Kit Fox (*Vulpes macrotis*): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

August 21, 2006

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Peer Review Administered by
Society for Conservation Biology

Meaney, C.A., M. Reed-Eckert, and G.P. Beauvais. (2006, August 21). Kit Fox (*Vulpes macrotis*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/kitfox.pdf [date of access].

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COVER PHOTO CREDIT

The kit fox (*Vulpes macrotis*). Cover photo taken from Internet, site no longer active.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF THE KIT FOX

The kit fox (*Vulpes macrotis*) is not a federally listed species; however, the San Joaquin subspecies (*V. macrotis mutica)*, which is restricted to the San Joaquin Valley and adjacent valleys in California, is currently listed as endangered under the Endangered Species Act. The kit fox is listed as endangered by the State of Colorado and as threatened by the State of Oregon. The present distribution of this species apparently includes its entire original range except for portions of California. Within USDA Forest Service, Rocky Mountain Region (Region 2), kit foxes occur only in far western Colorado. Populations in many states appear to be declining, and peripheral populations in Oregon, Idaho, and Colorado are small and a cause for concern.

Kit fox populations likely plummeted in the last half of the 19th century and early 20th century because of predator and rodent control campaigns. The extent to which they may have rebounded after the institution of regulatory control of poisons and harvest limits is unclear. Current kit fox abundance in Colorado is very low, with fewer than 100 animals in the state and little evidence of a self-sustaining population. The kit fox may be close to extirpation from the state. Current abundance of kit foxes in California is probably much lower than historic levels. Populations in Oregon and Idaho are extremely low, and those in the Great Basin, including Utah and Nevada, may now be in decline. Population trends in Arizona, New Mexico, and Texas are unknown but presumed stable as these states continue to permit harvest of the species.

Changes in canid communities, including the extirpation of the wolf (*Canis lupus*) from most of the continental United States, the subsequent success of the generalist coyote (*C. latrans*), and the recent range expansion of the red fox (*Vulpes vulpes*), have had negative consequences for kit foxes. Coyotes are likely a major cause of mortality of kit foxes in Colorado and elsewhere. Although coyote predation on kit foxes can be severe, red foxes may pose an even greater threat to kit fox populations because of their greater ecological overlap and potential for competition.

Degradation, fragmentation, and loss of habitat, and impacts from development, roads, recreation, and domestic livestock grazing may also threaten kit foxes in Colorado. Development results in habitat loss, degradation, and fragmentation, reducing the potential for successful dispersal. Irrigated croplands fragment habitat. Western Colorado is currently experiencing a boom in oil and gas and residential development, as well as recreational and off-road vehicle (ORV) use. The resulting loss and fragmentation of habitat, and human disturbance to kit fox denning areas by recreational enthusiasts, especially ORV users, may pose a major threat to kit foxes in Colorado. Continued population growth within the range of the kit fox in Colorado will likely result in further habitat fragmentation and increased recreational pressure on public lands inhabited by kit foxes. Impacts of livestock grazing may relate to reduced small mammal prey abundance. The amount of predator and rodent control at present is unclear but may have both direct and indirect effects. The potential importance of white-tailed prairie dogs (*Cynomys luecurus*) as prey and as providers of dens and escape burrows is exacerbated by their apparent decline due to plague, oil and gas development, and shooting.

The biogeography of kit foxes provides a backdrop of potential vulnerability to populations in the state. At the periphery of their range in Colorado, they have switched to alternate prey (murid rodents) rather than kangaroo rats (*Dipodomys* spp.), lagomorphs (*Lepus* spp., *Sylvilagus* spp.), and prairie dogs (*Cynomys* spp.) typical in other parts of their range, presumably due to low densities of the three taxa. Available den sites and the number of dens used by kit foxes in Colorado are lower than elsewhere, and den sites are a critical factor for predator avoidance. Loss of prairie dogs results in both loss of potential prey and escape burrows. Development vastly compromises the ability of reproductive individuals from source populations in adjacent states to immigrate to small populations in Colorado and maintain their viability. Recruitment is very low in Colorado, and the loss of a single reproductive pair becomes significant.

Creation of a recovery team and implementation of a conservation strategy/recovery plan for the species, with further assessments of the potential for augmentation, will be necessary for the continued presence of kit foxes in Region 2 and avoidance of their extirpation in Colorado. Protecting important foraging and historic denning areas and surrounding habitat may lessen the impacts to kit foxes resulting from land use activities. Local restrictions on recreational or grazing uses of important areas may be needed. Preservation or re-establishment of connectivity between habitat blocks is crucial. A relatively new and promising management approach is the placement of artificial escape structures and dens, which may reduce coyote- and red fox-caused mortality, especially for dispersing young.

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INTRODUCTION

This conservation assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). The kit fox (*Vulpes macrotis*) is the focus of an assessment because Region 2 lists it as a sensitive species. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide land managers, biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on current scientific knowledge. Assessment goals limit the scope of the work to critical summaries and syntheses of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. While the assessment is not intended to prescribe management for the USFS, it does provide the ecological background upon which management must be based and offers insight into the conservation needs of the species in this region. The assessment focuses on the consequences of changes in the environment that result from management (i.e., management implications), which managers can use to direct land management decisions. Furthermore, we cite management recommendations proposed elsewhere and examine the success of those recommendations that have been implemented.

Scope

This species conservation assessment examines the biology, ecology, conservation status, and management of the kit fox with specific reference to the geographic and ecological characteristics of Region 2. Although a majority of the literature on the species originates from field investigations outside the region, this document places that literature in the ecological and social contexts of the southern Rocky Mountains. Similarly, this assessment is concerned with characteristics of kit foxes in the context of the current environment. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context. In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on kit foxes are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism and used only when published information was unavailable or when it contributed important insights to our understanding of kit fox in this region. Unpublished data (e.g., Natural Heritage Program records) were important in estimating the geographic distribution of the kit fox. These data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences, and often observations, inference, good thinking, and models must be relied upon to guide the understanding of ecological relationships (Chamberlain 1897, Hilborn and Mangel 1997).

In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described where appropriate. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference were accepted as sound approaches to understanding kit foxes. When dealing with uncertainty in this assessment, we always noted when inferences were made, and we used phrases such as 'is likely to,' 'is probable that,' and 'might be' when the strength of evidence for particular ideas was not certain. Much of the uncertainty in this assessment relates to the lack of available information.

Publication of Assessment on the World Wide Web

To facilitate use of the species conservation assessments, they are being published on the USFS Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists, managers, and the public more rapidly than publishing them as reports. More important, it facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Conservation assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This report was reviewed through a process administered by the Society for Conservation Biology, which chose two recognized experts in this or related taxa to provide critical input on the manuscript. Peer review is designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Federal Endangered Species Act

The kit fox has no federal status at the species level, so primary regulatory and management authority rests with the states. A subspecies of kit fox that is restricted to the San Joaquin Valley and some adjacent valleys in California, the San Joaquin kit fox (*Vulpes macrotis mutica*), is federally listed as endangered under the Endangered Species Act. Threats to its continued existence in California include loss, degradation, and fragmentation of habitat due to agricultural, industrial, and urban development (U.S. Fish and Wildlife Service 1983). The USFWS completed a federal recovery plan for this subspecies in 1983 and approved an updated multi-species recovery plan that includes the San Joaquin kit fox in 1998.

USDA Forest Service

The range of the kit fox encompasses portions of six USFS regions: the Rocky Mountain Region (Region 2), Southwestern Region (Region 3), Intermountain Region (Region 4), continental portion of the Pacific Southwest Region (Region 5), Pacific Northwest Region (Region 6), and Southern Region (Region 8). Only the Rocky Mountain Region formally designates kit fox as a sensitive species (http://www.fs.fed.us/biology/tes/index.html). Sensitive species designation by USFS requires the development and implementation of conservation strategies, including coordinated management objectives with state and federal agencies and other cooperators as appropriate. Approaches may include collaboratively developing individual species or multi-species conservation strategies, formalizing interagency conservation agreements, and incorporating recommendations into management direction set forth in Land and Resource Management plans (USDA Forest Service 2003).

Bureau of Land Management

State offices of the Bureau of Land Management (BLM) in Utah and Idaho include the kit fox on their sensitive species lists. The kit fox currently is not on the sensitive species lists of Arizona, Nevada, New Mexico, Texas, or Colorado state offices, but its status is being reviewed in Colorado. It is listed as Threatened in Oregon, following that state's Department of Fish and Wildlife status. The sensitive species designation is meant to provide protection for species with respect to BLM land management actions that is at least equivalent to the federal policy for candidate species under the Endangered Species Act (BLM manual 6840) http://www.ca.blm.gov/pdfs/pa_pdfs/biology_pdfs/6840_ManualFinal.pdf). This generally means that the BLM must review programs and activities to determine their potential impact on these species.

State wildlife agencies

Kit fox status designations by state wildlife agencies range from endangered to harvested furbearer (**Table 1**). The kit fox is listed as endangered in Colorado, threatened in Oregon, species of special concern in Utah, and a protected non-game species in Idaho. In California, the San Joaquin subspecies is listed as threatened; remaining subspecies in the state are not listed. Regulated harvests of kit foxes are permitted in Arizona where the species is listed as a predator and in New Mexico, Nevada, and Texas where the species is listed as a furbearer. Colorado maintains a biological ranking of imperilment system, the Colorado Vertebrate Ranking System, in which the kit fox is assigned a 91. This high ranking was used to inform the endangered listing for the state.

Table 1. Status of the kit fox in states throughout its range.

State	Natural Heritage Rank[a]	Classification by State Wildlife Management Agency
Arizona	S4	Predator – Legally harvested
California	S2S3	Threatened
Colorado	S1	Endangered
Idaho	S1	Protected non-game species
Nevada	S3	Furbearer – Legally harvested
New Mexico	S4	Furbearer – Legally harvested
Oregon	S1	Threatened
Texas	S4	Furbearer – Legally harvested
Utah	S3?	Special concern – Not a statutory category

[a]S – State rank:

1 Critically imperiled because of extreme rarity (5 or fewer records of occurrence in the state or less than 1000 individuals) or because of extreme vulnerability to extinction within the state due to some natural or man-made factor.

2 Imperiled because of rarity (6 to 20 occurrences or less than 3000 individuals) or because of vulnerability to extinction within the state due to some natural or man-made factor.

3 Vulnerable throughout its range within the state or found locally in a restricted range (known from 21 to 100 occurrences or less than 10,000 individuals).

4 Apparently secure within the state though it may be quite rare in parts of its range, especially at the periphery (usually more than 100 occurrences and 10,000 animals).

Natural heritage ranks

The Natural Heritage Network assigns range-wide and state-level ranks to species based on established evaluation criteria. The kit fox merits a global rank of G4, which means that when the range-wide population is considered, Heritage scientists deem the species to be apparently secure (NatureServe Explorer 2005). Species with this rank are uncommon but not rare, and there is some cause for long-term concern due to declines or other factors. The global rank is based on a synthesis of state ranks and biological evidence. Although apparently secure at the global level, at the regional level kit foxes can be quite rare, and have therefore received less secure rankings in many states.

Current state ranks for the kit fox range from S1 to S4. In general, state ranks are assigned based on the assessed risk of extinction within a state, where S1 species are deemed critically imperiled and S5 are deemed demonstrably secure. These assessments are based on biological information on population status, natural history, and threats at the state level. Specific state ranks are shown in **Table 1**.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

The primary authority for management of the kit fox throughout its range in the United States belongs to each state's wildlife management agency, except in California where the endemic kit fox subspecies, the San Joaquin kit fox, is listed as endangered under the Endangered Species Act; a federal recovery plan is being implemented for this subspecies in California (U.S. Fish and Wildlife Service 1998). The kit fox as a species is classified as threatened by the States of California and Oregon, and endangered by the State of Colorado. Despite special status listings in Colorado and several other states, state management plans or conservation strategies pertaining explicitly to kit fox do not exist.

The BLM in Colorado does not currently list this species as sensitive although it is known to occur on lands managed by this agency. While kit fox occupancy of National Forest System lands in Region 2 has not been verified, the USFS does list the kit fox as a sensitive species because they are considered "likely to occur" on the Grand Mesa, Uncompahgre, Gunnison, and San Juan national forests. The BLM and the USFS are pioneering a concept known as Service First, which is a partnership strategy that provides leadership in all aspects of land management for the two agencies as one unit in southwestern Colorado. This provides an opportunity for a meaningful and cohesive conservation strategy for kit foxes on public lands in the region (http://www.fs.fed.us/r2/projects/scp/evalrationale/evaluations/mammals/kitfox.pdf).

A non-regulatory conservation strategy (Kahn et al. 1997) has been developed for the swift fox (*Vulpes velox*), a closely related species with similar biology and facing similar threats. The swift fox received "candidate" status under the Endangered Species Act in 1994 but was removed from the list in 2000.

In 1985, wildlife professionals in Colorado raised concern regarding the continued legal harvest of kit foxes in Colorado as furbearers despite a paucity of information on the species in the state (Fitzgerald 1996). Between 1987 and 1992, 15 kit foxes were reported to have been harvested (R. Kahn personal communication 2006). As a result of increasing interest among Colorado Division of Wildlife (CDOW) researchers and public concern regarding the status of harvested furbearers in Colorado, the CDOW contracted in 1992 with the University of Northern Colorado for a study to clarify the distribution and status of the kit fox. Preliminary results of the study led the Colorado Wildlife Commission in 1994 to declare the kit fox a species of special concern, to close hunting and trapping seasons for the species, and to institute special trapping regulations for the take of other species in the occupied areas. The kit fox has been on Colorado's endangered species list since 1998.

The U.S. Fish and Wildlife Service (USFWS) completed a recovery plan for the San Joaquin kit fox in 1983 and approved an updated multi-species recovery plan that includes the San Joaquin kit fox in 1998. Recovery actions include protection of essential habitat, and demographic and ecological research in both natural and anthropogenically modified landscapes. High priority recovery actions outlined in the plan at the regional or ecosystem level include establishing a viable complex of populations (i.e., viable metapopulation) on private and public lands throughout the range of the kit fox (U.S. Fish and Wildlife Service 1998). The plan calls for encompassing as much of the environmental variability of the historical range as possible to ensure that maximum genetic diversity is conserved so that the species can best respond to varying environmental conditions. The plan also stresses that connections between populations need to be established, maintained, and promoted to counteract negative consequences of inbreeding, random catastrophic events (e.g., droughts), and demographic factors. This will require conservation of kit foxes on private lands, which may be accomplished through "safe harbor" agreements that promote voluntary landowner cooperation in exchange for assurances regarding future regulatory restrictions, other initiatives, or through acquisition of title or conservation easements. The plan also outlines the following topics for investigation:

- ❖ ecological and demographic data to permit the refinement of population and metapopulation viability analyses and land-use optimization models
- ❖ status, distribution, and movements of the subspecies
- ❖ use of agricultural lands
- ❖ the relationship between prey populations and kit fox population dynamics
- ❖ factors that promote populations of prey species
- ❖ interactions between kit foxes and red foxes
- ❖ indirect impacts of rodenticide use
- ❖ influence of predator control activities
- ❖ better demographic data for kit foxes in natural, agricultural, residential, and industrial lands.

The importance of developing and establishing a scientifically valid population monitoring program at representative sites range-wide with periodic monitoring is emphasized.

The swift fox conservation strategy (Kahn et al. 1997) outlines needs that also apply to the kit fox and can serve as a model for development of a rangewide conservation strategy for the latter species. Objectives, strategies, and activities called for in the swift fox conservation strategy include:

- ❖ better demographic data for kit foxes in establishing a swift fox conservation team, whose primary purpose is to coordinate and assist in directing management and research
- ❖ better demographic data for kit foxes in establishing statewide population monitoring programs capable of detecting population trends and changes in local distribution
- ❖ better demographic data for kit foxes in determining minimum viable population size estimates and genetic integrity

- ❖ better demographic data for kit foxes in identifying and delineating suitable habitat within each state

- ❖ better demographic data for kit foxes in promoting habitat conservation and habitat management in occupied and suitable habitat

- ❖ better demographic data for kit foxes in identifying corridors between blocks of habitat

- ❖ better demographic data for kit foxes in expanding distribution of swift fox populations to occupy 50 percent of suitable habitat available

- ❖ identifying and monitoring threats to population expansion; promoting scientific management and a public education program

- ❖ implementing research on biology and ecology of the species, especially habitat requirements.

Biology and Ecology

Systematics and description

Taxonomy

The kit fox is a small-bodied fox that closely resembles the swift fox, to which it is closely related. The two species are sometimes referred to collectively as North American arid land foxes. Though recognized initially as distinct species, the taxonomy of kit and swift foxes has been revised a number of times with conflicting results (Mercure et al. 1993, Dragoo and Wayne 2003). Kit and swift foxes exhibit morphological and genetic differences, and they have different habitat affinities (Moehrenschlager et al. 2004). The ranges of kit and swift foxes approach each other in a narrow and historically stable contact zone less than or equal to 100 km in western Texas and eastern New Mexico (Cypher 2003). Although the two species are known to hybridize within this zone, selection apparently favors parental forms over hybrids (Rohwer and Kilgore 1973). While this and other evidence support species recognition (Packard and Bowers 1970, Thornton and Creel 1975, Mercure et al. 1993), substantial conflicting morphormetric and genetic evidence exists. Dragoo and Wayne (2003) reviewed the literature on taxonomy of kit and swift foxes and explained that the taxonomic designations assigned to the genetic subdivisions observed in these foxes differ according to which modern species/subspecies definitions are used. A definition derived from both the biological and phylogenetic species concepts defines species as monophyletic clades that do not interbreed or have limited interbreeding when barriers to dispersal are removed. In contrast, subspecies will interbreed freely when barriers are removed although they are otherwise phylogenetically distinct. After completing mtDNA analysis, Mercure et al. (1993) suggested that kit and swift foxes should be considered distinct species given that they define distinct monophyletic groups and that hybridization was geographically limited, which indicates some measure of reproductive isolation. On the other hand, Dragoo and Wayne (2003) suggested that the two foxes should be considered the same species based on microsatellite and mtDNA evidence of unconstrained breeding in the contact zone. Nevertheless, "kit and swift foxes are discrete genetic entities that are considered distinct taxa at either the subspecific or specific level" (Dragoo and Wayne 2003). The USFWS currently recognizes kit and swift foxes as distinct species, and comparative measurements in Colorado support the distinction between the two foxes (Fitzgerald 1996, D. Daitch personal communication 2005). The two species in Colorado are reproductively isolated from one another by the Southern Rocky Mountains and have distinct ecological requirements and, therefore, require very different management approaches (Fitzgerald et al. 1994).

