INTRODUCTION OF NON-NATIVE RED FOXES IN CALIFORNIA: IMPLICATIONS FOR THE SIERRA NEVADA RED FOX

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ABSTRACT: The range of the threatened Sierra Nevada red fox (*Vulpes vulpes necator*) encompasses high-elevation habitats of the Sierra Nevada and the Cascade Range of California. Since the late 1800's non-native red foxes were introduced into California for fur farming and fox hunting. From the 1920's to the 1940's, at least six fox farms occurred within the historical range of the Sierra Nevada red fox and more occurred near the margin of its range. Three fox farms also occurred in an area where observations of Sierra Nevada red foxes were reported most often. It was not uncommon for farm foxes to escape or to be released. We are uncertain whether non-native red foxes have interbred with Sierra Nevada red foxes. While data to test for interbreeding can be acquired, an investigation of genetic traits of foxes within the historical range might not be feasible.

Key words: California, fox farms, interbreeding, non-native red foxes, Sierra Nevada red fox, *Vulpes vulpes necator*.

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In California, the range of the native Sierra Nevada red fox (*Vulpes vulpes necator*) encompasses high-elevation habitats (above 4000') in the Sierra Nevada and Cascade Ranges (Grinnell et al. 1937). Relatively little is known about this fox. Sources of information include mammal surveys (Grinnell 1933, Grinnell et al. 1937), trapping data (Calif. Dept. Fish and Game, unpubl. data), reports of observations (Schempf and White 1977, Kucera 1995), and museum specimens. In recent decades, reports of Sierra Nevada red foxes have been rare (Kucera 1995). To protect the remaining fox population, the California Legislature closed the commercial trapping season in 1974 and the California Fish and Game Commission listed this subspecies as a threatened mammal in 1980.

Grinnell et al. (1937) also described a population of red foxes in the upper Sacramento Valley, which they suspected were introduced by humans in the late 1800's. Using morphological measures, Roest (1977) concluded that these valley red foxes were more closely related to midwestern red foxes (*V. v. regalis*) than to Sierra Nevada red foxes.

The distribution of red foxes outside the historical range of the Sierra Nevada red fox has expanded (Gray 1975, 1977, Gould 1980, Lewis et al. 1993) since it was described by Grinnell et al. (1937). Non-native red foxes now occupy many of the lowland areas of California (Lewis et al. 1993). However, because there are no reliable means to visually distinguish non-native red foxes from native Sierra Nevada red foxes, it has not been possible to determine from sighting records whether non-native red foxes were also introduced into the historical range of the Sierra Nevada red fox.

We use historical data, recent research findings, and literature to describe the introduction of non-native red foxes into California, with an emphasis on introductions that may have occurred within the historical range of the Sierra Nevada red fox. We also discuss the possibility that introduction of non-native red foxes within the historical range resulted in interbreeding and competition with, and disease transmission to, the native Sierra Nevada red fox, and evaluate the feasibility of investigating these interactions.

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NON-NATIVE RED FOX INTRODUCTION

Red foxes were probably introduced into the Sacramento Valley of California prior to 1885 (Grinnell 1933). Roest (1977) suggested that these foxes could have been brought to California from the midwest via the Transcontinental Railroad, completed in 1869. By 1900, California

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was well connected to the rest of the country via railroads, and railroads extended widely throughout the State (McAfee 1973). Like many other commodities brought to California prior to the 1900's, red foxes were probably brought by rail from a number of places and for various reasons.

In 1905, five red foxes from Missouri were brought to Orange County to provide game for fox hunters (Sleeper 1987). By 1919, 30 descendants of the original five had been released. In the late 1860's and early 1870's a variety of methods were being devised to control ground squirrels (*Spermophilus beecheyi*) in California (Jacobsen 1918), and it is conceivable that red foxes were released to control agricultural pests. Similarly, non-native red foxes were introduced to San Juan Island, Washington in 1947 to control a population of European rabbits (*Oryctolagus cuniculus*) (Schoen 1972).

Other means of red fox introduction include releases and escapes from fox farms (Aubry 1984), from transporting vehicles (Whitlow and Hall 1933), and from captivity as pets. Also, captured non-native foxes were further translocated by people (Estrada 1989).

