DISTRIBUTION AND HABITAT REQUIREMENTS OF THE SAN JOAQUIN KIT FOX IN THE NORTHERN EXTREME OF THEIR RANGE

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Abstract: Recent studies indicate that the distribution of the San Joaquin kit fox (Vulpes macrotis mutica) has been reduced in the last 10 years within the northern portion of their range. The northernmost population of this species is currently believed to be in the vicinity of Bethany Reservoir in northeastern Alameda County. Data derived from monitoring eight radio-collared kit fox and from a scat analysis indicate that habitat requirements for this northern population differ from those of the southern populations. Kit fox survival in this northern area appears to be heavily dependent on the presence of ground squirrels, which provide the principal source of both food and dens for the foxes. The kit fox population in this region is thought to be extremely sparse and highly susceptible to local extinction. Factors affecting the population include cattle grazing, agricultural development, ground squirrel poisoning, competition from other canids, wind turbine development, and suburban encroachment.

San Joaquin kit fox were once widely distributed throughout the Central Valley of California (Grinnell et al. 1937). Since the early 1900's, loss of habitat due to agricultural, industrial, and urban development has resulted in kit fox range reduction and population declines (O'Farrell 1983). Concerns over these declines led to listing this subspecies as federally endangered in 1966 and classifying it as California state rare in 1971 (all wildlife previously listed as rare are now classified as threatened under California law effective 1 January 1985).

San Joaquin kit fox in their northern range have received little study compared to southern populations. Of the early studies on distribution and abundance only Swick's (1973a) emphasized the northern range. Recent investigations by the California Department of Fish and Game conducted as part of the Los Vaqueros Reservoir (LVR) project (CDFG 1983a) and the Bethany Reservoir Wind Turbine Project (CDFG 1983b) represent the first studies since Swick (1973a) to emphasize the northern range, and also provide the only research on life history and habitat requirements of kit fox in the north. Both the LVR and Bethany studies focused on the same group of kit fox in the same general area.

The primary purpose of this paper is to summarize pertinent information on kit fox distribution and habitat requirements from the LVR (CDFG 1983a) and Bethany (CDFG 1983b) studies. Data from other recent unpublished studies on the status and distribution of kit fox in the north will also be presented (Bio-Tech 1983, Jones and Stokes 1983, BSAI 1983-1985).

STUDY AREA AND METHODS

The Los Vaqueros Reservoir and Bethany study sites are located in eastern Conta Costa and Alameda counties and cover approximately 300 square km (Fig. 1). This area, situated near the Altamont Pass between the northwest corner of the San Joaquin Valley and Mount Diablo, represents the northern extreme of the accepted range for kit fox.

Survey techniques included literature searches, landowner interviews, daytime ground surveys, scent station monitoring, night spotlighting, and live-trapping. The latter two activities comprised the primary field efforts. Spotlighting surveys comprised 35 nights of effort over a 22-month period commencing in February 1981. Live-trapping for kit fox began in October 1981 and consisted of 2,265 trap nights over a 1 year period.

All captured kit fox were radio-collared and monitored for 18 months, allowing preliminary determination of den use and characteristics, dispersal patterns, mortality rates, and habitat requirements. Data on den locations, characteristics, and use were gathered primarily by locating radio-collared kit fox at their dens. In addition, forty kit fox scats were collected at active dens and analyzed to obtain food habits information. Samples were stratified by seasons with a minimum of one sample per month.