Seven (Hall 1981) or eight (McGrew 1979) subspecies of kit foxes may be recognized, but there are no recent taxonomic studies. Two subspecies were recognized in Colorado. *Vulpes macrotis neomexicana* is the subspecies of the far southwestern corner of the state. The subspecies of the western-central valleys of Colorado has variously been assigned to *V. m. arispus* (Armstrong 1972), *V. m. nevadensis* (McGrew 1979), or *V. velox neomexicana* (where *V. macrotis* was assigned to *V. velox*) (Hall 1981).

Identification

Kit foxes can be distinguished externally from other North American foxes, except the swift fox and gray fox (*Urocyon cinereoargenteus*), by their small size and black-tipped tail (Egoscue 1979). Dorsal color of kit foxes is yellowish-gray to grizzled, ventral color is pale yellow to white, and the sides of the muzzle are dark (McGrew 1979). The pelt is thick and coarse and thus has little market value. Adult kit foxes stand 300 to 320 mm high at the shoulder. Total length is 730 to 840 mm, tail length is 260 to 323 mm, and ear length is 78 to 94 mm (Fitzgerald et al. 1994). Adult weight ranges from 1.5 to 2.5 kg. Though sexual dimorphism is not marked, females are 15 percent lighter on average than males (McGrew 1979). Standard measurements and weights of adult kit foxes from Colorado appear to be similar to those reported in the literature (Fitzgerald 1996). The kit fox can be distinguished from the swift fox by its larger ears (>75 mm from the notch in kit foxes and <75 mm in swift foxes), longer tail (62 percent of body length in kit foxes and 52 percent in swift foxes), and more angular appearance (McGrew 1979). Confusion with gray foxes occurs in some portions of kit fox range, especially when viewed at a distance. Gray foxes are slightly larger than kit foxes, have proportionally smaller ears and legs, and have a black ridge on the tail and lower back.

Distribution and abundance

Distribution

Kit foxes inhabit mixed-grass shrublands, shrublands, grasslands, and margins of pinyon-juniper woodlands over much of the Southwest (McGrew 1979, Fitzgerald et al. 1994). Their range is from northern Mexico and Baja California north through western Texas, west of the Rocky Mountains to southwestern Idaho and southeastern Oregon, and in portions of California, Arizona, Nevada, Utah, New Mexico, and western Colorado (**Figure 1**; Hall 1981). Continental-scale shifts in historic range have not been documented. The present distribution apparently includes the entire original range except a portion of California's San Joaquin Valley where the range of the San Joaquin kit fox is much reduced from historic accounts, and the Los Angeles Basin where native subspecies are extirpated or extinct (McGrew 1979). These range reductions have been attributed to habitat loss, degradation, and fragmentation resulting from agricultural, industrial, and urban development (U.S. Fish and Wildlife Service 1983). The current distribution of kit fox in other states is incompletely known, and there were few recent records of kit foxes in Oregon and Idaho (O'Farrell 1987).

Within Region 2, kit foxes occur only in far western Colorado (**Figure 2**). Little literature exists on the historic distribution of the kit fox in Colorado, and only recently has an attempt been made to clarify the distribution and status of the species in the state. As of 1972, kit foxes in Colorado were known only from two specimens and four additional records from

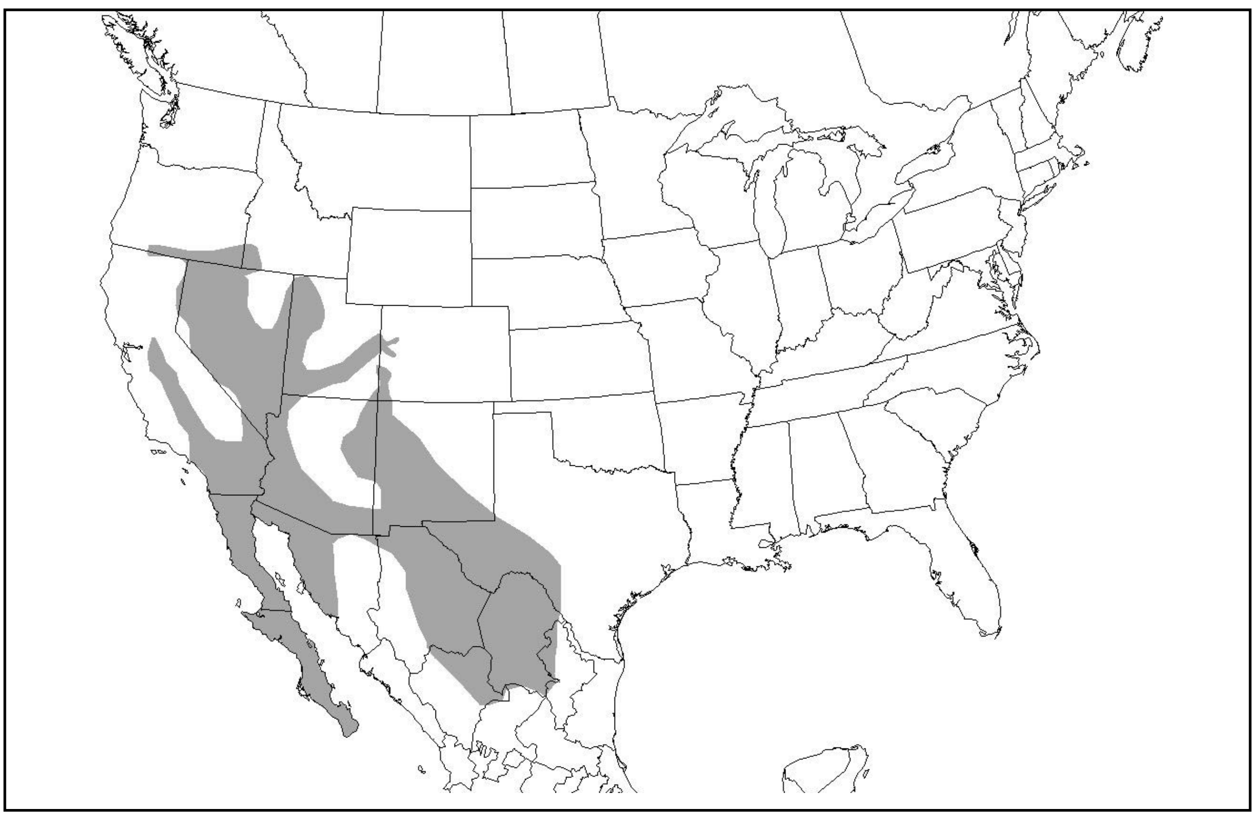

Figure 1. Geographic range of the kit fox in North America. Redrafted and modified from Fitzgerald et al. (1994) with permission.

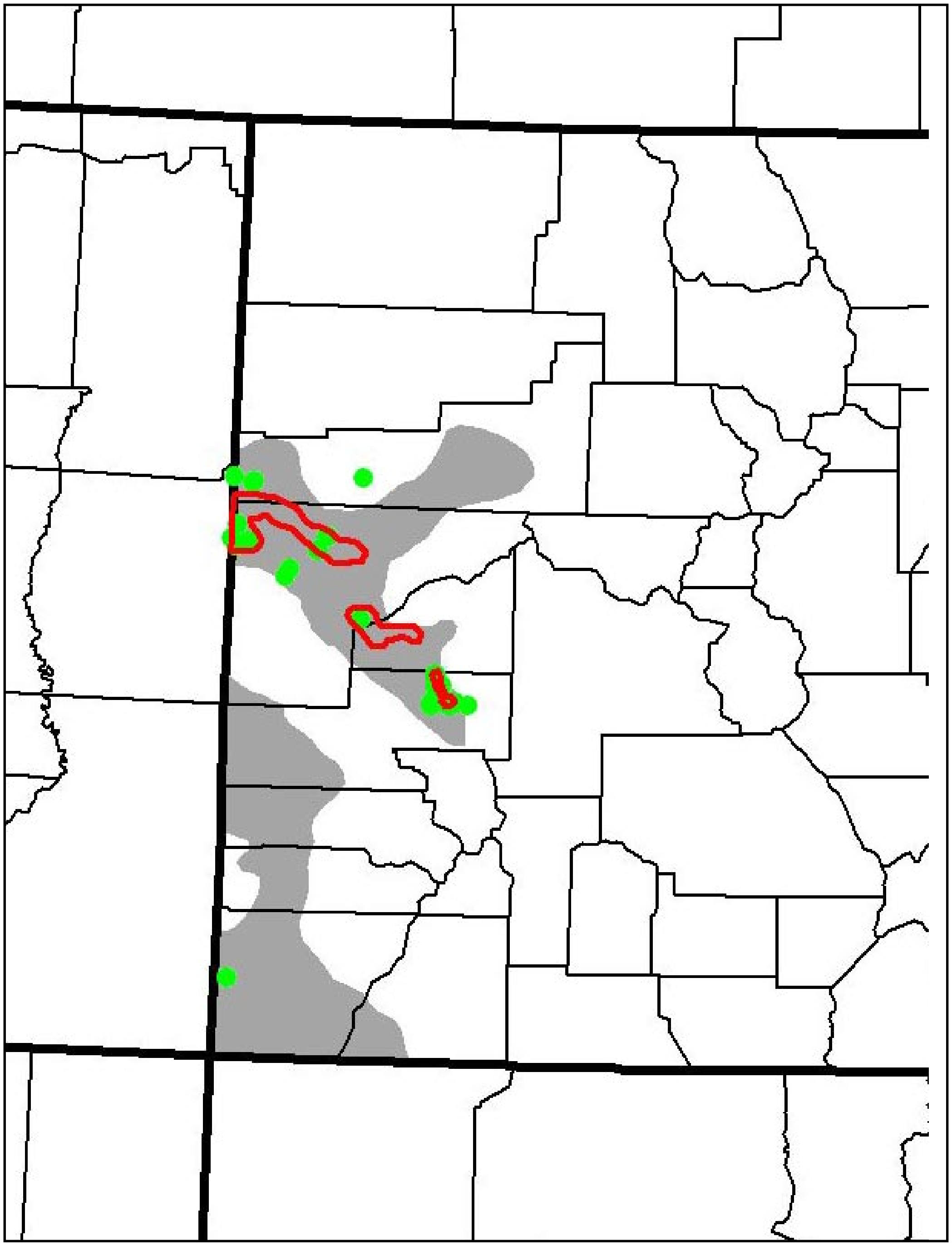

Figure 2. Historic and current distributions of kit fox in Colorado, adapted from Boyle and Reeder (2005), with permission. Red polygons depict current kit fox range; gray shading depicts historic range; green dots depict documented observations of kit fox (46 total) from the Colorado Gap Analysis Project and the Colorado Natural Heritage Program. The observation in extreme southwestern Colorado was made in 1962.

western Mesa and Montezuma counties (Egoscue 1964, Miller 1964 *in* Armstrong 1972, Miller and McCoy 1965, Armstrong 1972). Additional published accounts from neighboring states include four specimens from near Farmington and Broomfield, San Juan County, New Mexico about 32 km from the Colorado border (Findley et al. 1975); near Wide Ruins, on the Navajo Reservation in Arizona (Halloran and Taber 1965 *in* Fitzgerald 1996); and in Canyonlands National Park, Utah, 67 km from the Colorado border (Armstrong 1982). Recent work by Fitzgerald (1996) has clarified the distribution of kit foxes in Colorado, extending the known current range eastward into Montrose and Delta counties. However, historic and current distribution in the southwestern corner of the state in Montezuma County remains unclear.

Between 1992 and 1996, Fitzgerald (1996) conducted extensive trapping in eight counties in western Colorado, selected primarily on the basis of vegetation and elevation. Most study areas were in linear valleys draining to Utah, theoretically allowing corridors for immigration of kit foxes from any existing populations in eastern Utah. Kit foxes were not captured in all of the areas in which their presence was predicted based on elevational, topographical, and ecological similarities to habitats in Utah that had kit foxes (Fitzgerald 1996). Kit foxes were only observed or captured in the lower Colorado and lower Gunnison River drainages in Delta, Montrose, Garfield, and Mesa counties (**Table 2**).

The primary center of kit fox abundance in Colorado, Peach Valley and Montrose East, is located south of Delta from south of the Gunnison River to south of Flat Top Mesa in Delta and Montrose counties, east and north of Highway 50. Thirty-three kit foxes were trapped in this area. This is the only grouping of foxes found during the four years of trapping that had enough individuals to be considered a population, and the only area where foxes were captured during all years of the investigation (Fitzgerald 1996). However, the low number of den entrances, even on dens known to have produced pups in this area "may indicate that kit foxes in the Peach Valley and Montrose East areas are relatively new colonizers."

In the lower Grand Valley, which was trapped from the Utah border east to Mount Garfield at the mouth of DeBeque Canyon and south into Colorado National Monument, only 10 individuals were captured. Foxes trapped in Rabbit Valley and Prairie Canyon were within 9.6 km and 0.8 km, respectively, of the Utah border. Captures in Rabbit Valley also occurred in only one of four years of trapping. Rabbit Valley foxes may represent foxes that periodically enter Colorado from Utah but for unknown reasons fail to establish a population. Only one kit fox was captured and another

Table 2. Trapping locations and captures from field work conducted by Fitzgerald (1996). Field work involved 8497 trap nights and captures of 47 individual kit foxes, 1992 - 1996.

County	Location	Trap Nights	Kit Fox Captures
Moffat	Browns Park	636	0
Rio Blanco	Mellen Hill and Blue Mountain	72	0
Mesa	Lower Colorado River Valley/Grand Valley, including Horsethief Canyon, Reeder Mesa, South of Whitewater, and Colorado National Monument	253	0
Mesa	Gateway along the Dolores River	114	0
Mesa	Rabbit Valley	303	0
Mesa and Delta	Gunnison River Valley (Whitewater to Delta)	1036	3
Delta	West of Gunnison Gorge, Delta Airport	424	1
Delta	Dry/Sawmill Mesas, East of Austin, West of Wildlife Area, Lawhead Gulch	300	0
Delta and Montrose	Peach Valley	2173	20
Montrose	Montrose East	594	13
Montrose	Sinbad Valley	168	0
Montrose	Paradox Valley	141	0
San Miguel	Big Gypsum Valley	174	0
San Miguel	Disappointment Valley	141	0
San Miguel	McIntyre Canyon	77	0
Montezuma	McElmo Canyon	60	0
Garfield	DeBeque Parachute (eastern Garfield County)	172	0
Garfield	Lower Colorado River Valley/Grand Valley (Prairie Canyon) and Prairie Canyon to Mt. Garfield (western Garfield County)	1659	7

was observed in Prairie Canyon, where scat, tracks, and diggings suggested the presence of a small population during the investigation. Animals captured at Corcoran Point along the base of the Book Cliffs may have moved into the area from Rabbit Valley or Prairie Canyon, a distance of only 37 to 45 km along the base of the cliffs (Fitzgerald 1996). Because of the small size and isolated nature of this population, it was considered unlikely the foxes will persist here unless supplemented by immigrants from other areas. In the Lower Grand Valley, over 518 km^2 of apparently suitable kit fox habitat exists primarily on public lands, but this is either unoccupied or occupied at very low levels.

In potential habitat surveyed in the lower Gunnison River drainage from the town of Whitewater in Mesa County to Delta in Delta County and a few areas south of the Gunnison River, only four individuals were captured. These foxes came from the areas around Cheney Reservoir and the Delta Airport. It appears the Cheney Reservoir kit foxes represent a small, probably related, group of foxes similar to those at Corcoran Point and at Prairie Canyon (Fitzgerald 1996). The areas around Delta Airport and Alkali Gulch northwest of Delta do not appear to harbor resident foxes on a consistent basis, and the animals observed there appear to be migrants. One individual captured in Montrose East was recaptured at the airport, and two radio-collared in Peach Valley subsequently were located in Alkali Gulch.

Kit fox captures made in Rabbit Valley, Mesa County and Prairie Canyon, western Garfield County, were expected based on previous reports of kit foxes in the vicinity by Miller (1964 *in* Fitzgerald 1996), and from CDOW personnel and black-footed ferret crews, and harvest reports for Mesa County (Fitzgerald 1996). Kit foxes captured in Peach Valley (Montrose and Delta counties) and east of Montrose (Montrose County) represent new records of occurrence and an eastern range expansion in Colorado by approximately 96 km (Fitzgerald 1996). It is noteworthy that the center of abundance as determined from the study appears to be newly colonized.

