Effects of Four-Lane Highways on Desert Kit Fox and Swift Fox: Inferences for the San Joaquin Kit Fox Population

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Final Report

State of California, Department of Transportation

Division of Research and Innovation, Office of Materials and Infrastructure Research

April 30, 2010

Effects of Four-Lane Highways on Desert Kit Fox and Swift Fox: Inferences for the San Joaquin Kit Fox Population

Final Report

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15. SUPPLEMENTAL NOTES

Cover photo: Swift fox using a culvert to cross I-70 in eastern Colorado. Photo taken by remote triggered infrared camera.

16. ABSTRACT

Limited information is available on whether San Joaquin kit fox (*Vulpes macrotis mutica*) use below grade passages, design parameters that might facilitate their use, or what rate of passage is needed to offset habitat connectivity losses. This final report details four field studies conducted between September 2007 and January 2010. Swift fox (*Vulpes velox*) were studied in Colorado and South Dakota and desert kit fox (*Vulpes macrotis arsipus*) were studied in California. The aim of these companion studies was to investigate the movements and crossing behavior of swift and desert kit foxes around four-lane highways. The four-lane highways in our study areas were generally not a barrier to movement of swift fox and desert kit fox. Small sample sizes of fox crossings at monitored culverts prevented the ability to determine optimal crossing structure design for San Joaquin kit foxes. Nonetheless, some general principles with regard to design of wildlife crossings can be used as guidelines for this species. The best practice would be to install as many culverts or crossing structures as possible within San Joaquin kit fox range and where local habitat conditions are favorable.

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EXECUTIVE SUMMARY

Highway expansion projects are being planned in San Joaquin kit fox (*Vulpes macrotis mutica*) habitat. In an effort to maintain habitat connectivity, California Department of Transportation (Caltrans) has begun incorporating culvert-like conduits as wildlife crossing structures into these highway projects (Clevenger 2005). Limited information is available on whether kit fox use below grade passages such as culverts (Bremner-Harrison et al. 2007), design parameters that might facilitate their use, or what rate of passage is needed to offset habitat connectivity losses (Clevenger 2005).

This final report details four field studies conducted between September 2007 and January 2010. Swift fox (*Vulpes velox*) were studied in Colorado and South Dakota and desert kit fox (*Vulpes macrotis arsipus*) were studied in California. The aim of these companion studies was to investigate the movements and crossing behavior of swift and desert kit foxes around four-lane highways. We consider data collected on these surrogate species to be pertinent for making mitigation recommendations to benefit long-term San Joaquin kit fox recovery.

The four-lane highways in our study areas were generally not a barrier to movement of swift fox and desert kit fox. Thus, we can assert the same highway-crossing relationship is true for San Joaquin kit fox. Mortality of foxes does occur throughout the year but rates of mortality appear to be sustainable for local populations of foxes. Sustainable rates of mortality will likely occur in core areas of San Joaquin kit fox range. However, in non-core or marginal areas, road-related mortality could have serious negative consequences for local populations and pose a significant risk to long-term persistence.

Small sample sizes of fox crossings at monitored culverts prevented the ability to determine optimal wildlife crossing structure design for San Joaquin kit foxes. Nonetheless, some general principles with regard to design of wildlife crossing structures can be used as guidelines for this species (Clevenger and Huijser 2009).

The best practice would be to install as many culverts or wildlife crossing structures as possible within San Joaquin kit fox range and where local habitat conditions are favorable. Given the average home range size of San Joaquin kit foxes (5.9 km^2 with 2.7 km diameter; Nelson et al. 2007), we recommend a minimum of one culvert or crossing structure every 0.5 km (0.3 mi). This would result in multiple opportunities for below grade crossings in each fox home range. Culverts and crossing structures should be variable in size but a minimum diameter of 61 cm (24 in). In larger culverts, crossing structures and underpasses, escape dens should be constructed.

Solid median barriers have the potential to obstruct at-grade movement and can increase time spent on highways and thus the risk of road-related mortality. Therefore solid median barriers should not be constructed on highways in San Joaquin kit fox range. Alternative median barrier designs that allow for greater cross-highway movement should be incorporated into new highway designs. In the absence of median barriers, fencing is not necessary. When animals are successfully crossing roads and mortality from vehicles is not a limiting factor, fencing should be discouraged. If solid median barriers are present, then fencing may be beneficial in helping guide foxes to below grade crossing opportunities.

Critical to the effective planning of mitigation for San Joaquin kit foxes will be science-based information obtained from species occurrence surveys where transportation projects may impact local populations and their long-term persistence.

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1. BACKGROUND

1.1. Project purpose

Roads have the potential to negatively impact wildlife populations directly (e.g., vehicle strikes, habitat loss, habitat fragmentation) and indirectly (e.g., changes in prey availability, changes in predator abundance) (Forman and Alexander 1998; Bjurlin and Cypher 2003; National Research Council 2005). In the case of the federally endangered and California state threatened San Joaquin kit fox (*Vulpes macrotis mutica*), these impacts could result in mortality, reduced productivity or reduced genetic exchange, among other detrimental effects (Bjurlin and Cypher 2003). In short, the long-term persistence of the San Joaquin kit fox may be at risk in roaded habitats.

At least 549 km (341.3 mi) of highways through San Joaquin kit fox habitat are slated for widening from two to four lanes, some of which will also include median barrier construction (Clevenger 2005). In an effort to maintain habitat connectivity for the San Joaquin kit fox, California Department of Transportation (Caltrans) has begun incorporating culvert-like conduits as wildlife crossing structures into these highway projects (Clevenger 2005). Limited information is available on whether kit fox use below grade passages such as culverts (Bremner-Harrison et al. 2007), design parameters that might facilitate their use, or what rate of passage is needed to offset habitat connectivity losses (Clevenger 2005). Data collected thus far suggest that San Joaquin kit foxes enter culverts ranging in size from 33 cm x 61 cm (12.9 in x 24.0 in) (height x width) to 185 cm x 170 cm (72.8 in x 66.9 in) but do not use them to cross the road, and confirmed vehicle strikes further suggest kit foxes attempt to cross at-grade (Bremner-Harrison et al. 2007; B. Cypher, Endangered Species Recovery Program, pers. comm.).This final report details four field studies conducted between September 2007 and January 2010. Swift fox (*Vulpes velox*) were studied in Colorado and South Dakota (Chapter 2). Desert kit fox (*Vulpes macrotis arsipus*) were studied in California (Chapter 3). Conclusions are summarized in Chapter 4. Mitigation recommendations for San Joaquin kit fox in relation to four-lane highways, along with future research recommendations, are presented in Chapter 5.

This report uses several different terms pertaining to structures that allow wildlife to cross under highways. Caltrans defines a “culvert” as a closed conduit which allows water to pass under a highway (The Caltrans Highway Design Manual 2009). The term “culvert” is used widely in this report since the main purpose of the structures that we monitored was for drainage rather than the movement of wildlife, although wildlife has been documented to use them. In this report, the term “wildlife crossing structure” pertains to a structure designed with wildlife needs in mind. Collectively, the terms “below grade passage” or “below grade crossing opportunity” are used to denote any structure beneath the grade of the road that allows wildlife to pass from one side of the highway to the other, regardless of the original intent for its function.

1.2. Study approach

Due to limited evidence of San Joaquin kit fox use of below grade passages in relation to four-lane highways (Bremner-Harrison et al. 2007), surrogate species were selected to boost data collection potential. We consider data collected on swift fox and desert kit fox to be pertinent for making mitigation recommendations in regard to four-lane highways to benefit long-term San Joaquin kit fox recovery (Kociolek and Clevenger 2007; report prepared as part of this contract).

Swift fox were studied along Interstate 70 (I-70) near Limon in eastern Colorado and along Interstate 90 (I-90) near Wall in southwestern South Dakota. Desert kit fox were studied along California State Highway 58 (Hwy 58) near Barstow in southern California. The aim of these companion studies was to investigate the movements and crossing behavior of swift and desert kit foxes around four-lane highways to make inferences for San Joaquin kit foxes. Specific objectives of the studies included:

- To determine if four-lane divided highways inhibit fox movements;
- To quantify fox crossing rates of four-lane highways; and
- To determine the attributes of below-grade passages foxes use to cross four-lane highways.

During the first field season, Tellus Mini GPS/UHF (Geographic Positioning System/Ultra High Frequency) collars manufactured by TVP Positioning AB (also known as Televilt or Followit) in Sweden were deployed on ten swift foxes in Colorado and five desert kit foxes in California. These collars were intended to 1) be trackable via UHF at certain programmed times each day, and 2) to drop off the animal on a specified date at which time the GPS-gathered spatial data could be downloaded from the units. Several collars were range tested in Colorado and California prior to deployment and were detectable up to approximately 1 km (0.6 miles). Subsequent collar limitations and malfunctions are discussed in Chapters 2 and 3.

The work conducted in 2007–2008 did not produce enough data to inform the needs of this project, therefore a second field season was planned. Due to the experimental nature of GPS/UHF collars that are small and lightweight enough for swift/kit fox use, however, proven VHF (Very High Frequency) technology was instead used during the second field season. While VHF is more labor intensive and results in fewer data points, the collars are less costly and their use allows the collection of some real-time data on fox movements relative to the highway.

There would have been a distinct advantage for conducting a second field season (2008–2009) in the same study areas (e.g., establishment of local contacts, culverts already inventoried, etc.). There was also the possibility that previously GPS-collared foxes could be re-captured during the second season trapping effort, enabling retrieval of GPS data from the 2007–2008 effort. A stop work order pursuant to Governor Schwarzenegger's Executive Order S-09-08 relating to California's budgetary problems hampered efforts for a 2008–2009 field season (H. Hunt, Caltrans, pers. comm.).

By the time the second field season began in spring 2009, we were contacted by Badlands National Park to study its recently reintroduced swift fox population near I-90. The swift fox study area was switched to South Dakota mainly because more effort could be put on monitoring rather than trapping/collaring. Also, since more than a year and a half had elapsed since foxes were collared in Colorado, there was no guarantee that they still inhabited the study area or were still alive. Swift foxes typically live four to five years in the wild and they were adults when they were collared.

The California desert kit fox study area did not change, however, attempts to capture foxes during the second season were unsuccessful possibly due to drought and a reduced prey base (T. Esque, U.S. Geological Survey, pers. comm.). Funds that would have been used for California monitoring were instead transferred to the South Dakota effort to conduct a short-term fencing experiment (Section 2.2).

During both field seasons, below-grade passages were monitored with cameras and/or sand track beds. Landscape and passage attributes were also collected.

2. EFFECTS OF FOUR-LANE HIGHWAYS ON SWIFT FOX

2.1. First field season (October 2007 to January 2008), Colorado

2.1.1. Study area

The study area was focused on I-70, a four-lane divided highway in eastern Colorado, which is surrounded by large native tracts of prime swift fox habitat (C. Cooley, Area Habitat Biologist, Colorado Division of Wildlife, pers. comm.) (Figure 1). There is a viable population core of swift fox in Colorado (Stephens and Anderson 2005) and a variety of below-grade passages exist within the selected road section. See further discussion of site selection criteria in Kociolek and Clevenger (2007).

Figure 1. View of study area looking east.

The study area was composed of two road sections located between the towns of Agate (Exit 340) and Genoa (Exit 370). The study area west of Limon (Elbert County) spanned approximately 8.2 km (5.1 mi) from mile post (MP) 349.5 to MP 354.6 (Figure 2). The area east of Limon (Lincoln County) spanned approximately 4.3 km (2.7 mi) from MP 365.4 to MP 368.1 (Figure 3). Average annual daily traffic volume was approximately 8,800 to 11,200 vehicles in 2007, 2,000 to 3,000 of which were trucks (Colorado Department of Transportation 2009). Permission to conduct the study was obtained from the Colorado Department of Transportation.

Figure 2 and Figure 3 illustrate trapping locations; animals that were captured, tagged and/or collared; and existing below-grade passages that were monitored. Collared foxes are depicted with a circle (female) or a triangle (male). The label "CH" followed by a number indicates the factory-programmed channel number which corresponds to a particular UHF frequency. Below-grade passages are alphanumerically coded with a C, R or U to represent a concrete box culvert, a reinforced concrete pipe culvert, or an underpass, respectively; numbers refer to nearest one-tenth of a mile post.

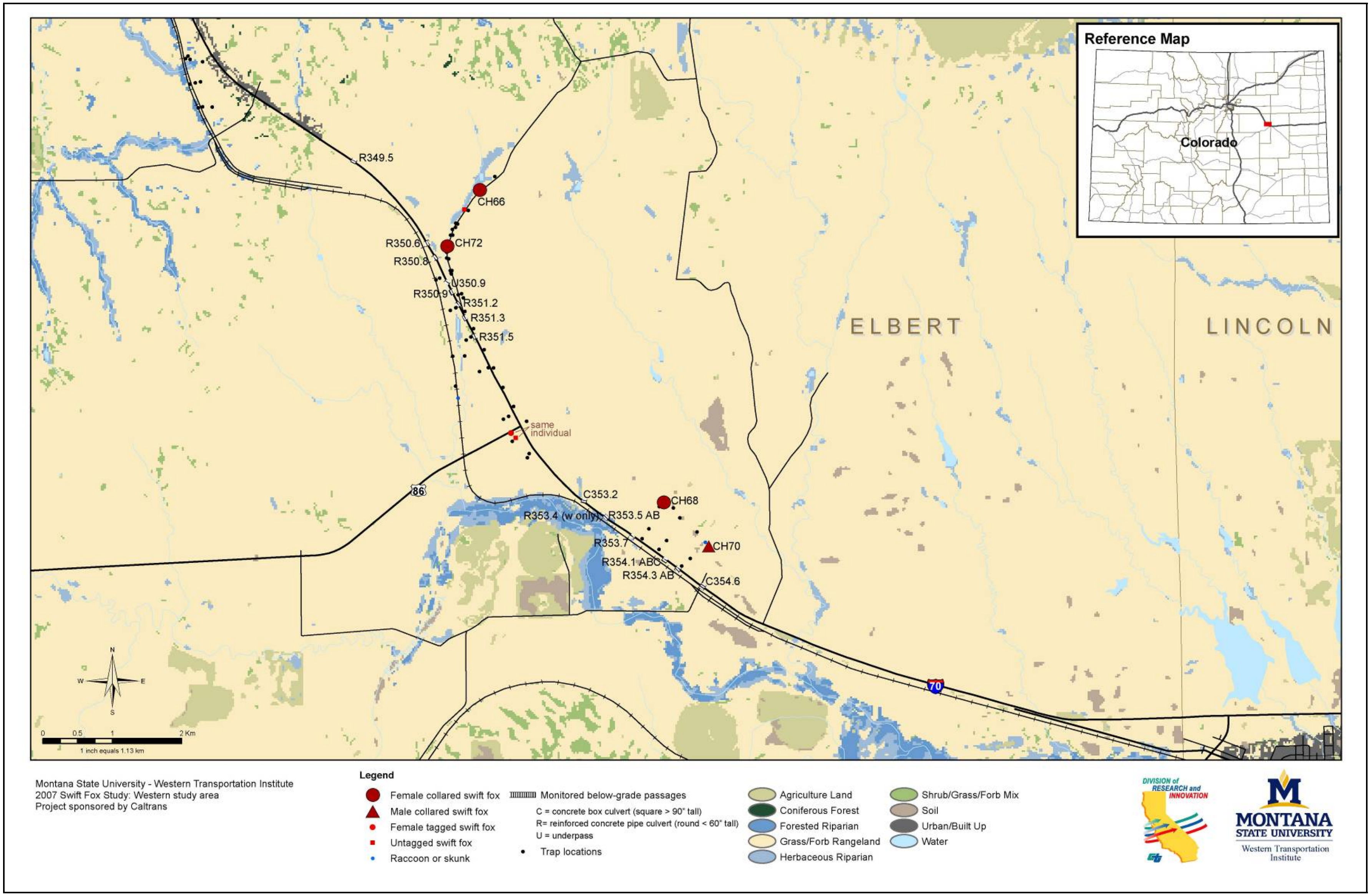

Figure 2. Study area west of Limon, Colorado.

