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Wildlife Impacts - Mammals

Chapter 10

....Wildlife Impacts

Mammals

BRIDGES AND WILDLIFE: ISSUES AND SOLUTIONS

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Problem Statement

The Washington State Department of Transportation (WSDOT) owns over 3,000 steel and concrete bridges, many of which are occupied by wildlife. Species documented occupying bridges range from birds of prey, such as ospreys, peregrines and owls, to mammals such as raccoons, bats and bushy tailed wood rats. While the bridges are playing an important role in providing habitat for wildlife, their presence can also lead to costly project delays.

Project Objective

The project objective is to develop a comprehensive approach to managing wildlife issues on bridges that will allow WSDOT to manage the bridges for wildlife where appropriate, and to address the regulatory issues that must be addressed for projects to proceed smoothly

Methods

WSDOT has developed a comprehensive approach to addressing wildlife and bridge issues. The approach includes: (1) education of bridge inspectors and maintenance workers on the species frequently seen on bridges, and the regulations that protect them; (2) maintenance of a database, which documents, by species, which bridges are inhabited by wildlife; (3) the development of guidelines for projects on how to avoid or minimize impacts to birds nesting on bridges; (4) coordination with regulatory agencies [e.g., the US Fish and Wildlife Service (USFWS) and the Washington Department of Fish and Wildlife (WDFW)] to obtain statewide permits for when eggs or young need to be removed due to a project.

Results

The first step was to educate the bridge inspectors and maintenance folks about the species residing on the bridges, their identifying characteristics, life histories, and the applicable laws and regulations that applied to each species. In addition to the talks, species fact sheets were developed along with a *Species on Bridges* brochure. The species fact sheets were designed to fit into the bridge inspectors' notebooks, and each sheet includes information on a species, its identifying characteristics, its life history, and the laws that protect it.

WSDOT also added several fields to its existing bridge inspection report and bridge database, allowing inspectors to record information about the wildlife species observed on the bridge. This information is used by the bridge inspection office to schedule bridge inspections outside the nesting season for sensitive species like peregrines and ospreys, and to provide warnings to the inspectors about what they may encounter on the bridge, such as irate great horned owls. The regional project offices also use this information when planning and permitting projects involving the bridge as painting projects.

Guidelines were developed which explained the applicable regulations (Migratory Bird Treaty Act, and state regulations) that must be met in regards to birds and other protected species. The Guidelines focus on methods that can be used to avoid impacts to nesting birds through the use of timing windows, exclusion methods, work avoidance zones, etc. Also included is a discussion of when and how to arrange for the removal of eggs or chicks for rearing at approved facilities if avoidance is not possible.

Since removal of eggs or young requires both federal and state permits, WSDOT is in the process of negotiating permits with the regulatory agencies that would allow for the removal of young or eggs when necessary. These permits will address how the removal will occur and the disposition of the eggs or young.

Application

Currently, WSDOT is using all of the tools that have been developed to help manage wildlife species residing on the bridges. Bridge inspectors and bridge maintenance personnel have been very enthusiastic about the training and about reporting wildlife that they encounter on the bridges. Project personnel are using the database tracking system to identify any Migratory Bird Treaty Act issues that may arise during a project.

Implications

WSDOT biologists would like to develop additional opportunities for wildlife species on bridges through the use of wildlife structures. However, WSDOT is also concerned about maintaining the ability to inspect and repair the bridges as needed without violating any laws relating to wildlife. While the various tools that have been developed to date have helped address a number of these concerns, additional in-house coordination will be necessary to develop a working solution that will where appropriate, encourage wildlife on bridges, while maintaining maximum flexibility for inspection and repair work.

THE EFFECT OF TRAFFIC VOLUME ON TRANSLOCATED SMALL MAMMAL MOVEMENT

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Abstract: We investigated whether white-footed mice (*Peromyscus leucopus*) and eastern chipmunks (*Tamias striatus*) were capable of crossing roads with varying levels of traffic volume. We live-trapped small mammals in 24 "home" patches. We uniquely marked and translocated 197 white-footed mice and 115 eastern chipmunks to nearby forest patches. Recaptured animals were recorded as successful returns. Forty five (22.8%) of the mice and 22 (19.1%) of the chipmunks returned to their home patches within six days of their release. Traffic on roads between the capture and release sites had a significant negative effect on small mammal return rates. No small mammals returned when moved across roads with average annual daily traffic over 11,000. Roads with low traffic may be weak barriers to movement, but high traffic prevents successful crossing.

Introduction

Barriers decrease connectivity between patches, and the extent to which roads act as barriers to animal movement is of particular interest for management. Highly connected patches are less prone to extinction events because inter-patch dispersal enables individuals to rescue threatened local populations from extirpation (Brown and Kodric-Brown 1977). If an extinction event does occur, high connectivity allows for quick recolonization and, as a result, may increase regional population persistence. Research in a variety of habitats including tropical (Goosem 2001) and temperate forests (Oxley et al. 1974, Mader 1984), grasslands (Wilkins 1982) and desert (Garland and Bradley 1984) has shown that linear barriers such as roads may inhibit small mammal movement. The barrier effect could be due to the difference in vegetation structure at the sides of roads, increased canopy openings, or increased traffic volume on the road (Andrews 1990).

In this study, we investigated the magnitude of road-crossing inhibition of small mammals due to traffic volume. We used translocation methods to determine whether animals were less likely to successfully return if translocated across roads that had higher traffic volumes than roads with lower volumes.

Methods

We live-trapped small mammals in 24 "home" patches or woodlots (<100 ha area) from June to October 1999, and May to July 2003. For each home patch, three to five nearby woodlots within 1,500m of the home patch were chosen for releases, and the sequence of release was randomized among them. In each home patch, we established four transects 10 to 50m apart. In each transect, we placed 18 Sherman® live-capture traps every 5 m, for a total of 72 traps in each home patch. We recorded the species, sex, and mass of each captured individual. We uniquely marked individual white-footed mouse (*Peromyscus leucopus*) and eastern chipmunk (*Tamias striatus*) individuals with metal ear tags and relocated them. If an animal returned to the home patch and was recaptured, we identified it by its ear tag number and recorded it as returning. These individuals were not relocated again. We sampled each home patch for six days.

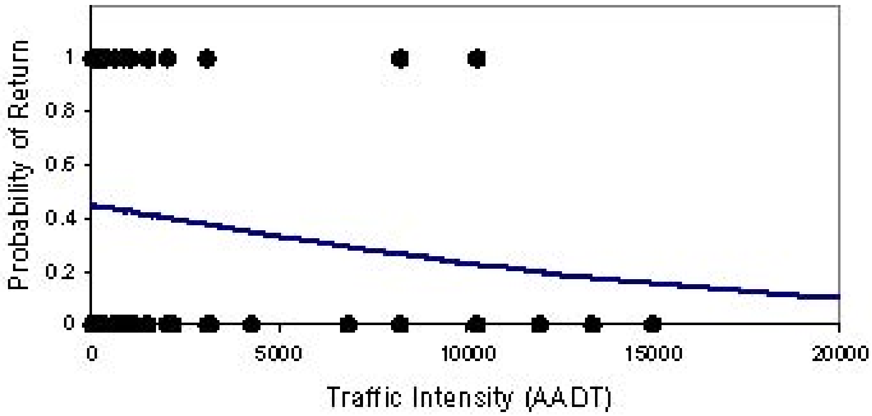
We obtained estimates of traffic levels (average annual daily traffic, AADT) for each road between each home and release patch pair. Traffic volume represented a combined total of the number of cars traveling on each of the roads between the home and release patches. We also measured the edge-to-edge distances between the release and home patches.

We performed multiple logistic regression analyses to determine whether traffic volume affected the return probability of small mammals. The response variable represented the success or failure of an individual to return to its home patch. Independent predictor variables included the total traffic density on those roads, species (white-footed mouse or eastern chipmunk), and the edge-to-edge distance between the home and release patches.