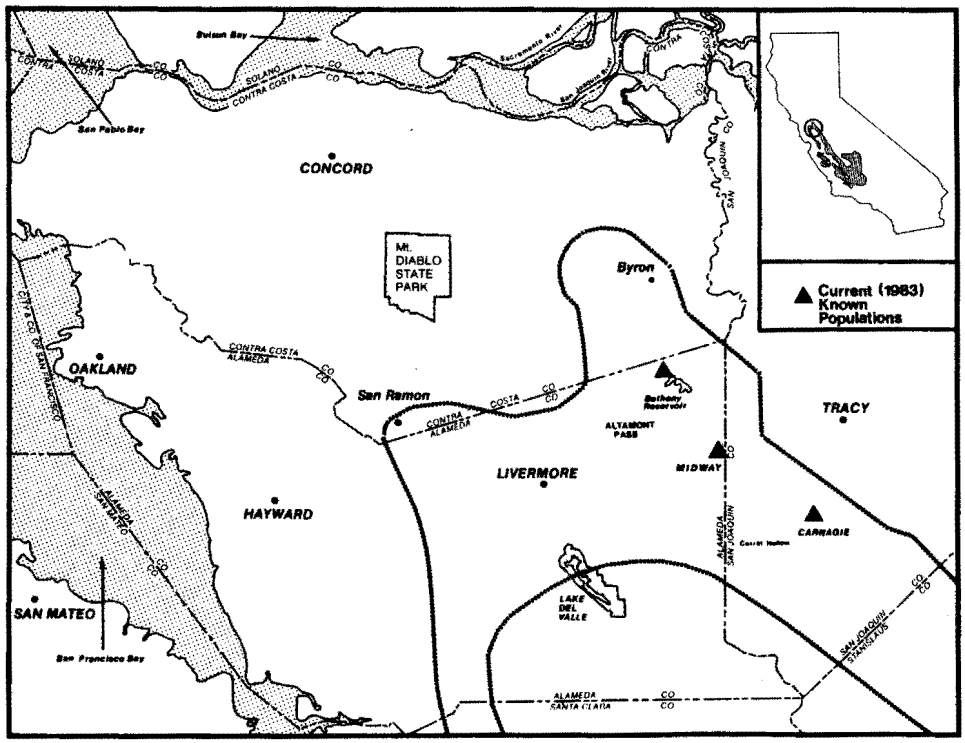

Fig 1. Northern distribution of San Joaquin kit fox in 1975 (after O'Farrell 1983, adopted from Morrell 1975).

Kit fox location records derived from these studies were compared to distribution records reported by Swick (1973a). Distribution changes were analyzed in relation to habitat changes since 1973. Details of all survey and analysis methods employed are described in CDFG (1983a,b).

RESULTS AND DISCUSSION

Historical.--Historically, the San Joaquin kit fox was reported to occur throughout the semi-arid habitats of California's Central Valley and adjacent low foothills from Kern County to as far north as Tracy in San Joaquin County. By the 1930's, wildlife authorities believed the original range had been reduced to the southern and western parts of the Central Valley (Grinnell et al. 1937).

Surveys in the 1970's extended the known distribution of kit fox into portions of their former original range, most notably in the northern San Joaquin Valley (Laughrin 1970, Jensen 1972, Swick 1973a, Waithman 1974, Morrell 1975). While Jensen (1972) was the first to document the occurrence of kit fox as far north as Byron in Contra Costa County, Swick (1973a) specified areas inhabited by kit fox in the northern counties of Contra Costa, Alameda and San Joaquin. Kit fox were also reported to occur in three counties not historically considered part of their range: Monterey and Santa Clara (Jensen 1972), and Santa Barbara (Waithman 1974). Thus, the only portion of their original range unoccupied by kit fox appeared to be the northeastern section of the San Joaquin Valley floor, an area of extensive agricultural developments.

Without reliable historical information on kit fox range, it is very difficult to determine whether they have always occupied certain areas without being noted, or whether apparent range changes represent true extensions resulting from changing land use practices. Laughrin (1970) was the first to postulate that as kit fox were eliminated from their traditional range on the valley floor, populations may have increased in some adjacent foothills and coastal range valleys.

Morrell (1975) confirmed the occurrence of kit fox in 14 counties of California,

including Contra Costa, Alameda, and San Joaquin, and updated and delineated the subspecies' known range. Morrell's 1975 distribution map was later adopted as the existing kit fox range in the 1983 San Joaquin Kit Fox Recovery Plan (O'Farrell 1983).

Current.--The LVR (CDFG 1983a) and Bethany (CDFG 1983b) studies reconfirm the occurrence of kit fox in Alameda County. Eight kit fox were captured and radio-collared near the Bethany Reservoir in the northeastern portion of the county (Fig. 1). This population currently represents the northernmost known occurrence of the subspecies in California.

