USE OF HIGHWAY CROSSING STRUCTURES BY KIT FOXES

PREPARED FOR THE CALIFORNIA DEPARTMENT OF TRANSPORTATION

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EXECUTIVE SUMMARY

San Joaquin kit foxes (*Vulpes macrotis mutica*) are Federally Endangered and California Threatened, primarily due to profound habitat degradation and loss. Roads potentially contribute to habitat fragmentation by creating barriers to animal movements. However, structures such as culverts, underpasses, and overpasses could mitigate fragmentation effects by providing road crossing opportunities for foxes.

We conducted a field investigation from 18 July 2005 to 21 June 2006 to determine (1) whether kit foxes use existing structures to cross highways, and (2) whether foxes exhibit any preferences among structure designs. The overall goal of this effort was to provide the California Department of Transportation with information that would contribute to mitigating impacts to kit foxes from four-lane divided highways. Data were collected at 3 study sites in Kern County: a 2-mile segment of Interstate 5 (I-5), a 20-mile segment of State Route 14 (Rte 14), and an 8-mile segment of State Route 58 (Hwy 58). Eight structures were monitored along I-5, 17 along Rte 14, and 21 along Hwy 58. Use of structures by kit foxes and other species was monitored using track stations established at the ends of structures and motion-activated digital cameras placed within structures. Additionally, hair sampling traps were deployed in each study site to collect genetic samples and weekly surveys were conducted at each site to locate any animals killed by vehicles on the roads.

In 1,542 track-station-weeks, kit fox tracks were detected 12 times at Hwy 58 and 7 times at I-5. However, kit fox tracks were always detected at only one end of a structure indicating that the foxes had not crossed through the structure. Tracks of at least 16 other species were detected as well. In 1,227 camera-station-nights, at least 9 species were detected within crossing structures, but no kit foxes were detected. No kit fox hair samples were collected in 248 trap-weeks. One vehicle-killed kit fox was found at Hwy 58 and another was found at Rte 14.

Kit fox presence was confirmed on all 3 study sites. However, during the 11-month period of data collection, no kit foxes were detected using crossing structures at any of the sites. We hypothesize that kit foxes may associate increased predation risk with the structures because of the relatively confined space within most structures. One caveat is that we were not able to effectively monitor very large structures, such as areas under bridges that crossed over large drainages, and it is possible that foxes use these crossing structures.

The two vehicle-killed kit foxes in conjunction with the lack of detections in the crossing structures indicated that foxes appear to be avoiding the structures and simply attempting to cross the roads. No exclusionary fencing or median barriers were present at the study sites to inhibit crossing attempts. Despite the two dead foxes, it is highly likely that some foxes successfully cross the roads, particularly because the foxes are nocturnal and likely attempt most crossings at night when traffic volumes are lower. Thus, these highways may not be functioning as barriers to genetic flow, and if mortality from vehicles is not excessive, then demographic flow is being maintained as well.

Plans to expand 2-lane roads to 4-lane divided highways within the range of the San Joaquin kit fox commonly include the installation of median barriers, which could trap foxes in traffic if they attempt to cross these highways. Along these highways, fencing is

recommended to prevent foxes from accessing the roads and also to direct foxes to crossing structures. Optimal crossing structure designs for kit foxes are still unknown, but generally such structures should be as large as feasible and provide an unobstructed view of habitat on the opposite side. Also, artificial dens should be installed within structures and near entrances to provide escape cover for kit foxes. Additional research is recommended to determine whether kit foxes indeed are routinely crossing 4-lane highways successfully or are primarily avoiding crossing attempts.

ACKNOWLEDGEMENTS

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INTRODUCTION

Roads can impact natural communities in many ways, including acting as movement barriers (Chruszcz et al. 2003) or causing habitat fragmentation (Forman et al. 2003). The resultant inhibition of demographic flow and gene flow created by habitat fragmentation can be particularly detrimental in the case of small populations, increasing the risk of extinction on a local scale. The significance of these impacts increases when a species that is already considered rare or endangered is involved.

San Joaquin kit foxes (*Vulpes macrotis mutica*) are endemic to the San Joaquin Valley, and are listed as Federally Endangered and California Threatened, primarily due to profound habitat loss and degradation. Much of the habitat within their former range has been displaced by agricultural, industrial, and urban development (U.S. Fish and Wildlife Service 1998). Remaining San Joaquin kit foxes subsist in small, fragmented populations in areas where suitable habitat can still be found. One side effect of these isolated populations is their increased vulnerability to local extinction as a result of stochastic events or genetic decline. Remaining habitats have been subjected to landscape alterations resulting from grazing, fire, and other anthropogenic disturbance.

Roads potentially are a significant cause of habitat and population fragmentation and may constitute a barrier to kit fox movements, dispersal, and genetic exchange. A number of 2-lane and 4-lane roads intersect remaining San Joaquin kit fox habitat. A review and synthesis of available literature on known and potential effects of roads on San Joaquin kit foxes determined that road effects likely were occurring and potentially could adversely affect kit fox conservation and recovery efforts (Cypher 2000). In 2001, the California Department of Transportation funded a project to examine effects of 2-lane roads on kit foxes. The conclusions of this project were that kit fox demography and ecology did not appear to be significantly affected by the presence of 2-lane roads in natural habitats.

The effects of larger roads (e.g., greater than 2 lanes, divided highways) on kit foxes are not known. Construction of new roads or expansion of existing roads may be causing significant impacts to kit foxes. As the human population of California continues to grow, many existing 2-lane highways will be expanded to 4 or more lanes, some will be divided, and many will likely have a median barrier increasing their level of impermeability. The effects of larger roads on San Joaquin kit fox have not been evaluated but could significantly impact populations.

Existing structures are present along many 4-lane roads that may be utilized by foxes to cross under or over roads rather than crossing the road itself. These can include drainage culverts of various sizes and types, underpasses for transportation or natural features such as water-courses, or overpasses for vehicles or pedestrians. The use of such structures to cross roads has been demonstrated for a number of common species, such as ungulates (Ng et al. 2004; Clevenger and Waltho 2005) and black bears (*Ursus americanus*; Clevenger and Waltho 2005) as well as rare species such as Florida panthers (*Puma concolor coryi*; Foster and Humphrey 1995) and grizzly bears (*Ursus arctos*; Clevenger and Waltho 2005). However, it is unknown whether San Joaquin kit foxes use these structures to cross roads, and if so whether they are exhibiting preferences for particular types or attributes of structures.

In order to ascertain the effectiveness of existing structures to facilitate the crossing of 4-lane divided highways by San Joaquin kit foxes, the following specific objectives were identified:

1. Measure the use of crossing structures by kits foxes in areas where suitable kit fox habitat exists on either side of the highway.
2. Assess and identify design and habitat factors associated with structures that may influence use or avoidance.
3. Assess the conservation value of drainage/crossing structures using DNA-based hair sampling.
4. Develop recommendations for constructing crossing structures for kit foxes.

METHODS

STUDY SITES

Study site criteria stipulated that each site consist of a four-lane highway with a variety of underpass (or overpass) crossings. In order to assess habitat connectivity, each site also had to bisect an area of suitable kit fox habitat. There are very few sites where San Joaquin kit fox populations are bisected by four-lane highways. Therefore, additional sites in the Mojave desert were assessed in areas populated by desert kit foxes (*Vulpes macrotis arsipus*), surmising that information regarding structure suitability would be relevant to both subspecies. Six sites were assessed for use: a section of the California Aquaduct running from Stockdale Hwy to State Route 58, Kern County; a section of State Route 119 from Elk Hills Road to Gosford Road, Kern County; a north-south section of I-5, bordered by the Kern Waterbank which is situated between Panama Lane and Stockdale Highway, Kern County; a north-south section of State Route 14 from the junction with Randsburg Cutoff to Red Rock Canyon State Park, Kern County; an east-west section of State Route 58 from Mojave out to Boron, Kern County; and another east-west section of State Route 58 from Kramer Junction (State Route 395 intersection) to Barstow, San Bernardino County (Figure 1).

Three sites were chosen based on the selection criteria outlined above. These were the Kern Waterbank section of I-5, the section of Route 14, and the section of Highway 58 running east of Kramer Junction towards Barstow (Figure 1). These sites are referred to as I-5, Route 14 and Highway 58 respectively. Due to limitations on the number of suitable sites within San Joaquin kit fox range, two of the selected sites (Highway 58 and Route 14) were located within desert kit fox range rather than San Joaquin kit fox range.

The various styles of crossing structures present at each of these sites represented existing structures that had been incorporated into the road design for reasons other than wildlife passages, such as drainage culverts for run-off, overpasses to facilitate movement of adjacent landowner’s vehicles, and culverts or bridges for the passage of seasonal waterways. Thus, the objective at these sites was to look at pre-existing structures and see which structural designs may be serving the secondary purpose of allowing foxes and other species to safely traverse the road.

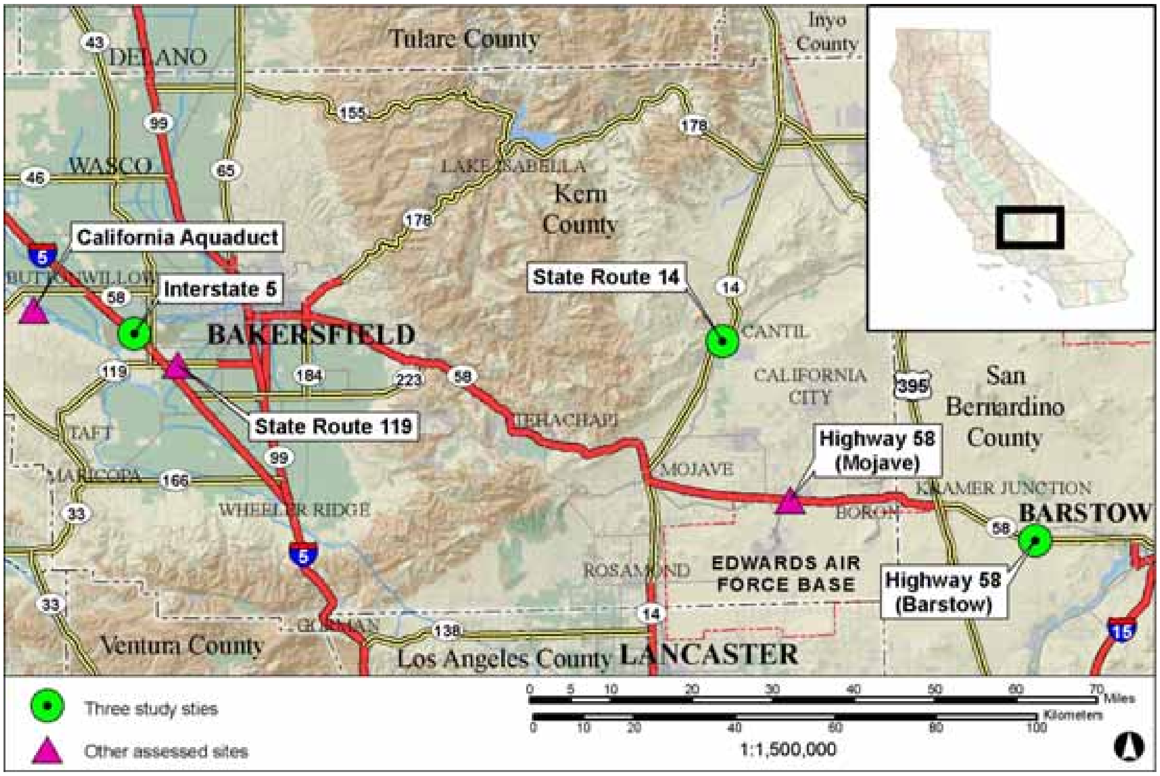

Figure 1. Six potential sites that were considered for inclusion in the study of use of highway crossing structures by kit foxes.

Interstate 5

The Interstate 5 (I-5) study area encompassed an approximately 3-mile segment of I-5. Habitat type in the I-5 study area consisted primarily of alkali sink with artificial wetlands in the form of percolation basins intended to recharge the underlying aquifer. The landowner along either side of this stretch of I-5 was the Kern Water Bank Authority. This is a Joint Powers Authority including water districts and a mutual water company. The Water Bank comprised approximately 20,000 acres in the southwestern end of the San Joaquin Valley that is bisected by I-5 (Figure 2).

The Kern Water Bank falls within the known current range of San Joaquin kit fox (Smith et al. 2006). Regular monitoring conducted by biological consultants on behalf of the Kern Water Bank has indicated the presence of kit foxes on both sides of the I-5 at this site. While numbers of foxes were not high during each of the monitoring years, foxes were shown to be consistently present for the years where data were available. Foxes were monitored using nighttime spotlighting (Figure 3; Kern Water Bank Authority 2001; 2004-2006) and scent stations (Figure 4; Kern Water Bank Authority 2001).