Results

Over the two field seasons, 312 small mammals (197 white-footed mice and 115 eastern chipmunks) were translocated from home patches, of which we recaptured 67 returning animals (21.5% recapture rate). Based on the multiple logistic regression analysis, the return probability of small mammals was negatively related to traffic volume (figure 1a: Wald chi-square = 3.93, $p = 0.0474$, df = 1) and the distance between home and release patches (figure 1b: Wald chi-square = 25.71, $p < 0.0001$, df = 1), but not affected by species (*P. leucopus* = 22.8%, *T. striatus* = 19.1%). No animals returned from translocations crossing roads whose combined traffic volume was in excess of 11,000 AADT.

a)



b)

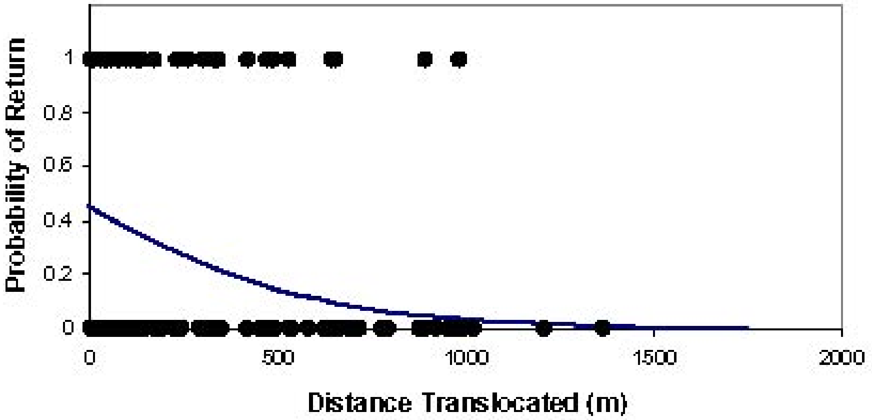


Fig. 1. Probability, as determined from logistic regression, that small mammals returned from translocations versus (a) traffic volume ($p = 0.0474$, $n = 312$, $df = 1$) and (b) translocation distance ($p < 0.0001$, $n = 312$, $df = 1$). Points represent individuals translocated: 1 = returned, 0 = did not return. Logistic equation: $\ln(p/1-p) = -0.197 - 0.00314\,(\text{distance}) - 0.00010\,(\text{traffic})$.

Discussion

As traffic increases, the ability of small mammals to cross roads decreases. Animals failed to cross roads at very high levels of traffic volume (i.e., 11,000 AADT), but not at moderate (5,000-7,000 AADT) or low (< 2,000 AADT) traffic volumes. Traffic volume on roads has been shown to inhibit movement of small mammals such as hedgehogs (Rondinini and Doncaster 2002), badgers (Clarke et al. 1998), mice and voles (Clark et al. 2001), and it also affected white-footed mice and chipmunks in our study. Neither species successfully returned from translocations across roads with high traffic volumes.

There are several possible mechanisms behind the decreased small mammal movement at roads. Width (Oxley et al. 1974), number of lanes (Oxley et al. 1974, Wilkins 1982), canopy closure (Goosem 2001) and type of road (i.e., paved vs. gravel; Clark et al. 2001) have all been shown to inhibit small mammal movement. Roads with high traffic volume are complete barriers to small mammal movement, effectively isolating populations on both sides of the roads. Increased crossing structures (e.g., culverts) may be necessary to facilitate movement across high traffic volume roads (Goosem 2001).

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References

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. *Australian Zoologist* 26 (3&4): 130-141.

Brown, J. and A. Krodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. *Ecology* 58: 445-449.

Clark, B.K., B.S. Clark, L.A. Johnson and M.T. Haynie. 2001. Influence of roads on movements of small mammals. *The Southwestern Naturalist* 46 (3): 338-344.

Clarke, G.P., P.C.L. White, and S. Harris. 1998. Effects of roads on badger *Meles meles* populations in south-west England. *Biological Conservation* 86: 117-124.

Garland, T. and W.G. Bradley. 1984. Effects of a highway on Mojave Desert rodent populations. American *Midland Naturalist* 111: 47-56.

Goosem, M. 2001. Effects of tropical rainforest roads on small mammals: inhibition of crossing movements. *Wildlife Research* 28: 351-364.

Goosem, M. 2002. Effects of tropical rainforest roads on small mammals: fragmentation, edge effects and traffic disturbance. *Wildlife Research* 29: 277-289.

Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. *Biological Conservation* 29: 81-96.

Oxley, D., M. Fenton, and G. Carmody. 1974. The effects of roads on populations of small mammals. *Journal of Applied Ecology* 11: 51-59.

Rondinini, C. and C.P. Doncaster. 2002. Roads as barriers to movement for hedgehogs. *Functional Ecology* 16: 504-509.

Scott, L.K., I.E. Hume and C.R. Dickman. 1999. Ecology and population biology of long-nosed bandicoots (*Perameles nasuta*) at North Head, Sydney Harbour National Park. *Wildlife Research* 26: 805-821.

Wilkins, K.T. 1982. Highways as barriers to rodent dispersal. *Southwest Naturalist* 27: 549-460.

EFFECTS OF ROADS ON SAN JOAQUIN KIT FOXES: A REVIEW AND SYNTHESIS OF EXISTING DATA

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Abstract: Roads have a variety of adverse impacts on wildlife populations and can seriously impact rare species. Numerous roads are present throughout the range of the endangered San Joaquin kit fox (*Vulpes macrotis mutica*), and many more are planned. We review existing literature and data to assess potential impacts from roads on kit fox conservation and recovery. In addition, we discuss mitigation strategies with their potential benefits.

Introduction

In the United States, over 200 million vehicles are in use on approximately 6.2 million kilometers of public roads (Natural Research Council 1997). Roads result in a number of environmental impacts, including endangerment of wildlife populations. The direct impacts of vehicle-related mortality and habitat loss have long been recognized. Lalo (1987) estimated that about one million vertebrates are killed by vehicles each day in the United States, and Forman (2000) calculated that approximately 1 percent of the land area, roughly the size of South Carolina, is paved. Additional direct effects include habitat fragmentation, disturbance and stress, contaminants, and destruction of shelter (Hourdequin 2000). Roads also may indirectly impact wildlife by altering ecosystem processes, such as changes in prey availability, competition, non-native species colonization, fire regime, and human access and associated development. Direct and indirect impacts may be detectable over one kilometer (0.6 mi) from roads resulting in a "road-effect zone" (Forman and Deblinger 1998), and leading one author to estimate that approximately 19 percent of the total area of the conterminous United States is affected (Forman 2000). Not surprisingly, road effects have been detected for a number of rare species including gray wolves (*Canis lupus*; e.g., Thiel 1985), Florida panthers (*Felis concolor coryi*; e.g., Maehr et al. 1991), desert tortoises (*Gopherus agassizii*; e.g., Boarman 1996), and Sonoran pronghorn (*Antilocapra Americana sonoriensis*; e.g., Castillo-Sáchez 1999). While impacts on common species are undesirable, road-related depletion of threatened and endangered species is particularly troubling and warrants careful evaluation and management.

A diversity of threatened and endangered animal species occur in the San Joaquin Valley of California (U.S. Fish and Wildlife Service 1998). Most are rare due to habitat loss from agricultural, industrial, and urban development. Among them is the endangered San Joaquin kit fox (*Vulpes macrotis mutica*), a small, nocturnal canid that has undergone an estimated 95 percent reduction in habitat (Grinnell et al. 1937, Hall 1981, Mercure et al. 1993, U.S. Fish and Wildlife Service 1998). While the effects of roads on San Joaquin kit foxes have not been directly evaluated, the relatively large space requirements and high mobility of this species makes road crossings likely throughout much of their current range. Furthermore, the human population in the San Joaquin Valley is expected to nearly triple in the next 40 years (Great Valley Center 2000), with associated construction of new roads, expansion of existing roads, and increased traffic volumes.

Some of the potential impacts on San Joaquin kit foxes are obvious and direct, such as vehicle strikes, habitat loss associated with road construction, habitat loss associated with concomitant industrial and urban development, landscape fragmentation, disturbance, and environmental contamination. Others are more subtle and indirect, such as invasions by non-native species, changes in prey availability, predator abundance, or fire regime. The aforementioned could have a variety of detrimental effects on kit foxes, including mortality, morbidity, disrupted social ecology, reduced productivity, displacement, altered space use, inhibited dispersal, reduced genetic exchange, and decreased carrying capacity.

Our objectives are to (1) summarize available data on the direct and indirect effects of roads on populations of San Joaquin kit foxes, (2) identify factors that exert the greatest influence on kit fox conservation and recovery efforts, and (3) identify critical information needs for future research and mitigation.