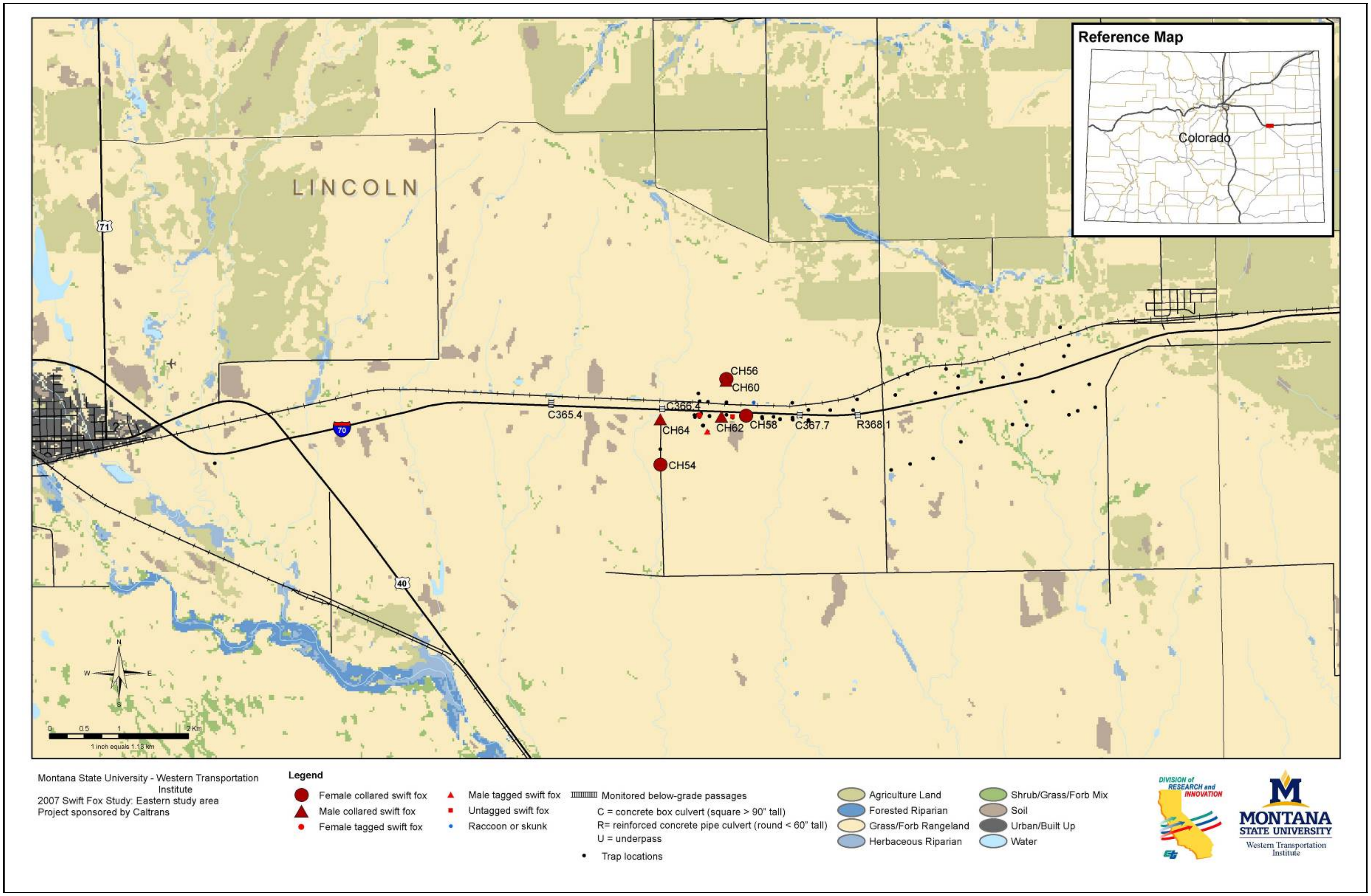

Figure 3. Study area east of Limon, Colorado.

2.1.2. Methods

2.1.2.1. Trapping and collaring

In October 2007, swift foxes were captured using live traps (81 x 25 x 30 cm [32 x 10 x 12 in.]; single door; Tomahawk Equipment Company, Tomahawk, Wisconsin USA) and (81 x 25 x 30 cm; single door; Havahart-Woodstream Corporation, Lititz, Pennsylvania USA) under a scientific collector's permit (#07TR1226) and with assistance from the Colorado Division of Wildlife. Private landowner access and trapping permission was obtained. Traps were retrofitted according to Moehrenschlager et al. (2003) and handling procedures were approved by Montana State University's Institutional Animal Care and Use Committee. Each trap was covered with a canvas cloth and/or green–brown plastic tarpaulin to provide shelter from the elements and to simulate den conditions for captured animals. Bait consisted of a mixture of road-killed pronghorn, chicken parts, mackerel, canned cat food, and hamburger. Traps were set approximately one hour before sunset and checked at sunrise the following morning. Trapping efforts were focused along barbed-wire fence lines and in pastures within 0.8 km (0.5 mi) of I-70 in road sections with a variety of below-grade passages. In some cases, animals were trapped as far as 1.6 km (1 mi) from I-70. Captured foxes were kept in a cloth bag and physically restrained without chemicals. Trapped foxes were weighed, sexed, aged, ear tagged, and dye marked, and hair samples were taken.

2.1.2.2. Tracking and GPS data

Ten of the trapped foxes determined to be adults were fitted with Tellus Mini GPS/UHF collars. Collars were factory programmed to obtain a location fix via satellite every eight hours (three positions per day) and to drop off in 90 days. Collars are designed such that once they are retrieved, GPS data can be downloaded. To obtain real-time data in the interim, attempts were made to track via UHF during pre-programmed beacon times at least once, but more often multiple times, weekly. Tracking via UHF was unsuccessful. A single 24-hour monitoring was also conducted to ensure the collars were not transmitting at an unspecified time.

Due to the inability to track collars via UHF, an unexpected re-trapping effort ensued in an attempt to retrieve collars from foxes prior to programmed drop-off dates. From 7 to 20 January 2008, attempts were made to recapture collared foxes near their original capture locations and den sites. Infrared remote trigger cameras (Reconyx PM35 or PM35M13 Silent Image Professional 1.3 megapixel monochrome; Reconyx, Inc., Holmen, Wisconsin, USA) were used to determine if any collared foxes were visiting traps.

2.1.2.3. Below-grade passage monitoring

All below-grade passages within 1.6 linear highway kilometers (1 mi) of each collaring location were identified. Each was named to represent its location along the highway by estimating the nearest one-tenth of a mile. The distribution of the monitored passages is depicted in Figure 2 and Figure 3.

There were a total of 24 below-grade passages in the two study areas combined:

- six square-shaped concrete box culverts ranging in size from 234 x 305 cm (92 x 120 in; height x width) to 488 x 488 cm (192 x 192 in)

- 17 oval, round or semi-round (i.e., flat bottomed) reinforced concrete pipe culverts ranging in size from 28 x 84 cm (11 x 33 in) to 152 x 152 cm (60 x 60 in)
- one underpass

In some cases, there were multiple culverts immediately adjacent to one another. In total, there were 19 locations in the two study areas combined:

- C366.4 is a double culvert (i.e., two culvert entrances side by side).
- R353.5 and R354.3 are double culverts.
- R354.1 is a triple culvert (i.e., three culvert entrances side by side).
- All other culverts and the underpass were stand-alone structures.

Sand track beds and/or cameras were installed at each passage to be monitored. The use of a track bed versus a camera was primarily dictated by the size of the structure and prevailing winds. Cameras were generally installed in concrete box culvert situations but a temporary camera was used in reinforced concrete pipe culvert situations as needed to confirm track identifications. From 29 October 2007 to 10 January 2008 below-grade passages were monitored for fox activity one to two times per week. Landscape variables and attributes were recorded for each below-grade passage for future analysis.

2.1.2.4. Barrier assessment

Linear features that might act as barriers to fox movements were recorded along the entire length of the study area from Agate (Exit 340) and Genoa (Exit 370).

2.1.3. Results

2.1.3.1. Trapping and collaring

Ten adult foxes, six females and four males, were captured and fitted with GPS collars (Table 1). Six of the collared foxes inhabited the area east of Limon and four inhabited the area west of Limon. Individuals believed to be young of the year were not collared.

Table 1. Captured fox data.

MILE POST	CHANNEL	GENDER	MAGNET REMOVED	CAPTURE DATE	EXPECTED COLLAR DROP OFF DATE	EAR TAG NO.	DYE PATTERN
east of Limon							
366	54	F	8-Oct-07	8-Oct-07	6-Jan-08	6352	adult 1
367	56	F	9-Oct-07	9-Oct-07	7-Jan-08	6353	adult 2
367	58	F	9-Oct-07	9-Oct-07	7-Jan-08	6350	adult 3
367	60	M	10-Oct-07	10-Oct-07	8-Jan-08	6354	adult 4
367	62	M	12-Oct-07	19-Oct-07	10-Jan-08	6358	adult 10
366	64	M	9-Oct-07	9-Oct-07	7-Jan-08	6341	adult 6
west of Limon							
350	66	F	11-Oct-07	14-Oct-07	10-Jan-08	6355	adult 5
353	68	F	12-Oct-07	16-Oct-07	10-Jan-08	6356	adult 9
353	70	M	12-Oct-07	17-Oct-07	10-Jan-08	6357	adult 9*
350	72	F	12-Oct-07	17-Oct-07	10-Jan-08	6343	adult 8
* mistakenly given the same dye mark as other fox in the area							
Other foxes not collared but tagged							
352	NA	F	not collared; young of year	16-Oct-07	NA	6342	young 6
366	NA	F	not collared; quota met	19-Oct-07	NA	6359	adult 11
366	NA	M	not collared; quota met	19-Oct-07	NA	6360	adult 12

2.1.3.2. Tracking and GPS data

Attempts at UHF tracking during pre-programmed beacon times were almost completely unsuccessful with the exception of obtaining a weak signal from one collar (Channel [CH] 54) on two occasions in the entire three-month period. Both detections were on the side of the highway that the animal was collared. Collars failed to drop off in 90 days as programmed by the manufacturer. Images of two collared individuals were obtained days after the factory programmed drop-off date, illustrating the collars did not drop off as intended (Figure 4 and Figure 5).

One (CH66) of ten collars was successfully recovered during recapture efforts and data were downloaded. None of the 393 data points obtained between 15 October 2007 and 10 January 2008 are on the opposite side of I-70 from original capture location. These data imply that this four-lane highway may have acted as a barrier for this adult female during the study period. It should be noted, however, that no location points were obtained on five days during the 88-day period. Downloaded GPS data was reformatted into a KML file and imported into Google Earth (Figure 6). See Section 2.1.3.3 for discussion of possible culvert use by this individual.

Figure 4. Remotely triggered image taken on 15 January 2008, eight days past programmed drop-off date. After several attempts, this fox was not recaptured.

Figure 5. Remotely triggered image taken on 14 January 2008, four days past programmed drop-off date. This female fox (CH66) was recaptured on 18 January 2008.

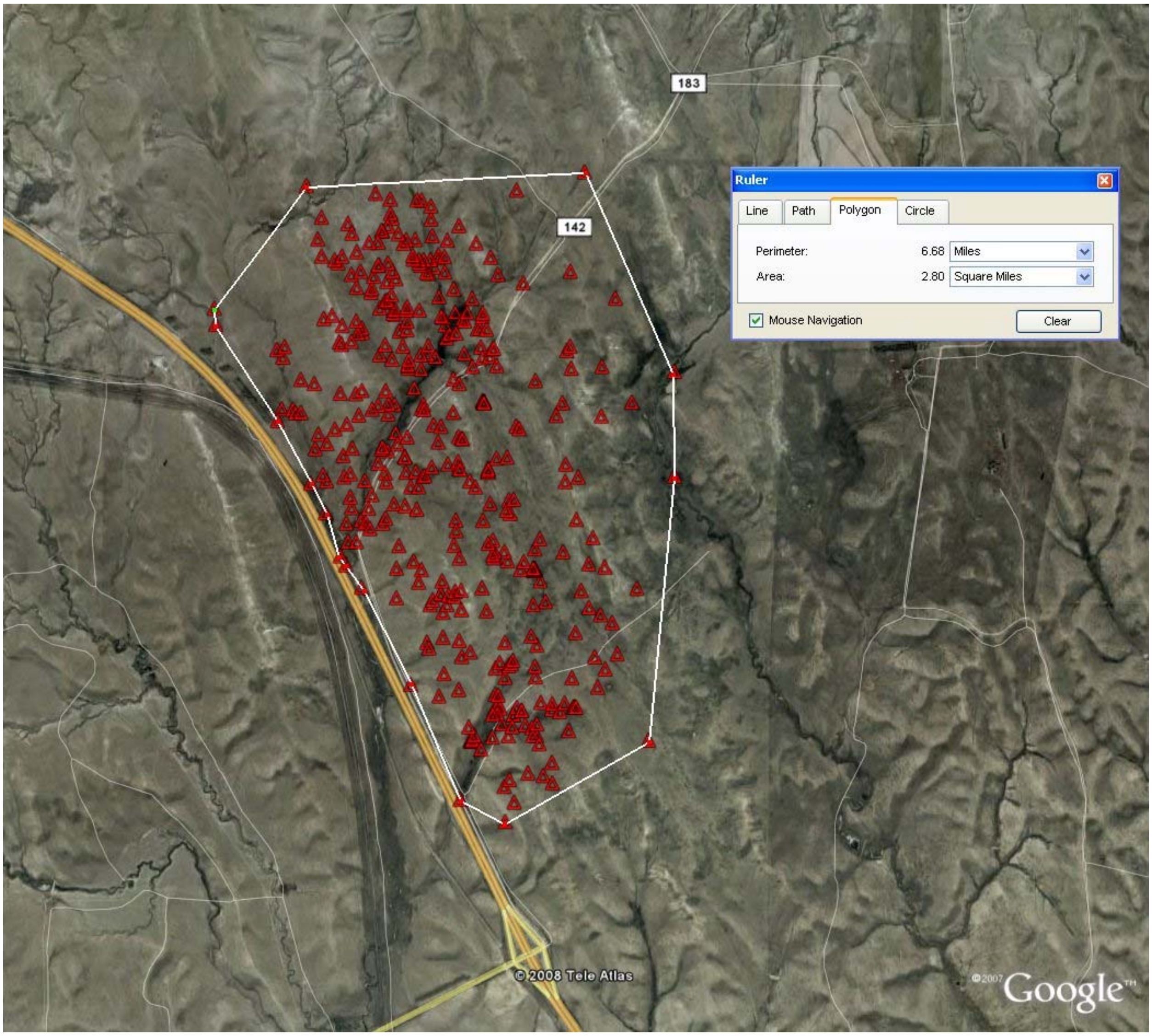

Figure 6. Seasonal home range of an adult GPS-collared female swift fox (CH 66) in relation to I-70 west near Limon, Colorado. Triangles represent GPS location fixes. This location is in the upper left quadrant of the western study area map.