Study efforts were unable to document the present occurrence of kit fox populations in Contra Costa County (CDFG 1983a,b). Moreover, other recent studies conducted in Contra Costa County were also unsuccessful at finding evidence of kit fox occurrence. These studies included 15 surveys for proposed wind turbine generating developments (windfarms) (BSAI 1983-85) and an intensive field survey at Camp Parks Army Base near San Ramon (Jones and Stokes Associates 1983). Field techniques employed during the windfarm and Camp Parks studies were limited to daytime ground surveys, scent station monitoring, and night spotlighting.

The LVR (CDFG 1983a) and Bethany (CDFG 1983b) studies together with the windfarm (BSAI 1983-85) and Camp Parks surveys (Jones and Stokes 1983) encompassed the entire unurbanized area identified by previous authors (Swick 1983a, Morrell 1975, O'Farrell 1983) as kit fox range in Contra Costa County. Comparison of recent distribution records from Bethany (CDFG 1983b) with those from Swick (1973a) indicate that a significant reduction in kit fox range has probably occurred in Conta Costa County since 1973. Factors that may have contributed to this reduction are discussed below under potential impacts.

Recent sightings of kit fox during field surveys at Carnegie New Town, in northwestern San Joaquin County (Bio-Tech 1983), and near Midway substation on the San Joaquin and Alameda county border (S. Orloff, unpublished data), represent the nearest known neighboring populations to that at Bethany (Fig. 1). Locations of the Carnegie sightings correspond to those reported by Swick (1973a) and reconfirm the distribution of kit fox in San Joaquin County. Whether the Bethany kit fox population is contiguous with the Carnegie and Midway populations is uncertain. Almost all the Altamont Pass area of Alameda County has good to excellent kit fox habitat, although no other occurrence has been recently confirmed within this area. Our research indicates that populations might be very sparse through this area and consequently additional occurrences will be undoubtedly very difficult to confirm.

HABITAT

The Bethany as well as the Carnegie and Midway kit fox populations inhabit California annual grasslands on low rolling hills. Elevation of this habitat type ranges from 73 m to 244 m for the Bethany area, 85 m to 395 m for Carnegie, and 100 m to 150 m for Midway. Livestock grazing has been the primary land use in these areas for over 150 years. All three sites are fairly isolated from human activities and are located at least 8 km from heavy development. For a more complete discussion of habitat characteristics and plant associations in these areas, refer to CDFG (1983a,b), and Bio-Tech 1983).

In contrast to most of the San Joaquin kit fox range (O'Farrell 1983), the Bethany, Carnegie, and Midway habitats have higher precipitation, steeper slopes (up to 40 degrees), and denser soils. The soils at these three sites are generally hard-packed clays or clay loams. Kit fox, however, are most typically associated with loose-textured soils and are thought to be absent or scarce in areas with hardpans (Morrell 1975).

DENNING

Fifty-one kit fox dens, including one natal den, were used by the eight kit foxes monitored during the Bethany study (CDFG 1983b). Seven of these kit fox were members of the same family group. The number of dens used by just members of the family group was 43. Maximum number of dens used by an individual fox was 23. Denning was concentrated within an area of approximately 150 ha, however, the adult male occasionally used dens over 2 km from the main denning area.

Kit fox dens were situated at elevations and on slopes representative of the Bethany study area, ranging from 80 m to 120 m in elevation and 2% to 14% slope. Over 90% of the dens were located on the lower part of the slope. Den entrances typically faced at least 90 degrees away from strong prevailing southwest winds. Diameter of den openings varied from 15 to 24 cm, a size range slightly smaller than in the south (Morrell 1971, O'Farrell 1983). Although entrances to California

ground squirrel (Spermophilus beecheyi) burrows are generally smaller than 15 cm, they sometimes overlapped in size with those of kit fox dens.

No evidence was found that kit fox in the Bethany study area construct their own dens. Most dens appeared to have been constructed by ground squirrels. Kit fox are reputedly poor diggers (Laughrin 1970, Jensen 1972, Morrell 1972), and the highclay content of most soils in the Altamont Pass area would probably preclude kit fox from digging dens in this area. However, they are capable of enlarging dens previously built by other animals. Our research concurs with both Jensen's (1972) and Morrell's (1972) findings that kit fox frequently use and modify burrows built by rodents and other animals. Morrell (1972) speculates that badgers digging for ground squirrels break through the shallow hardpan layer of some soils and thus make it easier for kit fox to excavate the earth beneath. Kit fox at the Bethany site were also found to occupy man-made structures, such as culverts.