Fox Farms in California

Fox farming was probably a major contributor to the introductions of non-native red foxes in California. Commercial fox farms were established in California around 1920 (USDA 1922, Ashbrook 1923, Anon. 1926). By 1930, there were at least 58 fox farms in California (Anon. 1930), and approximately 125 by 1942 (Vail 1942). These farms were widely distributed (Fig. 1). Although silver foxes (red foxes exhibiting a silver and black fur coloration) were the predominant color phase raised for pelt production, red fox and cross fox color phases existed on these farms.

Fox farming originated on Prince Edward Island, Canada in the late 1890's, where wild red foxes were imported from nearly every province in Canada for breeding stock (Ashbrook 1923). Because one of the first fox farmers in California previously owned a number of fox farms in Minnesota (Anon. 1926), we assume he brought his breeding stock with him from Minnesota. Many of California's fox farmers, especially the early ones, probably imported breeding stock from existing farms in other states or Canada.

Although some fox farms had elaborate facilities to prevent the escape or theft of foxes (Dearborn 1915, Ashbrook 1923), escapes and releases from fox farms were not uncommon (Aubry 1984). Consequently, a special trap was designed by the U. S. Department of Agriculture for the injury-free capture of escaped farm foxes (Bassett 1939).

At least six fox farms were identified from CDFG files as occurring within the historical range of the Sierra Nevada red fox (Fig. 1), and a number of other farms were within the dispersal distance for a red fox. Mean dispersal distances for rural red fox males were 43 km (Storm et al. 1976 as calculated by Trewhella et al. 1988), but red foxes have dispersed distances exceeding 200 km (Longley 1962, Ables 1965, Storm et al. 1976). In addition to known fox farms, dispersal of non-native red foxes from outside the historical range should be considered as potentially affecting the Sierra Nevada red fox.

Schempf and White (1977) compiled records of Sierra Nevada red foxes and found the largest group occurred in the vicinity of Lassen National Park. There were fox farms in three towns in this part of the historical range during the 1930's and 1940's: Chester, Westwood, and Almanor. In addition, Susanville, located approximately 48 km east of Lassen National Park, had at least five fox farms.

In 1989, wildlife rehabilitators released two non-native red foxes from Orange County into the Sierra Nevada red fox range at Sequoia National Park (Estrada 1989), approximately 290 air-kilometers to the north of where the foxes were acquired.

RESEARCH NEEDS FOR THE SIERRA NEVADA RED FOX

Non-native red foxes may have interbred with native Sierra Nevada red foxes, and consequently introgression of

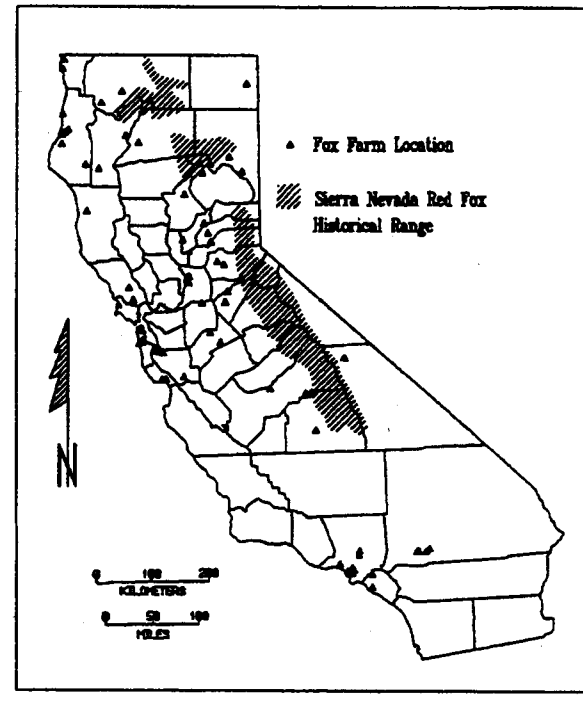

Fig. 1. Locations of known fox farms in California from the 1920's to 1940's (n = 69)(Calif. Dept. Fish and Game, unpubl. data). A few locations may represent the home address of the farm owner rather than the fox farm location.

non-native red fox traits may have occurred within the Sierra Nevada red fox population. Such introgression would bring into question whether the Sierra Nevada red fox is still a distinct subspecies (see Wayne and Jenks 1991). Its effect on the fitness of hybrid individuals is unknown.