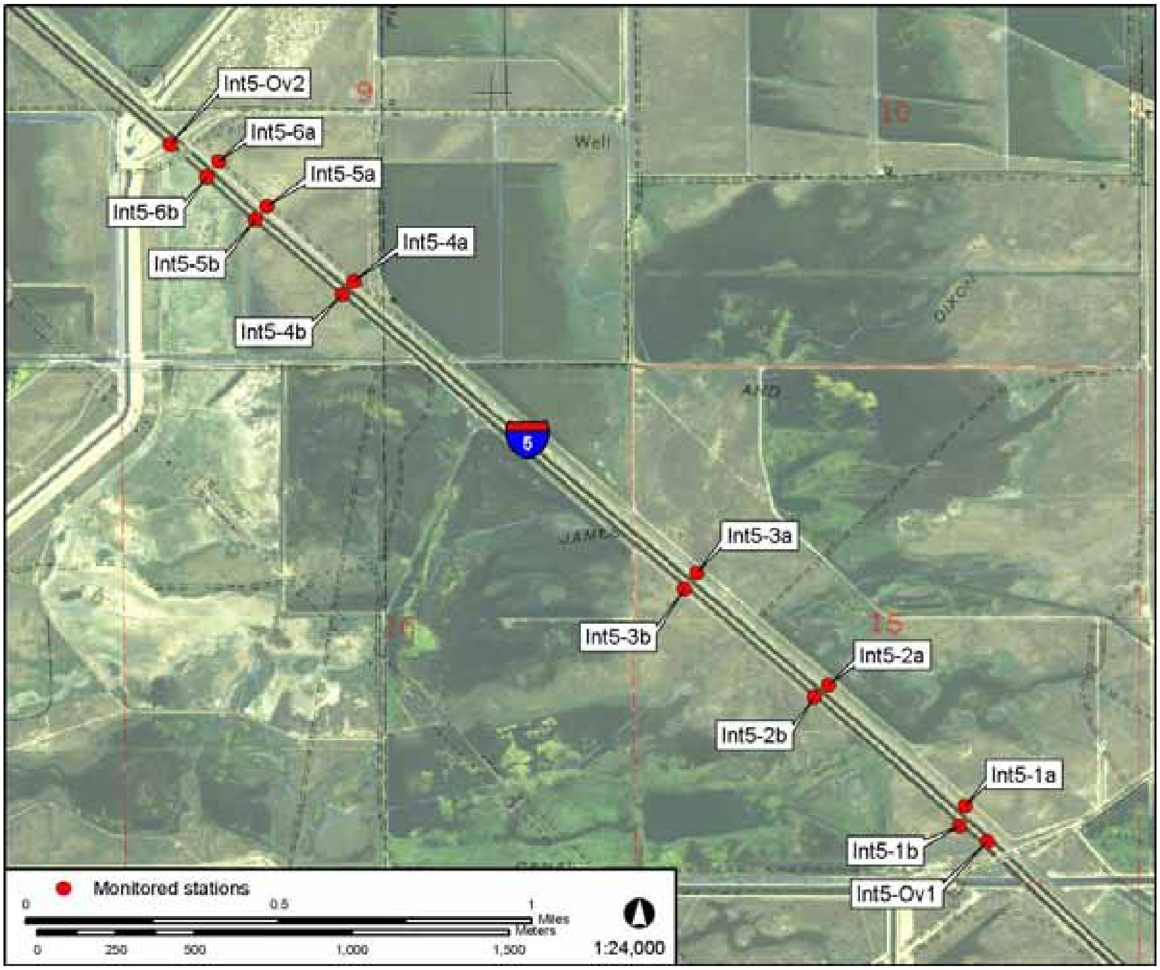

Figure 2. Interstate 5 study site and the locations of the crossing structures that were monitored.

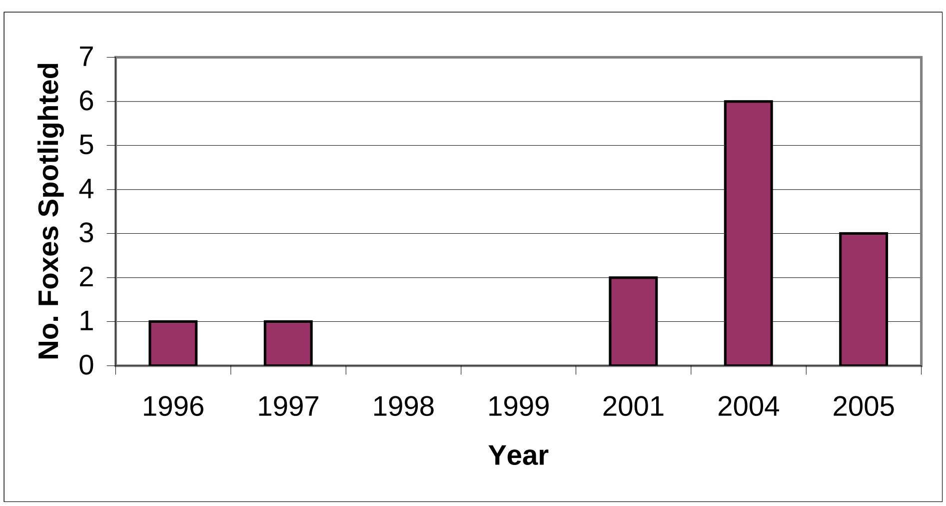

Figure 3. Results of nighttime spotlighting for kit foxes at the Kern Water Bank.

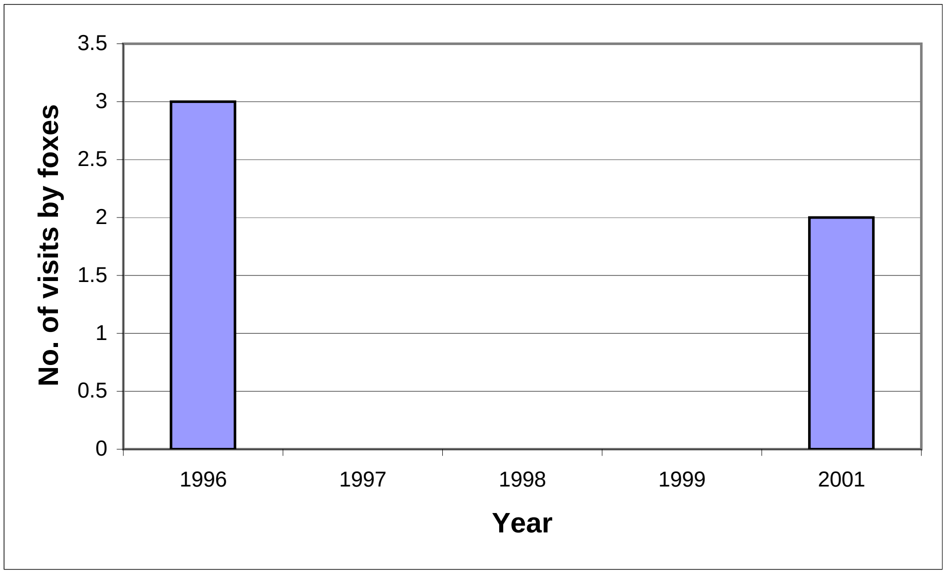

Figure 4. Results of scent station monitoring for kit foxes at the Kern Water Bank.

Crossing structures at the I-5 site included two overpasses and six culvert underpasses (Figure 5 and Figure 6). Specifications of the six culverts are shown in Table 1. All culverts on this stretch of I-5 had a median break. No median barrier was present at this study site. Culverts were extremely overgrown at the start of the study period (Figure 7 and Figure 8). Entrances were often difficult to locate until extensive vegetation clearance was undertaken. In several cases, the original dimensions of the culvert had been considerably reduced due to soil build-up within the culvert (Figure 9).

The average annual daily traffic total (AADT) represents the average number of vehicles passing a given point on a road per day for a particular year, with a higher AADT value representing a busier roadway (California Department of Transportation 2007). The stretch of I-5 that incorporated the study site contained 2 points where traffic volume data was collected, and we calculated the average between these points to determine the AADT volume passing through the study area. Data were available for 2006, for the section of I-5 that traverses the Kern Water Bank there was an AADT of 32,250 across all lanes.

Figure 5. Two-lane overpass crossing structure over Interstate 5.

Figure 6. Example of a concrete circular culvert under Interstate 5.

Table 1. Attributes of crossing structures at the Interstate 5 study site. The letters a and b in the table following the station ID number refer to the two ends of the structure, with 'a' referring to the end on the east side of Int5 and 'b' referring to the end on the west side.

Station ID	Station Type	Height (m)	Width (m)	Total crossing length (m)	Openness factor[2]	Dist to road (m)	Station Materials	Median Break	Habitat Type at Station[1]
Int5-01a	Culvert	0.99	1.2	225	0.006	9.19	Concrete	yes	Disturbed roadside
Int5-01b		1.15	1.22			9.65			Disturbed roadside
Int5-02a	Culvert	0.23	0.5	191	0.001	10.08	Concrete	yes	Disturbed roadside
Int5-02b		0.34	0.61			8.75			Disturbed roadside
Int5-03a	Culvert	0.28	0.65	216	0.001	11.65	Concrete	yes	Disturbed roadside
Int5-03b		0.33	0.62			8.25			Disturbed roadside
Int5-04a	Culvert	0.33	0.61	188	0.001	8.30	Concrete	yes	Disturbed roadside
Int5-04b		0.53	0.62			8.25			Disturbed roadside
Int5-05a	Culvert	0.45	0.62	186	0.001	8.60	Concrete	yes	Disturbed roadside
Int5-05b		0.35	0.57			8.35			Disturbed roadside
Int5-06a	Culvert	0.17	0.6	203	0.001	7.90	Concrete	yes	Disturbed roadside
Int5-06b		0.5	0.6			8.35			Disturbed roadside
Int5-Ov1	Overpass				n/a		Concrete	No	Disturbed roadside
Int5-Ov2	Overpass				n/a		Concrete	No	Disturbed roadside

[1]Surrounding habitat type for all stations = Alkali sink/Wetland.

[2]Openness factor is equal to (width x height/length, Reed & Ward 1985). Height and width calculated as means of two end values.

Figure 7. Example of an overgrown culvert under Interstate 5.

Figure 8. Example of an overgrown culvert under Interstate 5.

Figure 9. Example of a soil filled culvert under Interstate 5.

Route 14

This site was situated along an approximately 8-mile stretch of Route 14 starting approximately 6.5 miles north of the Randsburg Cutoff Road and ending approximately 3 miles south of the entrance to Red Rock Canyon State Park (Figure 10). Habitat type in this area consisted primarily of desert scrub. Landowners at this site comprised a combination of Bureau of Land Management and private absentee landowners. This site falls within the range of the desert kit fox (O'Farrell and Gilbertson 1986).

Crossing structures were primarily situated in drainage washes and comprised three types: large concrete box structures, a concrete bridge structure, and either single or double metal culvert pipes of varying sizes. Within the stretch of Route 14 selected for study there were two 2-x box structures, one 6-x box structure, three bridge structures, eleven single pipe culverts and one double pipe culvert. The dimensions and other physical characteristics of each station are shown in Table 2.

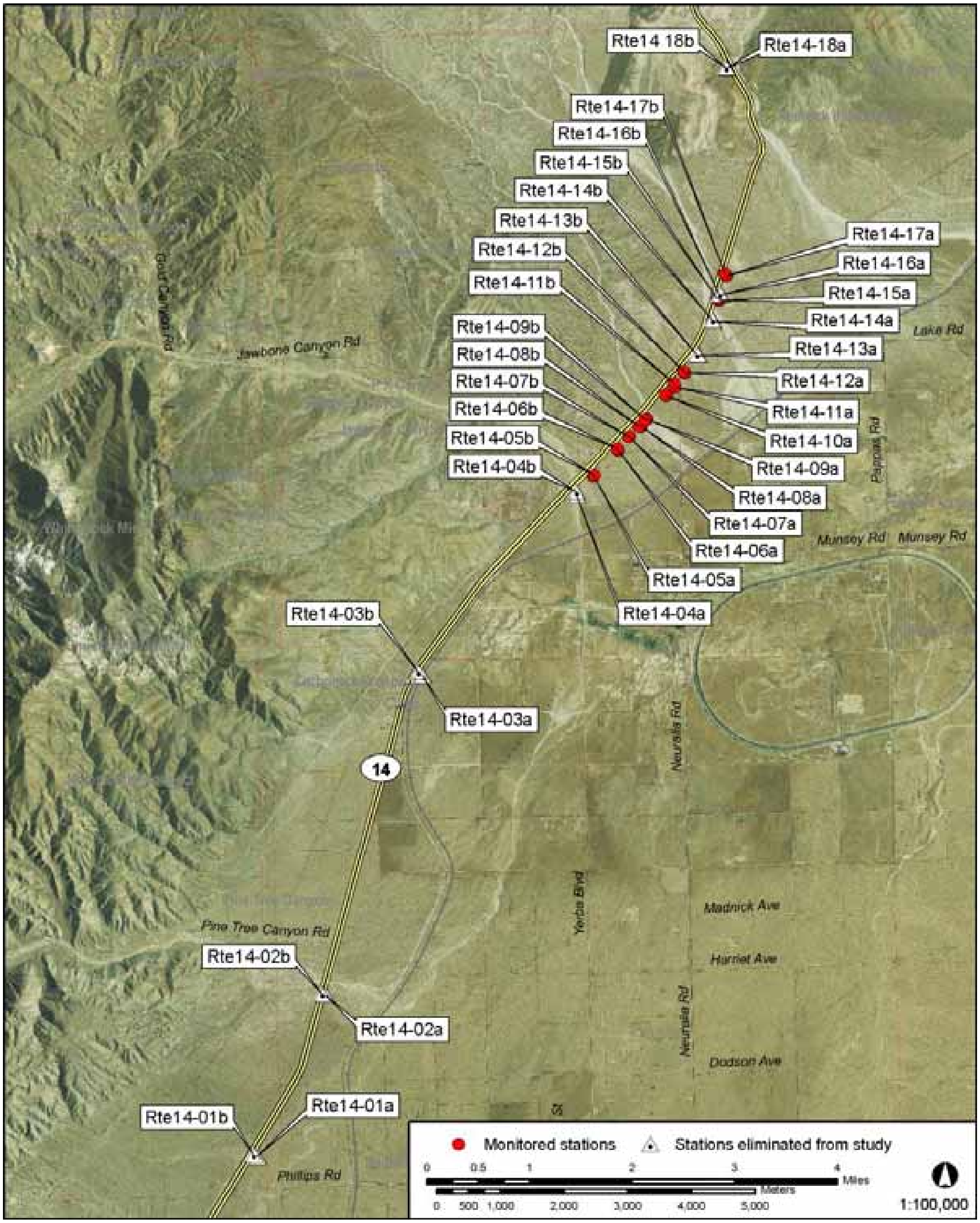

Figure 10. Route 14 study site showing the location of monitored and eliminated crossing structures.

Table 2. Attributes of crossing structures at the Route 14 study site. The letters following the station ID number refer to the two ends of the structure with 'a' referring to the east end of the structure and 'b' referring to the west end.