2.1.3.3. Below-grade passage monitoring

Twenty-four below-grade passages at 19 different locations were monitored 21 times between 29 October 2007 and 10 January 2008. In addition to swift fox, birds—including an accipiter hawk (*Accipiter* sp.), small rodents (e.g., mice), hares or rabbits (family *Leporidae*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*) and domestic cattle were detected in or near entrances of passages by their tracks or camera images (Figure 7 and Figure 8). In some cases, tracks could not be identified.

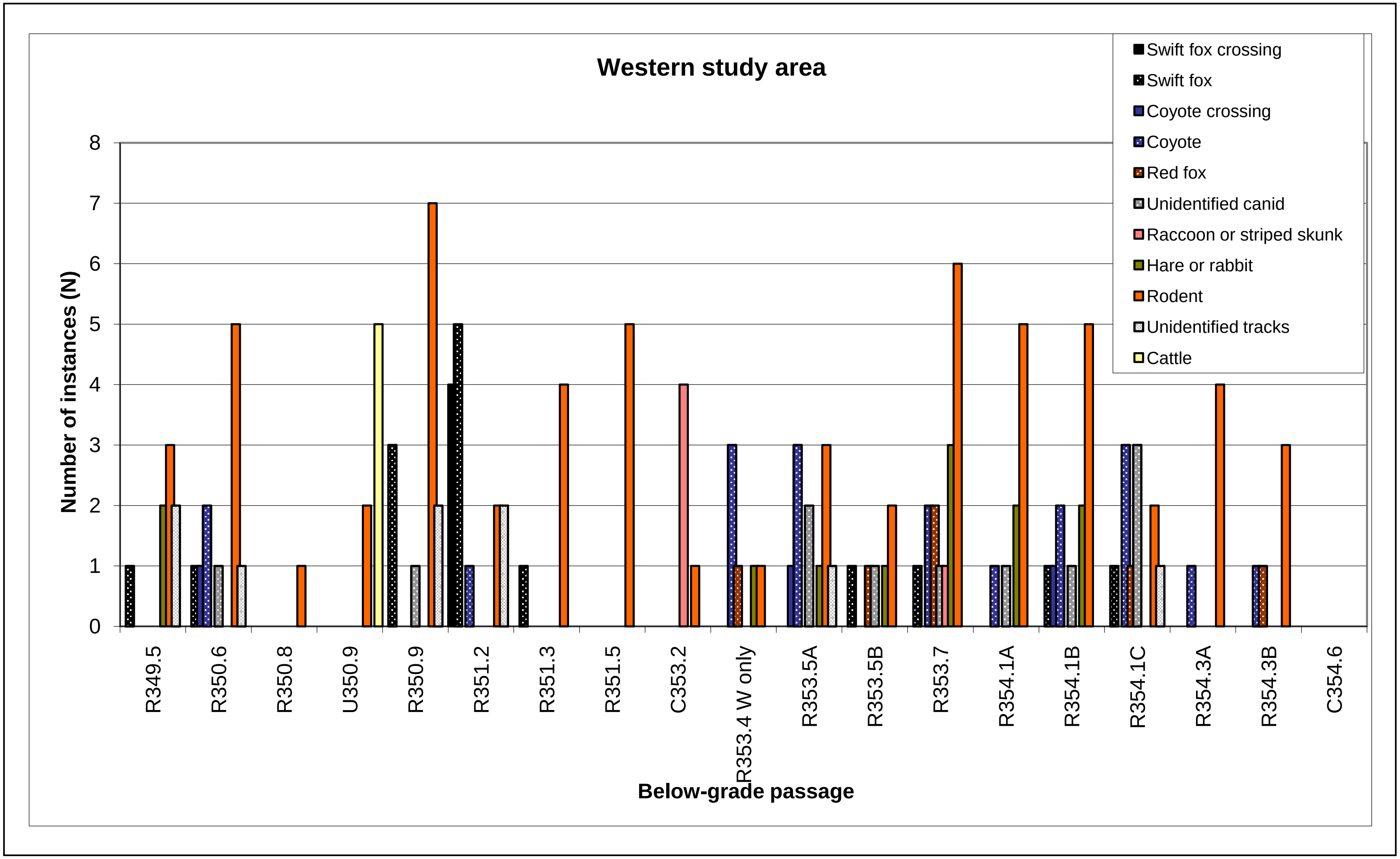

Figure 7. Number of instances of species (or groups) detected in or near entrances of below-grade passages in western study area.

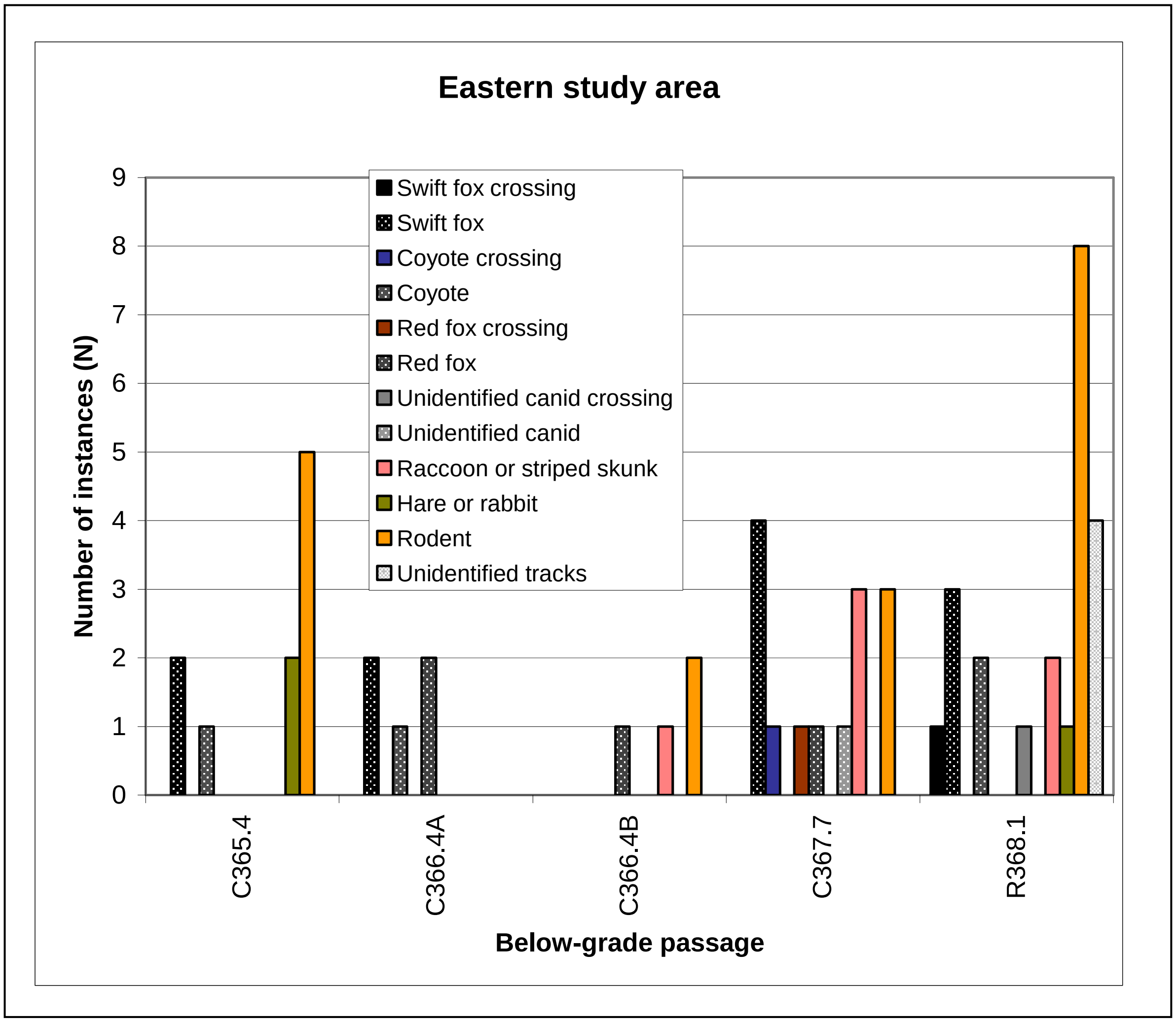

Figure 8. Number of instances of species (or groups) detected in or near entrances of below-grade passages in eastern study area.

There were several instances where swift fox tracks entered a culvert partway and retreated. Complete crossings by swift fox through two different reinforced concrete pipe culverts were documented five times via tracks and/or image data. Complete crossings are defined as the presence of tracks at both entrances traveling in the same direction. While there were six instances indicating complete crossings by coyote, red fox or an unidentified canid, only the unidentified canid crossing occurred in a culvert in which a complete swift fox crossing also took place (in R368.1).

On some monitoring days, standing water, snow drifts, snow-packed entrances, or frozen track beds precluded the ability to detect tracks in some below-grade passages (Figure 9). The two culverts in which complete swift fox crossings were detected (R368.1 and R351.2) did not have these issues.

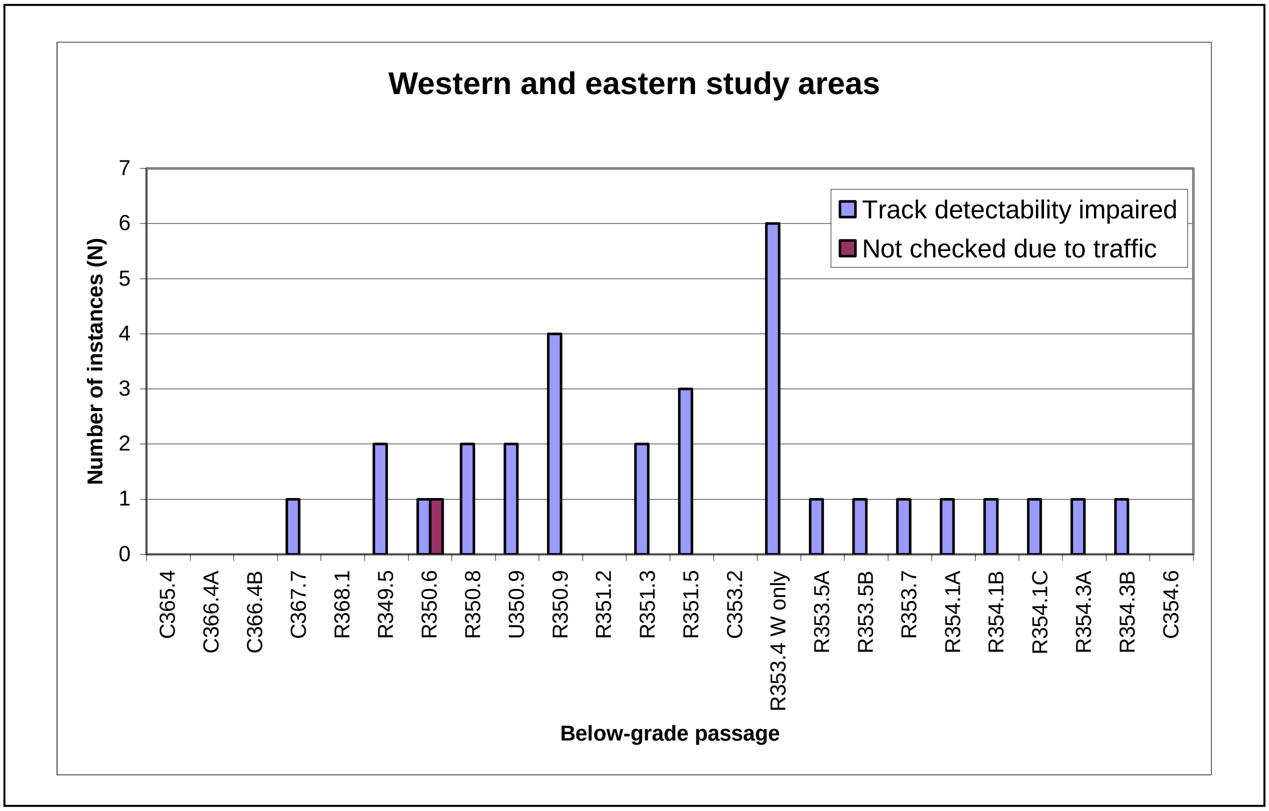

Figure 9. Number of instances when track bed condition precluded track detectability. There was an instance where a culvert was not monitored because of an unsafe traffic situation.

Probable swift fox tracks were originally detected at R351.2 (western study area) on 7 November 2007 and again on 13 November 2007; both sets of tracks indicated the fox moved just inside or around the entrance of the culvert but not through. On 21 November 2007, swift fox tracks were found at both ends of the culvert heading in the same direction indicating a complete crossing through the culvert. On several other occasions swift fox tracks were found only on one side or the other. To confirm tracks at R351.2 as swift fox tracks, a temporary camera was placed at one entrance on 28 November 2007. On 14 December 2007, an unmarked swift fox was documented on camera (Figure 10) and tracks at both ends were heading in the same direction. It is speculated that this fox may have been hunting rodents that have been detected in this structure (Figure 11).

Figure 10. Swift fox documented inside reinforced concrete pipe culvert (R351.2) confirms a crossing occurred via the culvert. Snow can be seen in foreground.

Figure 11. Another view of the individual in Figure 10 confirms it is an unmarked fox. This individual appears to be attracted to the seam where a rodent might live.

On 21 December 2007, an unmarked fox was documented on camera in R351.2 (Figure 12) and tracks at both ends indicated it was a complete crossing. It is unknown whether the foxes documented on 14 December and 21 December 2007 is the same individual.

Figure 12. A second instance of a swift fox documented crossing via R351.2.