No foxes were captured from a small population of foxes believed to occur in extreme northern Moffat County, despite periodic reports to the CDOW of animals in the northwestern part of the state and observations by wildlife professionals (Fitzgerald et al. 1994, Fitzgerald 1996). The reported animals may be swift foxes that moved into the area from populations in eastern Wyoming rather than moving across more inhospitable habitat from Utah to occupy the area. Studies of swift fox distribution in Wyoming support this assertion although these investigations are based only on track surveys and species identification has not been otherwise verified (Woolley et al. 1995 *in* Fitzgerald 1996).

The study was unable to verify the presence of kit foxes in Rio Blanco or eastern Garfield counties. No trapping was conducted in Gunnison County proper, where two kit foxes were reported trapped in 1989, but foxes were trapped approximately 32 km from the Gunnison County line. These individuals may venture as far east as Gunnison County, but it is unlikely because higher elevations and dense oakbrush (*Quercus gambelli*) or pinyon-juniper woodlands predominate along the border (Fitzgerald 1996). Kit foxes likely do not exist in Gateway, Sinbad, Big Gypsum, Paradox Valley, Disappointment, and McIntyre Canyon given the lack of trap success, lack of observations of kit foxes in these isolated valleys by area residents, and the small fragmented numbers of kit foxes present in the lower Colorado and Gunnison River basins.

The study also failed to capture kit foxes in the McElmo Canyon area, Montezuma County, where much of the habitat along the Colorado-Utah border appears to be marginal (Fitzgerald 1996). The McElmo Canyon area was thought to be a good potential site given the records of foxes reported by Egoscue (1964, 1975) and the predictive range map generated for Colorado based on climate, soils, and vegetation (Beauvais et al. 2003) does encompass the area (**Figure 3**).

Abundance

Knowledge of kit fox abundance is lacking for populations throughout much of their range, and virtually no published data exist documenting long-term trends or changes in abundance at range-wide or state-wide levels. The assigned Natural Heritage Program ranks do provide an indirect measure of abundance. The kit fox range-wide Natural Heritage Program rank is G4, which means that the species is uncommon but not rare, and although it is "apparently secure," there is some cause for long-term concern due to declines or other factors. State-level ranks assigned to kit fox range from S4 (apparently secure) to S1 (critically imperiled); in Colorado, it is considered critically imperiled (**Table 1**).

Kit fox density fluctuates with annual environmental conditions dependent on precipitation (Cypher et al. 2000). Reported densities throughout their range vary from 0.1 to 1.7 animals per km^2.

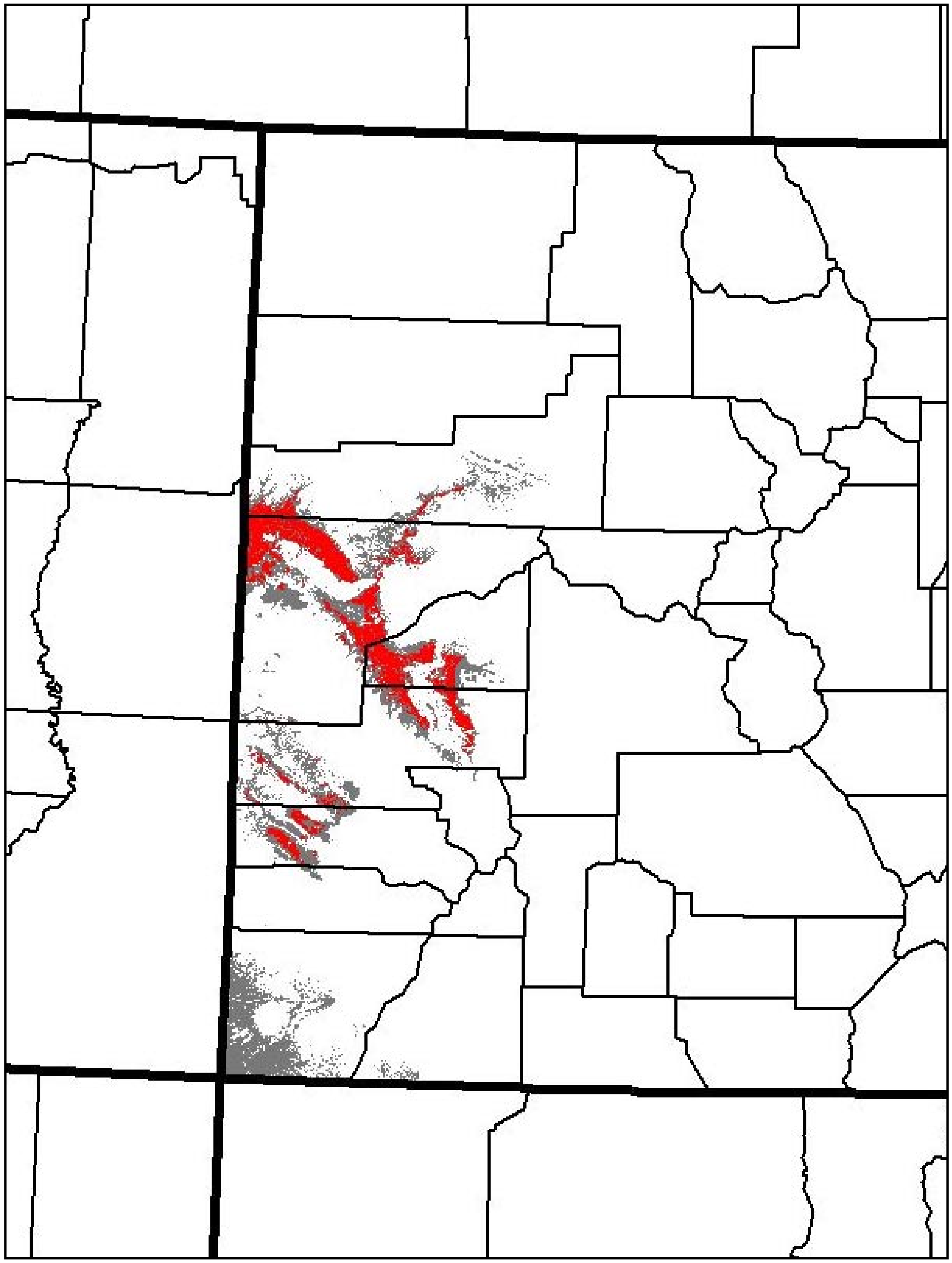

Figure 3. Overlay of two predictive distribution models for the kit fox in Colorado. Red shading depicts the model that considers climate, soils, and vegetation (adapted from Beauvais et al. 2003); gray shading depicts the model that is based on South West Regional Gap land cover types, habitat requirements, and elevation (adapted from Boyle and Reeder 2005). Refer to Figure 2 for documented observations of kit fox.

Densities observed in Utah ranged from 0.1 to 0.8 animals per km^2 (Egoscue 1956, 1975). Density at one study area in California varied from 0.15 to 0.24 animals per km^2 over a three-year period (White et al. 1996) and ranged from 0.2 to 1.7 animals per km^2 over 15 years on another site in California (Cypher et al. 2000). Density in a prairie dog town complex in Mexico was between 0.32 and 0.8 animals per km^2 (List 1997).

Historical kit fox densities in Colorado may have been low given the paucity of records. This attenuation of abundance is typical at the periphery of a species' range where tolerance limits for habitat conditions are met. However, a dearth of historical records is not, in and of itself, a true measure of abundance in the past. Current kit fox abundance in Colorado is very low. Low numbers of animals captured and recaptured, the lapse of time between captures, and distances between captured foxes made it difficult for Fitzgerald (1996) to estimate numbers. He indicated that there were probably fewer than 100 animals in the state and that there was no evidence of a self-sustaining population in the region. However, "none of the areas being used by kit foxes in western Colorado offer habitat characters that appear to be uniquely different from hundreds of square miles of the Colorado-Gunnison River drainage" (**Figure 3**; Fitzgerald 1996).

Long-term reductions in abundance throughout the range of the kit fox, documented or otherwise, appear to be the consequence of degradation, fragmentation, and loss of habitat resulting from agricultural, industrial, and urban development, interspecific competition with larger canids, and probably also poisoning (McGrew 1979, O'Farrell 1987, Cypher 2003, Cypher et al. 2003, List and Cypher 2004). Future kit fox abundance in Colorado is likely to be strongly influenced by urban and exurban development and possibly by recreational impacts (Fitzgerald 1996). See Threats section of this assessment for more information on causes of kit fox population decline.

Population Trend

Kit fox populations appear to be declining in parts of their range, including Colorado. The extent of apparent declines, however, is largely unknown as population data are lacking for kit foxes throughout much of their range (Dobkin and Sauder 2004), even in California where numbers still are not well known after 25 years of extensive study (Gerrard et al. 2001). Population estimates for the state of California range from 1000 to 3000 animals (Laughrin 1970 *in* Gerrard et al. 2001) to 7,000 to 14,000 animals (Morrell 1975 *in* Gerrard et al. 2001, O'Farrell 1983 *in* Gerrard et al. 2001). Current distribution and abundance of San Joaquin kit foxes in California are thought to be much lower than historic levels, and despite being federally listed as endangered since 1967, the species apparently has not made significant progress toward recovery. There have been few recent records of the species from the periphery of its range in Oregon and Idaho (O'Farrell 1987). Although populations in Oregon and Idaho have likely always been small, an intensive survey in historically occupied habitat in Oregon recorded only three observations, and populations there are thought to be extremely low (Wilson 1985 *in* Dobkin and Sauder 2004, DeStefano 1992 *in* Dobkin and Sauder 2004, Keister and Immell 1994 *in* Dobkin and Sauder 2004, C. Bruce personal communication 2006). Kit foxes have been considered common throughout Nevada and western Utah; however, recent trapping results suggest that populations in the Great Basin may now be in decline. Harvest of kit fox pelts in Utah declined steadily from more than 600 in 1983 to fewer than 100 in 1993 (Thacker et al. 1995 *in* Dobkin and Sauder 2004). Population trends in Arizona, New Mexico, and Texas are unknown but presumed stable as these states continue to permit harvest of the species.

Although a paucity of historic records hints that kit fox numbers have likely always been low in Colorado, populations in the state appear to be declining. Following four years of study, Fitzgerald (1996) speculated that fewer than 100 kit foxes inhabited Colorado and stated there was no evidence of a self-sustaining population in the region. This speculation is supported by the results of follow-up work by Beck (1997, 1998, 1999, 2000), who found that the already small population had declined sharply as evidenced by:

- poor survival of adults and juveniles east of Montrose in 1997
- lack of reproduction among three mated pairs in Gunnison and Uncompahgre Valleys in 1998
- apparent lack of successful reproduction at historic dens in Uncompahgre Valley in 1999
- failure to locate any active kit fox dens in Uncompahgre Valley in 2000.

Apparently, the kit fox is close to extirpation from the state. No census has been conducted in the state since 2000.

Variations in annual abundance of kit foxes may be pronounced, and the primary factor driving these variations is food availability (Cypher 2003). The desert systems that kit foxes inhabit are characterized by unpredictable fluctuations in precipitation, which contribute to high-frequency, high-amplitude fluctuations in the abundance of mammalian prey such as lagomorphs and small mammals (White and Garrot 1999). Although year-to-year changes in abundance of San Joaquin kit foxes were significant, monitoring revealed no long-term population decline (Ralls and White 1995, Ralls and Eberhardt 1997). Given the fluctuating, cyclical nature of kit fox populations in other areas, estimates of kit fox populations throughout their range must occur frequently to document and understand long-term population trends.

Activity pattern and movements

Daily and seasonal activity patterns

Kit foxes are active year round and are primarily nocturnal, with peaks in activity occurring during crepuscular periods. Daytime hours are usually spent resting in or near the den. Although nightly movements may vary seasonally (Cypher 2003), kit foxes in Utah normally did not move more than 3 km from their dens while foraging (Egoscue 1956, 1962). Nightly movements observed in Colorado in late fall and early winter were estimated to average 6.1 km but may have been influenced by the presence of observers (Fitzgerald 1996). Nightly movements are greatest during the breeding season and more restricted during gestation and pup-rearing (Zoellick et al. 1989, 2002). Nightly movement distances observed in California were 10.7 km during pup-rearing (mid February-May), 9.4 km during pup dispersal (May-September), and 14.6 km during the breeding season (December-mid-February) (Zoellick et al. 2002). While males often make greater nocturnal forays than do females (Zoellick et al. 1989, Koopman 1995 *in* Cypher 2003), home range sizes for males and females usually do not differ (Cypher 2003). Home range estimates vary from 251 to 1,160 ha (Cypher 2003). Differences in home range size among areas are probably related to food availability (Spiegel 1996, Zoellick et al. 2002). Home ranges overlap, and territorial behavior is rare.

Male kit foxes provision the female for the first few weeks of pup-rearing while she is nursing and attending the pups (McGrew 1979). At weaning, both parents bring food to the den. Pups emerge when they are four to five weeks old and begin to forage with the parents at three to four months of age (McGrew 1979, Fitzgerald et al. 1994). Young generally disperse in October.

Dispersal

Among kit and other foxes, the proportion of individuals dispersing, onset of dispersal, and dispersal distances vary spatially and temporally with population density, mortality rates among parents, and annual food availability (Cypher 2003). Dispersal usually involves juveniles and is typically male biased, but adult kit foxes of both sexes are known to disperse on occasion (O'Neal et al. 1987, Koopman et al. 2000). Koopman et al. (2000) studied dispersal patterns of kit foxes on the Naval Petroleum Reserves, California; between 1980 and 1996, 33 percent of 209 San Joaquin kit foxes radio-collared as juveniles dispersed from their natal home range. This included 44 percent of males and 21 percent of females. Annual dispersal rates varied from 0 to 52 percent for males and females combined, 0 to 79 percent for males, and 0 to 50 percent for females. Male dispersal was weakly correlated to mean annual litter size, and female dispersal was weakly and inversely correlated to small-mammal abundance. Eighty-seven percent dispersed in the first year, and mean age at dispersal was eight months.

Although survival increased with age at dispersal, 65 percent of dispersing individuals died within 10 days (Koopman et al. 2000). Predators were the primary cause of mortality. Survival was similar among dispersing males and females, but philopatric males had lower survival rates than philopatric females. Survival of philopatric males also was lower than for dispersing males, but it was similar among dispersing and philopatric females. Interestingly, mean weight of dispersing males was marginally higher than that of philopatric males, and mean weight of philopatric females was higher than that of dispersing females. Dispersal of monitored juveniles began in June and peaked in July, but individuals dispersed in nearly every month.

In Utah, dispersal occurred in October, with young of the year making the longest movements (Egoscue 1956, 1962). Mean dispersal distance of juveniles at a study site in California was 7.8 km and did not differ among males and females (Scrivner et al. 1987 *in* Cypher 2003). Juvenile dispersal rates among family groups receiving supplemental food were lower than those not receiving supplemental food (Warrick et al. 1999 *in* Cypher 2003) .

Because kit fox populations are often small and isolated, it is of interest to know potential travel distances and to identify potential barriers to movement. Kit foxes tagged as kits have been recaptured as far as 32 km from their original point of capture, and one adult female kept as a pet was recaptured in her original den approximately 32 km from where she escaped (Egoscue 1956). In Colorado, an adult male moved 32 km from his natal den, an adult female moved over 40 km (Fitzgerald 1996), and another individual dispersed a distance of 69 km (Beck 1997). Physical barriers restricting or precluding movement, and thus resulting in isolation of populations, may include major rivers such as the Colorado River, mountain ranges such as the Sierra-Nevada mountain range, and expanses of inhospitable habitat (Dragoo and Wayne 2003).

Habitat

Kit foxes are adapted to desert and semiarid habitats, inhabiting mixed-grass shrublands, shrublands, and margins of pinyon-juniper woodlands over much of the Southwest (McGrew 1979, Fitzgerald et al. 1994). Typical habitat is composed of plant communities dominated by saltbrush (*Atriplex polycarpa*) in central California; shadscale (*A. confertifolia*) and creosote bush (*Larrea tridentata*) in the Mohave Desert; and shadscale, greasewood (*Sarcobatus vermiculatus*), and sagebrush (*Artemisia tridentata*) in the Great Basin (McGrew 1979). Kit foxes captured between 1992 and 1996 in western Colorado were in cold desert shrubland habitats in the lower Colorado and lower Gunnison River drainages (Fitzgerald 1996). Characteristics of kit fox habitat in Colorado are similar to those described by McGrew (1977 *in* Fitzgerald 1996) for Utah and include sage-saltbrush grasslands, mat saltbrush, greasewood-saltbrush stands, and shrub-grasslands intermingling with pinyon-juniper woodlands (Fitzgerald 1996). Additional observations of kit foxes in Colorado National Monument were most frequently in mixed juniper-sagebrush communities and in rimrock (Miller 1964 *in* Fitzgerald et al. 1994). Kit foxes prefer areas with little ground cover (McGrew 1977 *in* McGrew 1979) and loose textured soils (Egoscue 1962, Laughrin 1970 *in* Cypher 2003, McGrew 1977 *in* McGrew 1979). Seventy-five percent of 92 sightings during a two-year study in Utah were in areas with loamy desert soils and less than 20 percent ground cover (McGrew 1977 *in* McGrew 1979).

