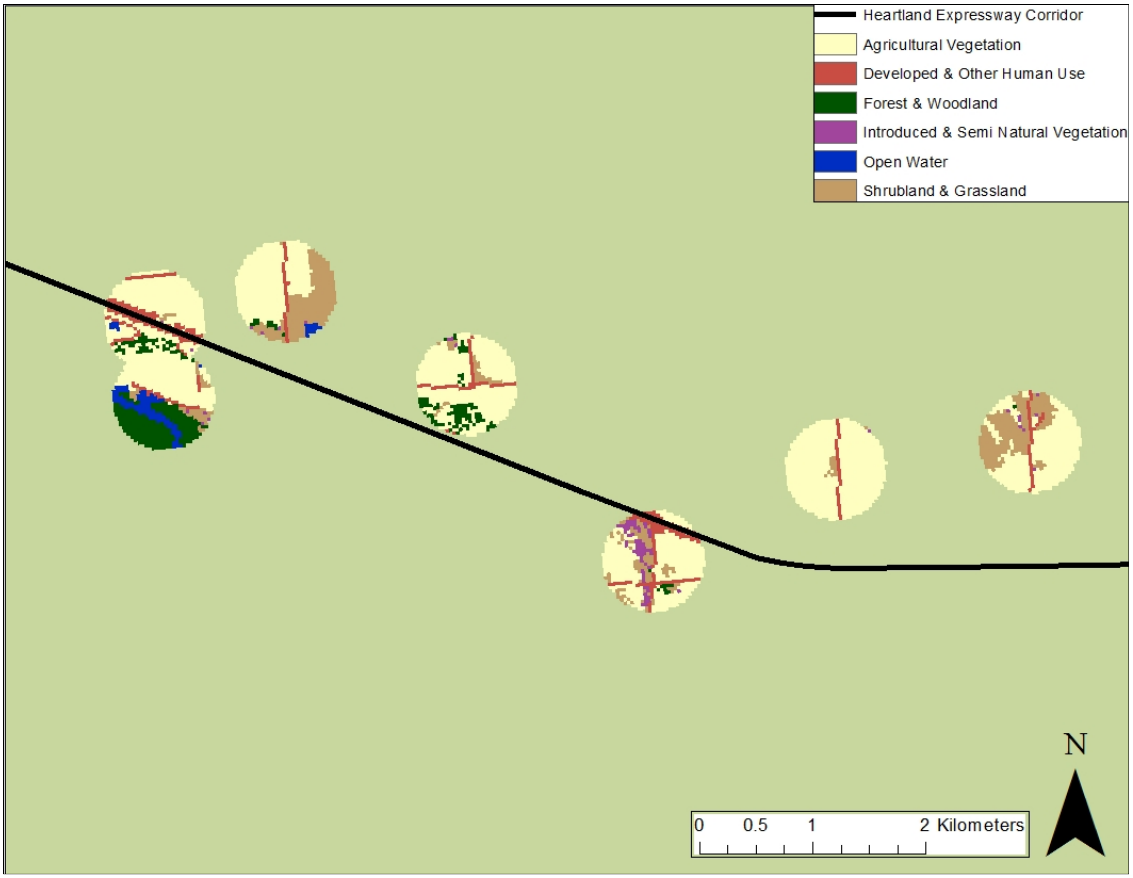

Figure 4.2: Example of buffers surrounding stations recording raccoons during the camera survey in the summer of 2014. Buffers illustrate Nebraska GAP vegetation categories (ESRI 2014; UNL SNR 2005).

Figure 4.3: Stations along the HEC where raccoons were documented during the summer of 2014 (ESRI 2014).

Figure 4.4: Photo documentation of raccoons on 18 June 2014 in Scotts Bluff County.

Figure 4.5: Stations along the HEC where mule and white-tailed deer were documented during the summer of 2014(ESRI 2014).

Figure 4.6: Photo documentation of mule deer on 5 June 2014 in Kimball County.