One more complete crossing by a swift fox was noted in R351.2 on 6 January 2008. The R351.2 structure and adjacent landscape are pictured in Figure 13.

Figure 13. View of R351.2 entrance (152 cm [60 in]) in diameter (left) and adjacent landscape (right).

A total of six reinforced concrete pipe culverts and one underpass exist within CH66's home range (Figure 6). It is unknown whether the R351.2 crossings on 21 November 2007 or 6 January 2008—documented by tracks only—were by CH66.

The only other possible complete crossing by swift fox was detected in R368.1 (eastern study area) on 19 November 2007. R368.1 spans a two-lane unpaved frontage road in addition to the four-lane divided highway (Figure 14).

Figure 14. View of both entrances of R368.1; 52 x 104 cm (20.5 x 41 in; height x width) at eastbound entrance (left) and 93 x 118 cm (36.5 x 46.5 in) at westbound entrance (right).

2.1.4. Discussion

GPS/UHF collar malfunctions severely limited the amount of data garnered about swift fox movements in relation to I-70. Data downloaded from a single retrieved collar (CH66) indicates the four-lane divided highway may be acting as a barrier for at least this one adult female. None of the 393 location points obtained over an 88-day period were on the opposite side of the highway from where the animal was collared. Habitat may have played a role in CH66's movements. Its home range encompassed ample grass–forb rangeland and the habitat across the highway included more shrub cover and more waterways, in addition to a rail line (Figure 2).

An incidental sighting of a crossing at-grade and swift fox tracks found in snow illustrate that some swift fox do attempt to cross I-70. These successful crossings took place where no solid median barriers exist.

Monitoring all the below-grade passages within one linear mile of all collaring locations yielded evidence that at least two individuals used culverts to cross under I-70. The two culverts where swift fox crossings were detected are 27.3 km (17 mi) apart, a distance much greater than individual foxes in the area are known to travel, at least when not actively dispersing (Figure 6). The dimensions of R351.2 (152 cm [60 in] in diameter) and R368.1 (52 x 104 cm [20.5 x 41 in] – 93 x 118 cm [36.5 x 46.5 in]) fall within the size range of culverts studied by Bremner-Harrison et al. (2007) where no complete crossings by foxes were documented. It is likely that the presence of prey (e.g., rodents) plays a role in attracting foxes to these culverts. Some swift fox appear to use some reinforced concrete pipe culverts to cross under four lanes of highway and as many as, the approximate equivalent of, six lanes when considering culverts that span a frontage road in addition to the highway.

Standing water, snow drifts, snow-packed entrances or frozen track beds made some culverts impassable or made tracks indiscernible on some days. Tumbleweed chronically persists in some structures although none of the structures monitored were completely inaccessible due to its presence.

2.2. Second field season (May 2009 to January 2010), South Dakota

2.2.1. Study area

The study area was centered along I-90, a four-lane divided highway north of Badlands National Park in southwestern South Dakota. The area of interest extended beyond the right-of-way to the extent a radio telemetry signal from a collared fox could be detected, approximately 1.6 km (1 mi). Average daily traffic volume in 2008 ranged from approximately 5,000 to 6,000 vehicles, 1,400 to 1,500 of which were trucks (South Dakota Department of Transportation 2010). The surrounding area is largely considered to be swift fox habitat and is composed of public and private mixed grass prairie ranchlands (Russell 2006). Swift fox reintroductions began in the area in 2003 (Schroeder 2007). The Western Transportation Institute collaborated with Badlands National Park to take advantage of the fact that more than 100 swift foxes in the area were already radio collared (G. Schroeder, Badlands National Park, pers. comm.). Badland National Park's handling procedures were reviewed and approved by Montana State University's Institutional Animal Care and Use Committee. Permission to conduct the study was obtained from the South Dakota Department of Transportation.

Swift fox monitoring was focused on three discrete subsections along a 41.8-km (26-mi) section from MP 117 to MP 143 (Figure 15). The subsections either are known to be inhabited by swift fox or are considered likely for habitation (G. Schroeder, Badlands National Park, pers. comm.). Subsections I, II, and III roughly span MP 117 to MP 123, MP 126 to MP 132.8, and MP 136.5 to MP 143, respectively. The red zones in Figure 15 indicate areas not likely to be inhabited by swift fox (G. Schroeder, Badlands National Park, pers. comm.) and, therefore, were not monitored.

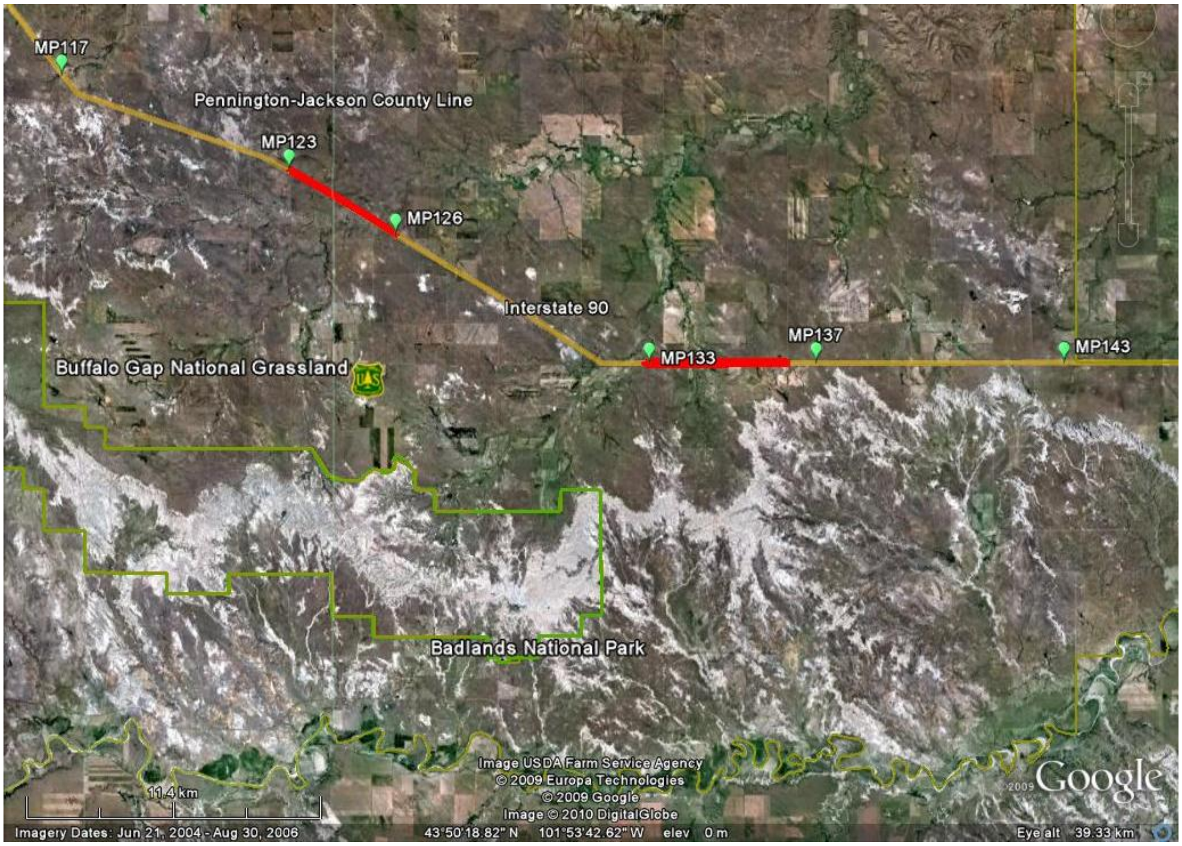

Figure 15. Study area along I-90, east of Wall, South Dakota.

This highway section has a grassy median with no median barrier. A variety of below-grade passages, including concrete pipe and box culverts, exist. There are no underpasses.

See Section 1.2 for more information regarding the timing and change of location of the second swift fox field season.

2.2.2. Methods

2.2.2.1. Nocturnal VHF tracking

Badlands National Park biologists provided the Western Transportation Institute with VHF frequencies of all their collared foxes, obviating the need to trap for this project alone. They also provided all known natal den locations within the I-90 corridor. There was an understanding that Park biologists would collar additional foxes if/when any uncollared animals were observed in our area of interest.

The goal of this VHF tracking effort was determine the location of a given fox relative to I-90. That is, no attempt was made to pinpoint the location of the actual fox but rather to determine whether the fox was north of I-90, south of I-90, or in the grassy median. The majority of telemetry attempts were conducted from overpasses and shoulders of I-90. Telemetry was also conducted from adjacent bisecting roads but no farther than 1.6 km (1 mi) from the highway corridor, as needed, to pick up a signal. Multiple passes were made along I-90 from MP 117 to MP 143 during each telemetry session. By performing multiple passes in a session, data on the movements and crossing behavior of individual foxes could be obtained. An R-1000 telemetry receiver (Communications Specialists, Inc., Orange, California, USA), three-element folding yagi and a vehicle-mounted omni-directional dipole antenna (Advanced Telemetry Systems, Isanti, Minnesota, USA) were used for this purpose. Visual observations of foxes were also noted.

2.2.2.2. Below-grade passage monitoring

All below-grade passages within the three discrete subsections were identified. Alphanumeric codes were assigned to signify location of culverts relative to mileposts.

There are a total of 51 culverts in the three subsections combined. Two box culverts have high human activity and, therefore, were not monitored.

The remaining 49 culverts are composed of:

- four square-shaped concrete box culverts ranging in size from 213 x 213 cm (84 x 84 in; height x width) to 358 x 302 cm (141 x119 in);
- 43 round reinforced concrete pipe culverts ranging in size from 43 x 46 cm (17 x 18 in) to 213 x 213 cm (84 x 84 in); and
- two elliptical or semi-round culverts ranging in size from 56 x 91 cm (22 x 36 in) to 66 x 109 cm (26 x 43 in).

Culverts vary in the number of lanes they span (i.e., two lanes on each side of highway, opening into the median; four lanes; and six lanes, including exit/entrance ramps).

Sand track beds were installed at terminal ends of each culvert to be monitored (i.e., if a culvert was a two-lane culvert pair and opened into the median, only the side entrances had track beds and the median entrances did not). From 25 June to 30 October 2009 track beds were monitored for fox activity one to two times per week, unless they became inoperable due to weather/hydrological events.

Six cameras were employed. Three were semi-permanently installed in culverts from early to mid-July to 19 November 2009, ranging from 120 to 131 days each. The other three cameras were temporarily installed at ten weather/hydrology-affected culverts, ranging from five to 69 days during the study period. See Appendix A for complete monitoring scheme. Landscape variables and attributes were recorded for each culvert within 1.6 linear kilometers (1 mi) of known natal dens for future analysis. Monitored culverts and known natal dens are shown in Figure 16.

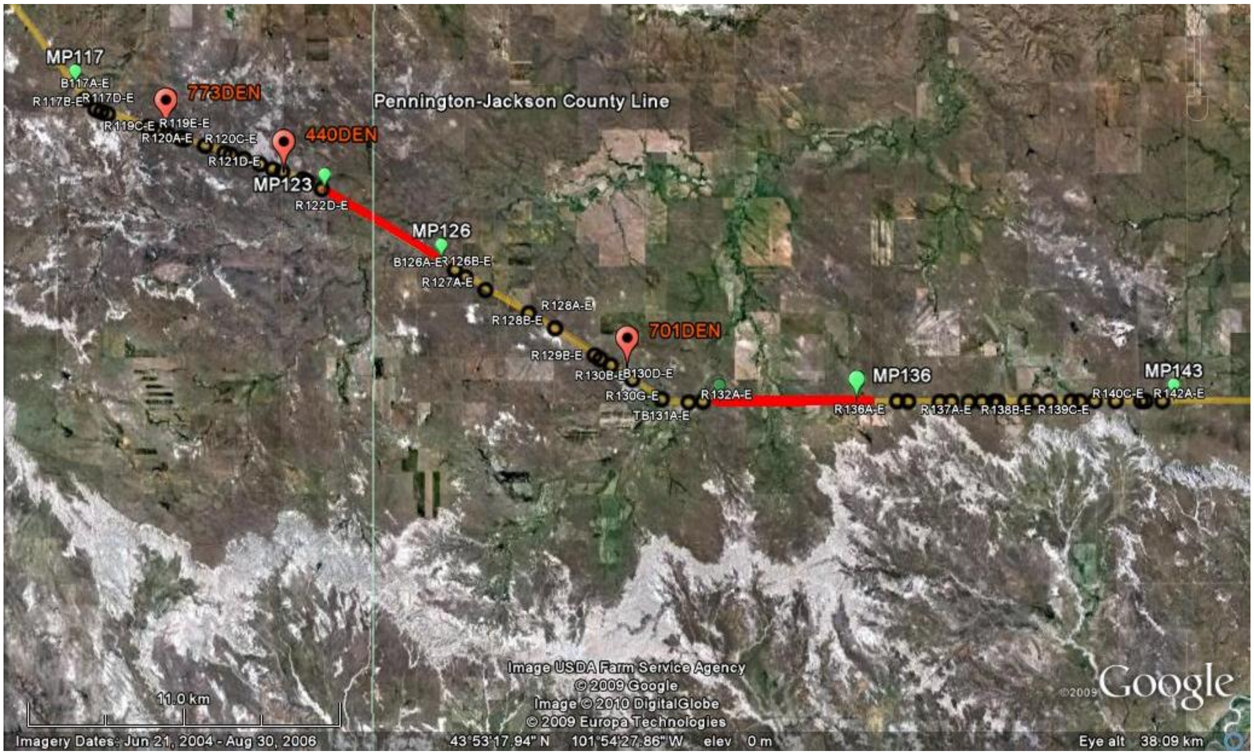

Figure 16. Distribution of culverts (black rings) and natal den locations (red balloons). For ease of viewing, only culvert entrances on the eastbound side of the highway (-E) are shown. B – concrete box culvert, TB – concrete tunnel box culvert (discovered to have high human use, therefore, not monitored), R – reinforced concrete pipe culvert. The elliptical-shaped reinforced concrete pipe culvert label is not shown on map.

2.2.2.3. Roadkill monitoring

Badlands National Park biologists shared swift fox roadkill observations. Monitoring is fairly consistent since they drive the highway most days twice per day (to and from work). They also receive roadkill reports from the public. In addition, we reported swift fox roadkills to Park biologists.

2.2.2.4. Experimental fencing

There was an opportunity to determine if it is possible to funnel foxes to culverts and encourage below-grade crossings. After the regularly scheduled field season ended on 31 October 2009, fencing was installed along both right-of-way fence lines for approximately 2.7 km (1.7 mi) between the southeastern entrance/exits ramps of Exit 127 (near MP 128) and a westbound side pullout (near MP 129.6). Permission was obtained from the South Dakota Department of Transportation before installation.