During the Bethany study, kit fox signs (tracks, scats, or prey remains) were found at only 30% of the recently active dens surveyed in the spring and summer. Scats were found more often than prey remains. Ground squirrel tail-tips were the most commonly found prey remain. No tracks were found at den sites during the surveys and very few were discovered at active dens (i.e., recently used by kit fox) on other occasions. In addition, kit fox dens in the Bethany area generally lacked the characteristic dirt ramp often found at the entrances of those in the southern range (Morrell 1971, O'Farrell 1983). Other recent studies in areas of known occurrence in the north also found no evidence of dirt ramps at suspected kit fox dens (Bio-Tech 1983, S. Orloff, unpublished data).

The low percentage of recently occupied dens showing evidence of prior use, and the lack of characteristic dirt ramps, make it very difficult to locate and positively identify active kit fox dens in this part of the range. An abundance of other burrowing grassland animals, particularly ground squirrels, further complicates the problems associated with accurate identification of dens. Ground squirrel pellets were present at most active dens, indicating that ground squirrels and kit foxes alternately used the same den.

This problem of den identification was exemplified during the Bethany study. Preconstruction ground surveys located 38 potential dens (a potential den is defined as a burrow that is of appropriate size and shape for kit fox). None of these 38 dens were subsequently used by collared kit fox. However, six previously undetected dens, located by following radio-collared foxes, were inhabited.

FOOD HABITS

California ground squirrel was the most common prey item by both frequency (85%) and volume (52%) found in the 40 scatscollected during the Bethany study (CDFG 1983b) (Table 1). Insects were the next most common prey item, particularly in the fall. Other major food items included lagomorphs and cricetid rodents.

Most studies have reported kangaroo rats (Dipodomys ssp.) and lagomorphs to be the major food items of the San Joaquin kit fox (Grinnell et al. 1937, Laughrin 1970, Jensen 1972, Morrell 1972, Knapp 1978). At the Bethany study site no kangaroo rats were observed or trapped and no evidence of this group was found in any scats or prey remains.

The abundance of California ground squirrel remains encountered in the food habits analysis presents an anomaly. While ground squirrels are diurnally active mammals, kit fox have been reported to be nocturnal hunters (Grinnell et al. 1937, Morrell 1972). During the Bethany study observations of diurnal foraging and captures of prey species (almost exclusively ground squirrels) by kit fox were fairly common in the late spring and early summer afternoons. Only the adult male parent was actually observed capturing prey.

During the Bethany study the female parent was struck and killed by a vehicle one month after giving birth. The five pups were already weaned, and the male parent assumed care and feeding responsibilities. The parent's diurnal hunting was first considered a response to being the only provider for the young. However, scat analysis indicated that ground squirrels continued to be an important food item for all kit foxes in all seasons, even though diurnal prey captures were not documented during other times of the year. It is also possible that kit fox are somehow extracting ground squirrels from their burrows at night.

The Carnegie New Town study also indicated that California ground squirrels were an important food item. They were the most common prey remains found at dens (Bio-Tech 1983). Another study, conducted at Camp Roberts in the southern range, showed that California ground squirrels were an important prey item for San Joaquin kit fox, even in an area where kangaroo

Table 1. Relative frequency of occurrence and percent volume of prey remains in San Joaquin kit fox scat from the Bethany study area, Alameda County, California.