Figure 4.7: Stations along the HEC where striped skunks were documented during the summer of 2014 (ESRI 2014).

Figure 4.8: Photo documentation of a striped skunk on 5 June 2014 in Kimball County.

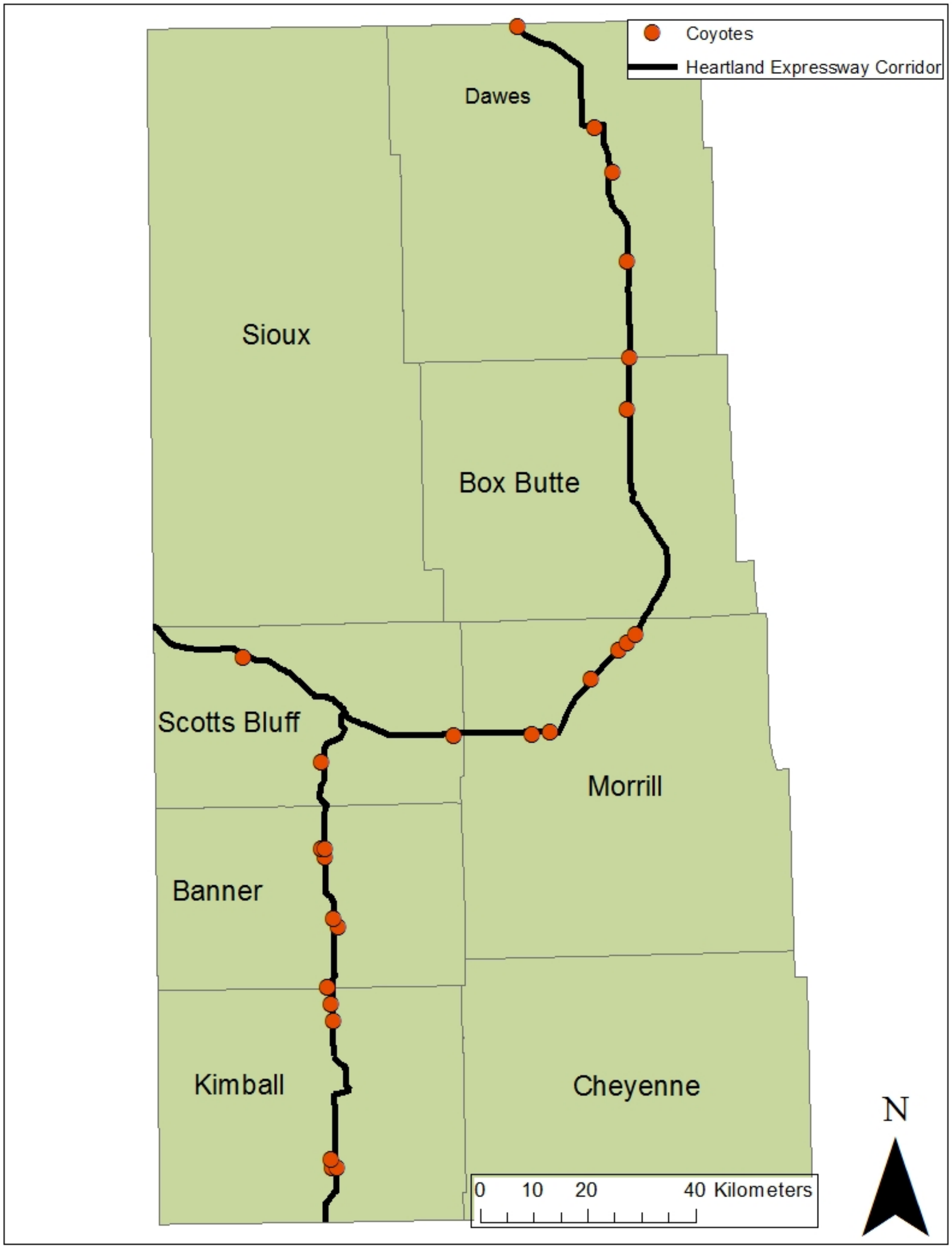

Figure 4.9: Stations along the HEC where coyotes were documented during the summer of 2014 (ESRI 2014).