Fencing consisted of 122 cm (48 in) tall chicken wire (2.5 cm [1 in] mesh), metal hog rings to attach to the existing barbed-wire fence line, 10-gauge metal landscape staples 5 x 20 cm (2 x 8 in) to anchor mesh to the ground, and t-posts to provide attachment points for fencing leading to culvert entrances (Figure 17).

The fenced area included two reinforced concrete pipe culverts, one that spans all four lanes (R128A) and one that is a two-lane pair opening into the median (R128B). A chicken-wire tunnel connected culvert entrances of the two-lane culvert pair in the open median.

Cameras were installed at all six culvert entrances in the fenced section. Nocturnal VHF tracking was conducted within the fenced area and up to 3.2 km (2 mi) in either direction multiple times per week, weather permitting. All known frequencies were scanned during each session to determine if new collared foxes were in the area. Emphasis was put on tracking those collared foxes known to be in the area. The plan was to monitor fox movements for two months, commencing after installation was completed in late November 2009. Local wisdom indicated that the greatest snow accumulations typically occur in February.

Figure 17. Fence installation (clockwise from top left: a vehicle-mounted spool aids in laying out ~5.6 km (3.5 mi) of fencing; several inches of mesh stapled to the ground creates a barrier to digging under the fence line; t-posts enable angling the mesh away from the right-of-way fence line (foreground) to the culvert entrances (location of workers in the mid-ground).

2.2.3. Results

2.2.3.1. Nocturnal VHF tracking

A total of eight radio-collared foxes that inhabited the study area were tracked via VHF over the course of 55 sessions between 8 June and 30 October 2009 (Table 2). During the course of the season, several uncollared adult foxes were observed near I-90 in the study area; however, attempts to capture these individuals were unsuccessful.

Table 2. Collared fox data.

Den ID	Fox ID	Frequency	Gender	Age
773	773	164.814	M	adult
	463	167.666	F	adult
440	440	165.020	F	adult
	577	165.151	M	adult
701	701	165.282	F	adult
	715	164.091	M	adult
unknown	568	164.543	F	adult
unknown	768	164.803	M	adult

Tracking typically occurred during dusk and hours of darkness when foxes are most active (i.e., between 8 pm and 2 am) although some daytime tracking was conducted as well. Not all collared foxes were able to be located during every session. Radio signals were affected by fox location on the landscape, whether the fox was above or below ground, subtle changes in topography, manmade objects, etc. Telemetry attempts ceased during periods of lightning, rain, and high winds. Visual observations of at-grade crossings were documented. Table 3 summarizes known crossings for each collared fox in the study area.

Table 3. Summary of crossings via telemetry and visual observation.

Den ID	Fox ID	Total no. of detections (telemetry)	No. of 2-lane crossings (telemetry)	No. of 4-lane crossings (telemetry)	No. of 2- or 4-lane at-grade crossings also visually observed	Percent of all detections on opposite side of highway from previous
773	773	79	13	28	3	35%
	463	82	4	35	1	43%
440	440	63	14	19	0	30%
	577	48	12	14	1	29%
701	701	99	6	36	6	36%
	715	27	5	11	2	41%
unknown	568	79	28	23	15	29%
unknown	768	33	0	12	1	36%

Each collared fox was detected via telemetry an average of 64 times. On average, each fox was located on the opposite side of the highway from its last known location 35 percent of the time.

Foxes were frequently observed within the right-of-way during tracking sessions. Successful crossings as well as failed crossing attempts in the form of retreats were documented. No real-time roadkills were observed.

2.2.3.2. Below-grade passage monitoring

Frequent rain storms and subsequent ground saturation and flooding posed great challenges for culvert monitoring via track beds. Despite attempts to replace tracking material and/or improve drainage with a pea gravel substrate beneath the sand, many of the track beds became inoperable to the point of abandonment.

Of the 46 culverts without a semi-permanent camera, only 10 held the tracking substrate to enable fairly consistent monitoring via track beds, although even these had periods of inoperability (i.e., due to wind scouring, skunk digging, etc.). Twenty-eight culverts were severely affected by rain and/or ground saturation thereby rendering track beds inoperable for all or most of the study period. However, during the month of September, swift fox tracks were documented in five of the affected culverts since tracking material remained in at least one entrance while the other was underwater or washed out.

Swift foxes were detected in or near the entrances of eight different culverts (Table 4) out of 49 that were monitored for some portion of the study period. Five with swift fox detections are reinforced concrete pipe culvert sets (i.e., paired culverts that span two lanes each and open into the median). Only the entrances on the outer edge of the highway were monitored. The entrances located in the median were not. There were several reasons for this approach: 1) safety issues associated with highway traffic, 2) this study is interested in four-lane crossings, 3) the sheer number of culverts to be monitored already posed a logistical challenge, and 4) most of the culverts that opened into the median were on lower ground, thus, highly affected by weather/hydrology. The remaining three culverts with swift fox detections consisted of two concrete box culverts that span four lanes and one reinforced concrete pipe culvert that spans six lanes, including entrance/exit ramps. Seven of the eight culverts with swift fox detections were within 1.6 km (1 mi) of a known natal den.

There were a total of 19 fox detections in culverts (8 via tracks, 11 via camera images). In three images, the fox did not enter the culvert. Of the remaining 16 detections, three were definitely not complete four-lane crossings. Not including the six-lane culvert, one of the remaining twelve detections appeared to be a complete four-lane crossing by an uncollared fox. It is unknown whether the remaining eleven detections constituted complete four-lane crossings, but at least three were complete two-lane crossings with seven additional two-lane crossings likely to have occurred. It is possible that a complete six-lane crossing occurred, however, the fox could have entered the culvert via a grate in the median, thereby, limiting certainty to a complete three-lane crossing.

Due to the small sample size of fox crossings, statistical analysis was not possible. Attributes of culverts with swift fox detections are listed in Table 5. Species detections in culverts are shown in Table 6.

Table 4. Swift fox detections and crossing activity.

Sub-section	Den	Culvert ID	No. Lanes	Evidence	No. Events	Collared	Direction of travel	Track and/or bed condition	Complete 4-lane crossing?
I	773 (mate 463)	R118C	2 + 2 open median	tracks on E	2	NA	E to W	E fair & W inoperable	unknown; (2-lane likely)
							E to W	E poor & W inoperable	unknown; (2-lane likely)
	773 (mate 463)	R119B	2 + 2 open median	tracks on E	1	NA	W to E	E & W good	no; (2-lane likely)
				image on E	1	unknown	W to E	W inoperable	unknown; (at least one 2-lane incomplete; saw camera on E and retreated)
	773 (mate 463)	R119C	2 + 2 open median	tracks on E	2	NA	E to W	E & W good	no; (2-lane likely)
							W to E	E poor & W inoperable	unknown; (2-lane likely)
				images on E	5	yes	W to E	W inoperable	unknown
						no (juvenile?)	W to E		unknown; (2-lane complete)
						yes	W to E		unknown; (2-lane complete)
						unknown	did not enter		no
						no (juvenile?)	W to E		unknown; (2-lane complete)
	773 (mate 463)	R120A	2 + 2 open median	tracks on E	1	NA	W to E	E poor & W inoperable	unknown; (2-lane likely)
	440 (mate 577)	R121C	2 + 2 open median	images on E	3	unknown	did not enter	NA	NA
						unknown	did not enter	NA	NA
						no	E to W	W inoperable	unknown; (2-lane likely)
	440 (mate 577)	R121D	6 grated opening in median	tracks on W	2	NA	E to W	E inoperable & W fair	unknown; (6-lane possible but unsure if accessed via grate in median; 3-lane complete)
II	none known	B126A	4	image in middle	1	unknown	E to W	NA	unknown; (only hind half of body pictured, unsure if camera delay or if animal retreated when saw camera)
	701 (mate 715)	B130D	4	image in middle	1	unknown (juvenile?)	unknown	NA	yes
III	none known	-	-	none	NA				

Key: E and W refer to highway travel direction, i.e., eastbound side and westbound side, respectively.

Table 5. Attributes of culverts with swift fox detections.

Culvert ID	Shape	H (in)	W (in)	No. Lanes	Vis. (0-1)	Median	Drop inlets	Slope to road (%)	Hypotenuse (ft)	Terrain (100 m)	Substrate at entrance	Substrate in culvert	Culvert follows natural creek?
R118C-E	r	24	24	2	1	open	no	20	18.5	rolling	vegetation, concrete	concrete	no
R118C-W	r	24	24	2	1	open	no	10	26.0	rolling	vegetation, concrete, water	sediment, concrete, water	no
R119B-E	r	37	36	2	1	open	no	20	43.0	flat	vegetation, water, concrete	concrete	yes
R119B-W	r	37	36	2	1	open	no	10	19.5	rolling	vegetation, water, concrete	concrete, water	no
R119C-E	r	24	25	2	1	open	no	10	28.5	flat	vegetation, sediment	concrete, sediment, water	yes
R119C-W	r	24	24	2	1	open	no	15	21.0	rolling	vegetation	concrete, water	no
R120A-E	r	24	24	2	1	open	no	15	28.5	flat	vegetation, rock, concrete	concrete, water	yes
R120A-W	r	18	18	2	3/4	open	no	10	23.0	flat	vegetation, water, concrete	concrete, water	no
R121C-E	r	60	57	2	1	open	no	10	30.0	rolling	vegetation, sand, rip rap, metal wire	concrete	yes
R121C-W	r	60	55	2	1	open	no	10	20.0	flat	vegetation, concrete, water, sediment	concrete, sediment, water	no
R121D-E	r	22	24	6	1/2	below, concrete grate	yes	20	71.5	rolling	sediment	concrete, sediment	yes
R121D-W	r	24	24	6	1/2	below, concrete grate	yes	20	30.0	rolling	vegetation, sediment	concrete	yes
B126A-E	s	84	84	4	1	below	yes	30	20.5	rolling	vegetation, concrete	vegetation, sediment	no
B126A-W	s	84	84	4	1	below	yes	30	5.5	rolling	vegetation, concrete	vegetation, sediment	no
B130D-E	s	84	84	4	3/4	below	no	20	25.0	flat	concrete, mud, vegetation, tumbleweed	concrete, sediment, water/mud, tumbleweed	no
B130D-W	s	84	84	4	3/4	below	no	20	22.5	rolling	concrete, mud, vegetation, tumbleweed	concrete, sediment, tumbleweed	yes

Key: Shape (r – round, s – square); H – height, W – width; Vis. – visibility (amount of light through distal opening when viewed from proximal opening); Slope to road (from culvert opening to road grade); Hypotenuse (distance of culvert opening to road); Terrain (as viewed from culvert entrance looking 180 degrees away from highway). Additional attribute data, such as percent cover estimates, were collected but not included here since small sample size precludes usefulness.

Table 6. Species detections in culverts.

Culvert ID	SWIFT FOX	Leopard frog	Snake sp.	Bird sp.	Bat sp.	Mouse sp.	Jackrabbit or Cottontail	Raccoon	Skunk	Porcupine	Badger	Red fox	Domestic cat	Cattle	Unknown
B117A									c						
R117B							t		t						
R117C			t						t						t
R117D							t								t
R118C	t		t	t			t								
R119A				t				t							
R119B	t, c							c							
R119C	t, c					c									
R119D						c									
R119E							t								
R120A	t						t								
R120B									t						
R120C				t					t						
R121A						c									
R121C	c			c	c	c	c	c	c						c
R121D	t								t						
R122A									t						
R122B			t				t	t	t						t
R122D			t						t						
B126A	c		t	t, c		c	c	t, c	t, c				t, c		t
R126B							t		t						t
R127A			t	t			t	t	t						
R128A			t						t						t
R128B			t				t, c	t	t		t				t
R129B									t						
R130B									t						
B130D	c			t		c	c	c	c			c		c	t, c
R132A			t					t	t		t	t			t
E132B			t				t	t	t						t
R136A								t	t						t
R137A				t				t	t		t				
R137B							t	t	t						t
R138A			t						t						
R138B		t	t	t				t	t				t		t
R138C			t	t				t	t						
R139B			t					t	t	t					
R139D				t				t	t						t
E140B							t	t	t						
R140C				c		c		t, c	t, c		t		c		t
R141A							t	t	t						
R141B			t						t						t
R142A															t
R142B			t												
R142C									t						

Key: Detections via tracks (t) and camera images (c). Note: Culverts not listed in this table had no signs of wildlife presence.

2.2.3.3. Roadkill monitoring

Nine swift fox roadkills were documented on I-90 between 22 June and 31 August 2009. Most of these were believed to be juveniles although at least one sub-adult female was also struck.

2.2.3.4. Experimental fencing

The post-fencing monitoring began on 30 November 2009 but was terminated prematurely due to a massive blizzard that affected the study area on 25 December 2009. I-90 was shut down and safe travel was not possible for several days. The snow sealed off culvert entrances and buried the chicken wire fence, destroying some sections (Figure 18). It was not feasible to dig out the fenced study area to allow for culvert use. Travel conditions continued to be unsafe and, therefore, precluded regular radio tracking. During the second week of January the decision was made to terminate data collection given that the study area would likely continue to be affected by winter weather issues.

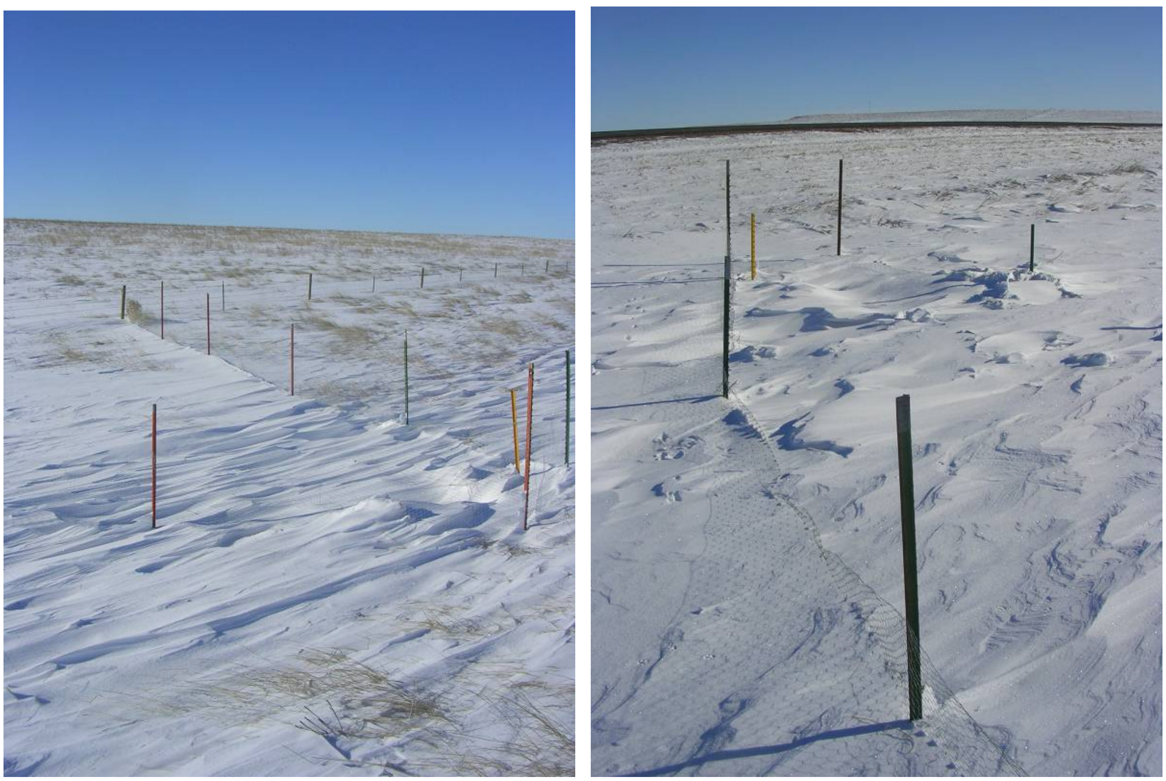

Figure 18. Snow filled culvert entrances and negated the effectiveness of the fencing. T-posts delineate where chicken wire fencing funneled to culvert entrances.