	Winter N = 10		Spring N = 10		Summer N = 10		Fall N = 10		Average N = 40	
	% freq occ	% by vol	% freq occ	% by vol	% freq occ	% by vol	% freq occ	% by vol	% freq occ	% by vol
Vegetation										
Unidentifiable grasses (Poaceae)	--	--	10	Tr	--	--	--	--	3	Tr
Unidentifiable vegetation	90	<1	70	<1	90	4	70	<1	80	1
Insects										
Jerusalem cricket (Gryllacrididae)	30	27	30	1	--	--	50	20	28	12
Hister beetle (Histeridae)	--	--	10	<1	--	--	--	--	3	<1
Coleopteran beetle (Coleoptera)	--	--	10	<1	--	--	10	Tr	5	<1
Unidentifiable insects	30	<1	30	--	60	<1	20	4	35	1
Reptiles										
Western fence lizard (Sceloporus occidentalis)	10	Tr	40	Tr	--	--	--	--	13	Tr
Unidentifiable snake	--	--	--	--	10	<1	--	--	3	<1
Unidentidiable reptiles	--	--	10	1	--	--	--	--	3	<1
Birds										
Unidentifiable birds	20	2	10	1	10	<1	20	10	15	3
Mammals										
Desert cottontail (Sylvilagus audubonii)	--	--	--	--	--	--	10	1	3	<1
Rabbits (Leporidae)	10	3	30	5	10	Tr	20	5	18	3
California ground squirrel (Spermophilus beecheyi)	80	35	100	62	100	83	60	27	85	52
California pocket mouse (Perognathus californicus	--	--	--	--	10	2	--	--	3	<1
Pocket mice (Perognathus sp.)	10	2	30	5	10	<1	50	13	25	5
Western harvest mouse (Reithrodontomys megalotis)	40	17	40	10	--	--	30	7	28	8
Peromyscus sp.	50	13	40	11	10	5	20	9	30	10
Unidentifiable crecitid rodents (Cricetidae)	--	--	--	--	30	4	10	5	10	2
Miscellaneous	70	2	90	5	50	2	20	Tr	58	2

rats were also abundant (Balestreri 1981). A third study, of kit fox in Arizona (Vulpes macrotis arsipus) showed that theydepended upon diurnal ground squirrels for prey when nocturnal rodent populations were low (Fisher 1981).

The San Joaquin kit foxes' apparent preference for ground squirrels in certain parts of their range suggests the possibility that both the abundance and the relatively large size of ground squirrels make them the most economical in terms of the energetics of capture. Although kit fox tend to be opportunistic feeders (Laughrin 1973, Morrell 1972, Fisher 1982), they do not always demonstrate the adaptability to prey on diurnal species. Egoscue (1975) found no evidence that kit fox in Utah (Vulpes macrotis nevadensis) exploited an abundant ground squirrel population when primary prey species declined.

JUVENILE DISPERSAL AND DENNING

Information on dispersal of juvenile kit foxes in the Bethany study was generally based on diurnal denning and mortality location records. As juvenile kit fox became older they tended to disperse to den sites farther from the natal den. Until the pups were about 5 months old, they usually denned less than 1 km from the natal den. The maximum distance any juvenile denned from its birthplace was about 1.4 km. The longest surviving male pup (8 months) was found dead above ground 7.7 km from the natal den.

As radio-collared juvenile foxes dispersed, individuals often shared dens with one or more other sibling juvenile foxes. Den sharing decreased as juveniles became more independent, and juveniles surviving the longest tended to den independently rather than with siblings. The male parent shared dens with one or more juveniles only 7% of the time (4 out of 56 den location records). However, until the pups were 6 months old, he generally occupied dens less than 5 meters from them. Behavioral observations suggested that his dens were separate and not just another entrance to the pups' den.

MORTALITY

Mortality rates for five juveniles and three adult kit foxes over the 18 months of the Bethany study were 80% and 67%, respectively. For juveniles this rate was consistent with O'Farrell's (1984) findings in the southern portion of the kit fox range.

Cause of death was determined for two of the six kit fox mortalities. The adult female was struck and killed by a vehicle, and one male pup was killed by a large canid, probably a coyote. The other four carcasses were too decomposed and scavenged to determine cause of death. However, coyotes appear to be the most likely cause. All kit fox suspected of having been killed by coyotes were found above ground at least 1/3 km from any known fox den. Without a nearby den to escape into, kit fox are probably more vulnerable to coyote predation.

Despite 2 years of intensive observation, trapping and monitoring at both the Los Vaqueros and Bethany sites, by mid-1983 only two San Joaquin kit foxes were known to survive in this area. Both of these foxes were females, and neither produced pups in 1983.