Station ID	Station Type	Height (m)	Width (m)	Total crossing length (m)	Openness factor[2]	Dist to road (m)	Station Materials	Median Break	Habitat Type at Station[1]
Rte14-01a	2x box culvert	1.33	4.92	217.6	0.03	8.70	Concrete w/sand bottom	Yes	~5m wide saltbush wash
Rte14-01b		1.2	4.96			8.65			
Rte14-02a	6x box culvert	2.09	14.76	220.5	0.15	8.70	Concrete w/sand bottom	Yes	25-30m saltbush wash,
Rte14-02b		2.42	14.64			8.60			
Rte14-03a	2x box culvert	0.8	4.9	290.73	0.02	8.70	Concrete w/sand bottom	Yes	wash, saltbush on low banks, brome
Rte14-03b		1.6	4.9			8.75			
Rte14-04a	Bridge	3.5	50	144.44	1.21	N/A	Concrete w/sand bottom	No	Dry wash with scattered shrubs
Rte14-04b		3.5	50			N/A			
Rte14-05a	Pipe culvert	0.48	0.62	63.41	0.004	8.25	Metal w/sand bottom	No	Drainage bank
Rte14-05b		0.28	0.63			8.13			
Rte14-06a	Pipe culvert	0.23	0.64	98.5	0.003	4.35	Metal w/sand bottom	No	Drainage bank
Rte14-06b		0.63	0.77			1.98			
Rte14-07a	Pipe culvert	0.46	0.49	34.41	0.006	4.35	Metal w/sand bottom	No	Small drainage wash, no veg
Rte14-07b		0.45	0.45			4.26			
Rte14-08a	Pipe culvert	0.47	0.21	105.45	0.001	5.00	Metal w/sand bottom	No	drainage wash
Rte14-08b		0.45	0.45			4.30			
Rte14-09a	Pipe culvert	0.95	1.61	116.5	0.014	4.60	Metal, flat at bottom	No	Drainage wash
Rte14-09b		0.94	1.88			2.00			Large wash
Rte14-10a	Pipe culvert	0.64	0.61	85	0.004	6.50	Metal	No	Small drainage wash w/vegetation
Rte14-10b		0.58	0.58			5.50			
Rte14-11a	Pipe culvert	0.61	0.61	205.75	0.002	5.75	Metal w/sand bottom	No	Drainage wash
Rte14-11b		0.43	0.61			10.1, 4.1			
Rte14-12a	2x pipe culvert	0.58(N),0.61(S)	62(N),61(S)	109.2	0.003	7.60	Metal w/sand bottom	No	Large sandy wash
Rte14-12b		48(N),53(N)	65(N),65(S)			5, 2.5			
Rte14-13a	Pipe culvert	0.5	0.5	113.2	0.002	N/A	Metal w/sand at 1 end	No	Very deep wash
Rte14-13b		0.41	0.48			5.00			
Rte14-14a	Bridge	4.5	20	61.5	1.46	N/A	Concrete	No	Wide wash, boulders on banks
Rte14-14b		4.5	20			N/A			
Rte14-15a	Pipe culvert	0.34	0.53	94.65	0.003	4.7, 4.2	Metal w/sand bottom	No	Drainage wash
Rte14-15b		0.65	0.47			3.35,2.95			
Rte14-16a	Pipe culvert	0.76	1.24	N/A	N/A	4.30	Metal w/sand bottom	No	Drainage wash
Rte14-16b		N/A	N/A			N/A			
Rte14-17a	Pipe culvert	0.35	0.48	119.7	0.002	9, 6.8	Metal w/sand bottom	No	Drainage wash
Rte14-17b		0.46	0.48			7.2, 7.8			
Rte14-18a	Bridge	5.00	8.00	105.1	0.38	2.30	Concrete	No	Very wide wash
Rte14-18b		5.00	8.00	217.6		2.42			

[1]Surrounding habitat type for all stations = Alkali desert scrub.

[2]Openness factor is equal to (width x height/length). Height and width calculated as means of two end values.

The concrete box structures consisted of either 2 or 6 adjoining box structures of varying heights (Figure 11 and Figure 12). A median break was incorporated at each of the box structures. No median barrier was present at this study site.

Each of the three bridge structures had a median break and was built in sections separated either by solid concrete walls (Figure 13) or by concrete posts (Figure 14 and Figure 15). All of the bridge structures had sloping sides, set with various sized boulders and cement. Each of the bridge-style underpasses traversed a large wash, ranging from 8 m to 50 m wide.

None of the metal culverts had a median break (i.e., each culvert started on one side of the highway and traversed directly through to the other side). All culverts were constructed from ridged metal pipe (Figure 16) and ranged in size from 47 cm high x 21 cm wide to 94 cm high x 188 cm wide. The majority of these culverts had a sand base created by rain run-off flowing through the pipe (Figure 17). The depth of the sand base varied across culverts and also throughout the duration of the study depending on weather conditions. Therefore, the amount of space available for an animal to pass through the culvert crossing structures varied over time.

The stretch of Route 14 that incorporated the study site contained 3 points where traffic volume data had been collected. Data were available for 2006, and the average AADT across these three points was 6,300 across all lanes of travel.

Figure 11. Two-x box-culvert crossing structure with median break at the Route 14 study site.

Figure 12. Six-x box-culvert crossing structure with a median break at the Route 14 study site.

Figure 13. Bridge style crossing structure with solid wall supports at the Route 14 site.

Figure 14. Bridge style crossing structure with double post supports at the Route 14 site.

Figure 15. Bridge style crossing structure with multiple post supports at the Route 14 study site.

Figure 16. Example of a metal culvert at the Route 14 site.

Figure 17. Sand base in a metal culvert crossing structure at the Route 14 site.

Highway 58

The third site was situated along Highway 58 in the Mojave Desert within the range of the surrogate desert kit fox subspecies (O'Farrell and Gilbertson 1986). The study site consisted of a four-lane stretch of highway that began approximately 30 miles east of Route 395/Kramer Junction and ran for approximately 26.5 miles to where Highway 58 reduced to two lanes (Figure 18). Landowners along either side of this stretch of Hwy 58 comprised either Bureau of Land Management or private landowners. Habitat type in this area consisted primarily of alkali desert scrub.

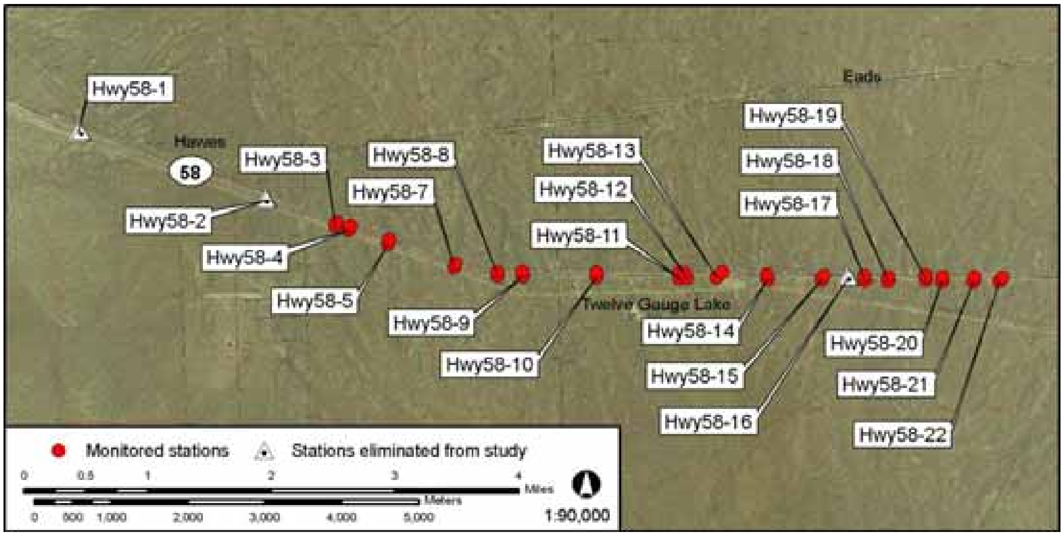

Figure 18. Highway 58 study site showing the location of monitored and eliminated crossing structures.

Crossing structures along this section of Hwy 58 comprised single or double metal pipe culverts (some of which were lined with a bituminous coating used to prevent corrosion of the corrugated metal pipe; Figure 19 and Figure 20), single or double concrete box structures (Figure 21), and concrete bridge structures supported by either one concrete support wall or three rows of support columns (Figure 22 and Figure 23). Round metal culverts and concrete box culverts did not have a median break in them, but the larger concrete bridge structures did have a median break. No median barrier was present along this stretch of Hwy 58. Details of the structures are shown in Table 3.

Drift fencing was present along this section of Hwy 58 (Figure 24) from a study conducted on Desert Tortoise (*Gopherus agassizii*; Boarman and Sazaki 1996). While this fencing may have facilitated in guiding kit foxes towards the crossing structures, it was not of an adequate height to prevent them from passing over the fence and crossing via the road. Drift fencing was not present at the median breaks in the bridge style crossing structures. It is probable that the slopes of the median break would be inaccessible to a desert tortoise, but a kit fox would likely be able to access the roads from these median breaks. Therefore, the drift fencing present on this site was not considered as affecting the fox's choice of whether to cross via a crossing structure or pass over the road surface.

The stretch of State Route 58 that incorporated the study site contained 5 points where traffic volume data had been collected. Data were available for 2006. The average AADT across these five points was 11,700 in both directions of travel.

Figure 19. Unlined double metal culvert crossing structure on Hwy 58.

Figure 20. Lined single metal culvert crossing structure on Hwy 58.

Figure 21. Single box culvert crossing structure on Hwy 58.

Figure 22. Concrete bridge crossing structure with one support wall on Hwy 58.

Figure 23. Concrete bridge style crossing structure with three rows of support columns on Hwy 58.

Figure 24. Drift fencing installed to guide desert tortoise to underpasses.

Table 3. Attributes of crossing structures at the Highway 58 study site. The letters following the station ID number refer to the two ends of the structure with 'a' referring to the north end and 'b' referring to the south end.

Station ID	Station Type	Height (m)	Width (m)	Total crossing length (m)	Openness factor[2]	Dist to road (m)	Station Materials	Median Break	Habitat Type at Station[1]
Hwy58-01a	Bridge	2.77	18.20	122.23	0.41	3.03	Concrete	Yes	alkali desert scrub
Hwy58-01b		2.77	18.20			3.20			
Hwy58-02a	Bridge	1.86	52.00	95.4	1.06	3.04	Concrete bridge	Yes	alkali desert scrub
Hwy58-02b		2.06	52.00			3.10			
Hwy58-03a	2x box culvert	1.90	7.50	157.6	0.09	5.67	Concrete	No	alkali desert scrub
Hwy58-03b		1.86	7.50			6.68			
Hwy58-04a	2x pipe culvert	1.40	1.31	171.7	0.01	7.50	Metal	No	alkali desert scrub
Hwy58-04b		1.42	1.30			10.00			
Hwy58-05a	Pipe culvert	1.56	1.40	202.1	0.01	6.05	Lined metal	No	alkali desert scrub
Hwy58-05b		1.50	1.40			7.16			
Hwy58-07a	Box culvert	1.82	3.02	181.9	0.03	8.07	Concrete	No	alkali desert scrub
Hwy58-07b		1.80	3.10			8.53			
Hwy58-08a	2x box culvert	1.88	6.10	151.6	0.08	8.78	Concrete	No	alkali desert scrub
Hwy58-08b		1.86	6.16			6.87			
Hwy58-09a	2x box culvert	1.88	6.10	161.1	0.07	7.85	Concrete	No	alkali desert scrub
Hwy58-09b		1.86	6.10			8.57			
Hwy58-10a	2x box culvert	3.12	6.10	174	0.11	8.07	Concrete	No	alkali desert scrub
Hwy58-10b		3.05	6.10			8.53			
Hwy58-11a	Pipe culvert	1.85	1.70	220.1	0.01	8.25	Lined metal	No	alkali desert scrub
Hwy58-11b		1.75	1.75			9.87			
Hwy58-12a	Pipe culvert	1.40	1.34	203.8	0.009	8.98	Lined metal	No	alkali desert scrub
Hwy58-12b		1.42	1.35			7.06			
Hwy58-13a	Pipe culvert	1.40	1.35	332.1	0.005	8.46	Lined metal	No	alkali desert scrub
Hwy58-13b		1.33	1.33			10.02			
Hwy58-14a	2x pipe culvert	1.21	1.13	187.4	0.007	6.21	Lined metal	No	alkali desert scrub
Hwy58-14b		1.20	1.17			8.05			
Hwy58-15a	2x box culvert	1.77	7.20	211.8	0.06	8.63	Concrete, sand floor	No	alkali desert scrub
Hwy58-15b		1.72	7.32			8.24			

Station ID	Station Type	Height (m)	Width (m)	Total crossing length (m)	Openness factor[2]	Dist to road (m)	Station Materials	Median Break	Habitat Type at Station[1]
Hwy58-16a	Bridge	3.11	50.00	29.5	5.70	3.21	Concrete	Yes	alkali desert scrub
Hwy58-16b		3.62	50.00			3.03			
Hwy58-17a	Pipe Culvert	0.97	0.93	204.3	0.004	9.55	Lined metal	No	alkali desert scrub
Hwy58-17b		0.87	0.92			12.30			
Hwy58-18a	2x box Culvert	1.53	1.49	181	0.01	7.44	Lined metal	No	alkali desert scrub
Hwy58-18b		1.66	1.48			9.61			
Hwy58-19a	2x pipe Culvert	1.77	7.30	171.4	0.07	6.35	Concrete	No	alkali desert scrub
Hwy58-19b		1.73	7.28			7.28			
Hwy58-20a	Pipe culvert	0.81	0.89	188.9	0.003	8.94	Lined metal	No	alkali desert scrub
Hwy58-20b		0.82	0.90			11.27			
Hwy58-21a	Pipe culvert	0.90	0.90	187.9	0.004	8.35	Lined metal	No	alkali desert scrub
Hwy58-21b		0.90	0.90			8.90			
Hwy58-22a	2x pipe Culvert	1.22	1.19	217	0.006	9.70, 8.18	Lined metal	No	alkali desert scrub
Hwy58-22b		1.20	1.16	29.5		7.20, 5.79			

[1]Surrounding habitat type for all stations = Alkali desert scrub.

[2]Openness factor is equal to ((width x height/length). Height and width calculated as means of two end values.

MONITORING METHODS

Monitoring methods comprised a combination of track stations, motion detector cameras, and DNA hair sampling devices. Each site was monitored on a weekly basis. Each crossing station was monitored by means of the method most suited to the structure design.

Track Stations

Track stations consisted of a layer of diatomaceous earth (DE) spread out at the entrance of each end of the pipe culverts (Figure 25). The area covered by the DE was large enough to ensure that at least one kit fox track would be captured within the tracking medium should a fox pass over the station. The DE was smoothed down using a soft rubber mat to ensure that any tracks would be clearly visible. Prior to setting the track station, any debris was removed from the culvert entrance. Sand-based track stations were also set at the box culverts on Rte 14. These culverts encompassed too large an area to cover using DE, and therefore the sand at these sites was raked to remove stone and other debris, and then covered with a layer of finely sifted sand (Figure 26).

Figure 25. Example of a diatomaceous earth track station.

Figure 26. Sand-based track stations at box culverts on Route 14.

Track station data were collected by examining the DE or sand at each site on a weekly basis. Identifiable tracks were recorded in an Arcpad data collection form on a handheld pc with an attached Global Positioning Unit. Tracks that were not identified at the site, or had some level of ambiguity, were photographed with a scale bar for further clarification. Tracks were confirmed using a variety of tracking field guides suited to the study site habitat types to give a wide range of comparison. If tracks still could not be identified they were classed as either Unknown, Unknown small mammal, or Unknown mammal. In addition to track data, the presence of any scat was recorded. Flooding occurred on a regular basis across all sites and was documented. Track and scat data were maintained in both Arcview and Excel databases.