Capture sites in Colorado ranged in elevation from 1463 to 1829 m, and most were between 1525 and 1708 m. While kit foxes in Colorado may use habitats with varying topography (Fitzgerald 1996), kit foxes in California prefer flat or gentle terrain with slopes less than 5 percent over more rugged terrain, where risk of predation may be greater (Warrick and Cypher 1998). Swift foxes benefit from low-growing vegetation by being able to scan for coyotes (*Canis latrans*), their main cause of mortality (Sovada et al. 1998, Olson and Lindzey 2002, Moehrenschlager and Sovada 2004); the same benefit is likely true for kit foxes. Kit foxes occur near and within some urban areas, such as Bakersfield, California (Jensen 1972 *in* Cypher 2003, Cypher and Warrick 1993). In fact, kit foxes in Bakersfield had higher survival rates compared to populations in adjacent natural areas because food resources were more predictable and coyotes were excluded in town (Cypher et al. 2003). Kit foxes can occur in areas adjacent to irrigated cropland (Swick 1973 *in* Cypher 2003, Morrell 1975 *in* Cypher 2003), and they may use orchards (Cypher 2003).

Dens

Kit foxes are semifossorial and rely on dens throughout the year for protection of both young and adults (Tannerfeldt et al. 2003). Dens are used as rest sites, shelter against harsh weather, to bear and rear young, and to escape predators. Because kit foxes are poorly adapted physiologically to cope with the seasonally high temperatures experienced throughout their range, diurnal den use is a critical behavioral adaptation to avoid extreme temperatures, reduce heat loads, and conserve water (Cypher 2003). Maximum carrying capacity of kit fox habitat is thought to be strongly related to availability of den sites and secondarily related to prey availability (Egoscue 1975). In Colorado, however, the expanse of area and similarity of soils and habitat in the lower Colorado and lower Gunnison River drainages would suggest that these kit foxes are not lacking in suitable denning sites for natal or escape dens (Fitzgerald 1996). Kit foxes can dig their own dens but will often enlarge burrows of badgers (*Taxidea taxus*) and other species including ground squirrels, kangaroo rats, and prairie dogs (Cypher 2003). Within the largest complex of black-tailed prairie dog (*Cynomys ludovicianus*) towns in North America, in Chihuahua, Mexico, 70 to 76 percent of kit fox dens were enlarged prairie dog or kangaroo rat burrows (Moehrenschlager and List 1996, List and Macdonald 2003). Kit foxes have been observed using rock outcrops as den sites in Colorado (Fitzgerald 1996). Dens are located in loose-textured, well-drained soils, and silty clay soils are favored for ease of digging (Egoscue 1956, Hoffmeister 1986, Cypher 2003). Soils throughout most of the region where kit foxes were captured in Colorado are derived from weathered sandstone or shale deposits and have high clay to clay-loam content (Fitzgerald 1996). It is noteworthy that kit foxes occur east of the Uncompahgre River, where soils have a high clay content, but not west of the river, where soils are more gravelly.

In California, kit fox dens are most common in areas with high concentrations of kangaroo rats (Laughrin 1970 *in* McGrew 1979). Entrances of kit fox burrows, 20 to 25 cm high and less than 20 cm wide (Egoscue 1962), are typically keyhole-shaped and narrow to exclude badgers and coyotes. Dens may have one to 24 entrances (Egoscue 1962), but most have two to seven (Berry et al. 1987a *in* Cypher 2003, Reese et al. 1992 *in* Cypher 2003). Escape and daytime resting dens are simple and commonly have only one entrance whereas natal dens are complex and typically have multiple entrances and one or more chambers (Egoscue 1962). Dens in Colorado rarely had more than three openings, and most had only two entrances (Fitzgerald 1996). Whelping dens occupied by different mated pairs are usually located 2 to 3.2 km apart (Egoscue 1962, O'Farrell and Gilbertson 1986).

Although investigators in Utah (Egoscue 1956, 1962, O'Neal et al. 1986) and California (Morrell 1972) reported dens on sites with little or no relief, slope and aspect of den sites in Colorado varied widely, and many were located on steep slopes or in gullies (Fitzgerald 1996). Of 26 dens observed in Colorado, all were located within 1.6 km of irrigation canals (Link 1995), seven were within 50 m of a dirt road, and three were less than 4 m from the road.

Link (1995) measured ground cover along transects at 10 dens in Colorado. Plants with the highest percent frequency of occurrence were shadscale, clasping peppergrass (*Lepidium perfoliatum*), and skeleton mustard (*Schoenocrambe linifolia*). Most common grasses included galletagrass (*Hilaria jamesii*), cheatgrass (*Bromus tectorum*), and foxtail barley (*Hordeum jubatum*). Other common plants near den sites included horsebrush (*Tetradymia canescens*), Indian pipeweed (*Eriogonum inflatum*), poison hemlock (*Conium maculatum*), winterfat (*Eurotia lanata*), Esteve's pincushin (*Chaenactis stevioides*), crane's bill (*Erodium cicutarium*), Russian thistle (*Salsola iberica*), yellow stonecrop (*Amerosedum lanceolatum*), and *Yucca* and *Opuntia* species. Percent cover around 11 of 13 dens was less than 50 percent, and average percent bare ground for all dens was 69 percent (range 37 to 100 percent). Average height of vegetation along transects at 12 dens was 23 cm. Characteristics of habitat surrounding dens described by Link (1995) are similar to those found in the literature. Eighty percent of dens in western Utah were found in sparsely vegetated, shadscale flats where average height of vegetation was 20 to 25 cm (Egoscue 1956). In Pine Valley, Utah, fox dens were located in flat, shrub-grassland areas where the height of the vegetation ranged from 30 to 90 cm (Daneke and Sunquist 1984 *in* Fitzgerald 1996). Shrub height at den sites in Utah ranged from 5 to 38 cm (O'Neal et al. 1986). The presence of little to no low-growing vegetation around dens likely reduces chances for ambush predation of kit foxes.

Dens are used primarily by the members of the resident family and may be used repeatedly over multiple generations. Natal dens in particular are reused over many generations and represent ancestral breeding or rearing sites that may be essential to the successful reproduction of the species (O'Farrell 1987). Home ranges possess multiple dens clustered in preferred areas (McGrew 1979). As many as eight to 10 dens per 1 to 2 ha have been observed (Egoscue 1956). The average number of dens used by individuals in one study was 15.5 (Reese et al. 1992 *in* Cypher 2003), and in another study it was 11.8 (Koopman et al. 1998); some individuals may use as many as 49 dens in a single year (Reese et al. 1992 *in* Cypher 2003). The number of dens used by radio-collared foxes in Colorado averaged 3.6 and ranged from two to 6 (Fitzgerald 1996). Kit foxes in Colorado appear to have fewer dens at their disposal and fewer entrances per den, compared with foxes at other locations. Where earth dens are unavailable, kit foxes may den in artificial dens or other human-made structures such as culverts, oilfield pipes, or under buildings (McGrew 1979, Cypher 2005). Frequent den switching is common during summer when pups are present and may be a response to flea infestations (Egoscue 1962).

Food and feeding habits

Kit foxes are opportunistic primary, secondary, and tertiary consumers and scavengers, likely regulated by prey abundance (Cypher 2003). They rely heavily on lagomorphs, prairie dogs, and kangaroo rats (McGrew 1979), but also will feed on ground nesting birds, especially horned larks (*Eremophila alpestris*) (O'Neal et al. 1987, Eussen 1999), reptiles, and insects (O'Farrell 1987). Kit foxes also commonly consume a variety of other small mammals including deer mice (*Peromyscus maniculatus*), pocket mice (*Perognathus* spp., *Chaetodipus* spp.), antelope squirrels (*Ammospermophilus leucurus*), and pocket gophers (*Thomomys* spp., *Geomys* spp.). Insects appear to be important when rodent availability is low (Spiegel

1996). Fleshy fruits are rarely consumed as they are usually not available in habitats occupied by kit foxes, but cactus fruits may be eaten if available (Egoscue 1956). In agricultural areas of California, kit foxes are known to eat cotton seeds, almonds, and tomatoes (Cypher 2003). They also will consume human foods (Cypher and Warrick 1993) and will cache food for use at a later time (Morrell 1972).

Primary food items

The primary item in the kit fox diet is usually the most abundant nocturnal rodent or lagomorph near the den (McGrew 1979). Where available, kangaroo rats are the favored rodent food item in the diet. In the cold desert regions of Utah, kit foxes rely heavily on black-tailed jackrabbits (*Lepus californicus*) (Egoscue 1962, O'Neal et al. 1987). Studies in California reveal primary food items vary and can include desert cottontails (*Sylvilagus audubonii*) (Knapp 1978), kangaroo rats (Laughrin 1970 *in* Cypher 2003, Morrell 1972, Spiegel 1996), ground squirrels (*Spermophilus* spp.) (Logan et al. 1992 *in* Cypher 2003, Cypher and Warrick 1993), and California pocket mice (*Chaetodipus californicus*) (White et al. 1996). The primary food item of kit foxes studied in Mexico was black-tailed prairie dogs (List et al. 2003).

In Colorado, murid rodents were the most common prey of kit foxes (Eussen 1999). Of 556 kit fox scats collected and examined from Montrose, Delta, and Mesa counties, Colorado, between May 1992 and June 1997, murids were the most common prey item (35 to 36 percent of occurrences), followed by scuirids (19 to 26 percent), and lagomorphs (17 to 18 percent). Murid remains consisted of mice (*Peromyscus* spp.), grasshopper mice (*Onychomys leucogaster*), woodrats (*Neotoma* spp.), and voles (*Microtus* spp.), with mice accounting for 74 to 93 percent of the murid remains. Murid rodents were also the most frequent prey item in swift fox diets in western Kansas (Sovada et al. 2001). Other rodents found in the kit fox scat included Ord's kangaroo rats (*Dipodomys ordii*), pocket mice (*Perognathus* spp.) and pocket gophers, collectively occurring in 7 to 9 percent of scats. The most common sciurid remains were white-tailed prairie dogs (*Cynomys leucurus*) and ground squirrels, probably rock squirrels (*Spermophilus variegatus*); these two items were found in 11 to 16 percent of scats. Chipmunks (*Neotamias* spp.) were also common (8 percent). Identifiable insect remains consisted primarily of beetles and grasshoppers (7 to 15 percent of scats). Bird remains, primarily of horned larks and sparrows (*Amphispiza* spp.), occurred in 2 to 5 percent of scats. Remains of shrews (Soricidae), voles, elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), snakes, and lizards were also identified in scats. Eussen (1999) found no significant differences in kit fox diet composition among seasons or locations even though habitat differed. Kit fox diets were also found to be similar in prey composition even when habitat characteristics differed in Utah and California (O'Neal et al. 1987, Vanderbilt White 1994 *in* Eussen 1999).

Food habits can vary markedly with annual availability. In a 15-year dietary study of kit foxes in California, 44 percent of scats included lagomorphs and 31 percent included kangaroo rats (Cypher et al. 2000). Use of lagomorphs varied from 7 to 94 percent and was highest when kangaroo rat abundance was low. Annual use of kangaroo rats varied from 3 to 84 percent. Dietary preference of these foxes was further clarified when kit foxes switched to feeding on kangaroo rats when they became more abundant. This preference for kangaroo rats has been noted by others (Grinnell et al. 1937, Laughrin 1970 *in* Cypher 2003, Morrell 1972, Fisher 1981 *in* Cypher 2003, Koopman 1995 *in* Cypher 2003). Kangaroo rat remains occurred in over 80 percent of 52 scats from California whereas lagomorph remains occurred in 52 percent (Morrell 1972); 80 to 90 percent of approximately 600 scats collected throughout the range of San Joaquin kit fox consisted of kangaroo rats (Laughrin 1970 *in* Cypher 2003). Grinnell et al. (1937) and Laughrin (1970 *in* McGrew 1979) suggested that a dependency on kangaroo rats accounts for San Joaquin kit fox distribution in California, and Benson (1938) noted that in the eastern part of its range, kit fox distribution closely parallels that of the banner-tailed kangaroo rat (*Dipodomys spectabilis*). In western Colorado, the same is true with Ord's kangaroo rat with the exception of the northwestern corner of the state where kangaroo rats occur but kit foxes do not.

Interestingly, Egoscue (1962) found that although kangaroo rats were among the most common rodents on his study area in western Utah, they were utilized by kit foxes far less than observed in other studies. Examination of prey remains collected at a den during whelping season revealed that black-tailed jackrabbits comprised more than 94 percent of the food eaten over a 64-day period by a family of two adults and five pups.

Energy requirements

Captive kit foxes consumed an average of 175 g of fresh meat per day (Egoscue 1962). Golightly (1981 *in* Cypher 2003) estimated that kit foxes require 101 g of prey in summer and 115 g in winter to meet energy needs, and Egoscue (1962) estimated a family of seven comprised of two adults and five juveniles required 44,605 g during the first 64 days following birth.

Water resources

Kit foxes will drink water if available but do not require free water as they are capable of obtaining adequate moisture from prey (Egoscue 1962, Morrell 1972). To meet water requirements, kit foxes must consume 175 g of prey daily, 40 percent more prey than is required to meet their daily energetic demands (Golightly and Ohmart 1984).

Food availability and population dynamics

The primary factor driving fluctuations in annual abundance of foxes, including kit foxes, is usually food availability (Cypher 2003). Low food availability results in reduced reproductive success and lower juvenile survival. In Utah, as black-tailed jackrabbit abundance declined, kit fox abundance, number of breeding females, number of litters, and litter size declined (Egoscue 1975). This kit fox population declined when lagomorph numbers dropped to 0.43 to 0.56 animals per km and recovered when lagomorphs reached 3.7 animals per km. Kit fox populations were also positively correlated with lagomorph populations in California (White and Ralls 1993, Cypher and Spencer 1998), where a decrease in female kit fox reproductive success was concurrent with a decline in the lagomorph population from 0.58 to 0.2 lagomorphs per km (White and Ralls 1993). Low food availability may also result in reduced adult survival and kit fox abundance as individuals are forced to forage further and longer, increasing the risk of mortality from predation and other sources (Cypher 2003). The highest and lowest numbers of kit foxes observed during a 15-year study in California occurred within a three-year period (Cypher et al. 2000). These and additional observed fluctuations in kit fox numbers appear to be driven by food availability, which is strongly influenced by annual precipitation (Ralls and Eberhardt 1997, White and Garrott 1997, Cypher et al. 2000). In California, kit fox abundance and reproductive success declined markedly during the late 1980's as food availability decreased due to drought (White and Ralls 1993, Spiegel 1996, Cypher et al. 2000). Because effects of annual precipitation on primary productivity and prey abundance occur after the kit fox reproductive season, the lag effect in response of kit foxes to environmental conditions is at least one year (Egoscue 1956, Ralls and Eberhardt 1997), and kit fox abundance may be influenced by the cumulative effect of precipitation from the previous three years (Cypher et al. 2000).

Spotlight surveying along roads in kit fox habitat in western Colorado revealed a lagomorph (primarily cottontails) density of 0.27 animals per km (Link 1995). Ord's kangaroo rat, the only kangaroo rat species in Colorado, was studied in Mesa County. Captures of the species were made in only five of 10 years, and densities were only 0.04 animals per ha when present (Lusby et al. 1971 *in* Fitzgerald et al. 1994). This low density of lagomorphs coupled with the reduction of a primary prey item may explain the strong reliance on murids and scuirids seen in Colorado (Eussen 1999).

Breeding biology

Reproductive females as young as 10 months of age begin searching for and preparing natal dens in September and October (O'Farrell 1987). A male joins the female at the natal den in October or November. Breeding may occur December through February. The extent of monogamy in kit foxes is not clear, as some pairs appear to mate for life while others do not, and males sometimes father two litters. Regardless, pair bonds last at least through one breeding season. Females are monoestrous. Gestation is 49 to 55 days. Litters of one to six pups (Cypher 2003) are born late January to March. Average litter size in Utah is 4.6 (O'Neal et al. 1987), and in central California it is 3.8 for adults more than one year old and 2.5 for yearlings (Cypher et al. 2000). The male provisions the female for the first few weeks of pup-rearing while she is nursing and stays with the pups. At weaning, both parents bring food to the den. Pups emerge when they are four to five weeks old and begin to forage with the parents at three to four months of age. Family groups generally split up in October although a number of pups or a pup and one of its parents may stay together in the den after the family separates. Pups achieve 90 percent adult mass by 10 months of age (Warrick and Cypher 1999).

At the northeastern periphery of their range in Colorado, kit foxes breed later and have smaller litters. Based on emergence of pups in mid-May, they probably mate in mid-February (Fitzgerald 1996). Among seven litters in Colorado, litter size ranged from two to four and averaged 2.9 pups (Fitzgerald 1996). The sex ratio is 1:1 (O'Farrell 1987).

Reproductive success is strongly influenced by food availability (Egoscue 1975, White and Garrett 1997, Cypher et al. 2000). In California, mean litter size during a period of low food availability was 2.0 (White and Ralls 1993), and annual reproductive success during 16 years varied from 20 to 100 percent for females more than one year old, with a mean of 61 percent (Cypher et al. 2000). Mean success for yearling females was 18 percent with no evidence of reproduction by yearlings in many years (Cypher et al. 2000). For more information, see Food availability and population dynamics section of this assessment. No specific information is available regarding site fidelity or limitations that natal den site availability may place on breeding.

Demography

Kit foxes have a relatively high reproductive potential, as females are capable of producing a litter of up to six pups every year starting from their first year. However, they are also relatively short-lived and susceptible to intrinsic and extrinsic population regulation. Kit fox populations are regulated by the following demographic factors:

- age at first reproduction
- litter size
- adult survival
- juvenile survival
- social mating system
- social spacing patterns.

See the Habitat, Food and feeding habits, and Breeding biology sections of this assessment for information on the primary ecological factors influencing kit fox demographics, prey abundance, and den site availability. See also the Community ecology section for information on interspecific competition with larger canids, a factor frequently cited as a primary control over kit fox populations.