Figure 4.10: Photo documentation of a coyote on 22 May 2014 in Dawes County.

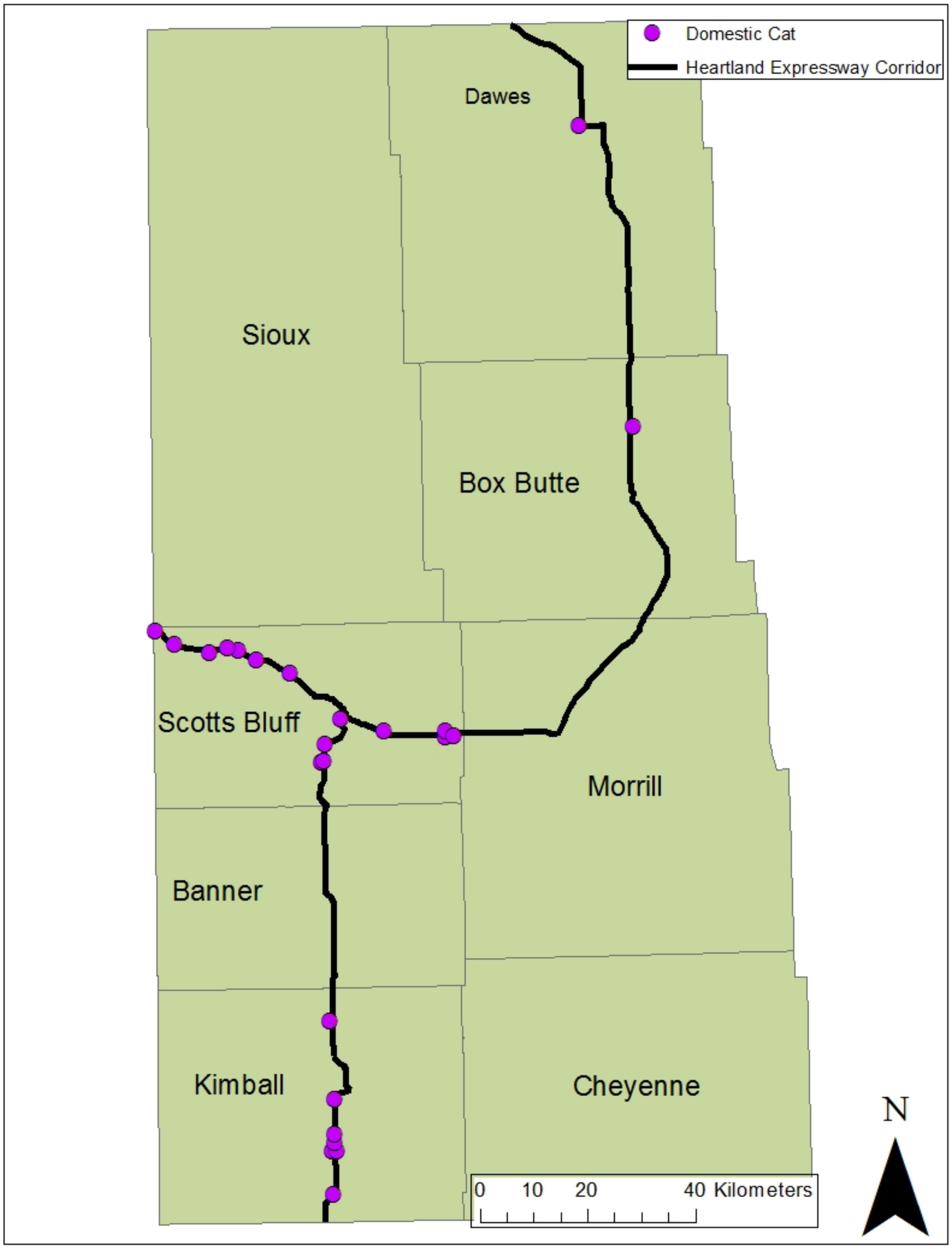

Figure 4.11: Stations along the HEC where feral cats were documented during the summer of 2014 (ESRI 2014).