Direct Effects

Vehicle Strikes

The majority of vehicle strikes occurs at night when many species are more active and driver visibility is at its lowest. For an animal the size of a kit fox, such strikes are typically fatal. If vehicle strikes were sufficiently frequent in a given locality, they could result in reduced fox abundance. Furthermore, the death of adult foxes during the breeding and pup-rearing seasons (Dec-May) negatively affects reproductive success and could result in the litter failure.

The proportion of deaths attributable to vehicle strikes rarely exceeds 10 percent for adult foxes (table 1). Clearly, the number and type of roads passing through fox habitat play an important role in determining impact. In the city of Bakersfield where roads were abundant, 23 percent of 35 adult kit fox mortalities and 17 percent of 25 juvenile mortalities were confirmed vehicle strikes. Furthermore, an additional 9 percent of adult and 8 percent of juvenile mortalities were suspected strikes. At this urban site where coyotes and bobcats were rare, vehicles were the most commonly attributable source of mortality. In natural lands, predators remain the primary cause of mortality for both adult and juvenile foxes (Briden et al. 1992, Standley et al. 1992, Ralls and White 1995, Spiegel and Disney 1996, Cypher et al. 2000).

Habitat Loss and Fragmentation

Paved roads are essentially permanent structures, and any habitat in the occupied area is therefore lost. The placement of a road also can fragment habitat into smaller blocks. This fragmentation effect is more likely with certain road configurations, such as multi-lane divided highways, or those with median barriers and adjacent fencing. Habitat loss and fragmentation can cause decreases in fox abundance through changes is social ecology, productivity, space use, dispersal, and survival.

Table 1
Proportion of mortalities attributable to vehicle strikes for kit and swift foxes.

Species	Location	Landuse	Period	Age	# Mortalities	% Vehicle Strike	Citations
Kit Fox	Kern County, CA	Oilfield	1980-95	Adult	225	9%	Cypher et al. 2000
Kit Fox	Kern County, CA	Oilfield	1980-95	Juvenile	142	8%	Cypher et al. 2000
Kit Fox	Kern County, CA	Natural Land	1989-93	Combined	31	3%	Spiegel and Disney 1996
Kit Fox	Kern County, CA	Oilfield	1989-93	Combined	29	0%	Spiegel and Disney 1996
Kit Fox	Kern County, CA	Natural Land	2001-03	Adult	14	7%	Cypher unpub. data
Kit Fox	Kern County, CA	Natural Land	1989-91	Combined	22	5%	Ralls and White 1995
Kit Fox	Monterey and San Luis Obispo Counties, CA	Military Reservation	1988-92	Adult	35	6%	Standley et al. 1992
Kit Fox	Monterey and San Luis Obispo Counties, CA	Military Reservation	1988-92	Juvenile	14	0%	Standley et al. 1992
Kit Fox	Merced County, CA	Natural Land	1985-87	Combined	17	12%	Briden et al. 1992
Kit Fox	Bakersfield, CA	Urban	1997-2003	Adult	35	23%	Cypher unpub. data
Kit Fox	Bakersfield, CA	Urban	1997-2003	Juvenile	25	17%	Cypher unpub. data
Swift Fox	Alberta, Canada	Natural Land	1987-91	Combined	89	6%	Carbyn 1998
Swift Fox	Western Kansas	unknown	1996-97	Adult	18	0%	Sovada et al. 1998
Swift Fox	Western Kansas	unknown	1996-97	Juvenile	14	28%	Sovada et al. 1998

While the historic and current habitat loss directly attributable to roads is unknown, estimates of the converted area under the jurisdiction of Caltrans include 239ha for Kings County, 431ha for Merced County, 817ha for Fresno County, and 1,485ha for Kern County (K. Hau, California Department of Transportation, personal communication). These estimates are based on a standard lane width of 3.6 m, and not all of this area is in kit fox habitat. However, the estimates are limited to state roads and do not include road shoulders, medians, or associated developments (e.g., interchanges, signs), which significantly increase the affected area. Of equal or greater significance is the habitat loss from urban and industrial development that has been induced by road construction.

Habitat fragmentation likely has two profound effects: (1) reduction in suitability of habitat and (2) disruption of movements, dispersal, and gene flow. Roads reduce habitat suitability by creating patches that are too small for effective use by foxes and that increase the probability of local extirpation due to stochastic events. Estimates of the average home range size of a kit fox vary from 4.3km^2 (Koopman et al. 2001) to 11.6 km^2 (White and Ralls 1993), making it difficult to estimate patch size necessary to support a small population.

The probability of patch recolonization will depend upon the fragmenting artifacts (e.g., roads, canals, development). Large roads with high traffic volume can be impermeable to kit foxes. Knapp (1978) monitored movements of radio-collared foxes in Kern County in the vicinity of Interstate 5, a high volume four-lane highway. Numerous individuals used areas within 3km of the interstate, and most exhibited parallel movement and home range patterns. However, only on two occasions were foxes located on the opposite side of the highway from their primary areas of use.

Movement and dispersal corridors are critical to kit fox population dynamics, particularly because this species currently exists as a metapopulation consisting of multiple disjunct population centers. Movement and dispersal linkages are important for alleviating over-crowding and intraspecific competition during years when fox abundance is high and are essential for recolonization. Movement between population centers also maintains gene flow, reducing the probability of inbreeding, genetic drift, and founder effects.

Disturbance

Construction, maintenance, and operational activities associated with roads may result in a disturbance effect on nearby kit foxes. Disturbance can result from noise, vibration, odors, or human activity and can range from subtle to profound. Potential impacts include: (1) disrupted sensory perception leading to decreased ability to locate prey or detect predators, (2) induced stress leading to physiological or behavior changes, and (3) resultant changes in natural history including, energetic requirements, reproductive output, immunological function, productivity, space use patterns, displacement, and even death.

Kit foxes may not be significantly impacted by disturbance, even when the source is continuous. Kit foxes appear to acclimate quickly to disturbances and exhibit a high degree of tolerance. At the Naval Petroleum Reserves in California, foxes frequently used areas near petroleum production facilities (e.g., well pads, gas plants, offices) where noise, vibrations, odors, and human activity were common (Cypher et al. 2000). Similarly, Spiegel and Small (1996) found that kit foxes continued using a highly developed oil field where sulfurous gases were ubiquitous. Kit foxes at Camp Roberts frequently foraged and denned in areas that were subject to high human and vehicular traffic (Berry et al. 1992). Most notably, populations are known to inhabit the cities of Bakersfield and Taft, and in Bakersfield individuals likely number in the hundreds (Cypher submitted). Kit foxes in urban environments are continuously subjected to high levels of vehicular traffic, human activity, noise, and vibrations. Yet, these foxes successfully forage, locate mates, breed, rear young, and disperse.

Den Loss

Unlike most other canids, kit foxes use dens year-round on a daily basis (Koopman et al. 1998). Earth moving or vehicular traffic during road work jeopardizes kit fox dens. Because dens are of critical importance to avoid temperature extremes, rear young, and escape from predators (Seton 1925, Grinnell et al. 1937), den loss can result in displacement and altered space use patterns, leading to changes in social ecology and survival. Individual kit foxes use numerous dens in the course of a year (Koopman et al. 1998). Therefore, the loss of one or even several dens within an individual's home range may not constitute a significant impact. However, foxes appear to have moderate fidelity to natal dens, the loss of which could be more detrimental. Finally, earth moving and off-road traffic typically occurs during the day, a time when foxes are resting within dens. This could result in fox entombment and death.

Although the construction of roads may result in the loss of some dens, earth moving can create new denning opportunities. In Bakersfield, numerous kit fox dens have been located in the embankment of Highway 99, and several of these have served as natal dens. This is not surprising because kit foxes favor sloped locations for denning (Berry et al. 1987*a*, Reese et al. 1992). However, den sites along roads increase the risk of vehicle strikes, particularly when used to rear young. Egoscue (1962) reported that many of the kit foxes killed by vehicles on a study area in Utah were using dens near roads, and most of these were juveniles. This increased risk likely offsets any beneficial effect of increased den-site availability.

Contaminants

Roads contaminate natural lands in a variety of ways (see Forman et al. 2003 for a review). Substances used in road building or reconditioning can leach into adjacent habitat. Heavy metals (lead, aluminum, iron, cadmium, copper, manganese, titanium, nickel, zinc, and boron) and organic pollutants (dioxins, polychlorinated biphenyls) are all emitted in vehicle exhaust and may be higher in adjacent soils (Benfenati et al. 1992, Trombulak and Frissell 2000). Ozone levels are higher in the air near roads (Trombulak and Frissell 2000), and vehicles also leak hazardous substances (lubricants, antifreeze). Furthermore, a wide variety of pollutants could be introduced during small spills or catastrophic accidents.