Kit fox young-of-the-year generally do not breed (McGrew 1979) although females as young as 10 months of age have bred (O'Farrell 1987). Of 10 male and 8 female radio-collared pups monitored in Colorado, no females and only one male are believed to have bred at less than 12 months of age, and two males apparently never mated although they lived more than 20 months (Fitzgerald 1996). Two healthy reproductive females did not breed until about 33 months of age. Average litter size in Colorado is small (2.9 pups) compared to other studies. It would appear that kit fox reproductive potential is well-adapted to fluctuating environmental conditions since they can respond effectively and quickly when prey abundance is high. However, low prey abundance combined with other suboptimal factors appears to prevent Colorado's kit foxes from reaching their reproductive potential.

Captive kit foxes have lived 10 to 12 years, but life expectancy of wild kit foxes is much shorter. A seven year old wild fox showed advanced signs of aging including worn and broken teeth (Egoscue 1975). Of the animals studied by Fitzgerald (1996), the oldest male was estimated to be 3.2 years old at time of death, and the oldest female was estimated to be 4.3 years old.

Survival and mortality rates of kit foxes can vary substantially year to year. Annual mortality rates reported for adult kit foxes range from 44 to 61 percent, and juvenile kit fox survival rates range from 14 to 55 percent (Moehrenschlager et al. 2004). Ralls and White (1995) monitored the survival of 41 foxes on the Carrizo Plain Natural Area in California during the 1989 - 1991 drought, a period of reduced prey availability and reproductive success. Estimated annual survival rates for juvenile foxes ranged from 0.21 to 0.41, somewhat less than rates for adults, 0.58 to 0.61. Survival rates were similar across sexes and years. Also in California, Cypher and Spencer (1998) monitored 306 radio-collared kit foxes and estimated mortality rates at the Naval Petroleum Reserve where population dynamics appear to be influenced by competition from coyotes and food availability. Low precipitation during two years likely contributed to low prey abundance at the study area. Annual proportion of adult foxes that died within one year of being collared ranged from 30 to 84 percent, and the mean annual mortality rate was 61 percent. The proportion of juveniles that died prior to 30 November ranged from 50 to 100 percent, and the mean annual mortality rate was 83 percent. A significant portion of these mortalities was probably among dispersing individuals (Koopman et al. 2000).

A survivorship curve constructed for kit foxes on the Naval Petroleum Reserve in California and based on 144 animals marked as pups revealed a 74 percent mortality rate in pups during their first year with 9 percent surviving past two years of age (Berry et al. 1987b *in* Fitzgerald 1996). Of radio-collared foxes, 63 percent were dead before age three and 86 percent by four years of age. Juvenile mortality accounted for 50 percent of observed deaths. In Utah, adult mortality (or emigration) ranged from 10 to 58 percent annually, with pup mortality close to 75 percent annually (Egoscue 1975).

Of kit foxes studied in Colorado, 86 percent died or disappeared before reaching 36 months of age (Fitzgerald 1996). Forty-five percent of dead or missing kit foxes were pups, with 89 percent of them missing or dead by the end of their first year. None of the pups survived beyond three years of age. Of 22 kit foxes including 8 marked males and 9 marked females, average estimated minimum age at death was 27 months for females (range: 12 - 37 months) and 24 months for males (range: 8 - 39 months). The low reproductive success of kit foxes in Colorado and the low pup survival rates result in very low recruitment into existing populations.

The social mating system and spacing patterns of the kit fox may also influence demographics. Some kit fox pairs mate for life whereas others are primarily monogamous with occasional instances of polygyny (Egoscue 1962, Ralls et al. 2001). Intrinsic population regulation may occur in monogamous territorial species in which female offspring grow up in the presence of male relatives (Wolff 1997) as may be the case for kit foxes, where philopatric females exhibit reproductive inhibition. Cypher (2003) noted that philopatric female kit foxes usually do not produce their own litter. The proportion of female kit foxes that are philopatric may be high, as only 21 percent of females radio-collared as juveniles dispersed from their natal home range during an investigation by Koopman et al. (2000). Kit foxes may be especially susceptible to intrinsic population regulation where dispersal and recruitment are low. Mating systems also may influence rate of extinction. In passerine birds, monogamous mating led to a higher extinction rate than did polygynous mating, and extinction risk of monogamous species depends on the number of reproducing females (Legendre et al. 1999). Isolation and harem size contribute to intrinsic population vulnerability of monogamous carnivores (Brashares 2003). In kit foxes, it is possible that when random fluctuations lead to fewer males than females, unpaired, monogamous females may not reproduce. In contrast, polygynous species do not experience as great an increase in probability of extinction because all females reproduce. Although observed kit fox sex ratios are usually approximately 1:1 (Cypher et al. 2000) or slightly male biased (Egoscue 1962, 1975, Cypher et al. 2000), a female biased sex ratio was observed during a period when density was relatively low and food availability was increasing rapidly (Spiegel 1996) The social system may be crucial to population viability analysis. For the reasons discussed above, kit foxes may be subject to even greater risk of extinction, especially when populations are small, and this species may require a larger minimal viable population size than more polygynous species.

Reproductive potential of kit foxes in Colorado may currently be limited by a lack of reproductive-aged individuals. The large area in the Colorado and Gunnison River drainages and the low number of individuals may force young males to emigrate in search of mates. These dispersing males are subject to greater risk of mortality from coyote predation or other factors (Fitzgerald 1996). The instability in kit fox populations in western Colorado and probable lack of mates is further demonstrated by a lack of strong pair bonding as none of the kit foxes observed demonstrated long-term fidelity with mates.

Because kit and swift foxes share similar life history traits, conclusions drawn from the lifecycle graph generated for the swift fox by Stephens and Anderson (2005) are probably applicable to the kit fox. Their sensitivity analysis revealed that swift fox survival rates, especially first-year survival rates, are most important to population viability. The stochastic model generated to simulate the effect of environmental variation on population growth rate indicated that populations of swift foxes are vulnerable to stochastic fluctuations in survival, especially when the magnitude of fluctuations is high. However, the importance of adult survival to the lifecycle graph and the relatively even distribution of elasticity values may, to some degree, help buffer swift foxes against environmental stochasticity (Stephens and Anderson 2005). In addition, the authors found that the reproductive value of females more than one year old is higher than that of young of the year. Thus, adult females may act as a reservoir of population dynamics and a buffer against demographic stochasticity.

Community ecology

Symbiotic and mutualistic interactions

Kit foxes benefit from sharing their habitats with numerous fossorial and semifossorial species, as they will enlarge badger, kangaroo rat, ground squirrel, and prairie dog burrows into dens. Vacant dens of kit foxes may be used by other species of wildlife including burrowing owls (*Athene cunicularia*), striped skunks (*Mephitis mephitis*), and various small mammals, reptiles, and invertebrates (Cypher 2003). In the Recovery Plan for Upland Species of the San Joaquin Valley, California, (U.S. Fish and Wildlife Service 1998), the San Joaquin kit fox was referred to as an "umbrella species," indicating that its protection also encompassed a number of other species.

Kit foxes may be strongly associated with prairie dogs where their ranges overlap. In Chihuahua, Mexico, kit foxes rely heavily on black-tailed prairie dogs as a key prey item (List et al. 2003), and in Colorado white-tailed prairie dogs are an important component of the diet of the kit fox (Eussen 1999). Prairie dog remains constituted 18 percent and 6 to 16 percent of kit fox scats examined from Chihuahua, Mexico, and Colorado, respectively (List et al. 2003, Eussen 1999). Also important is the abundance of burrows on prairie dog colonies available to kit foxes for denning and escaping predators. The fact that kit foxes in Chihuahua, Mexico had a higher survival rate than swift foxes in Alberta and Saskatchewan, Canada despite a greater abundance of predators in Mexico has been attributed to the plethora of escape holes available in prairie dog towns (Moehrenschlager and List 1996). In addition, kit foxes in Mexico depend on prairie dogs to maintain the preferred open nature of their habitat and to prevent conversion to mesquite scrubland (List and MacDonald 2003). Reliance of kit foxes on prairie dogs may be lower in Colorado than in Mexico as white-tailed prairie dogs have more dispersed burrows than black-tailed prairie dogs, maintain relatively low densities, and inhabit less favorable areas with greater shrub cover (Fitzgerald et al. 1994). However, white-tailed prairie dog colonies are widespread throughout the region of known and potential kit fox occurrence in Colorado and are known to provide refugia for many prey species including cottontails and mice (Fitzgerald 1996).

Parasites and disease

Kit foxes may be infected by a number of diseases and parasites, most of which are not fatal or even debilitating. Only a few, including rabies, canine distemper, and sarcoptic mange, have the potential to produce population level impacts (Cypher 2003). Infectious diseases detected in kit foxes include brucellosis, Cache Valley virus, canine adenovirus, canine parvovirus, coccidiomycosis, Colorado tick fever, canine distemper, Jamestown Canyon virus, leptospirosis, toxoplasmosis, tularemia, vesicular stomatitus, and western equine encephalitis (Cypher 2003). Rabies epizootics have not been documented among kit foxes, but deaths attributable to rabies have been reported (Standley et al. 1992 *in* Cypher 2003); in California a population decline was concurrent with a rabies epizootic among skunks (White et al. 2000). Rabies virus is usually fatal once contracted by a fox. Antibodies to canine distemper are commonly detected in kit foxes, suggesting that most animals survive exposures to the virus (Cypher 2003).

Potential external parasites include fleas, lice, ticks, chiggers, and mites. Internal parasites include protozoans, trematodes (flukes), cestodes (tapeworms), nematodes (roundworms, hookworms), and acanthocephalans. Heartworm can cause serious debilitation among individual kit foxes but prevalence is generally low (Miller et al. 1998). Several species of fleas have been collected from kit foxes (Egoscue 1962, Egoscue 1985 *in* Cypher 2003, Harrison et al. 2003), infestations of which can be substantial on animals and in dens and may be the reason for frequent den switching (Egoscue 1962).

Predators

Coyotes are thought to be a major cause of mortality of kit foxes in Colorado (Fitzgerald et al. 1994) and elsewhere. Coyotes were responsible for nearly 50 percent of the observed mortality in radio-collared animals in Utah (O'Neal et al. 1987) and 50 to 100 percent in California with an annual proportion of 76 percent for adults and 83 percent for juveniles (Cypher and Spencer 1998). At Camp Roberts in California, coyotes were responsible for 59 percent of kit fox deaths during a four-year telemetry study (White et al. 2000). At the Carrizo Plains Natural Area in California, canids accounted for 78 percent of 23 verified deaths of kit foxes (Ralls and White 1995), with 15 mortalities attributed to coyotes, two to red foxes, and one to a domestic dog. Bobcats (*Lynx rufus*) have also been cited as a cause of significant mortality among kit foxes (Disney and Spiegel 1992 *in* Cypher and Spencer 1998). Additional potential predators of kit foxes include badgers, golden eagles (*Aquila chrysaetos*), large hawks, and great horned owls (*Bubo virginianus*).

Interspecific competition

Injuries inflected by coyotes are commonly cited as a primary cause of mortality in most kit fox populations today (Fitzgerald et al. 1994, Ralls and White 1995, Cypher and Spencer 1998, White et al. 2000). Coyotes usually do not consume the carcasses of kit foxes they have killed, so mortality is likely the result of competition rather than predation (Spiegel 1996, Cypher and Spencer 1998); a great deal of research has tried to examine the population level effects of interspecific competition with coyotes. Wildlife managers are also becoming increasingly concerned about the potential impact of competition with the larger and more aggressive red fox. Coyotes and red foxes may act to regulate and/or displace populations of kit foxes. High predation rates by larger canids, specifically coyotes and red foxes, in combination with poor reproduction due to reduced prey availability during a drought, contributed to a decrease in density of kit foxes in two study areas in California (Cypher and Scrivner 1992 *in* White and Garrot 1994, White and Ralls 1993). Coyotes may have a significant adverse impact on populations of kit foxes especially during periods of low reproduction in kit foxes, and coyotes may have the ability to eliminate kit foxes from some areas where low recruitment and high predation persist for many years (Ralls and White 1995). Similar concerns have been expressed for swift foxes (Kitchen et al. 1999).

Although coyote predation on foxes can be severe, red foxes may pose an even greater threat to kit fox populations (Ralls and White 1995). Red foxes appear to be rapidly expanding into areas of kit fox habitat and displacing them. Red foxes may be a greater threat to kit fox conservation because they are closer morphologically and taxonomically and likely have higher dietary overlap than coyotes. Red foxes also compete with kit foxes for den sites. For these reasons, exploitative competition may be more intense with red foxes than with coyotes, and coyotes may actually reduce the negative impact of red foxes on kit foxes by limiting red fox abundance and distribution (Cypher et al. 2001, Moehrenschlager et al. 2004). Because red foxes lack the predator-avoidance strategies of kit foxes, such as year-round den use, they may be more vulnerable to competitive exclusion by coyotes. Coyotes are known to exclude red foxes but not kit foxes from their home ranges. Red foxes were historically uncommon or absent in habitats occupied by kit foxes; therefore, kit foxes have not coevolved strategies for mitigating competition from red foxes (Cypher 2003).

CONSERVATION

Threats to Kit Fox Viability in Region 2

Primary threats to the continued persistence of kit foxes throughout their range include degradation, fragmentation, and loss of habitat; interspecific competition with coyotes and red foxes; and roads. Impacts from recreation, domestic livestock grazing, and control of predators and rodents may also threaten kit foxes in Colorado. Another potential threat is the decline in white-tailed prairie dogs.

Habitat degradation, fragmentation, and loss as a result of agricultural, urban, and industrial development has been cited as the primary cause of decline of kit foxes in California (U.S. Fish and Wildlife Service 1983), and it is likely a significant threat to the continued existence of the species in Colorado. Energy and residential development in western Colorado are both burgeoning, and the Grand Junction area is one of the fastest growing regions in Colorado (Fitzgerald 1996). The result is degradation and destruction of kit fox habitat and the creation of an urban corridor that may effectively block movement of kit foxes between the Colorado and lower Gunnison River drainages, and through the Grand, Uncompahgre, and Gunnison Valleys. The spatial arrangement of irrigated lands (with attendant high numbers of coyotes and red foxes), as well as human activities including wandering domestic pets, can create obstacle courses and effectively reduce population connectivity (Beck 1998). Loss of dispersal corridors is a serious concern because of the loss of effective movement between sub-populations (Fitzgerald 1996). Small populations are more likely to go extinct in the short term due to stochastic events and a potential lack of immigration by reproductive individuals from adjacent populations. Because the addition of even an occasional reproductive animal from another population can make a relatively large difference in population persistence (Stacey and Taper 1992, 1997), habitat connectivity is crucial. Where dispersal is possible and frequent enough, extinction may be counteracted by immigration (Van Vuren 1998). In the longer term, genetic drift and inbreeding depression also present a problem in small isolated populations. The direct and indirect effects of relatively rapid development in semi-desert shrublands, and the loss of safe dispersal corridors between sub-populations, greatly diminish the likelihood of an ecologically viable kit fox population in Colorado (Boyle and Reeder 2005).

A sagebrush conservation assessment estimated that the historic range of kit foxes in Colorado (as judged from occurrence records, habitat associations, elevation limits, and expert opinion) encompassed 1.71 million ha, with current range encompassing 560,000 ha, of which 110,000 ha (20 percent) is kit fox sagebrush habitat and 450,000 ha (80 percent) is kit fox non-sagebrush habitat (Boyle and Reeder 2005). Of the 20 percent of habitat that is sagebrush, over half is under BLM jurisdiction and over a third is under private ownership; the remainder is USFS, other federal lands, state land board, and other state lands. Risk factors were evaluated, concluding that 100 percent of kit fox sagebrush habitat is at either moderate (14 percent) or high (86 percent) risk. High risk factors include pinyon-juniper encroachment (48 percent of kit fox sagebrush habitat), invasive herbaceous vegetation encroachment (62 percent), residential development (4 percent), and energy development (24 percent at high risk and 69 percent at moderate risk). However, because the majority of kit fox habitat in Colorado is not sagebrush habitat, management of sagebrush in western Colorado will likely be of relatively little consequence to the recovery of kit foxes in the state (Boyle and Reeder 2005).

White-tailed prairie dogs may be important to kit foxes as a food resource and for dens and escape burrows (see Community ecology section). White-tailed prairie dogs are classified as small game mammals with a year-round season. CDOW harvest records reveal that 1,492 and 9,098 white-tailed prairie dogs were harvested in 2005 in Delta and Montrose counties, respectively (http://wildlife.state.co.us/Hunting/SmallGame/Statistics/Statistics.html). It is not uncommon for hunters to come from out-of-state for this hunting experience. Studies on black-tailed prairie dogs have shown that shooting can have detrimental effects on survivors (Pauli 2005) and on populations (Reeve and Vosburgh 2006). In Colorado, there are an estimated 78,000 ha of active white-tailed prairie dog colonies and 19,000 ha of historic colonies with unknown status (Seglund et al. 2004). Much of white-tailed prairie dog habitat overlaps areas of oil and gas development, which has the potential to reduce available habitat for the species (Seglund et al. 2004). To the unknown extent that prairie dogs could be a valuable prey item and provide escape dens for kit foxes in Colorado, the reduction in numbers due to plague, which first arrived in Colorado in the 1940's (Ecke and Johnson 1952), and shooting could be significant vulnerability factors.

Interspecific competition with coyotes and red foxes poses a significant threat to kit foxes and appears to be the most important immediate mortality factor for dispersing juveniles. Eighty-nine percent of marked pups in Colorado were dead or missing by the end of their first year. Predation by coyotes is a key factor. See discussion in the Community ecology section.