POTENTIAL IMPACTS

Cattle Grazing.--Livestock grazing has been the primary land use in the Altamont Pass and Carnegie areas for over 150 years. Most authors believe that grazing is not detrimental to kit fox (Laughrin 1979, Jensen 1972, Morrell 1975). Some authors have speculated that heavy grazing can increase the suitability of the habitat for prey species (Laughrin 1970, Balestreri 1981). Jensen (1972) speculated that where there is light to no grazing, and grasses are consequently high, rodent activity and prey availability decrease. Heavy grazing may have also contributed to the range extension of kit fox from the San Joaquin Valley into some of the adjacent valleys and foothills (Jensen 1972).

Indirect and long-term effects of overgrazing on foxes are not well understood. Some authors believe that moderate to heavy grazing may lower densities of some important prey species (O'Farrell et al. 1980, O'Farrell and McCue 1981). O'Farrell (1983) speculated that traditional prey species such as kangaroo rats and pocket mice which feed primarily on seeds compete with livestock for food. Excessive grazing can therefore shift the composition of small mammal communities, decreasing primarily granivorous species and increasing such species as the California ground squirrel, which can exist on a greater variety of food items. Indeed, studies have shown that moderate to heavy grazing generally leads to an increase in ground squirrel populations (Jones and Stokes 1977).

Although this shift in prey species may be detrimental to kit foxes in parts of their southern range, where ground squirrels are not an important food item

(Hawbecker 1943, Morrell 1972, O'Farrell 1983), kit foxes in the northern extreme of their range seem to have adapted readily to the rodent composition normally associated with excessive grazing. In fact, without ground squirrels to provide an adequate prey base and suitable dens, many sections of their northern range might be unsuitable for kit fox. Consequently, grazing practices that maintain abundant ground squirrel populations appear to be beneficial to kit fox in this northern region.

Agricultural Development.--The greatest cause in the decline of San Joaquin kit fox populations has been the loss of habitat to agricultural development in the San Joaquin Valley (O'Farrell 1983). Kit fox do not adapt readily to most agricultural land practices. While some types of agriculture allow for marginal populations, intensively irrigated areas are apparently totally devoid of kit fox (Jensen 1973, Morrell 1975).

Present agricultural use in the Altamont Pass consists solely of some dry land wheat farming. Jensen (1972) found that kit fox can exist successfully adjacent to dry land agricultural areas. As long as areas under dry land cultivation are kept to a minimum, the current fox populations do not appear to be threatened. Although irrigated agriculture is not currently practiced in the Altamont area, several major aqueducts bring substantial amounts of water to this area and could pose future concern.

Ground Squirrel Poisoning.--The effects of rodent control programs on kit fox are difficult to evaluate and subject to controversy. Compound 1080 (sodium monofluoroacetate) is one of the most potent and widely used poisons for rodent control. While some reports indicate that proper application of compound 1080 for ground squirrel control has caused no observable detrimental effects on kit fox populations (Swick 1973b, Wallace 1976), other field studies have shown that ground squirrel poisoning programs kill individual carnivores (Hegdal et al. 1986). Laboratory studies by the U.S. Fish and Wildlife Service indicated that ground squirrels typically consume several times the lethal dose of 1980 for kit fox before dying themselves (Schitoskey 1975). Morrell (1975) postulated that although individual kit foxes may die from consuming poisoned ground squirrels, the total kit fox population is not threatened by these rodent control programs.

Because survival of kit foxes in the north apparently depends heavily on the presence of California ground squirrels, the effects of long-term poisoning could be much more significant there than in the south. Kit fox utilization of ground squirrels as a principal prey species increases their susceptibility to secondary poisoning, especially since they have been shown to consume carrion (Laughrin 1970, Morrell 1972) and even poisoned bait that coyotes ignore (Cahalane 1947). Thus, after poisoning campaigns, foxes could eat surface-killed rodents and also feed poisoned carcasses to their young (Schitoskey 1975). Furthermore, large scale poisoning campaigns can drastically reduce the kit fox prey base.