Kit foxes using areas adjacent to roads could be exposed to contaminants through inhalation, dermal contact, direct ingestion, and ingestion of contaminated flora or fauna. Exposure to contaminants could cause short- or long-term morbidity, possibly resulting in reduced productivity or even mortality. Carcinogenic substances could cause genetic damage, sterility, reduced productivity, or reduced fitness among progeny in foxes or their prey. Little information is available on the effects of contaminants on fox demographics. Morbidity or mortality likely would occur after animals have left the contaminated site, and more subtle effects such as genetic damage could only be detected through intense study and monitoring. However, at the Naval Petroleum Reserves in

California, three kit foxes are known to have died by drowning in spills of crude oil (Cypher et al. 2000). Also, Spiegel and Disney (1996) reported a fox that was covered with crude oil and later died, despite treatment.

Indirect Effects

Reduced Prey Availability

Road construction, maintenance, and operation could result in a local reduction in prey availability, indirectly affecting kit fox populations. Potential causes include direct mortality associated with construction activities or vehicle strikes, habitat loss or degradation, disturbance, contaminants, or alteration of adjacent vegetation communities. Reduced prey availability could cause fox avoidance of adjacent lands, reduced productivity, and in extreme cases morbidity or mortality.

Little information is available on the effects of roads on kit fox prey. Foxes primarily prey upon rodents, leporids, and insects, but will opportunistically eat a variety of natural and anthropogenic foods (Knapp 1978, Spiegel et al. 1996, White et al. 1996, Cypher et al. 2000). Disturbed habitats adjacent to roads may provide conditions favorable to colonization by California ground squirrels (e.g., Balestreri 1981, Hall 1983). California ground squirrels can displace giant kangaroo rats (*Dipodomys ingens*) as well as other kangaroo rats and San Joaquin antelope squirrels (*Ammospermophilus nelsoni*) that are commonly consumed by foxes (D. Williams, Endangered Species Recovery Program, pers. comm., Taylor 1916; Harris and Stearns 1991).

Increased Competition

Habitat modification associated with road construction and operation may create conditions more favorable for native species that compete for resources or kill kit foxes. Increased predation risk or decreased prey availability could reduce fox habitat quality and local carrying capacity, or exclude kit foxes altogether. At the Naval Petroleum Reserves in California, shrub density increased along roads, possibly due to increased moisture from precipitation runoff (pers. obs). Dense shrubs are known to provide cover for coyotes (*Canis latrans*) and bobcats (*Lynx rufus*) (Ralls and White 1995, White et al. 1995, Cypher and Spencer 1998, Warrick and Cypher 1998). Also, utility lines frequently are installed along roads and dramatically increase perching and nesting sites for raptors (Knight et al. 1995, 1999). Golden eagles occasionally kill kit foxes (Briden et al. 1992) and raptors and owls compete with foxes for food resources. Roads also may serve as travel corridors for other kit fox competitors, such as red foxes.

Invasive Species

Construction and maintenance of roads can sometimes facilitate the invasion of non-native species that flourish in disturbed environments. Roads also enable invasive species to hitchhike on vehicles and livestock into otherwise remote landscapes. Non-native plants and animals may reduce habitat quality for kit foxes or their prey. A particularly problematic species within the range of the San Joaquin kit fox is yellow star thistle (*Centaurea melitensis*), dense stands of which form along roadsides and then spread into adjacent habitat. Yellow star thistle competes with native plants for resources, does not appear to be used by kit fox prey, and may be difficult for foxes to move through due to its large size (up to 1m tall), dense growth habit, and numerous sharp spines. Other species of invasive flora include mustards (*Brassica spp.*) and Russian thistle (*Salsola tragus*) (Tellman 1997), but the effects of these plants on kit foxes or their prey species have not been assessed.

Nitrogen deposition from vehicle exhaust is another important factor that appears to promote growth of non-native flora, particularly exotic grasses (Weiss 1999). These grasses, such as red brome (*Bromus madritensis rubens*), create dense ground cover in the San Joaquin Valley, and may reduce habitat quality for certain rodents (e.g., kangaroo rats) that are important prey for kit foxes (Goldingay et al. 1997, Cypher 2000).

Roads also may serve as travel corridors for non-native red foxes, as has been reported in Australia (Bennett 1991). Red foxes kill and exclude kit foxes (Ralls and White 1995, Clark 2001) and likely compete for food and dens (Cypher et al. 2001). However, red foxes are only infrequently observed in large blocks of undisturbed habitat within the range of the San Joaquin kit fox, possibly due to the absence of anthropogenic water sources or the presence of coyotes.

Increased Public Access

Roads are established to facilitate human travel and commerce. Although posting adjacent lands or installing fences may reduce human use, they do not prevent it completely. While recreating on natural lands, people engage in a variety of activities that are detrimental to kit foxes, including illegal shooting or trapping, legal and illegal hunting of prey species, habitat destruction and degradation (e.g., off-road vehicle use), den destruction, and illegal dumping.

Most effects from increased public access have not been quantified, and can only be inferred. However, illegal fox hunting has been reported on several occasions and typically occurs near roads. While only one fox was found shot at the Naval Petroleum Reserves in California during 1980-95 (Cypher et al. 2000), Morrell (1972) reported that during a one-year period at NPRC, five of six fox deaths were caused by gunshot wounds. Four kit foxes were found shot at the Lokern Natural Area in western Kern County (Spiegel and Disney 1996), two at the California Aqueduct in Kern County (K. Brown, California Department of Water Resources, personal communication), and one in the Santa Nella area (S. Clifton, Endangered Species Recovery Program, personal communication). Most illegal kills are likely never discovered; therefore, the effect of this source of mortality on kit foxes is difficult to assess.

Associated Development

While human population and economic growth precipitates road construction, roads also can have a growth-inducing effect by increasing access to lands desirable for development. Development along roads commonly begins as transportation services, and later urban and industrial centers. Associated developments range from very small (1-2ha) to extensive (1km^2), ultimately producing entire cities in some cases.

Associated development produces all of the negative effects to kit foxes discussed above, the most significant of which are habitat loss, fragmentation, and degradation. Because associated development cannot always be accurately predicted, the long-term cumulative effects are likely underestimated in environmental reviews of road construction projects.

Changes in Fire Regime

Roads often are a source of wildfire in arid lands, with dramatic effects on ecosystem processes. Vehicle sparks, overheating engines and brakes, arson, and accidental ignition all contribute to increased fire frequency. In some landscapes where lightning strikes traditionally were rare, anthropogenic wildfires have dramatically altered vegetation, reducing vertical structure and creating conditions that are suitable for invasive species.

Because foxes maintain well-insulated dens throughout their home ranges, it is unlikely that they frequently die in wildfire. However, much of the kit fox's geographic range is dominated by shrubs and grasses, and frequent burns will make grasslands more common. Furthermore, changes in vegetation affect abundance of fox prey and predators. For example, both coyotes and leporids (desert cottontail and black-tailed jackrabbit) are known to favor shrublands in the southern San Joaquin Valley. The effect of fire upon kit fox ecology and life history is currently unknown, but significant impacts are to be expected as these relationships are investigated.

Potential Mitigation Strategies

Compensation for Loss of Habitat

Compensating for habitat loss is a mitigation strategy commonly implemented for kit foxes. This strategy involves protecting habitat of like or better quality in return for authorization to alter, disturb, or destroy habitat in another location. The amount of compensatory habitat required typically exceeds 1:1. This strategy has several shortcomings. First, new habitat is rarely created as a result of mitigation, so compensation results in a net loss of available lands. Second, there is an implicit assumption that the carrying capacity on compensatory habitat can be increased through habitat management such that the total carrying capacity across all lands remains unaffected. This assumption has never been validated and is questionable. Third, compensation is only required for the amount of habitat physically disturbed during road construction. Roads precipitate a slew of associated impacts described above for which compensation is rarely requested.

Avoidance of Important Habitats

Impacts to kit foxes can be reduced during the planning process by selecting project sites that avoid areas that are required for recovery of the species. Such areas include core and satellite populations and movement corridors. Understandably, there may be limited options in selecting the route for a proposed road. However, avoiding routes that transect large blocks of habitat would reduce detrimental effects significantly. A clear drawback to this strategy is increased project costs and decreased efficiency resulting from alternate routes. Rerouting of roads was identified as a key strategy to avoid fragmenting wildlife habitats in the Rocky Mountains (Reed et al. 1996) and also to avoid increased mortality to Florida scrub-jays (Mumme et al. 1999).