Camera Stations

Overpass crossing structures on Rte 14 were monitored using remote, motion-activated digital cameras. Two 1.3-megapixel digital scouting Stealthcam (DIGRC-XV) cameras were set on each overpass, one at either end of the structure. Plastic structures were constructed to protect the cameras both from excessive sunlight, and from being moved during strong winds (Figure 27). The cameras were attached to posts present at either end of the overpasses with straps or mounts that were part of the camera package and secured using a heavy duty chain and padlock. A smaller padlock was used to lock the camera body to prevent the memory card from being removed.

Figure 27. Stealthcam DIGRC-XV motion detector camera with shade at the Interstate 5 study site.

Camera stations were set up at seven box culverts along Hwy 58 using Cuddeback 3.0 megapixel scouting cameras. Due to the high probability of human disturbance at each of these sites the cameras were placed in security boxes designed and constructed for this project. Each box was mounted to the culvert wall by ‘hat plates’ epoxyed to the wall (Figure 28). Struts were bolted to the hat plate (Figure 29), and the box attached to the struts using security bolts (Figure 30 and Figure 31). A complete description of this camera security box system can be found in Fiehler et al. (2007).

Images from the cameras at both the I-5 and Hwy 58 sites were downloaded on a weekly basis onto a 2.0Gb Flash Trax digital multimedia storage device and player (SmartDisk Corporation, Florida, USA). This device allowed digital photographs to be stored and viewed in the field. The images were transferred from the digital camera to the Flash Trax via a memory card, which was then cleared and put back into the digital camera for further data collection. Images were then transferred onto a computer at a later date for enhanced viewing, cataloging and storage. Data from photographs were stored in an Excel database.

Figure 28. Hat plates for camera security boxes attached to the culvert wall using epoxy.

Figure 29. Struts for camera security boxes bolted to the hat plates.

Figure 30. Camera box containing Cuddeback camera – front view.

Figure 31. Camera box attached to the struts - back view.

Hair Traps

A single-sample hair collection device had previously been designed and tested for collecting hair DNA samples from San Joaquin kit fox (Figure 32; Bremner-Harrison et al. 2006). Hair traps were set at the I-5 and Hwy 58 sites. At the I-5 site, traps were set every 0.2 miles on both the east and west sides of the highway. Traps were set from the base of the southern overpass and extended north of the northern overpass into the Conservation Area of the Kern Waterbank (Figure 33). Due to an area of consistent flooding a gap of ca. 1 mi existed between trap 6a and 7a on the east side if I-5. At the Hwy 58 site, hair traps were set on the north and south sides of the highway at 0.5-mile intervals. The traps ran from station Hwy58-01 to Hwy58-22.

Figure 32. Single-sample hair snare device designed for use on kit foxes.

At each location, traps were baited with dry cat food placed inside a commercially available paper bag designed for holding loose-leaf tea. These bags were taped to the top of the bait door end of the hair trap. This bag system discouraged removal of the bait by insects (particularly ants) and non-target species (particularly rodents). A few pieces of dry cat food were placed on the floor of the hair trap below this bait bag, and several pieces were scattered around the outside of the trap. Traps were set and checked on a weekly basis. Data were collected using a handheld computer then transferred to an Excel database.

Roadkill Surveys

Any animals killed by vehicles were recorded on a weekly basis at each study site during the track station and camera station check period. When roadkills were located, the GPS position was entered into a handheld pc using Arcpad, along with the date, site, species and distance to nearest crossing structure. Kit fox roadkills were collected where possible, and hair samples were taken from other canid roadkills.

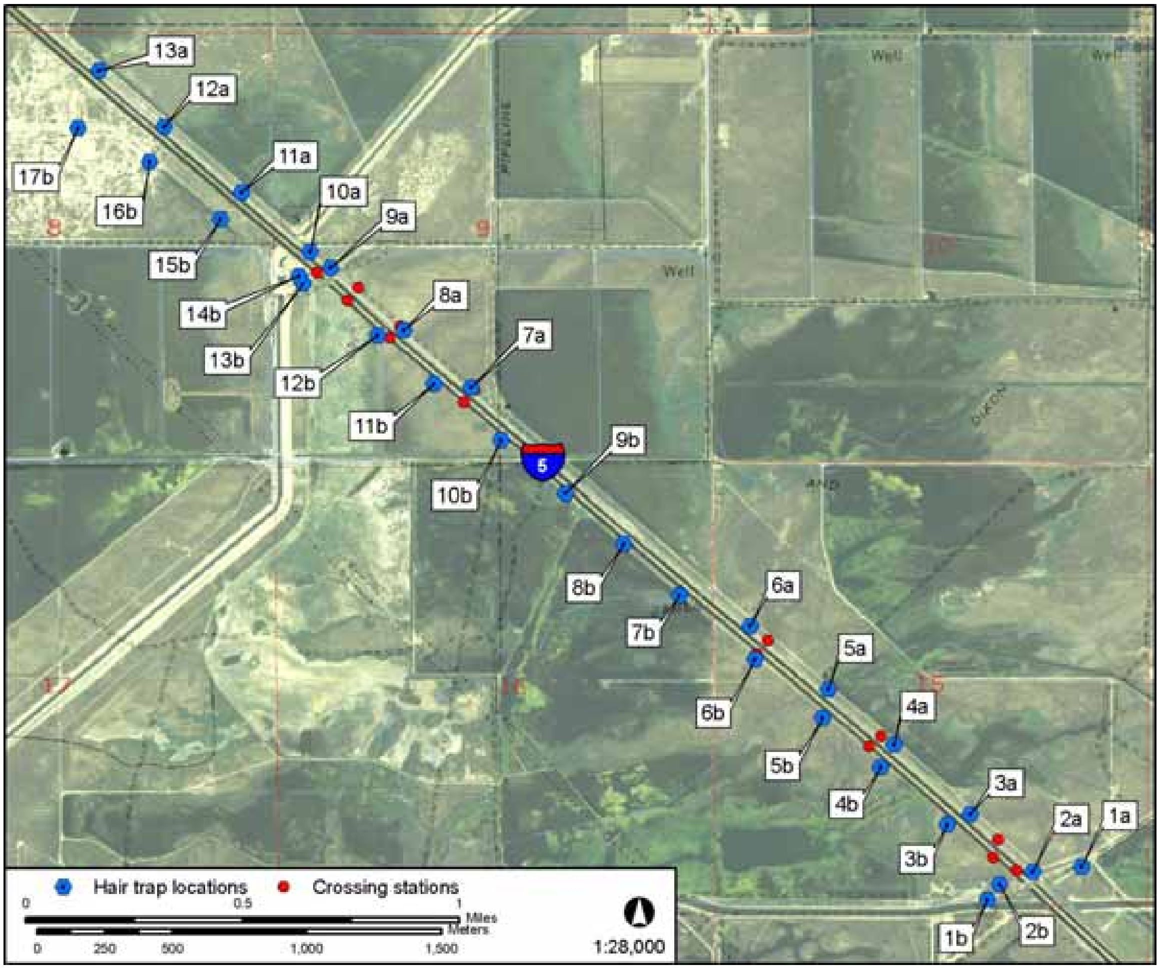

Figure 33. Locations of hair sampling traps at the Interstate 5 site.

Crossing Structure Selection

Table 1, Table 2, and Table 3 outline the types of crossing structures present on each site. Some of the structures were omitted from monitoring during the study period for reasons that are outlined below.

Sand-based track stations were attempted for several weeks at the Rte 14 site at the start of the study, but they were unsuccessful for a number of reasons. This site had a lot of high winds and track stations were not stable in the unsheltered box culverts. Initial attempts utilized shifted and smoothed sand, and further attempts used a combination of sand and DE or a sand and vegetable oil mix, but in all cases the tracking medium had blown away by the following week when track stations were checked. Each of these sites (Rte14-01, Rte14-02, Rte14-03) also showed signs of regular use by humans. In particular, Station Rte14-03 was situated in an area of high traffic for off-highway vehicles. On a number of occasions, tire tracks were observed passing through the 6x box culverts and the areas where track stations had been set. The high levels of use by humans in the areas associated with Stations Rte14-01, Rte14-02, and Rte14-03 also meant that these structures were considered unsuitable for camera stations. Local Bureau of Land Management officials strongly recommended against placing cameras at these stations as they considered them as being at a high risk of theft or vandalism. Therefore these three stations were not monitored after the first few weeks of the study.

Similar difficulties were incurred at the bridge style crossing Stations Rte14-04, Rte14-14, and Rte14-18 at the Rte 14 site, and Hwy58-01, Hwy58-02, and Hwy58-16 at the Hwy 58 site. Each of these structures was too large to be monitored with track stations, and were also sufficiently disturbed by people to be considered unsuitable for camera stations. In addition, stations Rte14-04, Rte14-18, Hwy58-02, Hwy58-06 and Hwy58-16 were too large to be effectively monitored by camera stations. Therefore, these stations were not monitored on a weekly basis. However, during the station characteristics phase of data collection any animal signs were noted, such as tracks or scat.

During the study, one end of stations Rte14-13 and Rte14-16 were damaged to the extent that a kit fox would not be able to pass through the culvert. Therefore, these two crossing stations were eliminated from the study. Final station monitoring methods are shown in Table 4.

Table 4. Monitoring methods per station at each of the three study sites.

Station ID	Monitoring Method	Station ID	Monitoring Method	Station ID	Monitoring Method
Int5-01	Track station	Rte14-01	Eliminated	Hwy58-01	Eliminated
Int5-02	Track station	Rte14-02	Eliminated	Hwy58-02	Eliminated
Int5-03	Track station	Rte14-03	Eliminated	Hwy58-03	Camera station
Int5-04	Track station	Rte14-04	Eliminated	Hwy58-04	Track station
Int5-05	Track station	Rte14-05	Track station	Hwy58-05	Track station
Int5-06	Track station	Rte14-06	Track station	Hwy58-06	Eliminated
Int5-Ov1	Camera station	Rte14-07	Track station	Hwy58-07	Camera station
Int5-Ov2	Camera station	Rte14-08	Track station	Hwy58-08	Camera station
		Rte14-09	Track station	Hwy58-09	Camera station
		Rte14-10	Track station	Hwy58-10	Camera station
		Rte14-11	Track station	Hwy58-11	Track station
		Rte14-12	Track station	Hwy58-12	Track station
		Rte14-13	Eliminated	Hwy58-13	Track station
		Rte14-14	Eliminated	Hwy58-14	Track station
		Rte14-15	Track station	Hwy58-15	Camera station
		Rte14-16	Eliminated	Hwy58-16	Eliminated
		Rte14-17	Track station	Hwy58-17	Track station
		Rte14-18	Eliminated	Hwy58-18	Track station
				Hwy58-19	Camera station
				Hwy58-20	Track station
				Hwy58-21	Track station
				Hwy58-22	Track station

DATA SUMMATION

Data for the track station, roadkill and hair trap monitoring methods were recorded in the field in Arcpad files on a handheld pc. These were then downloaded at the office and maintained in separate databases. Data were collated for each crossing structure per monitoring method.

RESULTS

Dates of monitoring are shown in Table 5. Dates varied as each site entailed some measure of preparation prior to the start of monitoring. Hair sampling stations were not utilized at the Rte 14 site as the field data collection period was truncated when data collection strategies were revised in response to lower than expected kit fox visitation rates at all sites. As mentioned previously, this site was also considered unsuitable for camera stations due to heavy human use.

Table 5. Monitoring dates at each of the three study sites for each monitoring method

Site	Monitoring Method	Start Date	End Date
I-5	Track Stations	09/15/2005	06/13/2006
	Camera Stations	07/18/2005	06/21/2006
	Hair sampling stations	02/28/2006	03/21/2006
Rte 14	Track Stations	07/19/2005	06/12/2006
Hwy 58	Track Stations	08/25/2005	06/12/2006
	Camera Stations	01/11/2006	06/20/2006
	Hair sampling stations	04/17/2006	05/08/2006

TRACK STATION RESULTS

The number of track station weeks at each site varied due to the level of site preparation required at each particular study site and the time it took to obtain access to the site. The number of track station weeks was calculated as: (no. of weeks) x (no. of culverts) x 2. The total number of track station weeks per site is shown in Table 6

Table 6. Total number of track station weeks for each of the three study sites.

Site	Total No. of Track Station Weeks
Hwy 58	962
Rte 14	858
I-5	444

Due to inclement weather there were many occasions where culverts were either flooded and the diatomaceous earth was consequently washed away and/or the entrance of the culvert had collapsed or become filled with sand rendering it impassable. The total number of occurrences of these events is shown in Figure 34, and the resultant corrected values for track station weeks following the removal of these dates are shown in Table 7.

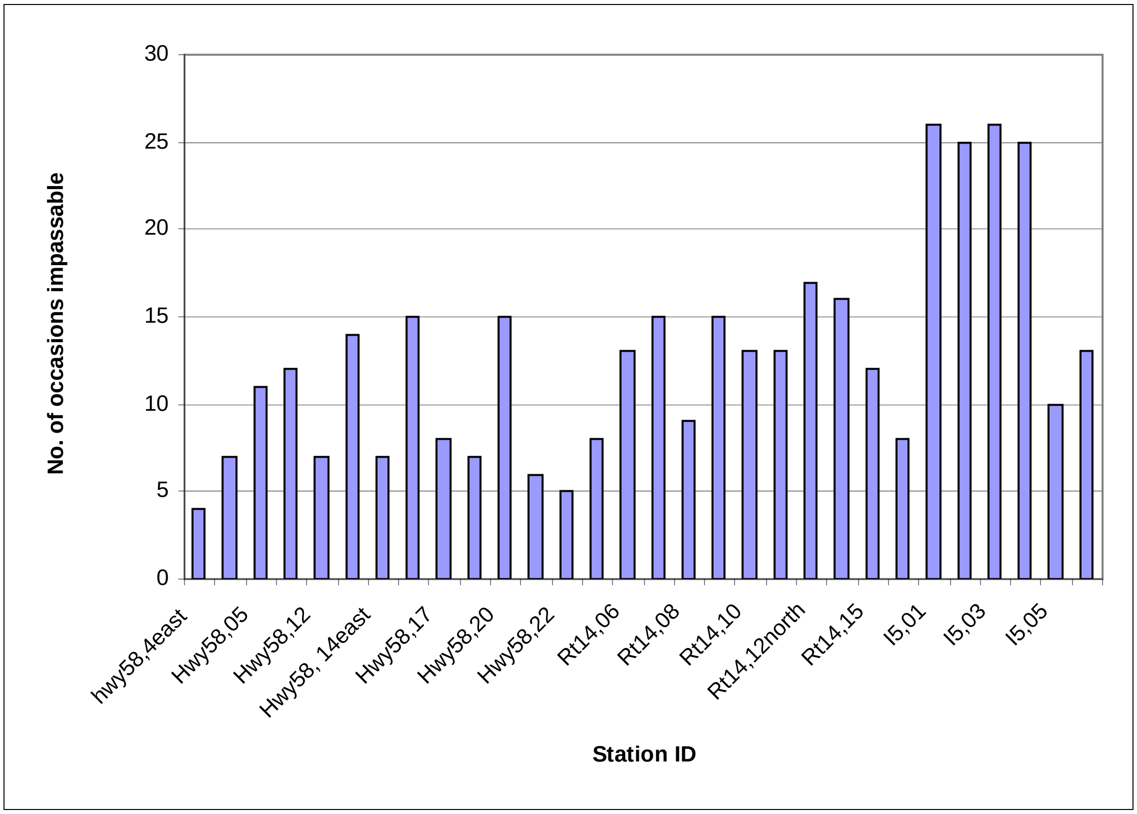

Figure 34. Number of occurrences when individual stations were impassable or track stations washed out as a result of inclement weather.