Roads have been cited as the second greatest threat to the persistence of San Joaquin kit foxes in California and pose a threat to the species in Colorado. Roads are known to contribute to vehicle-caused mortality and reduced habitat connectivity for many species of wildlife. The negative impact of roadways is proportional to road width, traffic volume, and speed limit. The barrier effect of roadways on kit foxes has not been examined, so the threshold at which a highway may become a substantial barrier to kit fox movement has not been identified. Although heavily traveled two-lane highways do not appear to be substantial barriers in California, they may pose an important mortality threat to kit foxes. Vehicle-caused mortality along highways and secondary roads poses a threat to swift foxes (Kahn et al. 1997, Sovada et al. 1998). As urban and exurban growth continues in central western Colorado, roads will grow wider, carry higher traffic volumes, and become more inhospitable to wildlife (Ruediger 1996). It is important to note that even narrow dirt roads may pose a threat to wildlife where they traverse important undeveloped habitat, permitting easy access to otherwise remote areas. Unforeseen human disturbances in such areas may go undetected and unmanaged with tremendous impact.

Human disturbance to kit fox denning areas by recreational enthusiasts, especially ORV users, may pose a major threat to kit foxes in Colorado (Fitzgerald 1996). All kit fox captures were in areas that receive ORV use by recreationists. Passing vehicles did not alter the behavior of kit foxes at two natal dens unless people stopped to watch them, at which time the foxes would casually retreat to their dens (Link 1995). Similar behavior was observed among other kit foxes exposed to vehicular traffic and to private citizens who regularly filmed them at their natal dens (Fitzgerald 1996). Kit foxes appeared to spend more time underground on the weekends when peaks in recreational use and human disturbance occurred (Link 1995). The degree of impact from frequent and prolonged human presence is exemplified by the fact that relatively constant monitoring of kit foxes in a study area during fall and winter 1994-1995 may have contributed to animals leaving the area for much of 1995 (Fitzgerald 1996). The authors were made aware of a situation in which all-terrain vehicle (ATV) users found an active den and came back repeatedly, resulting in the abandonment of that den. Continued human population growth within the range of the kit fox in Colorado will likely produce increased recreational pressure on public lands inhabited by kit foxes; these impacts will need to be monitored to assess the significance of this potential threat.

Impacts of livestock grazing and range management practices on kit fox populations are poorly understood throughout much of their range. All kit fox capture sites in Colorado are subject to livestock grazing by sheep or cattle (Fitzgerald 1996). Effects of range management on kit foxes are likely largely indirect and mediated by effects on kit fox prey and predators. Livestock grazing in California on marginal grasslands has depleted much of the native ground cover, reducing small mammal prey populations, thereby contributing to the decline of the fox. Numerous studies in the Intermountain West show that livestock grazing can significantly affect the floristic composition and vegetative structure of habitats and alter faunal abundance and diversity. Small mammal density and diversity were lower on grazed sites than on ungrazed sites in Nevada and Idaho (Reynolds and Trost 1980, Medin and Clary 1989), as well as in shrub-grasslands of the Colorado Plateau (Rosenstock 1996). However, in parts of California, dense growth by exotic grasses (e.g. *Bromus*, *Avena*) can reduce prey abundance and reduce the ability of kit foxes to detect and elude predators. In this situation, grazing is being investigated as a potential habitat management strategy and may well prove beneficial (Cypher et al. 2003). Because kit fox populations are regulated primarily by abundance of small mammal prey (Cypher 2003), range management practices may strongly influence kit fox success. In addition, placement of artificial water sources for use by livestock has permitted range expansion into arid areas by coyotes and red foxes.

Although not investigated thoroughly, direct and indirect effects of poisoning, trapping, and shooting of predators, or poisoning and rounding up and clubbing to death of rodents and lagomorphs for control purposes have been implicated as an important mortality factor for kit foxes in California (McGrew 1979) and as a threat to prior and continued persistence of kit foxes in Colorado (Fitzgerald et al. 1994, Fitzgerald 1996). Neither the USDA Wildlife Services nor the Colorado Department of Agriculture is currently involved in coyote or rodent control in western Colorado (M. Threlkeld personal communication 2006, M. Yeary personal communication 2006). Rodent control occurs on private lands, but the extent is difficult to assess. In the Montrose-Delta area, it is estimated that 5 to 10 percent of private landowners engage in prairie dog control (W. Cooley personal communication 2006). However, the extent of illegal and/or unreported poisoning remains unknown. The potential impact of this activity is the reduction of white-tailed prairie dogs as prey and reduction of escape routes for the foxes. Lagomorph control, other than occasional shooting, is not known to occur.

Poisoning has been cited as one of the primary causes of decline of swift fox populations in the Great Plains (Stephens and Anderson 2005). Inadvertent poisoning from strychnine-laced baits placed by professional "wolfers" and ranchers, formally common and widespread, resulted in death of thousands of swift foxes (Stephens and Anderson 2005). Poisoning impacts on swift fox populations were substantially reduced following the installation of regulatory controls over the use of control chemicals, initiated by the 1972 Presidential ban on predator toxicant use (e.g., strychnine, compound 1080) on Federal lands. However, primary or secondary poisoning continues to affect local swift fox populations, especially where rodenticides are used to control prairie dogs (Miller et al. 1994 *in* Stephens and Anderson 2005). Swift fox mortalities resulting from exposure to insecticides have also been documented (Sovada et al. 1998).

Conservation Status of the Kit Fox in Region 2

Within Region 2, kit foxes occur only in Colorado, where the current status and viability of populations are uncertain. Little literature exists on the historic distribution of the kit fox in Colorado, and only recently has an attempt been made to clarify its distribution and status in the state. Although a paucity of historic records suggests that kit fox numbers have likely always been low in Colorado, populations appear to be declining. Following four years of study, Fitzgerald (1996) speculated that fewer than 100 kit foxes inhabited Colorado and stated that there was no evidence of a self-sustaining population in the region. This speculation is supported by the results of follow-up work by Beck (1997, 1998, 1999, 2000), who found that the already small population had declined. The species apparently may be close to extirpation from Colorado.

Past and current predator and rodent control programs likely had and continue to have several adverse effects on kit foxes populations. Prior to their eradication, wolves limited the distribution and abundance of coyotes throughout their range, and community-level dynamics among native canids, including the kit fox, were likely much different than they are today (Schmidt 1991). Within five years of initiation of a formal federal wolf eradication program in 1915, wolves were largely eliminated from western Colorado (Lambeth 2005). Coyote distribution and abundance subsequently expanded, deleteriously affecting kit fox populations (Lambeth 2005). Wolf eradication may also be linked to a reduction in ungulate carrion available to swift and kit foxes. During campaigns, past and present, to reduce or eliminate wolves and coyotes, inadvertent trapping and poisoning of kit foxes (Robinson 1953 *in* Fitzgerald 1996) and swift foxes (Bunker 1940 *in* Fitzgerald 1996) occur. In Utah, where poison and coyote-getters were used for several years, 36 kit foxes were taken compared to only 13 coyotes (Robinson 1953 *in* Fitzgerald 1996). Such control methods could have a decidedly deleterious effect on small and sedentary populations of kit foxes. For rodent control, only zinc phosphide is currently available as a legal chemical poisoning agent, and it requires a permit for use. Although there is some acknowledged poisoning of rodents on private lands in western Colorado, the extent of illegal or unacknowledged rodent control remains unknown.

Primary causes of decline of the species in Colorado are not known, but speculation includes habitat loss, patchy prey availability, and predation by coyotes and red foxes. It is reasonable to suppose that factors leading to the decline of Colorado kit fox are similar to the causes of decline of the San Joaquin kit fox: habitat degradation, fragmentation, and loss resulting from agriculture, urban, and industrial development, and including potential loss of prairie dogs and other prey. In Colorado, the CDOW has recognized that a number of kit fox capture areas are on or near private land and are consequently extremely vulnerable to the development that has occurred in recent years (R. Kahn personal communication 2006). Others have argued that kit foxes may not be limited by habitat availability in Colorado, as "none of the areas being used by kit foxes in western Colorado offer habitat characters that appear to be uniquely different from hundreds of square miles of the Colorado-Gunnison River drainage" (**Figure 3**; Fitzgerald 1996). Rather, kit fox abundance may be limited by patchy availability of food resources combined with high juvenile mortality from predation (Fitzgerald 1996). It is not clear why prey availability may be patchy. Perhaps changing land management practices are having an effect on kit fox prey. For example, livestock grazing can alter vegetation communities that, in turn, can affect small mammal populations (Fleischner 1994). Recreational activity, on the other hand, is more recent and is growing; the use of ORVs and ATVs may pose a problem. Although data on the potential impact of recreation on kit foxes or their prey are not available, an incident of the abandonment of a den as a result of ATV activity suggests that this may pose a real and growing threat. However, kit foxes apparently exhibit a relatively wide tolerance to habitat change, occupying a broad range of anthropogenically modified habitats including agricultural, industrial, and urban areas. Speculated kit fox response to habitat change, whether related to management, land use, or abiotic environmental variables, is likely strongly regulated by the impact of these agents of change on prey abundance. Lastly, predation has been noted as a major factor (O'Neal et al. 1987, Fitzgerald et al. 1994, Ralls and White 1995, White and Garrott 1995, Cypher and Spencer 1998, White et al. 2000; see Community ecology section).

The biogeography of kit foxes provides a backdrop of potential vulnerability to populations in the state. At the peripheral distribution of their range, in Colorado, they have switched to alternate prey (murid rodents) rather than the standard kangaroo rat, lagomorph, and prairie dog fare typical in other parts of their range, presumably due to low densities of the latter taxa. The number of dens available to and used by kit foxes in Colorado appears lower than elsewhere, and dens are a critical factor in predator avoidance. Events such as energy and residential development have led to the loss and degradation of habitat, potential further reduction in prey, and reduced continuity of Colorado's peripheral kit foxes with source populations. The ability of reproductive individuals from source population in adjacent states to immigrate to small populations in Colorado and maintain their viability is vastly compromised. Additional factors have further exacerbated the situation, the most significant of which appears to be predation by coyotes and red foxes. The very high mortality of juveniles as a result of this predation creates a further problem in recruitment demographics. In Colorado, the loss of a single reproductive pair resulting from any disturbance, such as ORVs that drive over or near a den, becomes significant. This downward spiral in the numbers and reproductive output of kit foxes, combined with a lack of immigration to alleviate these effects, is part of the "extinction vortex" (Gilpin and Soule 1986). The extinction vortex is a positive feedback cycle of detrimental population dynamics. With low population size, low genetic variability, and a decrease in genetic stability causing further declines in reproduction and survival, there is a further reduction in population size and thus an increased susceptibility to environmental stochasticity.

Potential Management of the Kit Fox in Region 2

Implications and potential conservation elements

The critical elements for a self-sustaining population of kit foxes in Colorado include:

- ❖ a sufficient expanse of suitable, continuous habitat, not fragmented by irrigated lands and housing developments, with their associated red foxes, coyotes, and domestic dogs

- ❖ availability of soils that allow for digging of dens, or existing kit fox den sites or dens of other species that can be adapted by kit foxes and which serve as escape routes from coyote predation

- ❖ good prey densities of murid and heteromyid rodents, sciurids, and lagomorphs

- ❖ areas that are not characterized by high abundances of coyotes and/or red foxes, or a high intensity of recreation, energy development, or other disturbances.

A number of measures are required at this point to restore self-sustaining populations of kit foxes to suitable portions of western Colorado. The first step is an active recovery program led by CDOW. While steps were taken in this direction (Fitzgerald 1996, Beck 1997, 1998, 1999, 2000), they were dropped due to departmental reorganization and creation of the Species Conservation Section, as well changes in budgetary allocations and priorities. This has so far created a void in leadership for conservation of kit foxes in Colorado, exacerbating the very real potential for near-future extirpation of the species in the state. Establishment of a recovery plan, with identified "critical habitat" for the species, land use guidance and cooperative efforts with private landowners, and coordinated efforts with federal land management and local agencies, are critical.

Efforts to mitigate threats to kit foxes have rarely been attempted, and consequences of land management activities on distribution and abundance of kit foxes are not well studied. However, application of strategies that have been used with swift foxes (e.g., the Conservation Assessment and Strategy prepared by Kahn et al. (1997)), combined with research efforts, can vastly improve this situation. The primary threat to populations of kit foxes in Colorado likely is the degradation, fragmentation, and loss of habitat resulting from various land use activities and changes in land cover, as well as interspecific competition with coyotes and red foxes.

Protecting important foraging and historic denning areas and the surrounding habitat may lessen the impacts to kit foxes resulting from land use activities including domestic livestock grazing, energy development, and recreation. Localized restrictions on recreational or grazing uses of important kit fox habitats may be needed (Fitzgerald 1996). Preservation or re-establishment of connectivity between important habitat blocks and fox populations is crucial. Interspecific competition with coyotes and red foxes poses a significant threat to many populations of kit foxes. A coyote control program was implemented in an attempt to reduce interference competition and coyote-induced mortality of kit foxes at the Naval Petroleum Reserves in California. Capture indices and survival rates of kit foxes, however, did not increase even after four years of coyote control (Cypher and Scrivner 1992 *in* Ralls and White 1995), but several studies elsewhere have reported increased densities of various species of foxes following coyote-control programs (Ralls and White 1995). Careful attention should be paid to the local occurrence of red foxes when considering coyote control because the presence of coyotes may reduce the negative impacts of red foxes on kit foxes by limiting red fox abundance and distribution (White et al. 1994). Another measure taken to reduce interference competition with coyotes and red foxes includes placement of artificial escape structures on the landscape (see Population or habitat management approaches section) and removal of artificial water sources. The use of artificial den sites was apparently successful in California, and its utility in Colorado is currently under study by BLM.

Indirect effects of predator and rodent control and the concomitant reduction in prey abundance may pose a threat to the continued persistence of kit foxes in Colorado (Fitzgerald 1996). The use of poisons, especially 1080 (sodium monofluoroacetate), to control nuisance species apparently negatively affected and possibly decimated a number of kit fox populations. While some kit fox populations appear to have increased since 1080 was banned from public use in 1972 (O'Farrell 1987), kit foxes in Colorado do not appear to have rebounded similarly. Use of poisons to control nuisance species should, therefore, be carefully assessed and applied very cautiously to avoid direct and indirect impacts to kit fox and other non-target species until methods are devised to achieve both problem-specific animal damage control and protection of non-target species. Lastly, because kit fox populations are regulated primarily by prey abundance, special consideration must be given to potential impacts of management activities on prey species abundance.

A comparison of kit and swift foxes found that there were no substantial differences in home range size, den use, survival, dispersal, and population threats. Because of these similarities, it is strongly advised that common conservation planning for the two species can provide good results with a greater efficiency of resources (Moehrenschlager et al. 2004).

Tools and practices

Inventory and monitoring

Due to the extreme rarity of kit foxes in Region 2, ascertaining the presence of individuals is of necessity the first step towards their management. Because they are primarily nocturnal, they may often go undetected, especially where their numbers are very low (O'Farrell 1987). Once presence is established, the next level of inventory and monitoring attempts to determine relative abundance, which relies on some index of abundance that can be compared across sites and across time. Kit fox presence and relative abundance may be determined from scent-station surveys, den surveys, spotlight surveys, or livetrapping, preferably on an annual basis. Another tool that has been applied to kit foxes in Colorado is the use of active infra-red-activated cameras (Fitzgerald 1996, Beck 1998, 1999). Various types of remote-censusing cameras are available, and baits or scents can be used to attract target animals. Fecal DNA analyses can be applied to scat samples with the advantage of identification of individuals (Smith et al. 2002). Many of these techniques have the advantage of causing minimal disturbance to the animals.

Although no studies have been made on the relative effectiveness of these survey techniques to determine presence and index population trends (Fitzgerald 1996), kit foxes will readily visit scent stations (O'Farrell 1987). One disadvantage of scent-station surveys is the misidentification of tracks. While kit fox tracks are generally easy to identify, a novice may confuse them with those of coyote pups, grey foxes, small domestic dogs, domestic cats, and forepaws of cottontails and jackrabbits (Fitzgerald 1996). Photographs would likely eliminate this identification problem. It is important to note that scent stations may be of little value in areas where kit foxes occur at low densities in small populations. To increase the probability of kit fox visitation to scent stations in such conditions, the network of stations must be extensive.

Den surveys have also been used (O'Farrell 1987), searching from the ground or air for multiple-entrance dens along transects. Suspected dens observed from the air must be confirmed by ground visits. Although labor intensive, ground transects are preferred over aerial transects until the surveyors are confident that they can identify dens from fast-moving aircraft. Ground surveys are usually conducted at 200 m (656 ft.) intervals, and aerial surveys are flown at 500 m (1,640 ft.) intervals at the lowest possible safe altitude over the terrain. Den surveys may be more effective in spring when active dens, identified by freshly dug dirt berms and matted vegetation, are easier to find. Disadvantages of den surveys include cost and difficulty of distinguishing dens in areas with large concentrations of badger diggings or ground squirrel burrows that may be mistaken for kit fox dens at a distance. Den surveys may also be challenging where kit foxes often utilize atypical dens that cannot be easily observed from the transects. This may be the case in western Colorado where some kit foxes locate dens under rocks and where earthen dens have few entrances and entrances that do not posses the diagnostic key-hole shape.