Figure 4.12: Photo documentation of a feral cat on 7 June 2014 in Kimball County.

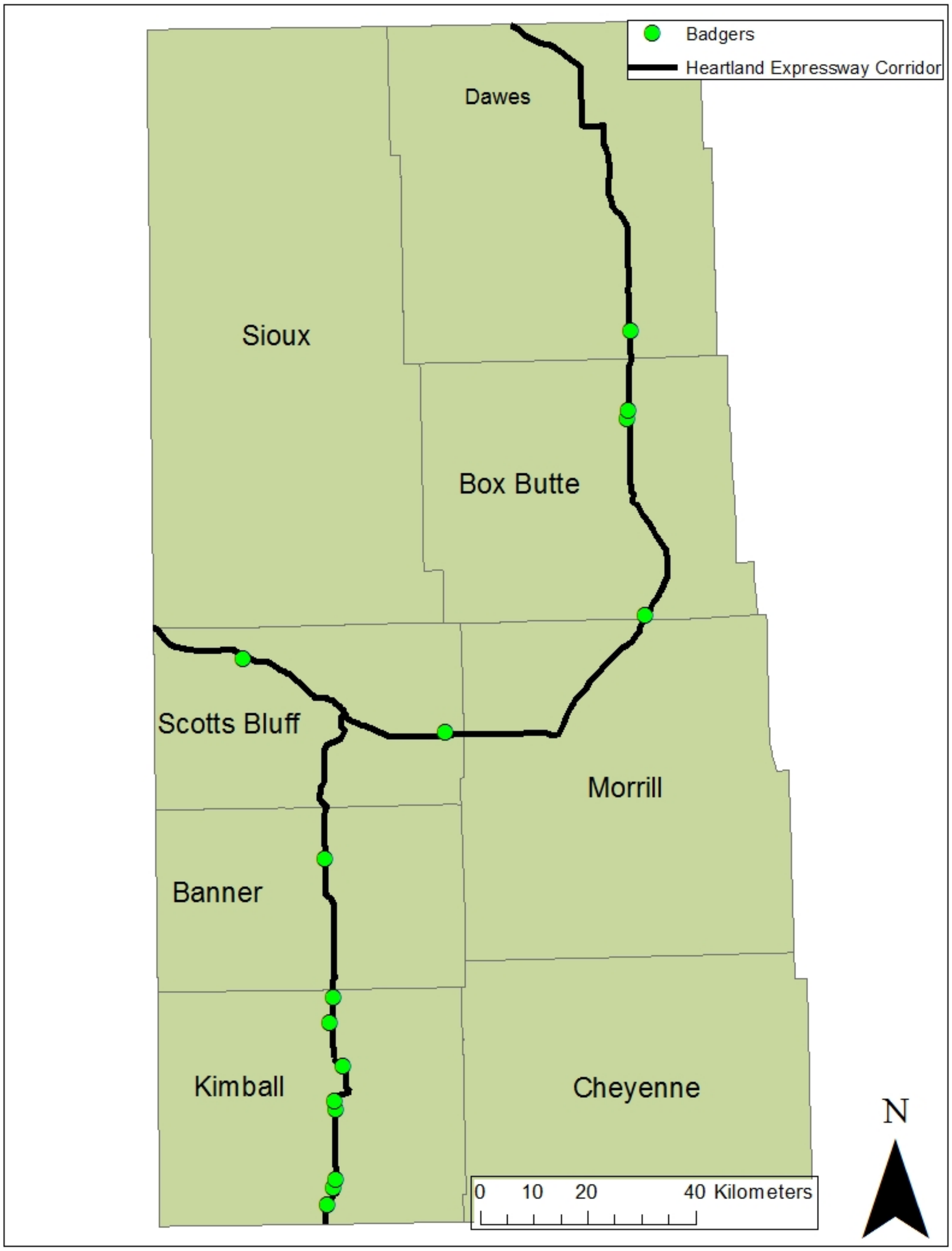

Figure 4.13: Stations along the HEC where American badgers were documented during the summer of 2014 (ESRI 2014).