Approximately 20 years ago, Contra Costa County mounted an intensive ground squirrel eradication program, using compound 1080, that left most of the county virtually devoid of ground squirrels. By 1972 these rodent populations were so reduced that the use of 1080 was stopped. Nonetheless, the eradication program continued using other types of poisons until 1978, when efforts were sharply diminished. Results of this long-term campaign are still obvious as evidenced by a noticeable increase in ground squirrel numbers near the border of Alameda County, which has conducted relatively little rodent control.

Our field observations suggest the probability that long-term use of ground squirrel poisons severely reduced kit fox populations in Contra Costa County through secondary poisoning and greatly suppressing populations of primary prey species. Habitat potential for kit fox is currently very poor. Both the prey base and denning sites have been greatly reduced in the county. Current poisoning programs in Contra Costa County are limited in scope and rarely use 1080. The majority of poisons used are anticoagulant types that are less injurious to canids. With time the areas' potential to support kit fox should improve.

Competition With Other Canids.--In the extreme northern range, kit fox live in close proximity to three other canids: gray fox, red fox, and coyote (Hall 1983). Interspecific dominance and displacement interactions occur when different species of North American canids coexist (Murie 1944, Young and Jackson 1951, Mech 1970). The dominance status among these species is usually based on size, resulting in a hierarchy in which kit fox are subordinate to larger canids. Coyotes are a primary cause of kit fox mortality in many parts of their range (Grinnell et al. 1937, Knapp 1978, O'Farrell 1983,1984).

Coyote populations appear to be increasing in Alameda and Contra Costa counties since the early 1970's when the use of compound 1080 was greatly curtailed for ground squirrel control by the local counties. Red fox were first noticed in the LVR study area in 1970, and they appear to be slowly expanding their range southward. This red fox population probably represent the southern expansion of the Sacramento Valley population. Red fox currently occupy portions of the LVR study area that were previously inhabited by kit fox in the 1970's (Swick 1973a). Kit fox populations are now believed to have been extirpated from these areas (CDFG 1983a). Red fox were also sighted at the Carnegie study site adjacent to areas associated with kit fox (Bio-Tech 1983). Southward expansion of red fox and increased numbers of coyote may be having a serious detrimental impact on kit fox in the northern limits of their range.

Windfarm Development.--Wind turbine generating developments (windfarms) in Alameda and Contra Costa counties have grown tremendously in recent years. Over 80 square kilometers of contiguous windfarm development now exists in the Altamont Pass area, and the amount of land under development continues to grow. The counties of Alameda, Contra Costa, and San Joaquin categorize this land use under agriculture. Applicants for county land use permits must conduct surveys for threatened and endangered species. No other biological assessment is required by the counties.

Considerably less than the total acreage of a windfarm project is actually disturbed during windfarm construction. The area disturbed varies according to terrain, construction methods, and types of wind turbine. Individual turbine pad sizes typically range from about 40 to 800 square meters, but larger areas are usually disturbed during construction. Other construction features such as access roads, underground conduits, and power-substations also cause habitat loss or disturbance. An average windfarm with 150 turbines on one square mile (1.6 square kilometers) would eliminate approximately 18 ha habitat (7% of project area). Total acreage typically disturbed by windfarm development ranges from approximately 10% to 50% of the project area.

The primary threat to kit fox is probably not from the actual habitat loss which is relatively minimal but from the destruction of active or potential dens. O'Farrell (1983) states in the Kit Fox Recovery Plan that, "Given an adequate prey base, San Joaquin kit fox appear to be adaptable to human activities that do not severely diminish the number of denning sites." Although turbines are generally located on ridgetops away from most dens, other construction features such as roads are typically located on lower slopes and drainages, which are prime kit fox denning areas. In addition, the operation of heavy machinery can cause nearby dens to cave in (Knapp 1978, Morrell 1975).

Mitigation measures that have been suggested in the threatened and endangered species surveys include establishing an undisturbed buffer zone (50 feet to 300 feet) around all potential and active or natal dens (BSAI 1983-1985). These buffer zones are probably adequate to protect dens from direct physical disturbances. However, as demonstrated in the Bethany study (CDFG 1983b), it is unlikely that all dens would be located during pre-construction surveys. In addition, these buffer zones offer uncertain protection to foxes against the indirect effects of human and operational disturbances. For instance, low-level noise and ground vibrations from wind turbine operation may have an adverse effect on local prey species.