Spotlight surveys have been used extensively in California for years, but they have limitations in western Colorado because of the large expanses of shrublands where vegetative height limits the visual field (Fitzgerald 1996). Livetrapping is an excellent method but labor intensive and may be ineffective where densities are low. Therefore, it may be better used to confirm presence only after other types of surveys have provided some evidence that kit foxes are present. Despite these apparent disadvantages, Fitzgerald (1996) used livetrapping as the primary search method during a four-year study in western Colorado. For details on livetrapping methods see O'Farrell (1987) and Fitzgerald (1996). A recent innovation is the tunnel trap, which had an 83 percent success rate in capturing kit foxes in Utah (Kozlowski et al. 2003).

In addition to the techniques outlined above for assessing kit fox presence and relative abundance, tracking plates (Woolley et al. 1995, Mote 1996, Dieni et al. 1997), collection of scat (Sovada and Roy 1996, Dieni et al. 1997), track surveys (Roy et al. 1999, Hoadland 2000), calling (Harrison et al. 2002), and spotlighting (Hillman and Sharps 1978, Woolley et al. 1995, Mote 1996, Sovada and Roy 1996, Dieni et al. 1997) have been employed with swift foxes. For the next level of monitoring, absolute abundance (density) techniques used with swift foxes include mark-resight (Roell 1999), mark-recapture (Cotterill 1997), and collection of scats coupled with genetic analysis (Harrison et al. 2002).

Because limited resources make surveying the complete distribution and relative or absolute abundance of a widely distributed, low-density, nocturnal species such as the kit fox difficult, assessments of potential habitat will be key to management and conservation of the species (Gerrard et al. 2001). Range-wide inventory of potential habitat may be accomplished with Geographic Information Systems (GIS) -based predictive models resulting in spatially explicit analyses of habitat value.

Two predictive distribution models have been generated for the kit fox in Colorado (**Figure 3**). One considers climate, soils, and vegetation (Beauvais et al. 2003), and another is based on South West Regional Gap (SWReGap) land cover types, habitat requirements, and elevation (Boyle and Reeder 2005). The area of overlap of the two models is a stronger predictor of suitable habitat than either model alone. Different assumptions are made with each model regarding habitat preferences and how those are selected, and other biotic and abiotic characteristics. Such predictive models can also be used to assess future threats to habitat. This approach was taken for the San Joaquin kit fox in eastern Contra Costa and Alameda counties, California (Gerrard et al. 2001) and in the Panoche area in the central western portion of San Joaquin Valley (Haight et al. 2001) where kit foxes are associated with annual grassland. The primary data layer for the former was a vegetative/land cover map, and for the latter it was slope.

Descriptions of habitats occupied by kit foxes are critical to understand the ecological requirements of the species. In western Colorado, kit fox capture sites and den sites were categorized in terms of the predominant vegetation and percent cover (Fitzgerald 1996). Transects 30.5 m (100 ft.) long were run north, east, south, and west from the main entrance of the dens used by monitored kit foxes. A modified Parker-loop system was used to determine cover at every 30.5 cm (1 ft.) interval along transects. The categories used were rock, bare ground, litter, forbs, shrubs, annual grass, and perennial grass. Soils are typically important selection factors for semi-fossorial species (Olson 2000; see discussion in Habitat and Dens sections).

Population and habitat monitoring are most valuable when accompanied by monitoring of ecological, and, perhaps even more importantly, anthropogenic factors that may affect kit fox abundance, such as coyote and red fox density, precipitation, small mammal and lagomorph prey density, extent of recreational activity, degree of exurbanization. With these measures in place, a decline in density or range could be correlated to a potential cause, which will, in turn, allow for more effective management.

Management approaches

Information regarding the effectiveness of kit fox population and habitat management approaches was not available in the published literature. Wildlife researchers and managers continue to search for solutions to reduce coyote-related mortalities. While some argue that predator control could potentially increase both the distribution and abundance of foxes, previous attempts at the Naval Petroleum Reserves in California were labor and cost intensive and did not produce satisfactory results even after the removal of almost 600 coyotes (Cypher and Scrivner 1992 *in* Warrick and Cypher 1998). Tracks have often indicated that there had been a short pursuit by a larger canid chasing a kit fox (Ralls and White 1995), which gave rise to the idea that frequent placement of artificial escape structures may be useful where coyote and red fox induced mortality is high (P. Kelly personal communication 2002). Personnel of the BLM office in Grand Junction placed 12 full-sized artificial natal dens at eight sites in the Grand Valley north and west of Grand Junction in August of 2004 and June of 2005 (Ron Lambeth 2005). In addition, 36 “quick escape dens” were placed near the full-sized dens, and another eight quick escape dens were placed in open habitat. No evidence of use was found at artificial dens following a snowfall during winter of 2004-05, but a month after the 2005 dens were installed, they were revisited; at the entrance of one full-sized den, a possible kit fox scat specimen was found. Monitoring of these artificial dens will continue, and additional dens will likely be installed in the future. Success of this management tool may depend on density of kit foxes, density of artificial dens, and the likelihood of their discovery.

Removal of introduced water sources may also help to reduce and even eliminate coyotes and red foxes from certain sites because kit foxes posses the ability to survive without free water and coyotes and red foxes do not. The recent range expansion of coyotes and red foxes into arid regions may be partially attributed to the anthropogenic introduction of water sources.

Public education is an important tool to advise the public of the existence and identifying characteristics of a rare or declining species. This is particularly true where humans are a factor in the decline. The Nebraska Game and Parks Commission publicized the presence of swift foxes and posted swift fox crossing signs along roads frequented by swift foxes (Hines and Case 1991 *in* Stephens and Anderson 2005). Such signage may be beneficial in very localized situations where, for example, a relatively high density of dens is known to occur near a roadway.

Reintroduction is expensive and should only be attempted when there is a good understanding of suitable habitat and conditions, when these are present at the reintroduction site, and when the conditions that caused population decline or extirpation in the first place have been removed or controlled. Beck (1999) conducted GAP and ground mapping to estimate the habitat potential for restoration of kit fox in Colorado. He identified three distinct areas: the Colorado, Gunnison, and Uncompahgre valleys. Successful restoration of kit fox throughout the 1,310 km^2 of suitable habitat in these three areas would result in kit fox populations varying from 182 to 728 animals, based on kit fox densities as summarized by White and Garrott (1997), of 0.16 to 0.7 animals per km^2. Contacts were made with Utah and Arizona for sources of kit foxes, and representatives of both states were confident of being able to provide kit foxes in adequate numbers should population augmentation occur (Beck 2000). At the time of these augmentation studies, the CDOW was undergoing reorganization and administrative delays in budget allocations. There are no plans at present to pursue augmentation plans. Swift foxes have been successfully reintroduced in Canada (Carbyn et al. 1994 *in* Stephens and Anderson 2005, Smeeton and Weagle 2000), as well as Montana and South Dakota (http://www.ceinst.org/blackfeet.htm, http://www.npca.org/magazine/2004/winter/fox.html).

Fitzgerald (1996) proposed the following management recommendations for kit foxes in Colorado:

- ❖ prepare a formal program for species recovery and maintenance
- ❖ establish a minimum of eight sub-populations
- ❖ evaluate and manage the habitats of those sub-populations to maximize quality and minimize disturbance factors
- ❖ establish a monitoring program to evaluate results of the enhancement/maintenance effort
- ❖ research the demographics and necessary behavioral ecology needed for appropriate management
- ❖ secure as critical kit fox habitat 518 km^2 in the Colorado River Drainage and 518 km^2 in the Gunnison River Drainage to protect existing populations through land use planning, wildlife management planning, and rodent and predator control
- ❖ investigate the possibility of releasing additional animals to the Peach Valley-Montrose East population to see if reproductive success can be increased; the presence of new development on private property in this area is, admittedly, a complicating factor.

The San Joaquin kit fox recovery plan also includes research needs (U.S. Fish and Wildlife Service 1998).

Another option is to modify certain types of habitats to decrease their suitability for coyotes and to increase the ability of foxes to detect and avoid coyotes (Warrick and Cypher 1998). For instance, shrub control may provide this type of advantage to kit foxes in some areas. The potential positive effects of this technique should be further investigated. However, this is very labor intensive, and the effects on other sensitive species that rely on shrub cover must be carefully considered.

Information Needs

Below is a list of information needs required to enhance management of kit fox populations, with an emphasis on Colorado research needs.

- ❖ create a multi-agency team, including organizations and private landowners, to develop and implement a conservation plan
- ❖ investigate the effects of interspecific competition with and predation by coyotes and red foxes on dispersal of kit foxes; a better understanding of the specific details of this vulnerability are needed
- ❖ determine whether there is a minimum density of dens necessary for breeding success and if this changes with predation pressure and/or quality of available dens
- ❖ study the relationship between the utility of aritificial dens sites and kit fox survival rates
- ❖ analyze preferred soil types, as this may be a limiting factor in kit fox distribution in Colorado and could help focus conservation and/or reintroduction efforts; fossorial species typically require specific soil types, and kit fox distribution in Colorado appears to follow clay soils on the east side of the Uncompahgre River, for example
- ❖ investigate the abundance of prey species in relation to land use practices and other factors

- ❖ study the relationship between prey populations and kit fox population dynamics
- ❖ evaluate what limits the number of dens in Colorado and the role of soils and artificial dens
- ❖ conduct population and habitat viability analyses
- ❖ assess the role of prairie dog expansion on recovery of kit fox populations
- ❖ gather demographic data for kit foxes in natural and anthropogenically modified landscapes for use in population viability analyses
- ❖ measure the response of kit fox populations to various land use practices including domestic livestock grazing, energy development, and recreation
- ❖ implement control strategies to reduce coyote and red fox predation on kit foxes
- ❖ find better methods for determining the age of individuals.
- ❖ use adequate and least invasive censusing techniques to permit population monitoring
- ❖ study the ecological differences at capture versus non-capture sites, including coyote and red fox abundance, ORV/ATV use, and small mammal abundance
- ❖ investigate the population dynamics and movement in adjacent populations in Utah and New Mexico

Additional research topics in Colorado identified by Fitzgerald (1996) are listed below:

- ❖ population biology of kit foxes in Peach Valley and Montrose East.
- ❖ home range characteristics of kit foxes in Peach Valley and Montrose East.
- ❖ how human disturbance disrupts the kit foxes in Peach Valley and Montrose East.
- ❖ the need for and possibility of release of additional animals to populations in Peach Valley and Montrose East.

References

Armstrong, D.M. 1972. Distribution of Mammals of Colorado. Monograph of the Museum of Natural History, University of Kansas No. 3. University of Kansas Printing Service, Lawrence, KS.

Armstrong, D.M. 1982. Mammals of the canyon country: a handbook of mammals of Canyonlands and vicinity, Utah. Canyonlands Natural History Association, Moab, UT.

Beauvais, G.P., R. Thurston, and D. Keinath. 2003. Predictive range maps for 15 species of management concern in the Rocky Mountain Region of the USDA Forest Service. Wyoming Natural Diversity Database, University of Wyoming, Laramie WY.

Beck, T.D.I. 1997. Kit fox (*Vulpes macrotis*) status in Colorado. Wildlife Research Report, Project No. W-153-R-10, Work Package No. 10A, Job No. 1: Colorado Division of Wildlife.

Beck, T.D.I. 1998. Kit fox conservation. Wildlife Research Report, Project No. W-153-R-11, Work Package 0663, Task No. 1: Colorado Division of Wildlife.

Beck, T.D.I. 1999. Kit fox conservation. Wildlife Research Report, Project No. W-153-R-12, Work Package 0663, Task No. 1: Colorado Division of Wildlife.

Beck, T.D.I. 2000. Kit fox augmentation study. Wildlife Research Report, Project No. W-153-R-13, WorkPackage 0663, Task No. 1: Colorado Division of Wildlife.

Benson, S.B. 1938. Notes on kit foxes (*Vulpes macrotis*) from Mexico. Proc. Biol. Soc. Washington 51:17-24.

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

Berry, W.H., J.H. Scrivener, T.O. O'Farrell, C.E. Harris, T.T. Kato, and P.M. McCue. 1987. Sources and rates of mortality of the San Joaquin kit fox, Naval Petroleum Reserve #1, Kern County, California, 1980-1986. Topical Report to U.S. Department of Energy, Washington, D.C.

Boyle, S.A. and D.R. Reeder. 2005. Colorado Sagebrush: a conservation assessment and strategy. Colorado Division of Wildlife, Grand Junction, CO.

Brashares, J.S. 2003. Ecological, behavioral, and life-history correlates of mammal extinctions in West Africa. Conservation Biology 17:733-743.

Bunker, C.D. 1940. The kit fox. Science. 92:35-36.

Carbyn, L.N., H.J. Armbruster, and C. Mamo. 1994. The swift fox reintroduction program in Canada from 1983-1992. Pages 247-271 *in* M.L. Bowles and C.J. Whelan, editors. Restoration of endangered species: Conceptual issues, planning, and implementation. Cambridge University Press, New York, NY.

Chamberlain, T.C. 1897. The method of multiple working hypotheses. Journal of Geology 5:837-848 (reprinted in Science 148:754-759.)

Cotterill, S.E. 1997. Population census of swift fox (*Vulpes velox*) in Canada: Winter 1996-1997. Swift Fox National Recovery Team. Alberta Environmental Protection, Natural Resources Service, Wildlife Management Division, Alberta, Canada.

Cypher, B.L. 2003. Foxes (*Vulpes* species, *Urocyon* species, and *Alopex lagopus*). Pages 511-546 *in* G.A. Feldhamer, B.C. Thompson, and J.A. Champan, editors. Wild Mammals of North America: Biology, Management, and Conservation. Second edition. Johns Hopkins University Press, Baltimore, MD.

Cypher, B.L. 2005. Use of artificial dens as a conservation tool for endangered San Joaquin kit foxes. The Western Section of the Wildlife Society. 2005 Annual Conference. Sacramento, CA.

Cypher, B.L., P.A. Kelly, and D.F. Williams. 2003. Factors incluencing populations of endangered San Joaquin kit foxes. Pages 125-137 *in* M.S. Sovada and L. Carbyn, editors. The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, University of Regina, Saskatchewan, Canada.

Cypher, B.L. and J.H. Scrivner. 1992. Coyote control to protect endangered San Joaquin kit foxes at the Naval Petroleum Reserves, California. *In*: J.E. Borrecco and R.E. Marsh, editors. Proceedings of the 15th Vertebrate Pest Conference, Newport Beach, California. University of California, Davis, CA.

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

Cypher, B.L. and G.D. Warrick. 1993. Use of human-derived food items by urban kit foxes. Transactions of the Western Section of the Wildlife Society 29:34-37.

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 145:1-43.

Daneke, D. and M. Sunquist. 1984. Notes on kit fox biology in Utah. Southwestern Naturalist 29:361-362.

Dieni, J.S., F.G. Lindzey, T.P. Woolley, and S.H. Anderson. 1997. Swift fox investigations in Wyoming: Annual report. Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, WY.

Disney, M. and L.K. Spiegel. 1992. Sources and rates of San Joaquin kit fox mortality in western Kern County, California. Transactions of the Western section of the Wildlife Society 28:73-82.

Dobkin, D.S. and J.D. Sauder. 2004. Shrubsteppe landscapes in jeopardy: distributions, abundances, and the uncertain future of birds and small mammals in the intermountain west. High Desert Ecological Research Institute, Bend, OR.

Dragoo, J.W. and R.K. Wayne. 2003. Systematics and population genetics of swift and kit foxes. Pages 207-222 *in* M.A. Sovada and L.N. Carbyn, editors. The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, University of Regina, Regina, Saskatchewan, Canada.

Ecke, D.H. and C.W. Johnson. 1952. Plague in Colorado. Part I. Plague in Colorado and Texas. U.S. Public Health Service, Public Health Monograph 6:1-54.

Egoscue, H.J. 1956. Preliminary studies of the kit fox in Utah. Journal of Mammalogy 37:351-357.

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

Egoscue, H.J. 1964. The kit fox in southwestern Colorado. Southwestern Naturalist 9:40.

Egoscue, H.J. 1975. Population dynamics of the kit fox in western Utah. Bulletin of the Southern California Academy of Science 74:122-127.

Egoscue, H.J. 1979. *Vulpes velox*. Mammalian Species 122:1-5.

Egoscue, H.J. 1985. Kit fox flea relationships on the Naval Petroleum reserves, Kern County, California. Bulletin of the Southern California Academy of Sciences 84:127-32.

Eussen, J.T. 1999. Food habits of the kit fox (*Vulpes macrotis*) and swift fox (*Vulpes velox*) in Colorado. Thesis, University of Northern Colorado, Greeley, CO.

Fisher, J.L. 1981. Kit fox diet in south-central Arizona. Thesis, University of Arizona, Tuscon, AZ.

Fitzgerald, J.P. 1996. Status and distribution of the kit fox (*Vulpes macrotis*) in western Colorado. Report to Colorado Division of Wildlife. University of Northern Colorado, Greeley, CO.

Fitzgerald, J.P., C. Meaney, and D.M Armstrong. 1994. Mammals of Colorado. Denver Museum of Natural History and University Press of Colorado, Niwot, CO.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8:629-644.

Gerrard, R., P. Stine, R. Church, and M. Gilpin. 2001. Habitat evaluation using GIS: A case study applied to the San Joaquin Kit Fox. Landscape and Urban Planning 52:239-255.

Gilpin, M.E. and M.E. Soule. 1986. Minimum viable populations: processes of species extinction. *In*: M.E. Soule, editor. Conservation Biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, MA.

Golightly, Jr., R.T. 1981. Comparative energetics of two desert canids: the coyote (*Canis latrans*) and the kit fox (*Vuples macrotis*). Dissertation, Arizona State University, Tempe, AZ.

Golightly, Jr., R.T. and R.D. Omhart. 1984. Water economy of two desert canids: Coyote and kit fox. Journal of Mammalogy 65:51-58.