Table 7. Corrected values for the number of track station weeks across the three study sites.

Site	Corrected No. of Track Station Weeks
Hwy 58	762
Rte 14	586
I-5	194

Kit fox tracks were observed in track stations a total of 19 times across the three study sites. Tracks were detected at both the Hwy 58 and I-5 sites but not the Rte 14 site (Figure 35). In addition, the presence of species other than kit foxes was recorded across all three study sites (Figure 36).

Kit fox tracks were observed a total of 12 times in track stations at eight different pipe culvert crossing structures at the Hwy 58 site (Figure 37). However, none of these occurrences indicated that foxes had passed through the crossing structures as in each instance tracks were only found at one end of the structure. At each of these eight crossing structures and in additional structures, tracks were observed from animals larger or of a comparable size to kit foxes (Figure 38). In several instances, tracks from these larger species were found at each end of the culvert suggesting that the animal had passed through the culvert. Table 8 depicts visits by kit foxes and comparably-sized species at each of the crossing structures, and whether these species had passed through the culvert or only were detected at one end. In the majority of cases where species had not passed through the crossing structures, tracks were found on both sides of the road, but on different dates indicating either that there were separate individuals of the species present on each side of the road, or individuals were crossing over the top of the road.

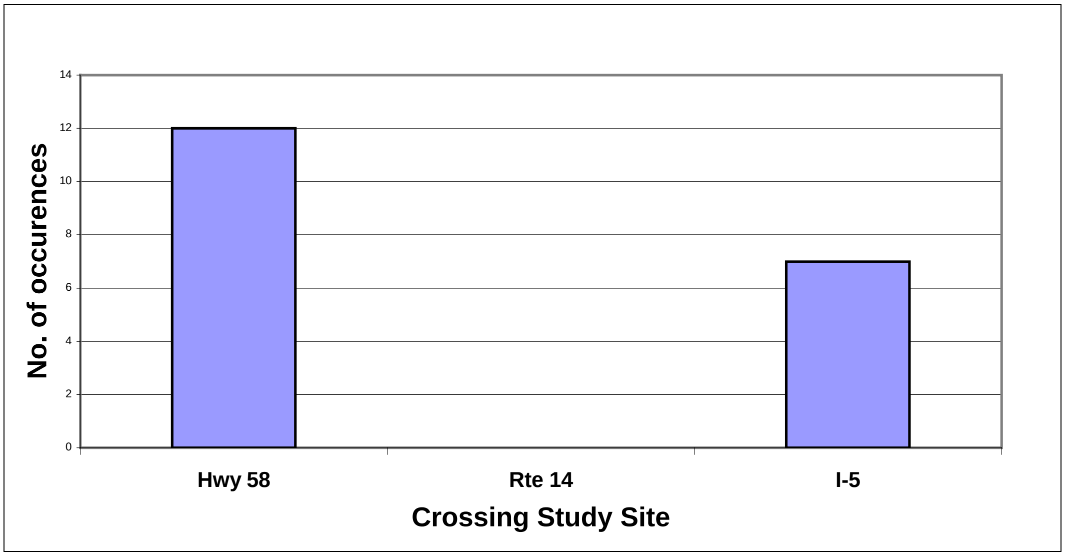

Figure 35. Number of occurrences of kit fox tracks detected in track stations across the three study sites.

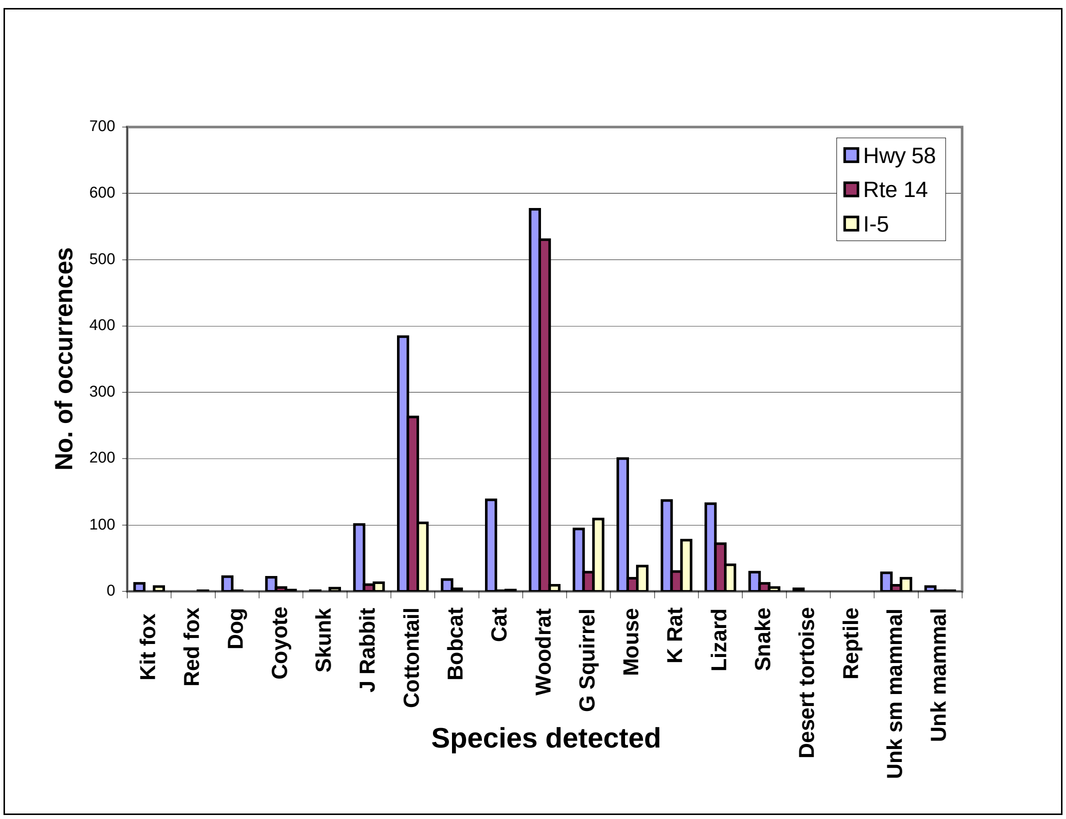

Figure 36. Number of visits by all species recorded in track stations across the three study sites.

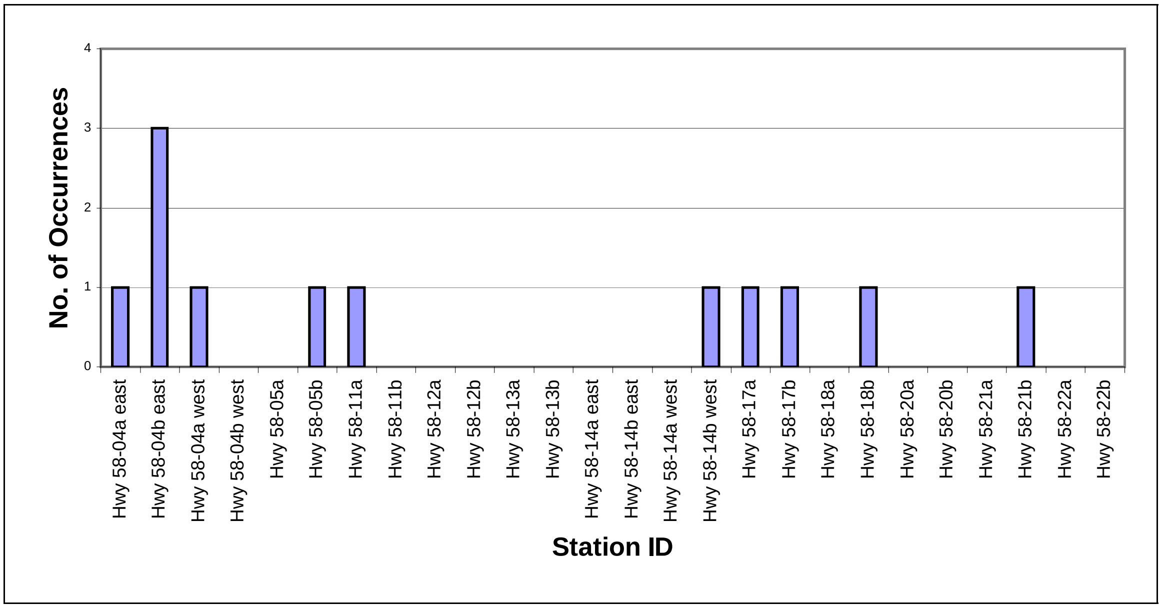

Figure 37. Number of occurrences of kit fox tracks at individual culverts at the Highway 58 site.

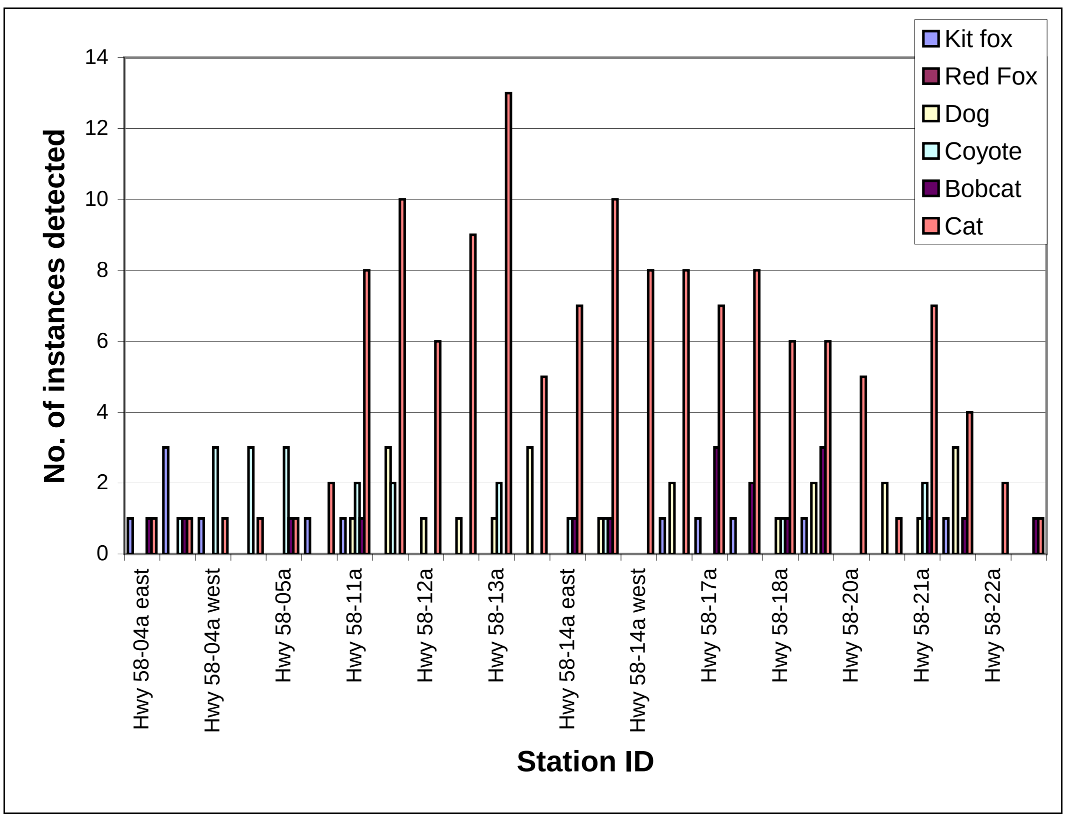

Figure 38. Number of instances of kit foxes and species of comparable or larger size detected in track stations at the Highway 58 study site.

Table 8. Presence of tracks of kit foxes and larger or comparably sized species at culvert track stations on Highway 58 and number of times passed through the culvert. (I = Investigated but did not pass through the culvert; P = passed through the culvert; figures in parenthesis show the number of times the species was detected either investigating or passing through the culvert.)

Station ID	Kit Fox	Red Fox	Domestic Dog	Coyote	Bobcat	Domestic Cat	Station Type	Height (m)	Width (m)	Total crossing length (m)	Openness factor
Hwy 58-4	I(5)			I(4), P(1)	I(2)	I(4)	2x pipe culvert	1.41	1.31	171.7	0.01
Hwy 58-5	I(1)			I(7)	I(1)	I(3)	Pipe culvert	1.53	1.4	202.1	0.01
Hwy58-11	I(1)		I(2), P(1)	I(2), P(1)	I(1)	I(6), P(6)	Pipe culvert	1.8	1.7	220.1	0.01
Hwy58-12			P(1)			I(7), P(4)	Pipe culvert	1.41	1.34	203.8	0.009
Hwy58-13			I(2), P(1)	I(2)		I(10), P(4)	Pipe culvert	1.37	1.34	332.1	0.005
Hwy 58-14	I(1)		I(3)	I(2)	I(2)	I(15), P(9)	2x pipe culvert	1.21	1.15	187.4	0.007
Hwy 58-17	I(2)				I(3), P(1)	I(10), P(4)	Pipe culvert	0.92	0.93	204.3	0.004
Hwy 58-18	I(1)		I(1), P(1)	I(1)	I(2), P(1)	I(3), P(3)	Pipe culvert	1.59	1.49	181	0.01
Hwy 58-20			I(2)			I(4), P(1)	Pipe culvert	0.82	0.89	188.9	0.003
Hwy 58-21	I(1)		I(2), P(1)	I(2)	I(2)	I(5), P(3)	Pipe culvert	0.9	0.9	187.9	0.004
Hwy 58-22					I(1)	I(3)	Pipe culvert	1.21	1.18	217	0.006

Kit fox tracks were not observed in any of the track stations at the Rte 14 site. Tracks from animals larger or of a comparable size to kit foxes were observed at several of the stations (Figure 39). Again, on several occasions tracks from these larger species were found at each end of the culvert, suggesting that the animal had passed through the culvert. Table 9 shows a breakdown of the presence of species of comparable size to kit fox at each of the crossing structures, and whether these species had passed through the culvert or were detected at one end. In the majority of cases where species had not passed through the crossing structures, tracks were found on both sides of the road, but on different dates.