Den Avoidance

Den avoidance is a common mitigation strategy employed on projects in kit fox habitat. Typically, work sites are prescreened for fox dens, and care is taken during construction to avoid sensitive areas. Den avoidance may be difficult when a kit fox den lies within the path of a proposed road. From a cost-benefit perspective, rerouting a road around a den is rarely feasible. If the den is currently active and the occupants do not leave voluntarily, relocation may be necessary. As mentioned previously, dens in the vicinity of roads may increase the risk of vehicle strikes, and this potential impact should be considered when deciding whether to protect dens or relocate occupants.

Relocation

Foxes are rarely relocated because of well-documented negative impacts, including low survival probability (Scrivner et al. 1993), injury, and attempted return to the area of origin. The release can either be "hard", whereby foxes are immediately released, or "soft", whereby foxes are released after a period (of days to months) of acclimation in a holding pen. A number of conditions must be met prior to relocation. First, the release site must be of suitable condition and size to support the number of transplanted individuals. Second, relocation must not negatively impact resident foxes at the release site. Third, if ongoing genetic studies identify distinct subpopulations, then foxes should only be moved within subpopulations and not between them. An optimal release site would be one that is occupied by kit foxes, but where the fox population currently is below carrying capacity. To be considered successful, relocated foxes should remain in the release area and exhibit survival rates similar to that of resident foxes. Several attempted relocation efforts were insufficiently monitored (Jensen 1972, Knapp 1978, Hansen 1988, Paveglio and Clifton 1988) or deemed unsuccessful (Scrivner et al. 1993).

Relocation may be appropriate when a small, isolated block of habitat occupied by kit foxes will be unavoidably fragmented by a road project. Additionally, persistent endangerment may be cause for relocation. For example, individuals occasionally return to denning and foraging sites that have recently been destroyed. Kit foxes continued to forage in the median of Highway 99 in Bakersfield after all vegetation had been removed (Perry Coy, California Department of Transportation, Fresno), while others were entombed after excavating and occupying a den on a construction site in Bakersfield (Endangered Species Recovery Program unpublished data).

Artificial Dens

Construction of artificial dens may be appropriate where den destruction is unavoidable or road construction has resulted in increased risk of predation. A variety of artificial den designs have been built or proposed. These designs range from a simple length of pipe placed above ground, to complex buried chambers and tunnels with multiple entrances. Use by kit foxes or other species rarely has been monitored and optimal den designs have not been identified. However, dens should be of appropriate size to exclude predators, provide additional burrowing options, and provide sufficient thermal protection.

Exclusionary Fencing

While exclusionary fencing likely would reduce vehicle strikes it is not appropriate for all roads. Unless crossing structures are available, fencing will increase negative impacts associated with habitat fragmentation. Along smaller roads (e.g., 2-lane roads) or larger roads with lower traffic volumes where the risk of vehicle strikes is not high, it would be better to allow kit foxes to cross roads to maintain movement corridors and facilitate local space use patterns.

Wildlife Overpasses and Underpasses

Overpasses and underpasses are being created with greater frequency for wildlife. Designs range from small culverts under roads to 200-m-wide overpasses that are planted with natural vegetation. The creation of crossing structures could benefit kit foxes. Individuals have been observed to use bridges in order to cross roads and canals (pers obs.). Foxes also regularly enter pipes and culverts, although their use for road crossing has not been documented. Underpasses likely would be the most appropriate structures, particularly because many roads within the range of the kit fox are on raised beds. The dimensions of underpasses probably would need to be at least 0.5m high and 0.5m wide to be used by kit foxes. To maintain normal daily movement patterns in occupied habitat, underpasses probably should be spaced at least every 0.5 km. Exclusionary fencing along roads with underpasses would be necessary to encourage foxes to use the structures.

Reduced Speed Limits

Reduced vehicle speeds through kit fox habitat is a simple and effective strategy to avoid incidental mortality. Reduced speed limits along one - or two-lane roads were credited with reducing the number of kit foxes killed by vehicles at the Naval Petroleum Reserves in California (Cypher et al. 2000) and at the Midway-Sunset oilfield (Spiegel and Disney 1996). This strategy will be more difficult to implement and enforce on larger roads with high traffic volumes. A related strategy is the use of signs along roads to warn drivers of the possible presence of kit foxes. Such signs are commonly used for other wildlife species (e.g., deer crossing signs), but their efficacy is debated.

Summary and Conclusions

The construction, operation, and maintenance of roads can have a variety of potential impacts on endangered San Joaquin kit foxes. While vehicle strikes have received the most attention, other negative effects may exert greater force on fox population dynamics. In natural lands, vehicle strikes rarely exceed ten percent of known mortality. When populations are robust, this may not significantly impact abundance, but where small populations are susceptible to local extirpation, roadkills may be of greater concern.

Habitat loss, fragmentation, and degradation associated with road activities likely has the greatest affect on fox populations. The long and narrow configuration of roads results in a considerable disturbance perimeter. Perimeter effects on wildlife are well documented and with the San Joaquin kit fox result in increased probability of road crossings, exposure to contaminants, and access to habitat by people. Furthermore, high traffic volume roads with no crossing structures can effectively stop fox dispersal, resulting in local extirpation and genetic damage. Fragmentation of remaining habitat poses one of the largest obstacles to kit fox recovery.

The growth-inducing effect of roads also presents a serious concern. Development that occurs along linear rights-of-way causes habitat loss, fragmentation, and degradation that can be orders of magnitude greater than that caused by road work. The potential impacts from associated development sometimes are recognized in assessments of project-specific “cumulative effects,” but no additional compensation or mitigation is required.

Other impacts associated with roads likely affect San Joaquin kit foxes on a relatively local scale. Although these local effects do not threaten the range-wide kit fox population, the cumulative effect of localized impacts could be substantial. Over time, these cumulative effects could affect kit fox conservation and recovery efforts.

A variety of potential mitigation strategies exist. Relatively few have been implemented for San Joaquin kit foxes, and virtually no data are available on mitigation efficacy. Many of the strategies that reduce detrimental impacts to habitat also help reduce kit fox mortality from vehicles. The following should be considered where roads and critical habitat or linkages coexist: (1) careful site selection for proposed projects, routing through non-habitat where possible, (2) habitat compensation, (3) road overpass and underpass structures, (4) exclusionary fencing, and (5) den avoidance or supplementation. Fox relocation is rarely successful or advisable. Future research needs include (1) quantifying factors that contribute to vehicle strikes of kit foxes, (2) assessing the effects of roads on fire ecology, (3) assessing invasions by non-native species along roads, and (4) evaluating the efficacy of mitigation strategies.

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References

Balestreri, A. N. 1981. Status of the San Joaquin kit fox at Camp Roberts, California, 1981. Department of the Army, Fort Ord, California. 30pp. + app.

Benfenati, E., S. Valzacchi, G. Maniani, L. Airoldi, and R. Farnelli. 1992. PCDD, PCDF, PCB, PAH, cadmium, and lead in roadside soil: relationship between road distance and concentration. *Chemosphere* 24:1077-1083.

Bennett, A. F. 1991. Roads, roadsides and wildlife conservation: a review. Pages 99-118. D. A. Saunders and R. J. Hobbs, editors. *Nature conservation: the role of corridors*. Surrey Beatty and Sons, Melbourne, Australia.

Berry, W. H., T. P. O’Farrell, T. T. Kato, and P. M. McCue. 1987*a*. Characteristics of dens used by radiocollared San Joaquin kit fox, (*Vulpes macrotis mutica*), Naval Petroleum Reserve #1, Kern County, California. U.S. Department of Energy Report EGG 10282-2177. 32pp.

Berry, W. H., W. G. Standley, T. P. O’Farrell, and T. T. Kato. 1992. Effects of military authorized activities on the San Joaquin kit fox (*Vulpes velox macrotis*) at Camp Roberts Army National Guard Training Site, California. U.S. Department of Energy Report EGG 10617-2159. 15 pp.

Boarman, W. I. 1996. Highway mortality in desert tortoises and small vertebrates: success of barrier fences and culverts. G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. *Trends in addressing transportation related wildlife mortality.* Florida Department of Transportation, Tallahassee.