During the Bethany wind turbine study, the number of occupied kit fox dens unexpectedly increased in the construction zones after construction started. Several factors may account for this observation. Numbers of ground squirrels and cottontails appeared to increase, presumably in response to additional cover created by construction equipment. Construction activities may also have displaced coyotes, allowing kit fox to more readily exploit local prey species. In addition, food left by construction workers seemed to attract foraging kit fox into the construction zone at night. Foraging and denning within construction zones exposes kit fox to construction-related hazards, such a falling into excavations or being buried in dens. Mitigation measures normally recommended for these impacts include requesting workers to properly dispose of their garbage and requiring that large open holes be covered at the end of each work day.

One important windfarm-related threat that is often overlooked is the potential development of subdivisions in areas now occupied by wind turbines. Turbine pads provide suitable building sites, road networks are already established, and electricity is readily available. With recent cuts in federal tax credits previously available to investors, smaller

windfarm companies may go bankrupt and the ranchers, often financially burdened already, would lose subsidies earned from leasing their lands. Consequently, conditions may then shift in favor of subdivision development.

Development of an individual windfarm site typically poses minimal threat to most wildlife, provided that appropriate mitigation measures are followed. Available data suggest that the Bethany wind turbine development has had no significant negative impact on kit fox in that area. However, long-term impacts of extensive development on this sparse population cannot be predicted without further research. Knapp (1978) has shown that local extirpation of isolated kit fox populations can go unnoticed. Although San Joaquin kit fox may coexist with many human activities throughout their range, their densities have been significantly reduced by long-term oil developments in the southern San Joaquin Valley (O'Farrell 1984), which produce impacts comparable to those of windfarm developments.

Suburban Encroachment.--Through the 1970's, suburban encroachments, including light industry and subdivisions, have gradually reduced preferred kit fox habitats in Contra Costa County. Subdivision, in particular, was probably one of the major factors in eliminating kit fox from sections of their northern range. The main threat from small isolated subdivisions is not so much the actual loss of habitat as the indirect effects of human presence, such as illegal shooting and predation on kit fox by domestic dogs. The potential for road kills also increases greatly near subdivisions. Road kills represent a major source of kit fox mortality in many portions of their range (Morrell 1975, O'Farrell 1983).

No major subdivisions have been constructed for several years within the northernmost range of kit fox. However, two large developments were recently proposed: Bankhead, to be located 10 km west of Bethany Reservoir in Contra Costa County, and Carnegie New Town in the southwestern portion of San Joaquin County. The northeastern portion of kit fox range is narrowly compressed between valley floor agricultural lands and Coast Range foothills. Genetic exchange with populations to the south probably depends on a contiguous kit fox range along this narrow strip of habitat. Development of large subdivisions, such as Carnegie New Town, along this strip of land could isolate the Altamont kit fox population, as well as eliminate kit foxes from the immediate area.

CONCLUSIONS

Major factors limiting the distribution of kit fox in the northern portion of their range include: inadequate prey base, unavailability of den sites, and competitive exclusion and predation by other canids, particularly coyotes.

In their northern range, kit fox appear heavily dependent on California ground squirrels, which provide the principal source of both food and dens. Because of the intense competition from coyotes and other predators, kit fox likely require abundant den sites for escape cover. Maintenance of this prey species may therefore be an essential factor in providing suitable habitat for kit fox in this region.

Our research suggests that kit fox have been extirpated within the last 10 years from their original range in Contra Costa County. We believe this range reduction is due primarily to an intensive ground squirrel eradication program. Both the prey base and the denning sites have been drastically reduced in the county. Since the intensive poisoning campaigns have been discontinued, populations of ground squirrels have started to increase, and with them, the area's potential to support kit fox.

The Altamont Pass area of Alameda County is ecologically well suited to support kit fox, as prey species and denning sites are both abundant. However, kit fox populations here are experiencing intense environmental pressure from both man-made developments and increased interspecific competition. Evidence suggests a gradual decline of an already sparse kit fox population in this increasingly disturbed area. The prognosis for continued survival of San Joaquin kit fox in their northernmost range is not very favorable.

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