Kit fox tracks were observed a total of 7 times in track stations at three different pipe culvert crossing structures at the I-5 site (Figure 40). Again, none of these occurrences indicated that foxes had passed through the crossing structures as tracks were only found at one end of the structure in each instance. At two of these three crossing structures, tracks from animals larger or of a comparable size to kit foxes were observed (Figure 41). None of these tracks indicated that the animals had passed through the crossing structures (Table 10). In the majority of cases where species had not passed through the crossing structures, tracks were again found on both sides of the road, but on different dates.

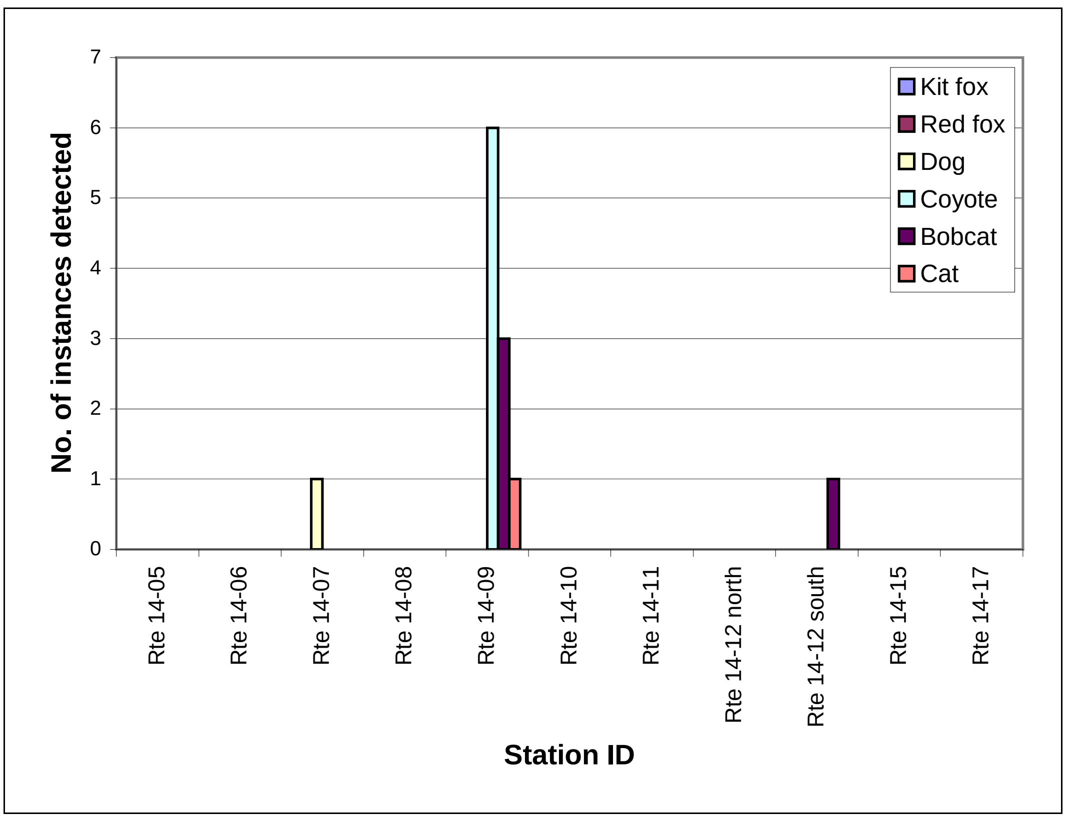

Figure 39. Number of instances of kit foxes and species of comparable or larger size detected in track stations at the Route 14 study site.

Table 9. Presence of tracks of kit foxes and larger or comparably sized species at culvert track stations on Route14 and number of times passed through the culvert. (I = Investigated but did not pass through the culvert; P = passed through the culvert; figures in parenthesis show the number of times the species was detected either investigating or passing through the culvert.)

Station ID	Kit Fox	Red Fox	Domestic Dog	Coyote	Bobcat	Domestic Cat	Station Type	Height (m)	Width (m)	Total crossing length (m)	Openness factor
Rte14-05							Pipe culvert	0.38	0.63	63.41	0.004
Rte14-06							Pipe culvert	0.43	0.71	98.5	0.003
Rte14-07			I(1)				Pipe culvert	0.46	0.47	34.41	0.006
Rte14-08							Pipe culvert	0.46	0.33	105.45	0.001
Rte14-09				I(4),P(1)	I(1),P(1)	I(1)	Pipe culvert	0.95	1.75	116.5	0.014
Rte14-10							Pipe culvert	0.61	0.60	85.0	0.004
Rte14-11							Pipe culvert	0.52	0.61	205.75	0.002
Rte14-12					I(1)		2x Pipe culvert	0.55	0.63	109.2	0.003
Rte14-15							Pipe culvert	0.50	0.50	94.65	0.003
Rte14-17							Pipe culvert	0.41	0.48	119.7	0.002

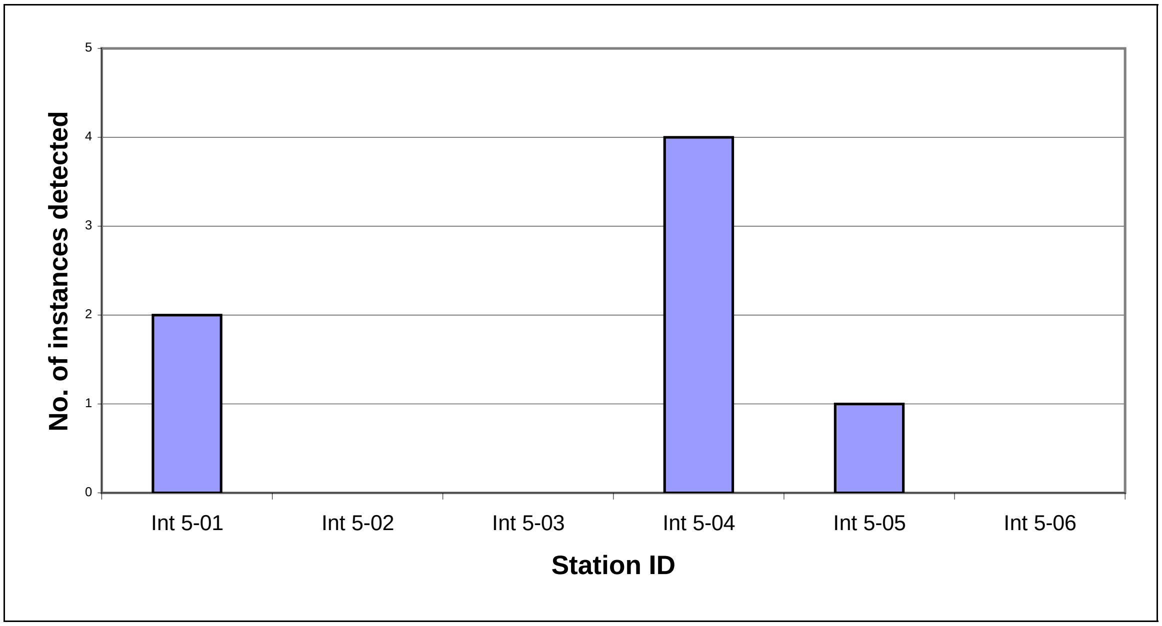

Figure 40. Number of occurrences of kit fox tracks at individual culverts at the Interstate 5 site.

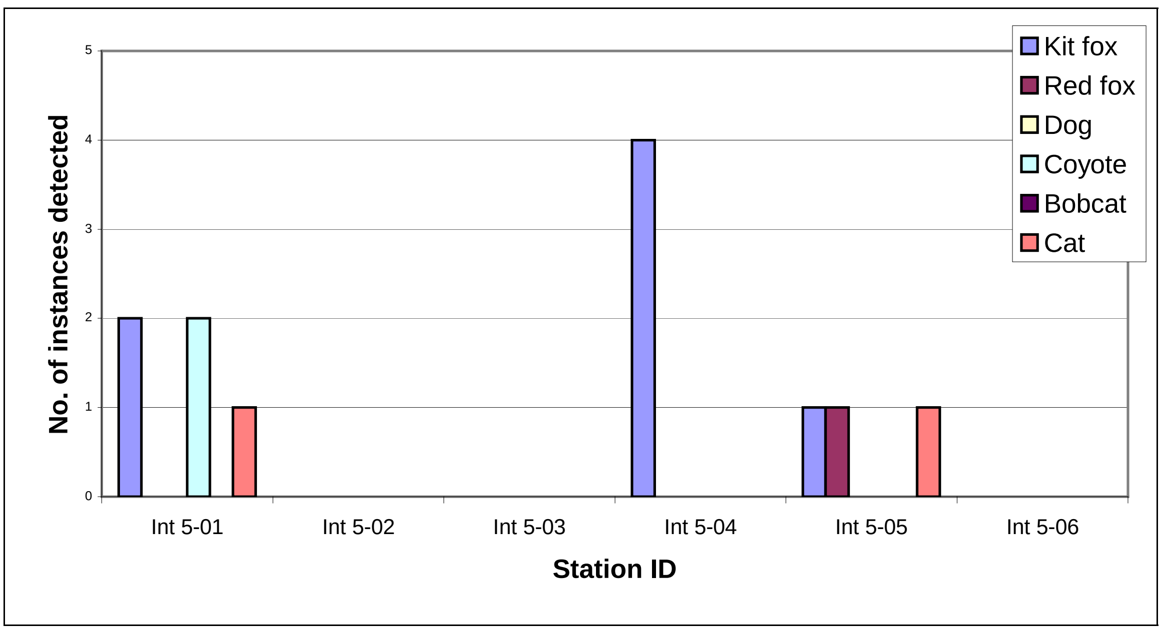

Figure 41. Number of instances of kit foxes and species of comparable or larger size detected in track stations at the Interstate 5 study site.

Table 10. Presence of tracks of kit foxes and larger or comparably sized species at culvert track stations on Route14 and number of times passed through the culvert. (I = Investigated but did not pass through the culvert; P = passed through the culvert; figures in parenthesis show the number of times the species was detected either investigating or passing through the culvert.)

Station ID	Kit Fox	Red Fox	Domestic Dog	Coyote	Bobcat	Domestic Cat	Station Type	Height (m)	Width (m)	Total crossing length (m)	Openness factor
Int5-01	I(2)			I(2)		I(1)	Pipe culvert	1.07	1.21	225.0	0.006
Int5-02							Pipe culvert	0.29	0.56	191.0	0.001
Int5-03							Pipe culvert	0.31	0.64	216.0	0.001
Int5-04	I(4)						Pipe culvert	0.43	0.62	188.0	0.001
Int5-05	I(1)	I(1)				I(1)	Pipe culvert	0.4	0.6	186.0	0.001
Int5-06							Pipe culvert	0.34	0.6	203.0	0.001

Tracks from small mammals were consistently detected in pipe culvert track stations across all three study sites (Figure 42). These consisted primarily of cottontail rabbits (*Sylvilagus audubonii*) and desert woodrats (*Neotoma lepida*) at the Hwy 58 and Rte 14 sites, and cottontail rabbits and ground squirrels (*Spermophilus beecheyi*)at the I-5 site.

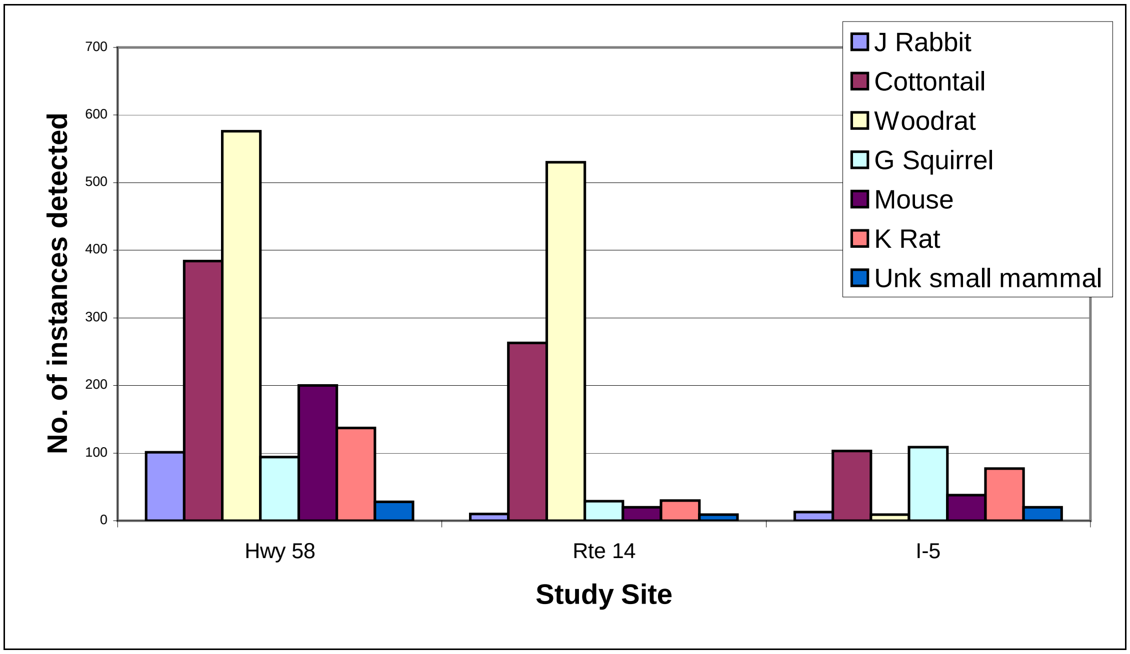

Figure 42. Number of instances of small mammals detected in track stations across all three study sites.

CAMERA STATION RESULTS

The number of camera station nights varied across the two sites where cameras were set. As discussed in the Methods section, cameras were not utilized at the Rte 14 site due to high levels of human activity. The number of camera station nights was calculated as: (number of nights cameras deployed) x (the number of cameras) (Table 11). The type of camera deployed at each site differed. Cuddeback 3.0 megapixel scouting cameras were used at each of the crossing structures monitored by camera at the Hwy 58 site. This particular model takes one photograph when the infra-red beam is tripped. Stealthcam (DIGRC-XV) cameras were set up on overpasses at the I-5 site. This model of camera takes 3 photographs each time the infra-red beam is triggered. Therefore, the total number of photographs obtained from the I-5 site over the duration of the study is substantially higher than the Hwy 58 site, but does not necessarily reflect a higher instance of animal detections.