Briden, L. E., M. Archon, and D. L. Chesemore. 1992. Ecology of the San Joaquin kit fox (*Vulpes macrotis mutica*) in western Merced County, California. Pages 81-87. D. F. Williams, S. Byrne, and T. A. *Rado, editors. Endangered and sensitive species of the San Joaquin Valley, California: their biology, management, and conservation.* California Energy Commission, Sacramento. 388 pp.

Carbyn, L. N., H. J. Armbruster, and C. Mamo. 1994. The swift fox reintroduction program in Canada from 1983 to 1992. Pages 247-270. M. L. Bowles and C. J. Whelan, editors. *Restoration of endangered species: conceptual issues, planning and implementation.* Cambridge University Press, Cambridge, England.

Castillo-Sánchez, C. 1999. Highways and wildlife conservaion in Mexico: the Sonoran pronghorn at El Pinacate y Gran Desierto de Altar Biosphere Reserve on the Mexico-USA border. Pages 289-292. G. L. Evink, P. Garrett, and D. Zeigler, editors. *Proceedings of the third international conference on wildlife ecology and transportation*. FL-ER-73-99 Florida Department of Transportation, Tallahassee.

Clark, H. O., Jr. 2001. Endangered San Joaquin kit fox and non-native red fox: interspecific competitive interactions. M.S. thesis, California State University, Fresno.

Cypher, B. L. Endangered kit foxes in urban environments: implications for foxes and humans. *Proceedings of the 4th International Symposium on Urban Wildlife Conservation.* Submitted.

Cypher, B. L. 2000. Spatiotemporal variation in abundance of rodents in the San Joaquin Valley, California: implications for conserving rare species. *Southwestern Naturalist* 45. In press.

Cypher, B. L., H. O. Clark, Jr., P. A. Kelly, C. Van Horn Job, G. D. Warrick, and D. F. Williams. 2001. Interspecific interactions among wild canids: implications for the conservation of endangered San Joaquin kit foxes. *Endangered Species UPDATE* 18:171-174.

Cypher, B. L., and K. A. Spencer. 1998. Competitive interactions between coyotes and San Joaquin kit foxes. *Journal of Mammalogy* 79:204-214.

Cypher, B. L., G. D. Warrick, M. R. M. Otten, T. P. O'Farrell, W. H. Berry, C. E. Harris, T. T. Kato, P. M. McCue, J. H. Scrivner, and B. W. Zoellick. 2000. Population dynamics of San Joaquin kit foxes at the Naval Petroleum Reserves in California. *Wildlife Monographs* 145. 43 pp.

Egoscue, H. J. 1962. Ecology and life history of the kit fox in Tooele County, Utah. *Ecology* 43:481-497.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. 2003. *Road Ecology: Science and Solutions*. Island Press, Washington, DC.

Forman, R. T. T. 2000. Estimate of the area affected ecologically by the road system in the United States. *Conservation Biology* 14:31-35.

Forman, R. T. T., and R. D. Deblinger. 1998. The ecological road-effect zone for transportation planning, and a Massachusetts highway example. Pages 78-96. G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. *Proceedings of the international conference on wildlife ecology and transportation*. Report FL-ER-69-68. Florida Department of Transportation, Tallahassee.

Goldingay, R. L., P. A. Kelly, and D. F. Williams. 1997. The kangaroo rats of California: endemism and conservation of keystone species. *Pacific Conservation Biology* 3:47-60.

Great Valley Center. 2000. Survey of current area needs. Great Valley Center, Modesto, California. 29 pp.

Grinnell, J., J. S. Dixon, and J. M. Linsdale. 1937. Fur-bearing mammals of California, Volume 2. University of California Press, Berkeley, California.

Hall, E. R. 1981. *The mammals of North America.* Second ed., Volume 1. John Wiley & Sons, New York, New York.

Hall, F. A., Jr. 1983. Status of the San Joaquin kit fox, *Vulpes macrotis mutica*, at the Bethany Wind Turbine Generating (WTG) project site, Alameda County, California. California Department of Fish and Game, Sacramento. 36pp.

Hansen, R. B. 1988. Porterville urban area boundary biotic survey. Unpublished report. Hansen's Biological Consulting, Visalia, California. 219pp.

Harris, J. H., and D. M. Stearns. 1991. Population density, census methods, habitat relationships, and home range of the San Joaquin antelope squirrel, 1988-89. California Department of Fish and Game, Nongame Bird and Mammal Section Report 91-02. 37pp.

Hourdequin, M. 2000. Ecological effects of roads. *Conservation Biology* 14:16-17.

Jensen, C. C. 1972. San Joaquin kit fox distribution. U.S. Fish and Wildlife Service, Sacramento, California. 18pp.

Knapp, D. K. 1978. Effects of agricultural development in Kern County, California, on the San Joaquin kit fox in 1977. California Department of Fish and Game, Nongame Wildlife Investigations Final Report, Project E-1-1, Jov V-1.21. 48pp. + app.

Knight, R. L., H. A. L. Knight, and R. J. Camp. 1995. Common ravens and number and type of linear rights-of-way. *Biol. Conserv.* 74:65-67.

Knight, R. L., R. J. Camp, W. I. Boarman, and H. A. L. Knight. 1999. Predatory bird populations in the east Mojave Desert, California. *Great Basin Nat.* 59:331; 338.

Koopman, M. E., B. L. Cypher, and D. R. McCullough. 2001. Factors influencing space and prey use by San Joaquin kit foxes. *Transactions of the Western Section of the Wildlife Society* 37:77-83.

Koopman, M. E., J. H. Scrivner, and T. T. Kato. 1998. Patterns of den use by San Joaquin kit foxes. *Journal of Wildlife Management* 62:373-379.

Lalo, J. 1987. The problem of roadkill. *American Forests* (Sept.-Oct.):50-52.

Maehr, D. S., E. D. Land, and M. E. Roelke. 1991. Mortality patterns of panthers in southwest Florida. *Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 45: 201-207.

Mercure, A. K., K. Ralls, K. P. Koepfli, and R. B. Wayne. 1993. Genetic subdivisions among small canids; mitochondrial DNA differentiation of swift, kit, and arctic foxes. *Evolution* 47:1313-1328.

Morrell, S. 1972. Life history of the San Joaquin kit fox. *California Fish and Game* 58:162-174.

Mumme, R. L., S. J. Schoech, G. E. Woolfenden, and J. W. Fitzpatrick. 1999. Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub-jay. *Conservation Biology* 14:501-512.

National Research Council. 1997. *Toward a sustainable future: addressing the long-term effects of motor vehicle transportation on climate and ecology.* National Academy Press, Washington, D.C.

Paveglio, R. L., and S. D. Clifton. 1988. Selenium accumulation by San Joaquin kit foxes and coyotes in the Kesterson National Wildlife Refuge area – draft. Unpublished Report. U.S. Fish and Wildlife Service, Los Banos, California. 59pp.

Ralls, K., and P. J. White. 1995. Predation on San Joaquin kit foxes by larger canids. *Journal of Mammalogy* 76:723-729.

Reed, R. A., J. Johnson-Barnard, and W. L. Baker. 1996. Contribution of roads to forest fragmentation in the Rocky Mountains. *Conservation Biology* 10:1098-1106.

Reese, E. A., W. G. Standley, and W. H. Berry. 1992. Habitat, soils, and den use of San Joaquin kit fox (*Vulpes velox macrotis*) at Camp Roberts Army National Guard Training Site, California. U.S. Department of Energy Report EGG 10617-2156. 36pp.

Scrivner, J. H., T. P. O'Farrell, and K. L. Hammer. 1993. Summary and evaluation of the kit fox relocation program, Naval Petroleum Reserve #1, Kern County, California. U.S. Department of Energy Topical Report 10617-2171. 88pp.

Seton, E. T. 1925. *Lives of game animals. Volume 1: Cats, wolves and foxes*. Doubleday, Doran and Company, New York, New York.

Sovada, M. A., C. C. Roy, J. B. Bright, and J. R. Gillis. 1998. Causes and rates of mortality of swift foxes in western Kansas. *Journal of Wildlife Management* 62:1300-1306.

Spiegel, L. K., B. L. Cypher, and T. C. Dao. 1996. Diet of the San Joaquin kit fox at three sites in western Kern County, California. Pages 39-52. L. K. Spiegel, editor. *Studies of the San Joaquin kit fox in undeveloped and oil-developed areas*. California Energy Commission, Sacramento.