A total of 12 telemetry sessions were conducted within 3.2 km (2 mi) of the fenced study area between 30 November and 30 December 2009. While all collared fox frequencies were scanned during each session, a total of four foxes were detected during the fencing study (Table 7). Almost all detections were of 701 and her pup 953, which were often tracked to the median. On 10 December 2009, their den was found in the median about 68.6 m (75 yd) from the western fence end. Interestingly, the foxes seemed to avoid the access afforded by western fence end, possibly due to the existence of tall grass, and instead traveled more than 2.4 km (1.5 mi) to the eastern fence end rather consistently (P. Roghair, pers. comm.). This new den is in addition to the 701 natal den pictured in Figure 16.

All crossings included in Table 7 were determined to be at-grade and around fence ends because there was no camera evidence of culvert use on these days. Also 701 and 953 would not have had access to their den via the two-lane culvert pair because a fence tunnel connected the two median entrances providing no access from the median itself.

Table 7. Summary of crossings detected via telemetry.

Fox ID	Gender/age/relationship	No. of session days detected	No. of detections	No. 2-lane crossings	No. 4-lane crossings
701	Female adult	12	59	12	7
953	Female pup of 701	9	44	10	2
568	Female adult	1	4	0	0
949	Female pup (relationship unknown)	1	1	NA	NA

Cameras were in place and functional from 30 November to 25 December 2009, when the snow began accumulating in the blizzard. Soon thereafter, all cameras were dug out and removed with the exception of one camera left at R128BE.

There was only one camera detection at the four-lane culvert R128A—on 12 December 2009 a collared fox entered partway but then retreated. Therefore, there is no evidence of a successful crossing via the four-lane culvert during the post-fencing period.

There were six series of crossing activities via R128B, the two-lane culvert pair system connected by a chicken-wire tunnel in the median (Table 8). All events appear to involve only 701 or her pup 953, based on two visual cues (i.e., eye reflectivity and collar antenna condition). One fox has conspicuously unequal reflectivity in its eyes and it is sometimes difficult to ascertain the presence of a collar. We surmise this is 701, an adult whose antenna could have been chewed off. The other fox has a prominent antenna consistent with that of a newly collared juvenile (953). See Figure 19 for comparison.

Table 8. Summary of crossings detected via cameras.

Date	Fox ID	Direction of travel
1-Dec-09	701	E to W
3-Dec-09	701	E to W
	701	W to E
6-Dec-09	701	W to E
8-Dec-09	953	E to W to E to W to partway E to W to E
31-Dec-09	953	E to W*
*only a single camera was in use, other entrances were snow-packed making a four-lane crossing improbable, however, no retreat was recorded		

Figure 19. Top two images feature an individual with unequal eye shine and no visible antenna, presumably 701 (adult female). Bottom two images feature an individual with equal eye shine and an obvious antenna even from a distance, presumably 953 (pup of the year).

2.2.4. Discussion

Part of the rationale for switching study areas from Colorado to South Dakota was the potential benefit of being able to monitor more than ten foxes, which was the original stated project objective. Badlands National Park is highly invested in monitoring the swift fox population that resulted from reintroduction efforts. Despite attempts to collar more individuals whose ranges encompass I-90, the total number of regularly trackable foxes was limited to eight. Each of the eight were tracked regularly (Table 2) and I-90 does not appear to be a barrier to movement for these individuals.

Standing water or washouts of the tracking substrate made it impossible to discern culvert use of many culverts throughout the season. Even so, there was documented fox use of culverts (i.e., tracks and camera images). However, none were four-lane crossings through a reinforced concrete pipe culvert, the most common culvert type in the area (Table 4). The only four-lane crossing was through a relatively large 213 x 213 cm (84 x 84 in) box culvert. Two-lane crossings were the most common. It is possible that a six-lane crossing occurred but the existence of an open grate in the median makes it impossible to confirm. The openness created by the drop inlet may have simulated the two-lane culvert pair variety, making the crossing more inviting than a closed culvert (i.e., no opening into the median). Alternatively, it is possible that the fox accessed the culvert midway in the median. The culverts that had evidence of swift fox use also had evidence of prey species and other meso-predators (Table 6).

Telemetry data and visual observations confirm that at-grade crossings are much more common than below-grade crossings. For the eight foxes regularly tracked in this study, I-90 is not an obvious barrier to movement. Vehicle strike does appear to be a major threat to juvenile foxes that den within the right-of-way or whose range encompasses I-90. There were nine documented roadkills on I-90 in a span of approximately ten weeks. Seventeen additional roadkills were documented on other roads monitored by Park biologists within a 30-week period. Park biologists noted that the number of road killed swift fox pups seemed to increase in wet years when vegetation was taller (G. Schroeder, Badlands National Park, pers. comm.). The reason for this is unclear. Possible explanations include foxes having greater difficulty observing approaching traffic before entering the roadway, or foxes spending more time near or even on roads to avoid dense vegetation.

The short-term experimental fencing study illustrated the possibility of funneling foxes toward culverts. Neither of the culverts monitored post-fencing (R128A and R128B) had any evidence of swift fox use prior to fence installation (Table 4). This is despite the fact that tracks beds were mostly operable during the pre-fencing period (May through October) and that snake species, *Leporidae* sp. (cottontail rabbit or jackrabbit), skunk, and raccoon were documented in them (Table 6). The absence of swift fox in R128A and R128B during the pre-fencing period could be partially explained by the greater than 1.6 km (1 mi) distance from 701’s natal den. All but one of the culverts that had documented fox use prior to fencing were within 1.6 km (1 mi) of a natal den (Table 4). There were no documented swift fox crossings post-fencing via R128A, a four-lane culvert, however, 701 and her pup, 953, did make complete four-lane crossings via the two-lane culvert pair with a chicken wire tunnel in the median (R128B). It is uncertain if the new den belonging to 701—found in the median of the fenced section in December—was created before or after fence installation in November.

Budget constraints limited the length of fencing installed. Because foxes can easily travel more than 2.7 km (1.7 mi) in a given night, the fencing probably did not pose much inconvenience to many individual foxes. The only foxes that appeared to cross via the culvert post-fencing also happened to live within the median of the fenced zone itself. The funnel effect of the fencing was not particularly convenient for these individuals because the chicken wire tunnel prevented them from accessing their den at the median opening between culverts.

The sample sizes in this study are too small and the monitoring regime too inconsistent for rigorous statistical analysis. However, an opportunistic observation during the study suggested that pressure may play a role in fox use of culverts. When a maintenance crew was re-tarring a section of the highway during the pre-fencing period, it was noted that foxes used culverts presumably as a way to avoid the sticky road grade surface (B. Smith, pers. comm.). This may suggest that, if pressured (i.e., due to an obstacle such as a tar barrier), the probability of fox use of culverts may increase.

3. EFFECTS OF FOUR-LANE HIGHWAYS ON DESERT KIT FOX

3.1. First field season (October 2007 to June 2008), California

3.1.1. Study area

The study area encompassed approximately 21.7 km^2 (13.5 mi^2) of the Mojave Desert in San Bernardino County, California. The area is intersected by numerous non-paved access roads and ephemeral washes. Habitat is dominated by xeric vegetation consistent with alkali desert scrub habitat (for further details of vegetation structure see Boarman and Sazaki 1996) and is within the known range of the desert kit fox (*Vulpes macrotis arsipus*) (McGrew 1979; O'Farrell and Gilbertson 1986).

The study area was bisected by an approximately 5.2-km (3.2-mi) section of California State Highway (Hwy) 58. The western boundary of this area was located approximately 15.5 km (9.6 mi) east of the Hwy 58/Hwy 395 intersection while the eastern boundary was located approximately 20 km (12.4 mi) west of Barstow. This section of Hwy 58 is a four-lane road with a central dirt median and no median barrier. The average daily traffic volume measured at five points in 2006 was 11,700 vehicles in both directions of travel.

Potential crossing opportunities consisted of a mixture of below grade, single and double, corrugated metal pipe and concrete box culverts, as well as concrete bridging structures. For further details of below grade passages along this section of Hwy 58 see Bremner-Harrison et al. (2007). Note that Bremner-Harrison et al. (2007) used the term "crossing structure" to denote "existing structures that had been incorporated into the road design for reasons other than wildlife passages, such as drainage culverts for run-off, and culverts and bridges for the passage of seasonal waterways." This report uses the more generic term "below grade passage" to describe the same, reserving the term "wildlife crossing structure" for those structures designed specifically for wildlife in mind. Drift fencing was present along both the north and south sides of Hwy 58 from a study conducted on desert tortoises (*Gopherus agassizii*; Boarman and Sazaki 1996). This fencing measured 30–45 cm (11.8–17.7 in) in height and was intended to guide tortoises to crossing opportunities. The fencing also may have helped guide kit foxes towards the passages, but it was not of an adequate height to prevent foxes from jumping over and attempting to cross the highway at grade.

3.1.2. Methods

3.1.2.1. Trapping

The initial trapping effort to deploy GPS collars on desert kit foxes was conducted during October–November 2007. Due to unexpected problems with the performance of collars, including the automated drop-off mechanism (see below), a second trapping effort was conducted during March–June 2008 in an attempt to re-trap collared animals and remove the collars so that the GPS telemetry data stored on the units could be retrieved. The re-trapping effort was initiated prior to the operational expiration date of the GPS units (140 days post-activation).

Trapping transects were established along dirt access roads throughout the study site. Wire mesh live traps (38 x 38 x 107 cm [15 x 15 x 42 in] double-door traps; Tomahawk Equipment

Company, Tomahawk, Wisconsin USA) were set along these roads and were no farther than 3 km (1.2 mi) from Hwy 58. A single trap was placed on either side of the transect road at intervals of approximately 0.3 km (0.2 mi) in areas that provided sufficient vegetative cover to hide the trap from view. Each trap was covered with a dark green tarpaulin to make them less conspicuous, provide shelter from the elements, and to simulate den conditions for captured animals. Bait consisted of a mixture of hotdogs, boiled eggs and canned cat food. Traps were set approximately one hour before sunset and checked at sunrise the following morning.

Capture and handling methods for kit foxes were approved by the California State University–Stanislaus Animal Welfare Committee and the Montana State University Institutional Animal Care and Use Committee. Methods were consistent with protocols established in a research permit (TE825573-2) from the United States Fish and Wildlife Service and a Memorandum of Understanding from the California Department of Fish and Game. Captured foxes were coaxed into a denim handling bag and were physically restrained without chemicals. Foxes were marked with a uniquely numbered metal ear tag, weighed, sexed, aged, and inspected for overall condition and injuries. Captured foxes were fitted with GPS/UHF collars from Televilt. A description of these collars and their functions were provided previously (Section 2.1.2.2).

3.1.2.2. Diurnal UHF tracking

Once collar deployment had begun, the study site was visited once per week, during the designated activity period of the UHF transmitter (1000–1300 hours) in an attempt to track collared foxes to diurnal den sites. A vehicle-mounted D-1 omni-directional antenna and a hand-held directional RX-Pro tracking receiver (Televilt, Sweden) were used for this purpose.

3.1.2.3. Camera stations

Additional steps were taken to detect further kit fox activity in the area and determine if foxes retained their collars after the programmed drop-off date. Four motion-activated camera stations (Cuddeback 3.0 mega pixel scouting cameras) were deployed at four locations within the study site. Cameras were mounted on 1 m (1 yd) steel utility fence posts, which were securely driven into the ground with a mallet. Bait consisted of Scented Predator Survey Disks (USDA Pocatello Supply Depot, Pocatello, Idaho USA) that were placed approximately 3–4 m (3.2–4.3 yd) in front of the camera (one disk per camera). Each camera was set to activate between 1700 hrs and 0600 hrs.

3.1.3. Results

3.1.3.1. Trapping

Between 30 October and 28 November 2007, five individual desert kit foxes were captured (one female and four males) and fitted with GPS collars at the Mojave Desert field site (Figure 20 and Figure 21). One fox (Male 6503), initially trapped on the south side of Hwy 58 on 30 October 2007, was recaptured on the north side of the highway on 15 November 2007 (Figure 20), thus providing initial evidence of successful crossing of Hwy 58.

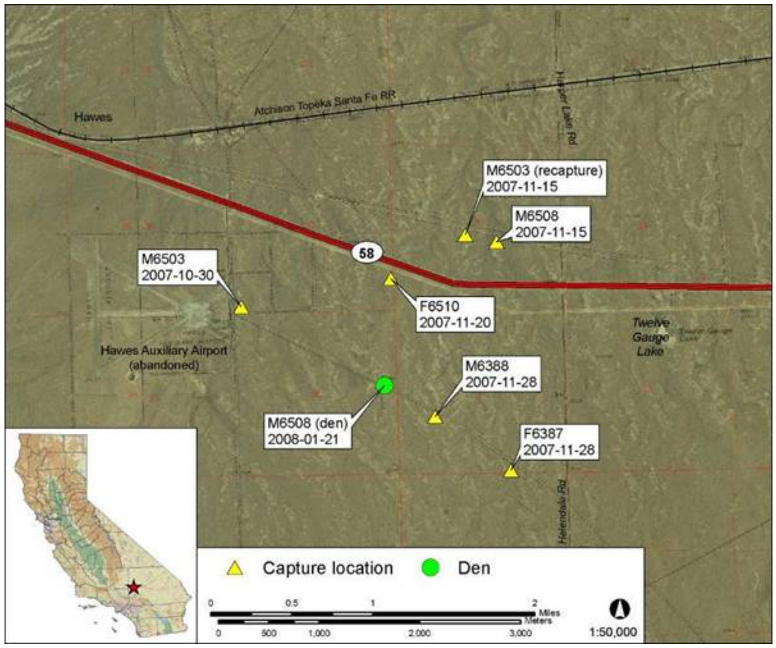

Figure 20. Kit fox capture and den locations at the Hwy 58 study site, California.

Figure 21. Desert kit fox with a GPS collar at the Hwy 58 study site, California.