Figure 4.14: Photo documentation of an American badger on 6 June 2014 in Kimball County.

Figure 4.15: Photo documentation of a swift fox on 11 June 2014 in Kimball County.

Figure 4.16: Photo documentation of a Virginia opossum on 16 June 2014 in Scotts Bluff County.

Figure 4.17: Photo documentation of a North American porcupine on 4 June 2014 in Kimball County.

TABLES

Table 4.1: Wildlife counts across all stations of the camera survey of the HEC, including Index of Relative Abundance (IRA), calculated by dividing the number of stations documenting a species by the number of stations, multiplied by 10000, and relative abundance index (RAI-Liu), calculated by dividing the number of stations documenting a species by the total number of animal documentations, multiplied by 100.

Species	# of stations	Index of relative Abundance (IRA) (Linhart and Knowlton 1975)	Relative Abundance Index (RAI-Liu) (Liu, et al. 2014)
Raccoon	47	170	19
Deer	37	130	15
Striped skunk	32	120	13
Coyote	26	90	10
Domestic cat	25	90	10
Rodent	17	60	7
Rabbit	15	50	6
Badger	15	50	6
Swift fox	7	30	3
Red fox	5	20	2
Miscellaneous	24	80	9

Table 4.2: Chi-Squared goodness-of-fit test for raccoon (*Procyon lotor*) habitat preference (number of pixels) versus available habitat within a 1.6 km buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship ($p<0.001$).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	1065.0	1761.4	275.3
Shrub/ Grassland	7068.0	14296	3654.4
Agricultural vegetation	19859.0	12785	3914.1
Recently disturbed/ Developed	3459.0	2857.1	126.8
Open Water	271.0	164.3	69.3
Miscellaneous	694.0	552.3	36.4
Totals	32416	32416	**8,076.4*** **

Table 4.3: Chi-Squared goodness-of-fit test for striped skunk (*Mephitis mephitis*) habitat preference (number of pixels) versus available habitat within a 1.6 km buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship ($p<0.001$).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	9909	6001.3	2544.5
Shrub Grassland	46449	48707.6	104.7
Agricultural vegetation	40465	43559.5	219.8
Recently disturbed/ Developed	9503	9734.2	5.5
Open Water	321	559.7	101.8
Miscellaneous	3797	1881.7	1949.6
Totals	110444	110444	**4,926.0*****

Table 4.4: Chi-Squared goodness-of-fit test for coyote (*Canis latrans*) habitat preference (number of pixels) versus available habitat within a 1.6 km buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship ($p<0.001$).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	4646	8302.5	1610.4
Shrub/ Grassland	79633	67384.7	2226.3
Agricultural vegetation	56526	60262.5	231.7
Recently disturbed/ Developed	9626	13466.8	1095.4
Open Water	357	774.3	224.9
Miscellaneous	2006	2603.2	137.0
Totals	152794	152794	**5,525.7*** **

Table 4.5: Chi-Squared goodness-of-fit test for badger (*Taxidea taxus*) habitat preference (number of pixels) versus available habitat within a 1.6 km buffer of the Heartland Expressway Corridor. Asterisks denote a significant relationship (p<0.001).

Vegetation category	Observed (pixels)	Expected (pixels)	χ^2
Forest/Woodland	576.0	3468.0	2411.7
Shrub/ Grassland	23993.0	28147.0	613.1
Agricultural vegetation	31438.0	25172.0	1559.8
Recently disturbed/ Developed	5492.0	5625.2	3.2
Open Water	64.0	323.4	208.1
Miscellaneous	2260.0	1087.4	1264.6
Totals	63823	63823	**6,060.4*** **

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