Spiegel, L. K., and M. Disney. 1996. Mortality sources and survival rates of San Joaquin kit foxes in oil-developed and undeveloped lands of southwestern Kern County, California. Pages 71-92. L. K. Spiegel, editor. *Studies of the San Joaquin kit fox in undeveloped and oil-developed areas.* California Energy Commission, Sacramento.

Spiegel, L. K., and M. Small. 1996. Estimation of relative abundance of San Joaquin kit foxes between an undeveloped site and an oil-developed site in Kern County, California. Pages 115-124. L. K. Spiegel, editor. *Studies of the San Joaquin kit fox in undeveloped and oil-developed areas*. California Energy Commission, Sacramento.

Standley, W. G., W. H. Berry, T. P. O'Farrell, and T. T. Kato. 1992. Mortality of San Joaquin kit fox (*Vulpes velox macrotis*) at Camp Roberts Army National Guard Training Site, California. U.S. Department of Energy Report EGG 10617-2157. 19pp.

Taylor, W. P. 1916. A new spermophile from the San Joaquin Valley, California, with notes on *Ammospermophilus nelsoni nelsoni* Merriam. University of California Publication in *Zoology* 17:15-20.

Tellman, B. 1997. Exotic pest plant introduction in the American southwest. *Desert Plants* 13:3-10.

Thiel, R. P. 1985. The relationship between road densities and wolf habitat suitability in Wisconsin. American *Midland Naturalist* 113:404-407.

Trombulak, S. C., and C. A. Frissell. 2000. The ecological effects of roads on terrestrial and aquatic communities: a review. *Conservation Biology* 14:18-30.

Turbak, G. 1999. Can American motorists yield the right-of-way to wild creatures? *National Wildlife* 37(6): 66-68.

Uptain, C. E., D. F. Williams, P. A. Kelly, L. P. Hamilton, and M. C. Potter. 1999. The status of Tipton kangaroo rats and the potential for their recovery. *Transactions of the Western Section of The Wildlife Society* 35: 1-9.

U.S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. U.S. Fish and Wildlife Service, Portland, Oregon. 319pp.

Warrick, G. D., and B. L. Cypher. 1998. Factors affecting the spatial distribution of a kit fox population. *Journal of Wildlife Management* 62:707-717.

Weiss, S. B. 1999. Cars, cows, and checkerspot butterflies: nitrogen deposition and management of nutrient-poor grasslands for a threatened species. *Conservation Biology* 13:1476-1486.

White, P. J., and K. Ralls. 1993. Reproduction and spacing patterns of kit foxes relative to changing prey availability. *Journal of Wildlife Management* 57:861-867.

White, P. J., K. Ralls, and C. A. Vanderbilt White. 1995. Overlap in habitat and food use between coyotes and San Joaquin kit foxes. *Southwestern Naturalist* 40:342-349.

White, P. J., C. A. Vanderbilt White, and K. Ralls. 1996. Functional and numerical responses of kit foxes to a short-term decline in mammalian prey. *Journal of Mammalogy* 57:351-369.

FREQUENCY AND DISTRIBUTION OF HIGHWAY CROSSINGS BY KENAI PENINSULA BROWN BEARS

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Abstract

Highway construction and expansion through bear habitat can negatively affect brown bear populations. Highway structures can decrease habitat availability through habitat loss and restricted access, roads often displace animals and cause re-direction of natural movements, and highways can act as barriers to decrease gene flow. Lastly, highway traffic can cause direct bear and human mortality through car-animal collisions.

We examined the spatial and temporal distribution of brown bear crossings of the Sterling and Seward Highways on the Kenai Peninsula, Alaska. Data were collected between 1995 and 2001 as part of an ongoing population study. We created random walking bears within each bear's home range and compared the geographic distribution of each bear's highway crossing locations to the random crossing locations to assess whether the number and pattern of crossing locations were different than expected. An information theoretic approach comparing logistic regression models was used to determine if traffic volume, distance to cover across the highway, road density, and distance to the closest stream crossing were related to locations bears crossed the highway. We conducted a second set of analyses comparing models based on the temporal factors of daylight versus darkness, mean bear movement per hour, and traffic volume. Most bears crossed the highway less frequently than expected. While locations where bears crossed the highway were clustered, none of the spatial models tested strongly explained the observed clustering. Bears were more likely to cross the highway during nighttime. Additional research will be necessary to identify the cues bears use to choose locations to cross the highway.

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GENETIC ANALYSIS OF MOVEMENT, DISPERSAL AND POPULATION FRAGMENTATION OF GRIZZLY BEARS IN SOUTHWESTERN CANADA

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Abstract

Habitat and population fragmentation as a result of human disturbance in the form of human transportation and settlement corridors is affecting the viability of wildlife populations worldwide. I studied dispersal, inter-population movement and population fragmentation of grizzly bears near the southern extent of their North American range in southwestern Canada and northwestern U.S.A. This area represents the interior portion of the southern edge of grizzly bear distribution following 100 years of range contraction. I address whether anthropogenic fragmentation has affected grizzly bear populations in this vulnerable area.

Human attitudes toward grizzly bears, and large carnivores in general, have experienced a paradigm shift from active persecution towards tolerance and respect. However, major forces underpinning range contraction, including human-caused mortality and fragmentation, may be still operating, albeit, more subtly and less intentionally. Checking further range contraction requires specific knowledge of the processes at work. Improvements have been made in managing and monitoring human-caused mortality; however, besides the obviously isolated populations (e.g., Yellowstone National Park), the status of fragmentation in this region was largely unknown.

My goals were to use genetic analyses to explore bear movement and dispersal within and between the relictually inhabited mountain ranges in southwestern Canada and test whether or not the human environment associated with linear transportation and settlement corridors is fragmenting grizzly bear populations. I genetically sampled and generated 15-locus microsatellite genotypes for 835 bears across approximately 100,000 km^2 in immediately adjacent geographic areas separated by various levels of human disturbance associated with highways and associated human development. I used population assignment techniques, parentage analysis, cluster analysis, multiple linear regression and several matrices of population genetics.

I found evidence of natural and human-caused fragmentation, identified fragmenting forces, established population and sub-population boundaries in the region, identified small vulnerable sub-populations, and discussed these in relation to factors that make bears susceptible to fragmentation. Female movement was restricted by human transportation and settlement corridors, and male movement appeared to be reduced in some areas. Fragmentation by north/south-oriented human-settled valleys and by major east/west transportation corridors has resulted in a partially fragmented set of local sub-populations varying in size and intensity of fragmentation. I found one small isolated population ($n < 100$) in the southern Selkirk Mountains, several small sub-populations ($n < 100$), including a "female demographic island," in the southern Purcell Mountains and several population sub-units that were relatively large ($n > 300$). Through multiple linear regression, I implicated human settlement patterns, human-caused mortality, and highway traffic volume as inhibiting inter-population movement.

Because several fragmented sub-units are small, maintaining regional connectivity may be necessary to ensure long-term persistence. Despite grizzly bear vagility, their conservative dispersal behaviour and difficulty in living close to humans makes maintenance of regional connectivity challenging. This work demonstrates, at a regional scale, the impact that transportation corridors and their associated settlements can have on movements of animals, and highlights the ultimate effect this may have on populations. The historical mechanisms of range contraction (fragmentation and human-caused mortality) appear to still be operating and require mitigating management strategies. My results suggest that these strategies must focus on linkage zone development and highway crossing structures, as well as mortality management beyond the roadway and within adjacent populations.

Biographical Sketch: Michael Proctor earned his bachelor of science degree in ecology from the University of British Columbia in 1995. Michael began working with grizzly bears in 1995 and became interested in using genetic analysis to answer ecological questions that were otherwise difficult using traditional ecological tools. After contributing to the development of a census technique using DNA and mark-recapture, he turned to questions of habitat and population fragmentation in grizzly bears. This eventually became the focus of his recently completed Ph.D. from the University of Calgary.