Table 11. Camera station results for Highway 58 and Interstate 5 study sites.

Site	Total no. of camera station nights	No. of stations monitored	No. of cameras per station	Total no. of photographs	Crossing events/ investigations photographed
Hwy 58	877	7	1	135	102
I-5	350	2	2	4,134	53

There were no instances of kit foxes recorded on camera from either of the two study sites where cameras were deployed. The species captured on camera at each site is shown in Figure 43. Visits to each station by species is shown in Figure 44 for Hwy 58 and Figure 45 for I-5. A large number of blank photographs were obtained from each site. Of the total number of photographs obtained from the cameras at the I-5 site, 86% were blank. Of the 135 photographs taken at the Hwy 58 site, 23% were blank. Cameras at the I-5 site were set on overpasses utilized on a regular basis by the landowners, the Kern Water Bank. Of the 4,134 photographs obtained from these two crossing structures, 537 (13%) were of vehicles. Vehicular crossings also likely contributed to the high percentage of blank photographs from the cameras set at the I-5 site (i.e., vehicles triggered the cameras but passed out of view before a picture was taken).

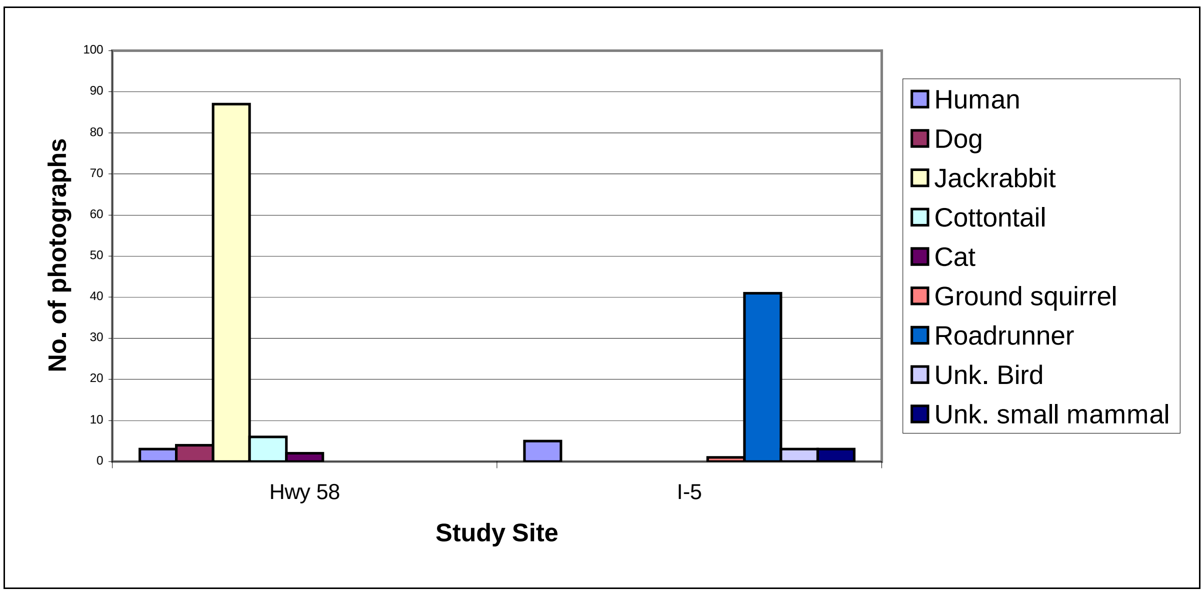

Figure 43. Number of photographs of species other than kit foxes obtained from the Highway 58 and Interstate 5 study sites

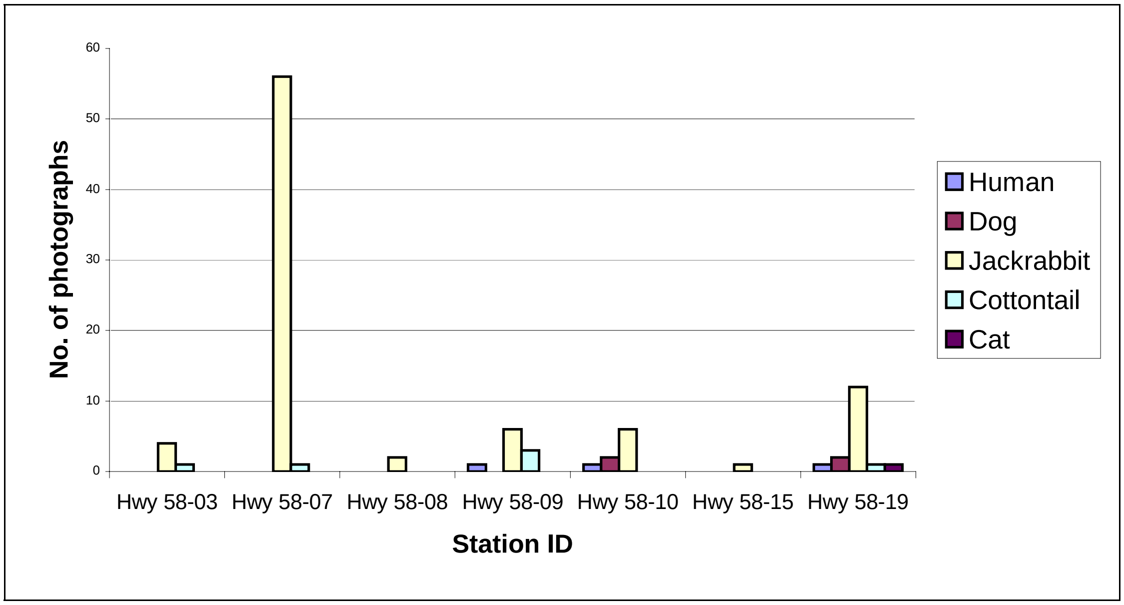

Figure 44. Number of photographs of species other than kit foxes obtained from the Highway 58 study site by individual station.

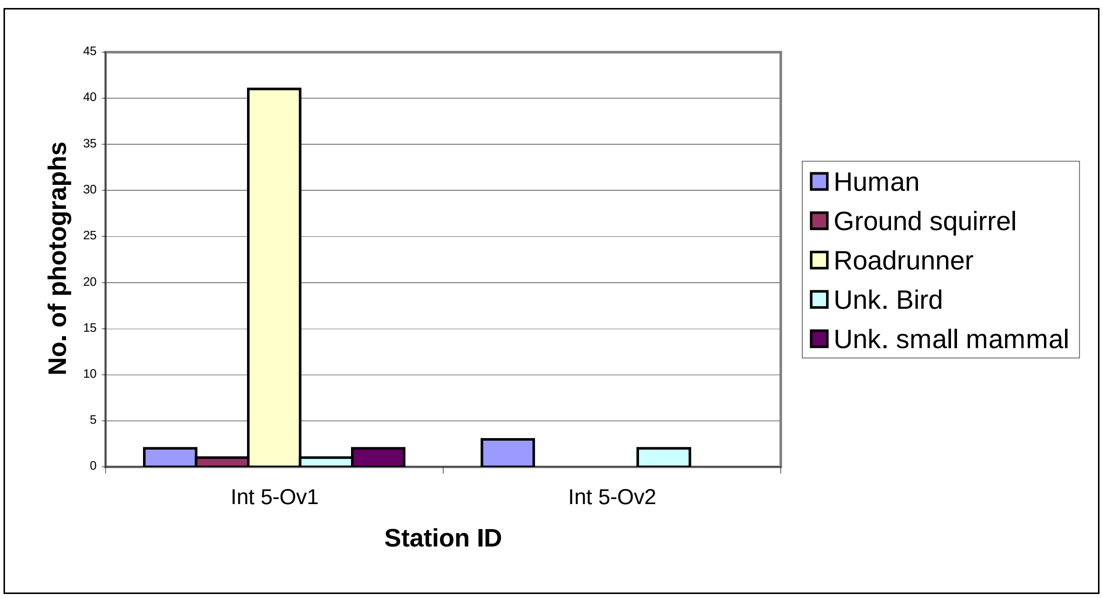

Figure 45. Number of photographs of species other than kit foxes obtained from the Interstate 5 study site by individual station.

Combining data from both the track station monitoring and the camera station monitoring provided an overall picture of use of existing crossing structures by kit foxes, their potential predators, and their potential prey. Table 12, Table 13, and Table 14 show use of each station at each site relative to predator or prey species along with the type of crossing structure. The size of each station was given in Table 1, Table 2, and Table 3. Again, the detection of a species does not necessarily indicate that the individual passed through the culvert.

Table 12. Number of track and camera detections of kit foxes and their potential predators and prey at each station on Highway 58.

Station	Type	Monitoring Method	Kit Fox	Predator[1]	Prey[2]	Human (inc. vehicles)	Height (m)	Width (m)	Total crossing length (m)	Openness factor
Hwy58-03	Box	Camera	0	0	1	0	1.88	7.5	157.6	0.09
Hwy58-04	Pipe	Track	5	9	301	0	1.41	1.31	171.7	0.01
Hwy58-05	Pipe	Track	1	4	140	0	1.53	1.4	202.1	0.01
Hwy58-07	Box	Camera	0	0	1	0	1.81	3.06	181.9	0.03
Hwy58-08	Box	Camera	0	0	0	0	1.87	6.13	151.6	0.08
Hwy58-09	Box	Camera	0	0	3	1	1.87	6.1	161.1	0.07
Hwy58-10	Box	Camera	0	2	0	1	3.09	6.1	174.0	0.11
Hwy58-11	Pipe	Track	1	9	93	0	1.8	1.7	220.1	0.01
Hwy58-12	Pipe	Track	0	2	122	0	1.41	1.34	203.8	0.009
Hwy58-13	Pipe	Track	0	6	83	0	1.37	1.34	332.1	0.005
Hwy58-14	Pipe	Track	1	7	193	0	1.21	1.15	187.4	0.007
Hwy58-15	Box	Camera	0	0	0	0	1.75	7.26	211.8	0.06
Hwy58-17	Pipe	Track	2	5	91	0	0.92	0.93	204.3	0.004
Hwy58-18	Pipe	Track	1	8	110	0	1.59	1.49	181.0	0.01
Hwy58-19	Box	Camera	0	2	1	1	1.75	7.29	171.4	0.07
Hwy58-20	Pipe	Track	0	2	86	0	0.82	0.89	188.9	0.003
Hwy58-21	Pipe	Track	1	8	103	0	0.9	0.9	187.9	0.004
Hwy58-22	Pipe	Track	0	1	97	0	1.21	1.18	217.0	0.006

[1] coyotes, bobcats, & domestic dogs.
[2] cottontail, woodrat, ground squirrel, mouse, kangaroo rat and unknown small mammal.

Table 13. Number of track and camera detections of kit foxes and their potential predators and prey at each station on Route 14.

Station	Type	Monitoring Method	Kit Fox	Predator[1]	Prey[2]	Human (inc. vehicles)	Height (m)	Width (m)	Total crossing length (m)	Openness factor
Rte14-05	Pipe	Track	0	0	88	0	0.38	0.63	63.41	0.004
Rte14-06	Pipe	Track	0	0	65	0	0.43	0.71	98.5	0.003
Rte14-07	Pipe	Track	0	1	72	0	0.46	0.47	34.41	0.006
Rte14-08	Pipe	Track	0	0	74	0	0.46	0.33	105.45	0.001
Rte14-09	Pipe	Track	0	9	92	0	0.95	1.75	116.5	0.014
Rte14-10	Pipe	Track	0	0	78	0	0.61	0.60	85.0	0.004
Rte14-11	Pipe	Track	0	0	72	0	0.52	0.61	205.75	0.002
Rte14-12	Pipe	Track	0	1	161	0	0.55	0.63	109.2	0.003
Rte14-15	Pipe	Track	0	0	84	0	0.50	0.50	94.65	0.003
Rte14-17	Pipe	Track	0	0	95	0	0.41	0.48	119.7	0.002

[1] coyotes, bobcats & domestic dogs.
[2] cottontail, woodrat, ground squirrel, mouse, kangaroo rat and unknown small mammal.

Table 14. Number of track and camera detections of kit foxes and their potential predators and prey at each station on Interstate 5.

Station	Type	Monitoring Method	Kit Fox	Predator[1]	Prey[2]	Human (inc. vehicles)	Height (m)	Width (m)	Total crossing length (m)	Openness factor
Int5-01	Pipe	Track	2	2	83	0	1.07	1.21	225.0	0.006
Int5-02	Pipe	Track	0	0	32	0	0.29	0.56	191.0	0.001
Int5-03	Pipe	Track	0	0	39	0	0.31	0.64	216.0	0.001
Int5-04	Pipe	Track	4	0	51	0	0.43	0.62	188.0	0.001
Int5-05	Pipe	Track	1	0	94	0	0.4	0.6	186.0	0.001
Int5-06	Pipe	Track	0	0	57	0	0.34	0.6	203.0	0.001
Int5-Ov1	Overpass	Camera	0	0	3	230				n/a
Int5-Ov2	Overpass	Camera	0	0	0	311				n/a

[1] coyotes, bobcats & domestic dogs.
[2] cottontail, woodrat, ground squirrel, mouse, kangaroo rat and unknown small mammals.

No crossing structure attributes were found to be significantly correlated with kit fox investigations or passage (Table 15). At the predator or prey group level, 2 crossing structure attributes were significantly correlated with structure use. Both width (r^2 = 0.319, P = 0.0005) and openness (r^2 = 0.315, P = 0.0005) were negatively correlated with structure use by prey species.

Table 15. Mean coefficient of determinants, their slope and level of significance for wildlife crossing structure interactions across all three study sites.

Structural Attributes	Kit fox	Predators[1]	Prey[2]
Height	ns	ns	ns
Width	ns	ns	-0.319
Length	ns	ns	ns
Openness	ns	ns	-0.315

[1] coyotes, bobcats & domestic dogs.
[2] cottontail, woodrat, ground squirrel, mouse, kangaroo rat and unknown small mammals.

HAIR TRAP RESULTS

Single-sampling exclusionary hair traps were set out at the Hwy 58 and I-5 study sites in an effort to obtain hair samples for DNA analysis. The number of trap station weeks at each site is shown in Table 16.

Table 16. Hair trap station weeks at the Highway 58 and Interstate 5 study sites.