Recovery trapping efforts initially focused on areas where kit foxes had been previously trapped and tracked to diurnal dens. However, due to a lack of success, the trapping effort was extended considerably beyond this area. No foxes were captured during this trapping effort and no GPS collars were recovered.

3.1.3.2. UHF tracking

Sub-optimal performance of the UHF transmitter component of the GPS collars resulted in diurnal denning location fixes for only one individual on one occasion. This fox (Male 6508), was initially captured on the north side of Hwy 58 on 11 November 2007 and was located on the south side of the highway on 21 January 2008 (Figure 20). Fox 6508 was tracked to a subterranean den situated in the north-facing bank of a man-made excavation. The UHF signal was very weak. The den containing the fox was detected from a distance of 10.5 m (11.5 yd), and the signal could not be heard beyond a distance of 22 m (24 yd) from the den. Telemetry tracking was discontinued in April 2008 due to the expiration of the UHF transmitter batteries.

3.1.3.3. Camera stations

Camera stations were deployed between 16 April and 9 May 2008 at four locations. These sites were situated in areas where the majority of foxes were initially captured and therefore in theory presented the optimal chance for detecting fox activity. Additionally, two of the cameras were situated close to kit fox dens and two were situated close to kit fox latrines. Images of black-tailed jackrabbits (*Lepus californicus*) visiting the stations were recorded by three of four cameras during the programmed activity time, indicating that the cameras were functioning properly. However, no kit fox activity was recorded by any of the cameras at any time.

3.1.4. Discussion

The GPS collars that were employed in this study did not perform as expected and this significantly inhibited our ability to collect data on movements of telemetered foxes. The UHF transmitters on the collars proved to be very weak. Despite extensive efforts to monitor collared foxes, on only one occasion was a signal detected, and this detection likely was a result of the collared fox being in a den immediately adjacent to the road upon which the monitoring vehicle was traveling. Subsequent tests revealed that the signal range was only about 20 m (22 yd), which means that the probability of detecting signals from collared foxes was extremely low. Consequently, virtually no information on fox movements was obtained via monitoring. Also, the collars were designed with an automated detachment mechanism. Ideally, the collars would have dropped off the foxes a few weeks prior to the expiration of the UHF transmitter battery so that the collars could be located. However, it is unclear whether the detachment system failed, or whether the collars did indeed drop off but could not be located due to the very weak UHF signals.

Reasons for the inability to re-trap any foxes remain uncertain. The relative ease with which foxes were trapped during the October/November 2007 trapping effort might suggest an element of seasonality in the occurrence of kit foxes in this area. In particular, our efforts to re-trap foxes were conducted during the early pup-rearing period when foxes may have been remaining close to natal dens and therefore less likely to encounter our traps. Evidence of kit fox denning activity was apparent and kit fox tracks and latrines were noted across the study site, indicating that foxes were still present in the area. However, it is unknown whether the collared animals were still present.

Despite the small number of foxes collared, the difficulty in tracking foxes, and the inability to retrieve GPS data, we still were able to establish that on two separate occasions, two collared foxes (6503 and 6508) did successfully cross Hwy 58. However, no inferences can be made as to the mode of these crossings (i.e., through below grade passages or simply over the highway) or the rate of successful crossings. Bremner-Harrison et al. (2007) found no indication that kit foxes utilized below-grade passages in this area. They did discover two road-killed foxes, including one at this same study site. This provided evidence that in the absence of median barriers and exclusionary fencing, kit foxes do occasionally attempt to cross over the surface of the highway. The successful crossings documented in the current study suggest that four-lane divided highways lacking exclusionary fencing and median barriers are not absolute barriers to kit fox movements.

3.2. Second field season (June to July 2009), California

3.2.1. Study area

The study area used during the second field season was the same as that used in the first season. See 3.1.1 above for a detailed description of the study area.

3.2.2. Methods

For the second field season, the plan was to capture kit foxes and deploy VHF radio collars on them. VHF transmitter technology is considered "conventional" and therefore more reliable than the much newer and relatively untested GPS collar technology. Radio collars were obtained from Advanced Telemetry Systems. Descriptions of these collars and their functions were provided previously (2.1.2.1).

Trapping efforts were identical to those described previously. See 3.1.2.1 above for a detailed description of trapping methods.

3.2.3. Results

Trapping efforts were conducted on seven nights during 11 June–30 July 2009. However, only two foxes were captured and collared (one female and one male). Both foxes were captured on the south side of Hwy 58. On the final night of trapping in July, the male was recaptured, again on the south side of Hwy 58, and the decision was made to remove his collar.

During July 2009, the female fox was relocated five times in three different dens. All of these dens were located on the south side of Hwy 58.

3.2.4. Discussion

For unknown reasons, kit fox capture rates on the study site were lower than expected. The region had experienced several consecutive years of below-average precipitation, and other biologists working in the region reported that prey abundance (e.g., nocturnal rodents, rabbits) might be depressed. Two foxes were not likely to provide meaningful data, nor warrant the time and expense that would have been required to monitor these animals. Therefore, the decision was made to terminate the effort in California and redirect resources elsewhere.

Trapping and monitoring efforts provided only limited information on kit fox movements, due to the low number of collared foxes. The information collected did not provide any evidence that foxes had crossed Hwy 58.

4. CONCLUSIONS

4.1. Colorado swift fox study

1. Based on data obtained from one retrieved GPS collar, I-70 appeared to act as a barrier for at least one adult female swift fox during an 88-day period. Available habitat might explain why this individual had no reason to cross.
2. One unmarked swift fox was seen crossing I-70 at grade and swift fox tracks crossing at grade in snow illustrate a swift fox attempt to cross this four-lane highway. For clarification, these successful crossings took place where no solid median barriers exist since most of the length of I-70 is divided only by a grassy median.
3. At least two swift foxes appeared to cross I-70 through two reinforced concrete pipe culverts in the study area; the two culverts are located ~27 km (17 mi) apart.
4. During the study period, swift fox tracks were detected in track beds at one end of a number of the below-grade passages on several occasions. Red fox and coyote tracks were also detected in and around culvert entrances with some indicating complete crossings. Swift fox crossings were detected in culverts where red fox and coyote crossings were not detected. Studies have shown that culverts can be prey traps in some areas (Doncaster 1999; Hunt et al. 1987).
5. The presence of prey may have attracted some swift foxes to some of the culverts.
6. The failure of the GPS-UHF technology used in this project severely limited our ability to study swift fox movements in relation to I-70.

4.2. South Dakota swift fox study

1. Based on VHF telemetry data and visual observation, I-90 does not act as a barrier to at-grade crossings. All eight tracked swift foxes were found on opposite sides of I-90 multiple times throughout the study.
2. Rainy weather and subsequent flooding/washouts made consistent culvert monitoring impossible. Still, swift fox use and/or crossings were documented in several different culverts.
3. There is evidence that swift foxes crossed I-90 through at least four two-lane, one four-lane and possibly a six-lane culvert. The four-lane crossing was through a box culvert. The six-lane crossing is not confirmed because the animal may have accessed the culvert via an open grate in the median.
4. Two swift foxes (adult–pup pair) made complete four-lane crossings via a two-lane culvert pair opening into the median when fencing was present. The same culvert system had no documented swift fox use prior to fencing. This may be explained by the geographic location of different active dens during the pre- and post-fencing study period. It may also indicate that fencing can be useful in funneling foxes to culverts.
5. The culverts that had documented swift fox crossings were relatively short in length (i.e., typically spanning two versus four lanes).

6. In the case of the single documented four-lane crossing, the culvert was relatively tall and wide (i.e., a 213 x 213 cm (84 x 84 in) box culvert) compared to the more readily available pipe culverts. Approximately 80% (n = 43) of the pipe culverts monitored measured 91 x 91 cm (36 x 36 in) or less
7. Of the swift foxes killed by traffic, pups are the most common.

4.3. California desert kit fox study

1. Two collared kit foxes were documented to have successfully crossed Hwy 58 on a study site in California. It is unknown whether the foxes crossed the road at grade or used below grade passages. No exclusionary fencing or median barrier is present along this stretch of Hwy 58.
2. The failure of the telemetry technology used in this project was disappointing and significantly inhibited our ability to achieve study objectives.
3. Use of below grade passages by foxes was not addressed during this investigation. Such passages were monitored during a previous investigation, but no use by kit foxes was detected (Bremner-Harrison et al. 2007). However, in another study conducted to examine use of below grade passages by desert tortoises on the Hwy 58 study site, kit foxes were detected using culverts with the following dimensions: 0.9–1.5 m (1–1.6 yd) diameter steel pipe; 1.4-m (1.5-yd) diameter concrete pipe; and concrete boxes 3–3.6 m (3.3–4 yd) wide by 1.8–3 m (2–3.3 yd) high (Boarman and Sazaki 1996).

5. RECOMMENDATIONS

Because we had limited data on San Joaquin kit fox use of below grade passages (i.e., culverts or bridge undercrossings) along four-lane highways (Bremner-Harrison et al. 2007), we used surrogate species to increase our data collection potential. In this report, we consider data collected on swift fox and desert kit fox (hereafter referred to as foxes, unless otherwise specified) to be valid for making mitigation recommendations for San Joaquin kit foxes throughout their range in California. The reasons that swift fox and desert kit fox data are applicable to San Joaquin kit fox mitigation are detailed in our literature review report to Caltrans (Clevenger and Kociolek 2007).

Swift fox were studied along Interstate 70 near Limon in eastern Colorado and along Interstate 90 near Wall in southwestern South Dakota. Desert kit fox were studied along California State Highway 58 near Barstow in southern California. The aim of these companion studies was to investigate the movements and highway crossing behavior of swift and desert kit foxes around four-lane highways to make inferences for San Joaquin kit foxes.

The four-lane highways in our study areas were generally not a barrier to movement of swift fox and desert kit fox. Thus, we can assert the same highway-crossing relationship is true in most cases for San Joaquin kit fox. As a baseline, the South Dakota site had an average daily traffic (ADT) of up to 6,000 vehicles in 2008, and the Colorado and California sites had relatively comparable ADT volumes of approximately 11,500 vehicles in 2006 and 2007. Mortality of foxes does occur throughout the year, primarily after pups are reared and young begin to travel more and disperse from natal ranges (Cypher et al. 2009). Rates of mortality vary from study area to study area, and in most instances appear to be sustainable for local populations of foxes. However, for the precarious San Joaquin kit fox population road-related mortality may exert a strong influence on the ability of local populations to persist over time. Particularly given the fact that traffic volumes will be increasing on highways in San Joaquin kit fox range and the risk of mortality while crossing these highways will increase from current conditions.

San Joaquin kit foxes exist in a demographically vulnerable metapopulation. Metapopulations are patchily distributed networks of localized sub-populations. In most cases, individual subpopulations cannot survive on their own and are subject to extirpation or “winking out.” Maintenance of sub-populations depends on the movement of individuals from “source” populations through the metapopulation network (Hanski 1999).

Within the San Joaquin kit fox metapopulation, six areas are considered to contain important kit fox populations (US Fish and Wildlife Service 1998). Three populations have been designated a high priority for enhancement and protection and are considered “source populations” for the larger San Joaquin kit fox metapopulation (Haight et al. 2002). Sustainable rates of road-related mortality will likely occur in the source populations of San Joaquin kit fox range, i.e., areas characterized by relatively high fox densities, productivity and dispersal potential. However, in non-source or marginal populations, characterized by low population density, low or variable reproduction and limited dispersal, road-related mortality could have serious negative consequences for the persistence of non-source populations, thus pose a significant risk to the long-term viability and stability of the metapopulation.

We provide recommendations with regard to highway mitigation practices in San Joaquin kit fox range with the goal of maintaining and restoring demographic and genetic connectivity within the metapopulation. These recommendations reflect conclusions in Chapter 4 of this report.

5.1. Connectivity zones

Movement and dispersal (hereafter referred to as movement) among source and non-source populations in the metapopulation will likely occur through three possible connectivity zones: (1) between two source populations, (2) between source and non-source populations or (3) between two non-source populations (Figure 22). It will be important for San Joaquin kit fox management to be able to identify where movement is likely to occur, what influences movement and gene interchange, and how transportation infrastructure may affect movement and the exchange of individuals and genes.

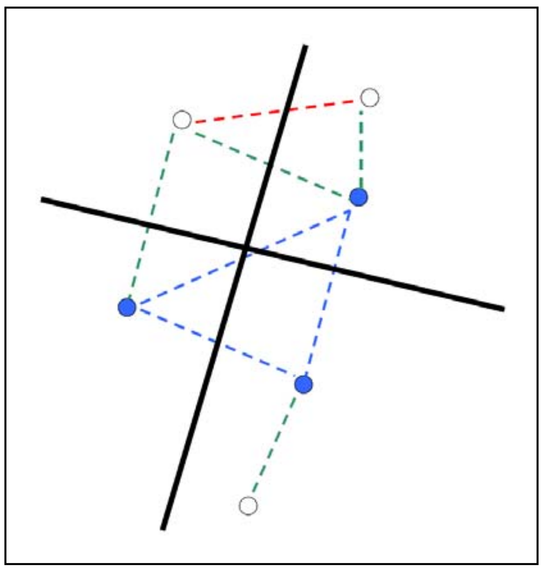

Figure 22. Conceptual movement patterns of individuals among populations within the San Joaquin kit fox metapopulation. Blue dots are source populations. White dots are non-source populations. Roads are solid black lines. Three possible connectivity zones show movement between source populations (blue dashed line), between source and non-source populations (green dashed line) and between non-source populations (red dashed line). This simple conceptual model shown assumes movement is typically between nearest populations.

<u>Research</u> – The following outlines steps required to help management in the planning, design and implementation of mitigation measures along Caltrans infrastructure within San Joaquin kit fox range. A critical first step in planning and designing measures for San Joaquin kit fox consists of identifying broad and fine-scale movement corridors (connectivity zones) within the metapopulation. These movement corridors can be identified from analysis of gene flow using genetic data previously collected for research on gene flow in the metapopulation (Schwartz et al. 2005). We recommend a multimodal landscape resistance approach be used and tested with available genetic data to help robustly delineate corridors for movement and gene flow within the metapopulation (Cushman et al. 2006). This approach models gene flow by evaluating the influence of landscape and environmental factors in the San Joaquin kit fox range.

With connectivity zones delineated and mapped, the second step requires identifying roads and other transportation infrastructure that bisect the three types of connectivity zones (Figure 22).

Once these “conflict areas” between roads and connectivity zones are identified, short-term and long-term mitigation plans can be developed to maintain and restore kit fox movement within the metapopulation.