THE IMPACTS OF INTENSITY OF HUMAN USE ON GRIZZLY BEAR HABITAT SELECTION

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Problem Statement

One of the major challenges to grizzly bear preservation in the greater Yellowstone area is the impact on grizzly bear habitat selection by various types and intensities of human activities. The most prevalent of these human activities is the presence and intensity of use of motorized transportation systems. These transportation systems provide increased access into grizzly bear habitat and thus increase the risk of mortality and dilute the effectiveness of their habitat (Brannon 1984, Archibald et. al 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990, Mace et. al. 1996, Matson et. al. 1993). Results of studies by Anue and Kasworm (1989) found that 63 percent of 43 grizzly bear mortalities on the Rocky Mountain front occurred within 1km of the nearest road. The Grizzly Bear Conservation Strategy Plan, a document developed for the management of grizzly bears, identifies the impact of motorized transportations systems as one of the key factors in the management of grizzly bear habitat. Metrics have been defined in the plan, including road densities, associated with motorized transportation systems and their use to monitor the effectiveness and change in grizzly bear habitat use. Even though there is a great deal of interest in the impacts of motorized transportation systems and their impact on grizzly bear habitat, there has been little research conducted to address this question in the Greater Yellowstone area. Most of the work that has been done in the Greater Yellowstone area has focused on Yellowstone National Park where road use is tightly controlled and firearms are not allowed. Areas managed for multiple use activities outside of Yellowstone National Park where road use has fewer restrictions and firearms are allowed have received little attention.

Objective

The emphasis of this paper is to look at the effect of two metrics of human use and their association with grizzly bear habitat selection.

Funding Source

The U.S. Geological Survey

Methodology

The nature of global positioning system (GPS) data available will provide the opportunity to look at distance to roads, road density as well as rates of movement measured in diurnal, nocturnal and crepuscular time periods and seasonal time periods. In addition to bear location data, infrared vehicle counters have been used to count all vehicles that pass by the counters during deployment. These counting devices were placed strategically throughout a geographically closed drainage for the past two non-denning seasons to obtain a measure of human use intensity. To date this project has retrieved 10 collars, equipped with GPS receivers and very high frequency (VHF) beacons. The collars were deployed onfour female and six male grizzly bears in the Yellowstone ecosystem, both within and outside Yellowstone National Park. The collars attempt to collect locations every 3.5 hours. These collars were on bears for 12 months and have collected over 10,000 locations. Two of these collars (from 1 male and 1 female) were retrieved in the same closed drainage where vehicle counters were deployed. The combination of the over 1,200 locations obtained and vehicle counter data will be used to examine associations of road use intensity and grizzly bear seasonal and daily habitat use patterns.

Summary of Findings

Thus far, we have GPS data from ten collars which were deployed on grizzly bears on multiple use lands. In addition to the GPS data, we have three seasons of traffic monitoring data. These data have provided important ecological insights to grizzly bear habitat use and management options.

Implications for Further Research

Based on current research and hypotheses that have been generated from this research, resource management agencies would be well served with efforts that would increase the geographic and temporal scale of this research. One example of this would be in developing management scenarios for implementation of new transportations plans.

URL

Web site for this project is currently under development

References

Archibald, W.R., R. Ellis and A. N. Hamilton. 1987. Responses of grizzly bears to logging truck traffic in the Kimquist River Valley, British Columbia. *International Conference on Bear Research and Management* 7:251-257.

Aune, K., and W. Kasworm. 1989. Final Report. East Front Grizzly Studies. Montana Department Fish, Wildlife and Parks, Helena, Montana, U.S.A..

Kasworm, W.F., and T.L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. *International Conference on Bear Research and Management* 8:79-84.

Mace, R. D., J.S. Waller, T. L. Manley, L. J. Lyon, and H. Zuuring. 1996. Relationships among grizzly bear, roads, and habitat in the Swan Mountains, Montana. *Journal Applied Ecology* 33:1395-1404.

McLellan, B. N., and D. M. Shackleton. 1988. Grizzly Bears and resource extraction industries: effects of road on behavior, habitat use and demography. *Journal Applied Ecology* 25:451-460.

Brannon, R.D.. 1984. Influence of Roads and Developments on Grizzly Bears In Yellowstone National Park. Thesis Montana State University, Bozeman, Montana, U.S.A.

SPATIAL AND TEMPORAL RESPONSE OF GRIZZLY BEARS TO RECREATIONAL USE ON TRAILS

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Abstract

Many human activities affect how bears use habitat. The effects of motorized recreational vehicle use on trails have not been formally assessed previously. Potential effects include displacement from and avoidance of high quality habitat, either temporally or spatially, which could affect reproduction and survival and result in fewer bears. Focusing on displacement, we used hourly locations from four GPS-collared female bears in the Badger-Two Medicine area in the Lewis and Clark National Forest to assess spatial and temporal distributions of bears relative to trail locations and to recreational use on trails. When availability was defined as circles equal to 95 percent of move distances around the previous bear location, all bears used areas near trails less than expected. We iteratively reclassified trail habitat versus non-trail habitat as increasing buffers in 50m increments around trails until we reached a buffer-width at which bears used areas near trails in proportion to availability. Compositional analysis results showed that bears selected against areas within 250 - 900m from ATV trails and within 450 - 600m from single-track trails, which had some motorbike use. The distance from trails at which bear use approximated availability varied by individual bear, by time of day, and by type of trail. Log-ratio differences were used to assess selection. Bears were less likely to spend time near trails with high (~5 trips/day average) motorized use than trails with low motorized use. We used an information-theoretic approach to select between nonlinear regression models with variables that included motorized use estimates, non-motorized use estimates, and trail density.

Funding

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USING GENETICS TO STUDY ROAD IMPACTS ON BEARS IN FLORIDA

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Abstract

Funding source: Florida Department of Transportation
Total Budget: $407,000
Project Period: April 2001 – April 2004

The Florida Fish and Wildlife Conservation Commission (FWC) has documented an increase in the number of transportation-related bear deaths (roadkill) since the late 1970's. In addition to impacts on bear populations, vehicle collisions with bears often are traumatic for the people involved and may cause significant collateral damage and personal injury. For these reasons, and because of the lack of definitive information on the subject, the FWC partnered with the Florida Department of Transportation to design a project that would quantify the impacts of roadkill on bear populations in Florida. Our study design incorporates two main features: population size enumeration and range delineation for bears in six core areas across Florida. As genetic analyses have improved and laboratory costs decreased, DNA techniques have been used for a wide variety of studies on bears. Our methodology involves sampling bears via hairs left on barbed wire strands surrounding bait sites (hair snare) randomly placed in a systematic grid across each study area. We will then derive population abundance estimates by using individual identification from the DNA analysis within a mark-recapture framework. We will determine both core and peripheral bear range across Florida. Core bear range is defined as that which contains breeding females and peripheral range as that which contains bear signs but no evidence of breeding females. Using an estimate of minimum patch size needed for bears, we sectioned the entire state into 10,000-acre blocks to determine whether bears are present or absent in each block. We polled local residents and area biologists to help ascertain areas occupied by bears. We will extrapolate densities derived from the mark-recapture abundance estimates to the entire area of core bear range within each of the six areas. The final product will be a detailed range map and corresponding population estimate for each of the core populations. We will calculate the impacts of roads within each core population and across the state by determining the proportion of roadkill in relation to abundance estimates derived from the DNA analysis. The numbers generated from this analysis will be compared to literature and published data on sustainable mortality rates for black bears. We will document and examine the relationship between roadkill, road density, traffic volume, and estimated abundance for trends in these parameters. We will identify areas of significant impact and, if necessary, make recommendations on how to improve the relationship between roads and black bears in these areas. Lastly, we will examine the updated bear range maps for signs of fragmentation and isolation related to roads.

Biographical Sketch: Thomas Eason is a wildlife biologist who has spent most of his career studying the American black bear. Thomas has completed his B.S. (at Virginia Tech) and M.S. (at the University of Tennessee) in wildlife science and his Ph.D. (at the University of Tennessee) in ecology. Thomas has conducted fieldwork throughout the Southeast including study sites in: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Tennessee, and Virginia, and has handled several hundred bears during this work. Thomas was the bear management section leader for four years and is now chief of the Wildlife Diversity and Conservation Bureau for the Florida Fish and Wildlife Conservation Commission.

Stephanie earned a B.S. in wildlife science (at Virginia Tech) and M.S. in environmental science and forest biology (at SUNY College of Environmental Science and Forestry). She is currently pursuing a Ph.D. in Geography through Florida State University. Stephanie has spent over 12 years working on American black bear research and management programs. She has worked with both captive and free-ranging bears in Virginia, New York, Washington and Florida. She has been working as the assistant bear management section leader for the past two years. Currently, she manages a statewide bear population study, and is collaborating on numerous projects including privatizing nuisance bear response and establishing local working groups.

Web Site
http://wildflorida.org