Investigating genetic traits to assess potential interbreeding of non-native and native red foxes occurring within the historical range would require the collection of tissues (e.g., blood, organ tissue, or hair). Tissue samples could be collected from foxes presently occupying the historical range of the Sierra Nevada red fox, foxes occurring outside the historical range in California, populations elsewhere in North America, and early museum specimens of Sierra Nevada red foxes. Early specimens of Sierra Nevada red foxes exist in museums. A number of these specimens, collected from remote locations early in the 1900's (Table 1), could represent the pure stock of Sierra Nevada red fox.

Tissues from red foxes now residing in the historical range of the Sierra Nevada red fox might be obtained by recovering road-killed animals or by live-trapping for research; however, sample size will surely be a problem given the paucity of recent sightings (e.g., see Kucera 1995). We now have adequate samples of tissue from foxes occurring outside the historical range in California (> 200 foxes).

There has been no investigation to ascertain whether disease transmission and competition has occurred between non-native and native red foxes in California. However, the potential exists. For example, Davidson et al. (1992) reported the illegal translocation of parasite-infested red foxes from Ohio to South Carolina for fox hunting. Distemper, paratyphoid, and enteritis were common infectious diseases on fox farms, and parasite infestations were also common (Shillinger 1942). Dissimilarities in endoparasitic helminth fauna of non-native and native red foxes (Aubry 1983) could suggest whether the transmission of parasites and diseases had occurred. Recent data on parasites of non-native foxes has been obtained on >120 foxes (R. Golightly, unpubl. data), but adequate collections from Sierra Nevada red foxes would be unlikely.

Table 1. Museum skin specimens of the Sierra Nevada red fox collected from the 1890's and the early 1900's. Museum specimens are part of collections of the Museum of Vertebrate Zoology at the University of California, Berkeley, and the Museum of Natural History, Smithsonian Institution.

County	n	Year(s)
Lassen	1	1925
Mariposa	1	1916
Mono	7	1922-1928
Siskyou	3	1904-1934
Tulare	6	1891-1911

MANAGEMENT CONSIDERATIONS

An investigation of genetic traits of red foxes within the historical range may not provide definitive results. The rarity of the Sierra Nevada red fox would make it difficult (logistically and financially) to acquire adequate samples. Variance in genetic traits within and between populations is unknown, and therefore distinguishing between non-native and native populations may be difficult.

If introgression of non-native red fox traits had occurred within the historical range of the Sierra Nevada red fox, it would imply a threat to the genetic integrity of an already threatened species. It would be unlikely that a wildlife agency could effectively manage for the genetic integrity of the Sierra Nevada red fox. However, introduction of non-native foxes does not automatically imply that interbreeding took place. Aubry (1984) found that non-native red foxes introduced to low elevation sites of the Olympic Peninsula, Washington had not invaded nearby high-elevation habitats. If testing revealed that introgression had not occurred, then the prevention of future introductions and invasions would become a management task of renewed importance.

It is unlikely that adequate samples would be available from native foxes to test the effects of disease transmission from non-native red foxes. Further, the co-occurrence of diseases or parasites would not conclusively indicate that disease transmission occurred between native and non-native foxes. While an investigation into the molecular genetics as outlined would be difficult, it may be the most logical and appropriate step in developing management strategies for the Sierra Nevada red fox.

LITERATURE CITED

Ables, E. D. 1965. An exceptional fox movement. J. Mamm. 46:102.

Anonymous. 1926. A unique fox ranch. Amer. Game 15(3):58.

_____. 1930. Agricultural news - northern California. Calif. Cultivator. Page 396. April 5, 1930.

Ashbrook, F. G. 1923. Silver fox farming. U. S. Dept. Agric., Dep. Bull. No. 1151. 59pp.

Aubry, K. B. 1983. The Cascade red fox: distribution, morphology, zoogeography and ecology. Ph.D. Dissertation. Univ. Washington, Seattle, WA. 151pp.

_____, K. B. 1984. The recent history and present distribution of the red fox in Washington. Northw. Sci. 58:69-79.

Bassett, C. F. 1939. An efficient trap for the fox ranch. U. S. Dept. Agric., Bur. Biol. Surv. Wildl. Res. Manage. Leaflet BS-127. 5pp.