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

Haight R.G., B. Cypher, P.A. Kelly, S. Phillips, H.P. Possingham, K. Ralls, A.M. Starfield, P.J. White, and D. Williams. 2002. Optimizing habitat protection using demographic models of population viability. Conservation Biology 16:1386-1397.

Hall, E.R. 1981. The Mammals of North America. Vol. 2. John Wiley & Sons, New York, NY.

Halloran, A.F. and F.E. Taber. 1965. Carnivore notes from the Navajo Indian Reservation. Southwestern Naturalist 10: 139-140.

Harrison, R.L., D.J. Barr, and J.W. Dragoo. 2002. A comparison of population survey techniques for swift foxes (*Vulpes velox*) in New Mexico. American Midland Naturalist 148:320-337.

Harrison, R.L., M.J. Patrick, and C.G. Schmitt. 2003. Foxes, fleas, and plague in New Mexico. Southwestern Naturalist 48:720-722.

Hilborn, R. and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, NJ.

Hillman, C.N. and J.C. Sharps. 1978. Return of the swift fox to the Northern Plains. Proceedings of the South Dakota Academy of Science 57:154-162.

Hines, T.D. and R.M. Case. 1991. Diet, home range, movements, and activity periods of swift fox in Nebraska. Prairie Naturalist 23:131-138.

Hoadland, J.W. 2000. Swift fox investigations in Oklahoma, 1999. Pages 48-58 *in* G. Schmitt, editor. Swift fox conservation team 1999 annual report. New Mexico Department of Game and Fish, Sante Fe, NM.

Hoffmeister, D.F. 1986. Mammals of Arizona. University of Arizona Press and Arizona Game and Fish Department, Tuscon, AZ.

Jensen, C.C. 1972. San Joaquin kit fox distribution. Bureau of Sport Fisheries and Wildlife, Division of Wildlife Services, Sacramento, CA.

Kahn, R., L. Fox, P. Horner, B. Giddings, and C. Roy. 1997. Conservation assessment and conservation strategy for swift fox in the United States. Colorado Division of Wildlife.

Kitchen, A.M., E.M. Gese, and E.R. Schauster. 1999. Resource partitioning between coyotes and swift foxes: space, time, and diet. Canadian Journal of Zoology 77:1645-1656.

Knapp, D.K. 1978. Effects of agricultural development in Kern County, California, on the San Joaquin kit fox in 1977 (Final Report, Project E-1-1, Job V-1, 21). California Department of Fish and Game, Non-game Wildlife Investigations, Sacramento, CA.

Koopman, M.E. 1995. Food habits, space use, and movements of the San Joaquin kit fox on the Elk Hills Naval Petroleum reserves in California. Thesis, University of California, Berkeley, CA.

Koopman, M.E., B.L. Cypher, and J.H. Scrivner. 2000. Dispersal patterns of San Joaquin kit foxes (*Vulpes macrotis mutica*). Journal of Mammalogy 81:213-222.

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.

Kozlowski, A.J., T.J. Bennett, E.M. Gese, and W.M. Arjo. 2003. Live capture of denning mammals using an improved box-trap enclosure: kit foxes as a test case. Wildlife Society Bulletin 31:630-633.

Lambeth, R. 2005. Kit fox artificial dens. Project Summary, Project No. 1927: US Bureau of Land Management, Grand Junction, CO.

Laughrin, L. 1970. San Joaquin kit fox, its distribution and abundance. (Administrative Report 70-2). California Department of Fish and Game, Wildlife Management Branch, Sacramento, CA.

Legendre S., J. Colbert, A. Moler, and G. Sorci. 1999. Demographic stochasticity and social mating system in the process of extinction of small populations: The case of passerines introduced to New Zealand. The American Naturalist 153:449-463.

Link, M.A. 1995. Kit fox (*Vulpes macrotis*) distribution in western Colorado. Thesis, University of Northern Colorado, Greeley, CO.

List, R. 1997. Ecology of the kit fox (*Vulpes macrotis*) and coyote (*Canis latrans*) and the conservation of the prairie dog ecosystem in northern Mexico. Dissertation, University of Oxford, Oxford, England.

List, R. and B.L. Cypher. 2004. *Vulpes macrotis*. Pages 105-109 *in* C. Sillero-Zubri, M. Hoffman, and D.W. MacDonald, editors. Canids: Foxes, Wolves, Jackles, and Dogs. Status Survey and Conservation Action Plan. IUCN/SSC Canid Specialist Group. Gland, Switzerland and Cambridge, U.K.

List, R. and D.W. MacDonald. 2003. Kit fox home range and habitat use in a prairie dog complex. Journal of Zoology 259:1-5.

List, R., P. Manzano-Fischer, and D.W. MacDonald. 2003. Coyote and kit fox diets in a prairie dog complex in Mexico. Pages 183-188 *in* M.S. Sovada and L. Carbyn, editors. The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, University of Regina, Saskatchewan, Canada.

Logan, C.G., W.H. Berry, W.G. Standley, and T.T. Kato. 1992. Prey abundance and food habits of SJ kit fox at Camp Roberts Army National Guard Training Site, California (Topical Report No. EGG 10617-2158). U.S. Department of Energy, Washington, D.C.

Lusby, G.C., V.H. Reid, and O.D. Knipe. 1971. Effects of grazing on the hydrology and biology of the Badger Wash Basin in western Colorado, 1953-1966. Water Supply Papers, U.S. Geologic Survey, 1532-D:1-90.

McGrew, J.C. 1977. Distribution and habitat characteristics of the kit fox (*Vulpes macrotis*) in Utah. Thesis, Utah State University, Logan, UT.

McGrew, J.C. 1979. *Vulpes macrotis*. Mammalian Species 123:1-6.

Medin, D.E. and W.P. Clary. 1989. Small mammal populations in a grazed and ungrazed riparian habitat in Nevada. Research Paper INT-413. USDA Forest Service, Intermountain Research Station, Ogden, UT.

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

Miller, B.G., G. Caballos, and R. Reading. 1994. The prairie dog and biotic diversity. Conservation Biology 8:677-681.

Miller, D.S., B.G. Campbell, R.G. McLean, E. Campos, and D.F. Covell. 1998. Parasites of swift fox (*Vulpes velox*) from southeastern Colorado. Southwestern Naturalist 43:476-79.

Miller, P.H. 1964. The ecological distribution of mammals in Colorado National Monument, Mesa County, Colorado. Thesis, Oklahoma State University, OK.

Miller, P.H. and C.J. McCoy, Jr. 1965. Kit fox in Colorado. Journal of Mammalogy 46:342-343.

Moehrenschlager, A., B. Cypher, K. Ralls, R. List, and M.A. Sovada. 2004a. Comparative ecology and conservation priorities of swift and kit foxes. Pages 185-198 *in* D.W. Macdonald and C. Sillero-Zubiri, editors. Biology and conservation of wild canids. Oxford University Press, Oxford, England.

Moehrenschlager, A. and M.A. Sovada. 2004. *Vulpes velox*. Pages 109-116 *in* C. Sillero-Zubri, M. Hoffman, and D. W. MacDonald, editors. Canids: Foxes, Wolves, Jackles, and Dogs. Status Survey and Conservation Action Plan. IUCN/SSC Canid Specialist Group. Gland, Switzerland and Cambridge, U.K.

Moehrenschlager, A., B. Cypher, K. Ralls, M.A. Sovada, and R. List. 2004b. Comparative ecology and conservation priorities of swift and kit foxes. Pages 185-198 *in* D.W. Macdonald and C. Sillero-Zubiri, editors. Biology and conservation of wild canids. Oxford University Press, Oxford, England.

Moehrenschlager, A. and R. List. 1996. Comparaitive ecology of North American foxes – conservation through collaboration. Pages 22-28 *in* D.W. MacDonald and F.H. Tattersall, editors. The WildCru Review. Wildlife Conservation Unit, Oxford, U.K.

Morrell, S. 1972. Life history of the San Joaquin kit fox. California Fish and Game 8:162-174.

Morrell, S. 1975. San Joaquin kit fox distribution and abundance in 1975 (Administrative Report 75-3). California Department of Fish and Game, Wildlife Management Branch, Sacramento, CA.

Mote, K. 1996. Swift fox investigations in Texas. Pages 50-52 *in* B. Luce and F.G. Lindzey, editors. Annual report of the swift fox conservation team 1996. Wyoming Game and Fish Department, Lander, WY.

NatureServe. 2005. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.6. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: January 20, 2006). December 9, 2005.

O'Farrell, T.P. 1987. Kit fox. Pages 423-431 *in* M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Trappers Association and Ontario Ministry of Natural Resources, Ontario, Canada.

O'Farrell, T.P. and L. Gilbertson. 1986. Ecology of the desert kit fox, *Vulpes macrotis arispus*, in the Mojave Desert of Southern California. Bulletin of the Southern California Academy of Science 85:1-15.

Olson, T.L. 2000. Population characteristics, habitat selection patterns, and diet of swift foxes in southeast Wyoming. Thesis, University of Wyoming, Laramie, WY.

Olson, T.L. and F.G. Lindzey. 2002. Swift fox survival and production in southeastern Wyoming. Journal of Mammalogy 83:199-206.

O'Neal, G.T., J.T. Flinders, and R.P. Clary. 1987. Behavioral ecology of the Nevada kit fox (*Vulpes macrotis nevadensis*) on a managed desert rangeland. Pages 443-481 *in* H. H. Genoways, editor, Current mammalogy 1: 1-519. Plenum Press, New York, NY.

Packard, R.L. and J.H. Bowers. 1970. Distributional notes on some foxes from western Texas and eastern New Mexico. Southwestern Naturalist 14:450-451.

Pauli, J.N. 2005. Ecological studies of the black-tailed prairie dog (*Cynomys ludovicianus*): Implications for biology and conservation. Thesis, University of Wyoming, Laramie, WY. 90 pages.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Ralls K., K. Pilgrim, P.J. White, E.E. Paxinos, and R.C. Fleischer. 2001. Kinship, social relationships, and den-sharing in kit foxes. Journal of Mammalogy 82:858-866.

Ralls, K. and L. Eberhardt. 1997. Assessment of abundance of San Joaquin kit foxes by spotlight surveys. Journal of Mammalogy 78:65-73.

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

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

Reeve, A.F. and T.C. Vosburgh. 2006. Recreational shooting of prairie dogs. Pages 139-156 *in* J. L. Hoogland, editor. Conservation of the black-tailed prairie dog. Island Press, Washington, D.C.

Reynolds, T.D. and C.H. Trost. 1980. The response of native vertebrate populations to crested wheatgrass planting and grazing by sheep. Journal of Range Management 33:122-125.

Robinson, W.B. 1953. Population trends of predators and fur animals in 1080 station areas. Journal of Mammalogy 34:220-227.

Roell, B.J. 1999. Demography and spatial use of swift fox (*Vulpes velox*) in northeastern Colorado. Thesis, University of Northern Colorado, Greeley, CO.

Rosenstock, S.S. 1996. Shrub-grassland small mammal and vegetation responses to rest from grazing. Journal of Range Management 49:199-203.

Rohwer, S.A. and D.L. Kilgore, Jr. 1973. Interbreeding in the aridland foxes, *Vulpes velox* and *V. macrotis*. Systematic Zoology 22:157-165.

Roy, C.C., M.A. Sovada, and G.A. Sargent. 1999. An improved method for determining the distribution of swift foxes in Kansas. Pages 4-17 *in* C.C. Roy, editor. 1998 Swift fox conservation team annual report. Kansas Department of Wildlife and Parks, Emporia, KS.

Ruediger, B. 1996. The relationship between rare carnivores and highways. Pages 1-7 *in* Trends in addressing transportation related wildlife mortality: Proceedings of the Transportation Related Wildlife Mortality Seminar. State of Florida, Department of Transportation.

Schmidt, R.H. 1991. Grey wolves in California: their presence and absence. California Fish and Game 77:79-85.

Scrivner, J.H., T.P. O'Farrell, and T.T. Kato. 1987. Dispersal of San Joaquin kit foxes, *Vulpes macrotis mutica*, on Naval Petroleum Reserve #1, Kern County, California (Topical Report EGG 10282-2190). U.S. Department of Energy, Washington, D.C.

Seglund, A.E., A.E. Ernst, M. Grenier, B. Luce, A. Puchniak, and P. Schnurr. 2004. White-tailed prairie dog conservation assessment.

Smith, D., K. Ralls, B. Adams, B.L. Cypher, and J.E. Maldonado. 2002. Scat-sniffing dogs and fecal DNA analyses: Comparing noninvasive techniques with radio telemetry monitoring. Carnivores 2002. From the Mountains to the Sea: A Conference on Carnivore Biology and Conservation. November 17-20. Monterey, CA.

Sovada, M.A. and C.C. Roy. 1996. Summary of research activities conducted in western Kansas — annual report. Pages 64-68 *in* B. Luce and F.G. Lindzey, editors. Annual report of the swift fox conservation team 1996. Wyoming Game and Fish Department, Lander, WY.

Sovada, M.A., C.C. Roy, and D.J. Telesco. 2001. Seasonal food habits of swift foxes in cropland and rangeland habitats in western Kansas. American Midland Naturalist 145:101-111.

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

Spiegel, L.K., editor. 1996. Studies of San Joaquin kit fox in undeveloped and oil-developed areas. California Energy Commission, Sacramento, CA.

Stacey, P.B. and M. Taper. 1992. Environmental variation and the persistence of small populations. Ecological Applications 2(1):18-29.

Stacey, P.B. and M. Taper. 1997. Migration within metapopulations: the impact upon local population dynamics. Pages 267-291 *in* Metapopulation Biology, Academic Press.

Standley, W.G., W.H. Berry, T.P. O'Farrell, and T.T. Kato. 1992. Mortality of San Joaquin kit fox at Camp Roberts Army National Guard Training Site, California (Topical Report EGG 10627-2157). U.S. Department of Energy, Washington, D.C.

Stevens, R.M. and S.H. Anderson. 2005. Swift Fox (*Vulpes velox*): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/swiftfox.pdf [2005, October 3].

Swick, C.D. 1973. Determination of San Joaquin kit fox range in Contra Costa, Alameda, San Joaquin, and Tulare Counties, 1973. (Special Wildlife Investigations Program Report W-54-R4). California Department of Fish and Game, Sacramento, CA.

Tannerfeldt, M., A. Moehrenschlager, and A. Angerbjorn. 2003. Den ecology of swift, kit and arctic foxes. Pages 167-181 *in* M.A. Sovada and L.N. Carbyn, editors. The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, University of Regina, Saskatchewan, Canada.

Thornton, W.A. and G.C. Creel. 1975. The taxonomic status of kit foxes. Texas Journal of Science 26:127-136.

USDA Forest Service. 2003. Forest Service Manual 2600: Wildlife, fish, and sensitive plant habitat management, Chapter 2670: Threatened, endangered and sensitive plants and animals. Supplement No.: 2600-2003-1. Rocky Mountain Region (Region 2), Denver, CO.

U.S. Fish and Wildlife Service. 1983. San Joaquin kit fox recovery plan. U.S. Fish and Wildlife Service, Region 1, Portland, OR.

U.S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. U.S. Fish and Wildlife Service, Region 1, Portland, OR.

Van Vuren, D.V. 1998. Mammalian dispersal and reserve design. Pages 369-393 *in* T. Caro, editor. Behavioral ecology and conservation biology, Oxford University Press, New York, NY.

Vanderbilt White, C.A. 1994. Dynamics of isolated populations: responses of different taxa to natural disasters. Dissertation, University of California, Davis, CA.

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.

Warrick, G.D. and B.L. Cypher. 1999. Variation in body mass of San Joaquin kit foxes. Journal of Mammalogy 80: 972-929.

Warrick G.D., J.H. Scrivner, and T.P. O’Farrell. 1999. Demographic responses of kit foxes to supplemental feeding. Southwestern Naturalist 44:367-374.

White, P.J. and R.A. Garrott. 1997. Factors regulating kit fox populations. Canadian Journal of Zoology 75:1982-1988.

White, P.J. and R.A. Garrott. 1999. Population dynamics of kit foxes. Canadian Journal of Zoology 77:486-493.

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 R.A. Garrott. 1994. Coyote-kit fox interactions as revealed by telemetry. Canadian Journal of Zoology 72:1831-1836.

White, P.J., C.A.V. White, and K. Ralls. 1996. Functional and numerical responses of kit foxes to a short-term decline in mammalian prey. Journal of Mammalogy 77:370-376.

White, P.J., W.H. Berry, J.J. Eliason, and M.T. Hanson. 2000. Catastrophic decrease in an isolated population of kit foxes. Southwestern Naturalist 45:204-211.

Wolff, J.O. 1997. Population regulation in mammals: an evolutionary perspective. Journal of Animal Ecology 66: 1-13.

Woolley, T.P., F.G. Lindzey, and R. Rothwell. 1995. Swift fox surveys in Wyoming - annual report. Pages 61-76 *in* S.H. Allen, J.W. Hoagland, and E. Dowd Stukel, editors. Report of the swift fox conservation team 1995. North Dakota Game and Fish Department, Bismark, ND.

Zoellick B.W., N.S. Smith, and R.S. Henry. 1989. Habitat use and movements of desert kit foxes in western Arizona. Journal of Wildlife Management 53:955-961.

Zoellick, B.W., C.E. Harris, B.T. Kelly, T.P. O'Farrell, T.T. Kato, and M.E. Koopman. 2002. Movements and home ranges of San Joaquin kit foxes relative to oil-field development. Western North American Naturalist 62:151-159.