The third and final step consists of developing solutions and plans for mitigating the conflict zones in the short and long term. Short-term mitigation options may consist of (1) removing existing solid median barriers (e.g., Jersey barriers) or (2) retrofitting existing below-grade passages (e.g., culverts, bridge undercrossings) as safe highway crossing structures for kit foxes and other wildlife. Long-term solutions generally will be part of highway expansion projects in San Joaquin kit fox range. Mitigation measures such as wildlife underpasses and overpasses could potentially be constructed to maintain and restore connectivity within the metapopulation; the latter if part of mitigation for pronghorn movement in the San Joaquin Valley. Although not part of Caltrans facilities, identifying conflict zones between kit fox movement and irrigation canals will be useful for making recommendations to irrigation districts to reduce their impact on movement and gene flow. Bridges over canals have been successfully used to mitigate movement of large and small mammals in Canada and Europe (A. Clevenger, pers. obs.).

Mitigation plans will be different among the three connectivity zones as the urgency of conservation efforts in each varies and depending on whether they intersect existing roads, planned road expansions (two- to four-lanes) and corresponding traffic volumes. We discuss short-term solutions for existing roads and long-term solutions for roads that eventually will be upgraded with additional lanes of traffic in Table 9. The recommendations encompass the types of mitigation discussed below.

Table 9. Short-term solutions for existing roads and long-term solutions for roads that eventually will be upgraded with additional lanes of traffic.

	Existing (short term)	Existing (short term)	Expansion (long term)
Connectivity zone	**Low volume**	**High volume**	**High volume**
Source – Source	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages** – Retrofit to enhance kit fox movement. **Not recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Not recommended.**	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages** - Retrofit to enhance kit fox movement. **Recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Not recommended.**	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages and/or wildlife crossing structures** - Retrofit and/or build to enhance kit fox movement. **Recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Recommended.**
Source – Non-source	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages** – Retrofit to enhance kit fox movement. **Recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Not recommended.**	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages** - Retrofit to enhance kit fox movement. **Recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Not recommended.**	**Median barriers** –Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages and/or wildlife crossing structures** – Retrofit and/or build to enhance kit fox movement. **Highly recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Recommended.**
Non-source - Non-source	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages** - Retrofit to enhance kit fox movement. – **Recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Not recommended.**	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages** – Retrofit to enhance kit fox movement. **Highly recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Recommended.**	**Median barriers** – Do not install. Replace with alternative designs that are more permeable for kit fox movement. **Highly recommended.** **Below-grade passages and/or wildlife crossing structures** – Retrofit and/or build to enhance kit fox movement. **Highly recommended.** **Fencing** – Can be used on bridge or culvert retrofits to enhance kit fox movement. **Recommended.**

5.2. Median barriers

Highway median barriers are used to divide opposing lanes of traffic flow and reduce the risk of cross median collisions. Clevenger and Kociolek (2006) synthesized a state of the practice with regard to median barriers for Caltrans. The following are excerpts from that report (Clevenger and Kociolek 2006):

1. The relative number of cross median accidents is low when compared to total accidents, but the proportion of associated fatalities and injuries is substantially higher (FHWA 2006a, Macedo 1999, Lynch et al. 1993).
2. The Federal Highway Administration has accepted as crashworthy a variety of concrete, metal beam, cable and other median barrier designs that have passed National Cooperative Highway Research Program (NCHRP) 350 Tests (FHWA 2006a and b).
3. The US Department of Transportation (USDOT) has stated the need for an alternative to traditional concrete and metal beam barriers because they can be expensive and difficult to install, citing a nationwide goal for each state to identify appropriate projects for deploying cable median barriers as a potential solution (USDOT 2006).
4. FHWA names cable barriers and rumble strips as two priority technologies with proven benefits and which are ready for deployment (Taylor 2005).

Solid median barriers have the potential to obstruct at-grade movement of San Joaquin kit foxes across highways and can increase the time they are on highways and thus the risk of road-related mortality. Clevenger and Kociolek (2006) assessed potential permeability and mortality risks associated with median barriers for small-, mid-, and large-bodied taxa. Mid-sized animals, including fox, had some of the highest combined risk scores for a variety of concrete median barrier types given that foxes are likely to be too big to utilize scuppers and may be too small to easily jump over barriers (Clevenger and Kociolek 2006).

As indicated above, solid median barriers should not be constructed on any highways or highway upgrade projects in San Joaquin kit fox range, particularly where any connectivity zones exists, even between source populations (Table 9). Where solid median barriers are found on existing sections of highway within the connectivity zones efforts need to be made to remove solid median barriers and replaced with the alternative barrier types listed below. If no solid median barriers are present along highways in connectivity zones, they should remain free of solid median barriers. Alternative median barrier designs should be incorporated into all new highway designs and retrofitting sections with solid median barriers in connectivity zones. Cable, box beam and even thrie-beam barriers will allow for greater cross-highway movement by foxes and pose less of a mortality risk for foxes choosing to cross at-grade.

<u>Research</u> – Additional research is needed to better understand the effects of highway median barriers of all types on movements and mortality risks of San Joaquin kit foxes.

5.3. Below and above grade passage design and planning

To ensure performance and function, below and above grade passages (i.e., drainage culverts and wildlife crossing structures built either below or above grade) should be situated in connectivity zones that serve to link populations. Information on San Joaquin kit fox occurrence, distribution and landscape connectivity will be essential for planning the location of culverts and crossing structures along highways in the San Joaquin kit fox metapopulation (see 5.1 Connectivity Zones above).

On existing highways with low traffic volumes (i.e., two lanes), retrofitting culverts and crossing structures is recommended in connectivity zones linking source and non-source populations and between non-source populations (Table 9). Retrofits are not recommended in connectivity zones linking source populations because even accounting for road-related mortality the source populations should be able to thrive. On existing highways with high traffic volumes (i.e., four lanes), efforts should be made to retrofit culverts and crossing structures to improve movements across highways and allow for exchange of individuals and genes between populations. When highway expansion projects occur within the metapopulation, a variety of culverts, underpasses, and overpasses are highly recommended in connectivity zones linking source and non-source populations and between non-source populations. However, in connectivity zones linking source populations crossing structures are recommended but less critical for kit fox conservation.

Culverts and crossing structures should be designed to conform to local topography. Drainage features should be included in crossing structures to minimize flooding within the structures. Culverts will inevitably have some standing or running water through them seasonally. Typically, more culverts and crossing structures provide greater highway permeability for foxes. The best practice would be to install as many culverts and/or crossing structures as possible within the San Joaquin kit fox metapopulation or range. Given the average home range size of San Joaquin kit foxes (5.9 km^2 with 2.7 km diameter; Nelson et al. 2007), we recommend a minimum of one culvert or crossing structure every 0.5 km (0.3 mi). This would result in multiple opportunities for safe below or above grade crossings in each fox home range.

The smallest diameter culvert used by swift fox to cross a highway in this study was 46 cm (18 in); however, it only facilitated a two-lane crossing. The only documented four-lane crossing was through a box culvert measuring 213 x 213 cm (84 x 84 in). We were unable to obtain sufficient data at the monitored culverts to make strong inferences regarding the design of culverts for San Joaquin kit foxes. Nonetheless, some general principles with regard to design of wildlife crossings can be used as guidelines for this species (Clevenger and Huijser 2009).

Culverts should be variable in size but a minimum diameter of 61 cm (24 in). In larger culverts and underpasses, escape dens should be constructed (see below).

Research – Within five years, if additional culverts and crossing structures are built on highways within the San Joaquin kit fox range, additional research should be carried out to better understand the relationship between fox movement, gene flow, mortality and crossing structure design. In the meantime, cameras may be installed to monitor existing culverts and crossing structures.

5.4. Fencing

The short amount of time we were able to test the effectiveness of fences to increase fox use of culverts provided interesting results. In the absence of median barriers, however, our broader results suggest that fencing is not necessary in most instances. On two-lane highways fencing will not be necessary as the risk of mortality is low. The same is true on four-lane highways in connectivity zones linking source populations and source and non-source populations as incidence of mortality will most likely have a negligible effect on the population (Table 9). In areas linking non-source populations, however, fencing to funnel movement to existing crossing structures is recommended.

Research – There is a need for more tests evaluating whether fencing will facilitate use of below grade passages by foxes. The temporary chicken-wire fencing used in this experiment was relatively inexpensive. The cost to install 5.5 km (3.4 mi) of fencing and encompassing two culverts was approximately $12,000. While permanent fencing would likely cost more, it would be a fraction of the cost of installing a culvert or crossing structure. Fencing may be a low-cost solution to improve below or above grade passage use by San Joaquin kit foxes and reduce road-related mortality. Additional studies should be conducted within San Joaquin kit fox range as to the efficacy of fencing on fox use of below or above grade passages.

5.5. Prey traps

Given the fact that competitor species (e.g., coyotes, red foxes) also were detected near and in below grade passages, mitigation should include escape dens within crossing structures. This consists of a 3-m (10-ft) length of 20-cm (8-in) diameter pipe anchored in the structure (with the entrance constricted to 10–15 cm [4–6 in] to exclude red foxes). This is becoming a common mitigation design for culverts and underpasses within the San Joaquin kit fox range. Alternatively, grating could be placed over the entrance of the structures that would allow kit foxes to pass, but not larger predators. This can only be implemented in areas where local hydrology does not allow trash and vegetation to collect on the grate and cause flooding.

5.6. GPS technology

GPS technology may still be useful for an investigation of this nature, however, not until the deficiencies we encountered are corrected. Other methodologies that could be employed to achieve study objectives include VHF telemetry and genetic analyses of fecal or hair samples collected from study sites.

5.7. Species occurrence surveys

Critical to effective and proactive planning of mitigation for San Joaquin kit foxes will be science-based information about current population status, distribution, and demographic trends. This information can be obtained from species occurrence surveys within the metapopulation with an eye on where transportation projects may impact connectivity zones, local populations and their long-term persistence. We recommend that Caltrans, in conjunction with California Fish and Game and the U.S. Fish and Wildlife Service, establish a long-term, population and genetic monitoring program for San Joaquin kit fox metapopulation. Once established, the monitoring program will track changes in the genetic variability and gene flow of kit fox in the San Joaquin Valley. With the recent development of non-invasive genetic sampling techniques (Smith et al. 2001, Bremner-Harrison et al. 2006) these monitoring efforts can be conducted without the major expenses of trapping studies and will provide important data on changes in kit fox genetics and demography. These types of efforts will also help detect unknown populations, if they exist, or at least help quantify individual foxes that may reside, and possibly breed, in the spaces between known populations. The data will provide current information on that status of the metapopulation, between population movement, help identify areas where highway-related mortality may have population-level impacts, and help retrofit existing infrastructure or design new mitigation measures (e.g., crossing structures) to increase highway permeability and reduce mortality. This will also make possible a more effective and proactive planning of highway mitigation actions on future highway expansion projects in San Joaquin kit fox range.

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7. APPENDIX A

7.1. 2009–2010 South Dakota culvert monitoring scheme and swift fox detections

Subsection	Culvert code	Monitoring tool	Monitoring period (month/day)	Swift fox detected
I	B117A	camera; too flooded for track bed	8/28-9/3; 9/28-10/5	no
	R117B	track bed	6/25-10/30; mostly inoperable	no
	R117C	track bed	6/25-10/30; mostly inoperable	no
	R117D	track bed	6/25-10/30; mostly inoperable	no
	R118C	track bed	6/25-10/30; mostly inoperable	yes
	R119A	track bed	6/25-10/30; mostly inoperable	no
	R119B	track bed	6/25-10/30; mostly inoperable	yes
		camera	9/2-9/14	yes
	R119C	track bed	6/25-10/30; mostly inoperable	yes
		camera	9/3-9/14; 9/16-9/22	yes
	R119D	camera; too flooded for track bed	9/28-10/5	no
	R119E	track bed	6/25-10/30; mostly inoperable	no
		camera	10/7-10/14	no
	R120A	track bed	6/25-10/30; mostly inoperable	yes
	B120B	track bed	6/25-10/30; mostly inoperable	no
	R120B	track bed	6/25-10/30; mostly inoperable	no
	R120C	track bed	6/25-10/30; mostly inoperable	no
	R121A	track bed	6/25-10/30; mostly inoperable	no
		camera	9/28-10/5	no
	R121C	track bed	6/25-10/30; mostly inoperable	no
		camera	7/13-10/6; 10/15-11/19	yes
	R121D	track bed	6/25-10/30; mostly inoperable	yes
		camera	10/7-10/14	no
	R121E	track bed	6/25-10/30; mostly inoperable	no
	R122A	track bed	6/25-10/30; mostly inoperable	no
	R122B	track bed	6/25-10/30; mostly inoperable	no
	R122D	track bed	6/25-10/30; mostly inoperable	no
II	B126A	track bed	6/25-10/30; mostly inoperable	no
		camera	7/2-10/6; 10/15-11/19	yes
	R126B	track bed	6/25-10/30; somewhat inoperable	no
	R127A	track bed	6/25-10/30; mostly inoperable	no
	R128A	track bed	6/25-10/30; mostly inoperable	no
		camera; post fencing	12/1-12/15	yes
	R128B	track bed	6/25-10/30; somewhat inoperable	no
		camera	8/28-9/2	no
		camera; post fencing	12/1-12/15	yes
	R129B	track bed	6/25-10/30; mostly inoperable	no
	R130B	track bed	6/25-10/30; mostly inoperable	no
	B130D	track bed	6/25-10/30; mostly inoperable	no
		camera	7/10-10/6; 10/14-11/19	yes
	R130G	track bed	6/25-10/30; mostly inoperable	no
	R132A	track bed	6/25-10/30; mostly inoperable	no
	E132B	track bed	6/25-10/30; somewhat inoperable	no

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Subsection	Culvert code	Monitoring tool	Monitoring period (month/day)	Swift fox detected
III	R136A	track bed	6/25-10/30; mostly inoperable	no
	R137A	track bed	6/25-10/30; mostly inoperable	no
	R137B	track bed	6/25-10/30; somewhat inoperable	no
	R138A	track bed	6/25-10/30; mostly inoperable	no
	R138B	track bed	6/25-10/30; mostly inoperable	no
	R138C	track bed	6/25-10/30; somewhat inoperable	no
	R139A	track bed	6/25-10/30; mostly inoperable	no
		camera	10/7-10/14	no
	R139B	track bed	6/25-10/30; mostly inoperable	no
	R139C	track bed	6/25-10/30; somewhat inoperable	no
	R139D	track bed	6/25-10/30; mostly inoperable	no
	E140B	track bed	6/25-10/30; somewhat inoperable	no
	R140C	track bed	6/25-10/30; somewhat inoperable	no
		camera	7/15-9/22	no
	R141A	track bed	6/25-10/30; mostly inoperable	no
	R141B	track bed	6/25-10/30; mostly inoperable	no
	R142A	track bed	6/25-10/30; mostly inoperable	no
	R142B	track bed	6/25-10/30; somewhat inoperable	no
	R142C	track bed	6/25-10/30; somewhat inoperable	no

NOTES:

Subsections are shown in Figure 15.

Inoperability was mainly caused by rain wash outs, saturated ground, standing water and, to a lesser degree, wind scouring and skunk digging.

Post fencing refers to the experimental fencing study discussed in section 2.2.