Site	No. of hair trap station weeks
Hwy 58	128
I-5	120

No hair samples were collected from kit foxes at either of the two sites, but the traps were visited on a number of occasions by lagomorphs, ground squirrels and unidentified small rodents (Figure 46). Five hair samples were collected from traps set at the Hwy 58 site and 4 hair samples were obtained from the I-5 site. The five hair samples from the Hwy 58 site were identified as rabbit (3) and unknown but not kit fox. The four hair samples from the I-5 site were identified as ground squirrel.

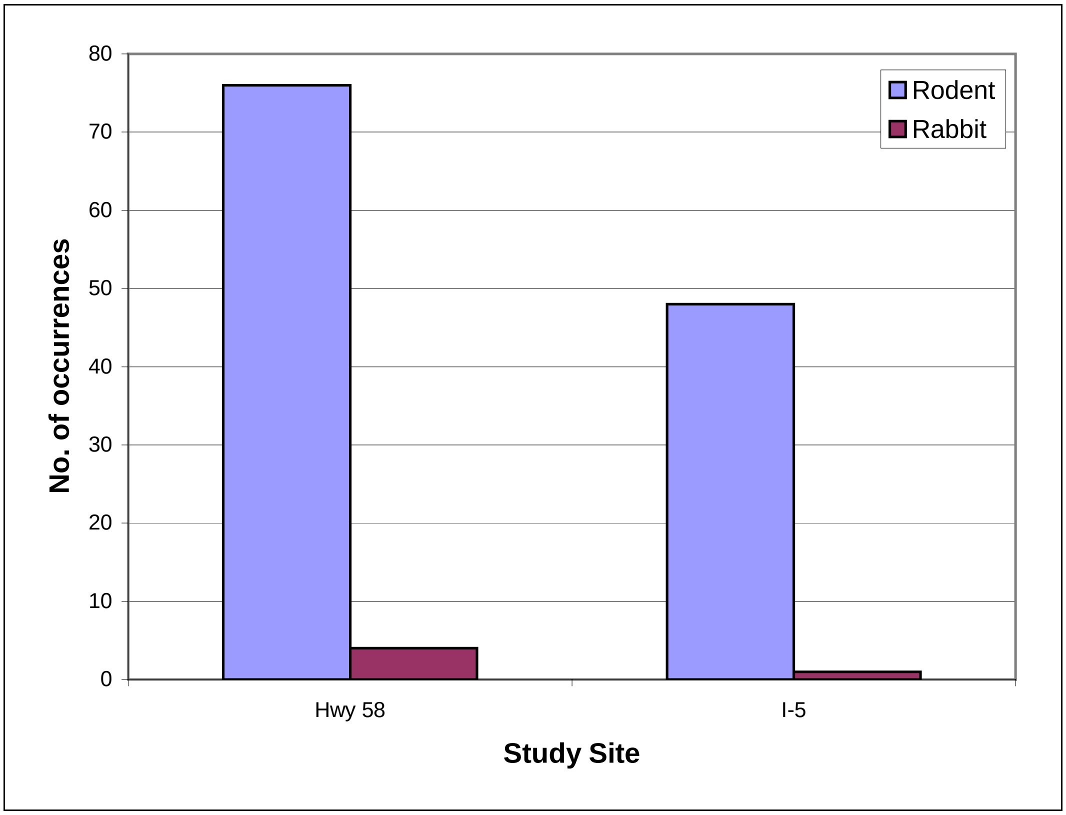

Figure 46. Presence of rodent and lagomorph sign in the hair traps at the Highway 58 and Interstate 5 study sites.

ROADKILL SURVEY RESULTS

A total of 19 roadkills were recorded at the three study sites: 9 at Hwy 58, 8 at Rte 14, and 2 at I-5. Two of these were confirmed kit fox kills: 1 at Hwy 58, and 1 at Rte 14. The distribution of species amongst the recorded road-kills is shown in Figure 47.

The kit fox killed at the Hwy 58 study site was located 3,061 m (1.9 mi) from the nearest available underpass (i.e. monitored or unmonitored). The road-killed kit fox on Rte 14 was 220 m (0.14 mi) from the nearest underpass crossing structure.

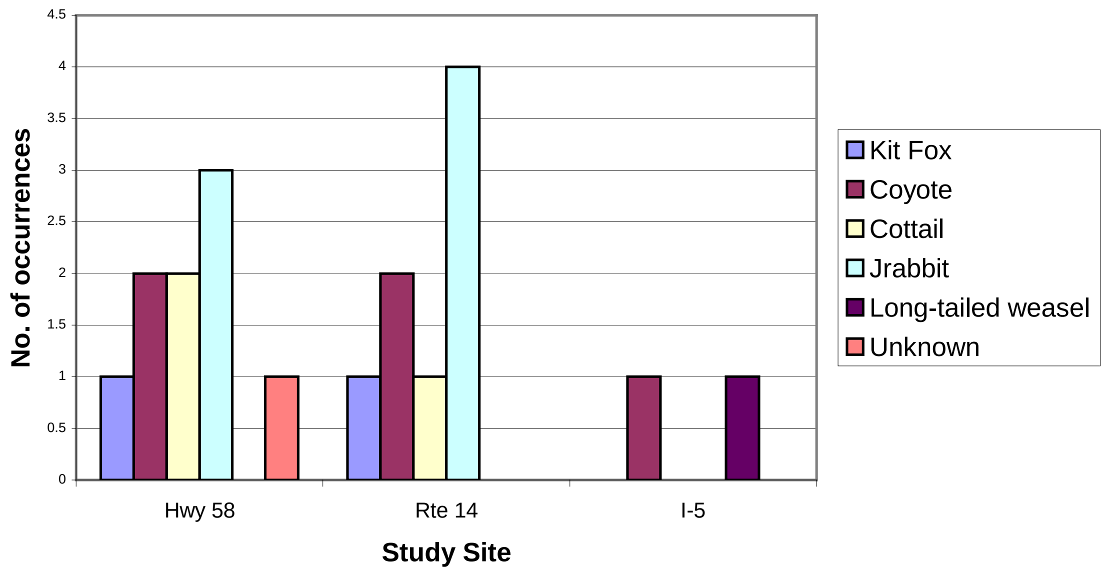

Figure 47. Road-killed species recorded at each of the three study sites throughout the duration of the study period.

DISCUSSION

Despite employing a variety of methods to monitor each of the crossing structures present at the three study sites, no evidence was found to suggest that kit foxes used existing crossing structures on these sites. However, on a number of occasions, kit fox tracks were found at track stations at one end of the structures but not the other end. This indicated that foxes were present in the areas and aware of the structures, but did not cross through.

The numerous detections of species other than kit foxes indicates that the methods used throughout the study were adequate for detecting the presence of animals using the crossing structures. Also, kit fox presence was recorded in several instances indicating that the monitoring methods were sufficient to detect kit foxes. Indeed, each of these monitoring methods (track stations, camera stations, hair trap stations, and road-kill surveys) previously has been successfully employed to detect kit foxes (e.g., Bremner-Harrison et al. 2006, Sargeant et al. 2003, Warrick and Harris 2001, California Department of Fish and Game unpublished data, CSUS Endangered Species Recovery Program unpublished data).

Predation risk potentially discouraged use of crossing structures by kit foxes. Track and camera station data revealed that coyotes (*Canis latrans*), bobcats (*Lynx rufus*) and large dogs were detected in and around the crossing structures. Studies in other locations found consistent use of underpass crossing structures by coyotes and bobcats (Boarman and Sazaki 1996; Haas 2000; Lyren 2001; Clevenger et al. 2001; Cain et al. 2003; Ng et al. 2004). Both coyotes and bobcats are primary sources of mortality for kit foxes in many locations (Ralls and White 1995; Cypher and Spencer 1998; Nelson 2005).

Interestingly, at all three sites, kit foxes and larger predators appeared more inclined to visit the structures that were used frequently by potential prey species. Through a literature study Little et al. (2002) examined the premise that wildlife passages may be utilized by predatory species as prey-traps. The authors determined that this rarely occurred, and most predatory events were opportunistic. They also indicated that predator and prey species tended to utilize different structures, however in our study structures that showed the presence of kit foxes were also those with regular predator sign. Thus, while kit foxes investigated the ends of many structures, they may have avoided entering and passing through the crossing structures due to a perceived high level of risk from larger predators. The confined space within structures, particularly smaller ones, may inhibit the ability of kit foxes to elude predators. Red squirrels (*Tamiasciurus hudsonius*) and snowshoe hares (*Lepus americanus*) avoided structures that also were used by weasels (*Mustela spp.*) and martens (*Martes Americana*) (Clevenger and Waltho 1999).

Larger, more open structures may provide a more attractive crossing alternative to kit foxes as these structures would provide a more unobstructed view of escape cover on the other side and also would provide more room to elude predators. Many species, particularly larger mammals, are more inclined to use structures that are large relative to their body size (Clevenger and Waltho 1999). One potential drawback for kit foxes is that Haas (2000) recorded increased frequency of use by coyotes at more open style crossing structures. Unfortunately, we were not able to effectively monitor use by kit foxes of the larger crossing structures (ranging in width from 18-52 m wide) on the study sites. Numerous animal tracks were present in these structures, but the tracks generally could not be identified due to unfavorable tracking substrate.

During the period of study, two instances of kit foxes killed by vehicles were recorded: 1 at Hwy 58 and 1 at Rte 14. These occurrences, in combination with the lack of use of existing structures, appear to indicate that kit foxes are avoiding the underpass structures and are simply trying to cross the roads. To foxes, the perceived risk of crossing a road may be lower than that associated with use of crossing structures. Some foxes likely are successful in crossing these highways for the following reasons: (1) kit foxes are primarily nocturnal and would most likely attempt crossings at night when traffic volume probably is lowest; (2) no median barriers are present on these sites to obstruct fox movements, and the absence of barriers provided foxes with an unobstructed view of traffic as well as habitat across the road; and (3) no exclusionary fencing is present at these sites to inhibit road crossing attempts. Indeed, when animals are successfully crossing roads and mortality from vehicles is not a limiting factor (unknown for these sites), exclusionary fencing is discouraged (Jaeger and Fahrig 2004).

If kit foxes are successfully crossing these 4-lane divided highways on our study sites, then there would be little incentive for foxes to use crossing structures. This also would indicate that these highways are not functioning as barriers to genetic flow, and if mortality from vehicles is not excessive, then demographic flow is being maintained as well. However, many of the current two-lane highways scheduled to be widened to four lanes within the range of the San Joaquin kit fox will include median barriers (Clevenger 2005). These barriers are installed for human safety, but can act as traps for wildlife (Forman et al. 2003).

If median barriers are installed along highways, certain measures potentially could mitigate adverse impacts to kit foxes. Fencing impermeable to kit foxes could serve two purposes. First, it could prevent foxes from attempting to cross the highway and potentially getting trapped in traffic by median barriers. Second, fencing could be used to direct kit foxes to crossing structures. This strategy has been used effectively in Banff National Park in Alberta, Canada for large mammals (Clevenger and Waltho 2000), bobcats in Texas (Cain et al. 2003), endangered Wyoming toads (*Bufo hemiophrys baxteri*) in Wyoming (Bonds 1999), spotted salamanders (*Ambystoma maculatum*) in Massachusetts (Jackson 1999), threatened desert tortoises in California (Boarman 1996), herptofauna in Florida (Aresco 2005), endangered Florida panthers (Turbak 1999), and large ungulates in several areas (e.g., Brown et al. 1999, Bonds 1999). In Montana, fencing and walls were used to direct mountain goats (*Oreamnos americanus*) to underpasses. This reduced vehicle strikes and allowed mountain goats to safely access traditional salt licks (Singer and Doherty 1985).

The optimal design of crossing structures for kit foxes remains unknown. This study found no interactions between structural attributes and structure use by kit foxes or their potential predators due to the small number of instances of structure use. In a previous study conducted on the Hwy 58 study site, kit foxes were detected using crossing structures with the following dimensions: 0.9-m to 1.5-m diameter steel pipe; 1.4-m diameter concrete pipe; and concrete boxes 3-3.6 m wide by 1.8-3 m high (Boarman and Sazaki 1996). In general, the larger the structure and the greater the degree of "openness", the higher the probability of use of kit foxes. Use of culverts by bobcats in south Texas was positively related to the openness ratio of the structures (Cain et al. 2003). Furthermore, kit foxes are members of a complex ecosystem. Roads can disrupt ecosystem processes, which could produce subtle effects that decrease long-term population viability for kit foxes. Thus, to help maintain a functional ecosystem, crossing structures minimally should be appropriate to accommodate use by the largest animal species in the ecosystem. In the case of the San Joaquin kit fox, the largest species in most locations is the coyote, but in a few locations the largest species are mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), and elk (*Cervus elaphus*).

One final consideration is escape cover in and near crossing structures. As discussed, increased predation risk potentially discourages use of such structures by kit foxes. One way to counteract this risk may be to install escape dens within the structures and near the entrances. Escape dens can be as simple as a length of pipe with openings of sufficient size to allow entry by foxes but exclude entry by coyotes and bobcats. San Joaquin kit foxes readily use such artificial escape dens (B. Cypher, CSUS Endangered Species Recovery Program, unpublished data). Also, such escape dens significantly improved survival of swift foxes in Texas (McGee et al. 2006).

CONCLUSIONS

1. Kit foxes did not pass through any of the existing crossing structures monitored at the three study sites.
2. Kit fox tracks were detected in track stations at one end of a number of the crossing structures on several occasions at the Highway 58 and Interstate 5 study sites.
3. Roadkill carcasses of kit foxes were recovered at the Highway 58 and Route 14 study sites.
4. Track station and roadkill surveys indicate that kit foxes were present at all three study sites.
5. Monitoring data suggests that if foxes were crossing the roads they were passing over the road surface rather than using any of the existing monitored crossing structures.
6. The absence of median barriers and exclusionary fencing at the study sites in conjunction with a potentially elevated predation risk associated with the crossing structures may have caused kit foxes to avoid the structures and simply attempt to cross the highways.

RECOMMENDATIONS

1. Conduct further field investigations to determine whether kit foxes are indeed avoiding structures and crossing roads, or are generally avoiding roads.
2. If opportunities arise, repeat this investigation in areas with median barriers to determine whether kit foxes are more likely to use crossing structures in such areas or simply abandon attempts to cross roads.
3. In areas where median barriers are present along highways, recommendations to reduce adverse impacts to kit foxes include:
   a. install fencing to exclude kit foxes from the highway and direct them to crossing structures;
   b. design crossing structures to accommodate use by the largest animal species occurring in the local ecosystem, and
   c. place artificial dens within crossing structures and near entrances to provide escape cover for kit foxes.

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