Davidson, W. R., M. J. Appel, G. L. Doster, O. E. Baker, and J.F. Brown. 1992. Diseases and parasites of red foxes, gray foxes, and coyotes from commercial sources selling to fox chasing enclosures. J. Wildl. Dis. 28:581-589.

Dearborn, N. 1915. Silver fox farming in eastern North America. U.S. Dept. Agric., Dep. Bull. No. 301. 35pp.

Estrada, J. 1989. Raising baby raccoons just comes with the job. Temple City Times, Temple City, CA. October 15, 1989.

Gould, G. I. 1980. Status of the red fox in California. Calif. Dept. of Fish and Game, Nongame Wildl. Invest., Job I-8, Progress Report. Sacramento, CA. 3pp.

Gray, R. L. 1975. Sacramento valley red fox survey. Calif. Dept. of Fish and Game, Nongame Wildl. Invest. Progress Report. Sacramento, CA. 6pp.

___. 1977. Extensions of red fox distribution in California. Calif. Fish and Game 63:58.

Grinnell, J. 1933. Review of recent mammal fauna of California. Univ. Calif. Publ. Zool. 40(2):71-234.

___, J. S. Dixon, and J. M. Linsdale. 1937. Fur -bearing mammals of California. Univ. of Calif. Press, Berkeley, CA. 777pp.

Jacobsen, W. C. 1918. A history of ground squirrel control in California. Calif. State Commission of Horticulture, *The Monthly Bull.* 7(11-12):129-169.

Kucera, T. E. 1995. Recent photograph of a Sierra Nevada red fox. Calif. Fish and Game 81:in press.

Lewis, J. C., K. L. Sallee, and R. T. Golightly. 1993. Introduced red fox in California. Calif. Dept. of Fish and Game, Nongame Bird and Mammal Sect. Rep. 93-10. Sacramento, CA. 70pp.

Longley, W. H. 1962. Movements of the red fox. J. Mamm. 43:107.

McAfee, W. 1973. California's railroad era, 1850-1911. Golden West Books, San Marino, CA. 256pp.

Roest, A. I. 1977. Taxonomic status of the red fox in California. Calif. Dept. Fish and Game, Nongame Wildl. Invest., Final Rep. Sacramento, CA. 15pp.

Schempf, P. F., and M. White. 1977. Status of six furbearer populations in the mountains of northern California. U. S. Dept. Agric., For. Serv., San Francisco, CA. 51pp.

Schoen, J. W. 1972. Mammals of the San Juan Archipelago: distribution and colonization of native land mammals and insularity in three populations of *Peromyscus maniculatus*. M. S. Thesis, Univ. Puget Sound, Tacoma, WA. 119pp.

Shillinger, J. E. 1942. Diseases of fur animals. Pp. 1232-1238 *In* U. S. Dep. Agric., Yearbook of Agric., 1942. U. S. Gov. Printing Office, Washington, D. C.

Sleeper, J. 1987. Bears to Briquets: A History of Irvine Park, 1897-1997. Calif. Classics, Trabuco Canyon, CA. 32pp.

Storm, G. L., R. D. Andrews, R. L. Phillips, R. A. Bishop, D. B. Siniff, and J. R. Tester. 1976. Morphology, reproduction, dispersal, and mortality of midwestern red fox populations. Wildl. Monogr. 49:82.

Trewhella, W. J., S. Harris, and F. E. McAllister. 1988. Dispersal distance, home-range size and population density in the red fox (*Vulpes vulpes*): a quantitative analysis. J. Appl. Ecol. 25:423-434.

United States Department of Agriculture. 1922. Report of the Chief of the Bureau of Biological Survey. Annu. Rep. Dept. Agric. U. S. Gov. Printing Office, Washington, D. C. 40pp.

Vail, E. L. 1942. Fox ranching in southern California. Calif. Fish and Game 28:87-88.

Wayne, R. K., and S. M. Jenks. 1991. Mitochondrial DNA analysis implying extensive hybridization of the endangered red wolf *Canis rufus*. Nature 351:565-568.

Whitlow, W. B., and E. R. Hall. 1933. Mammals of the Pocatello region of southeastern Idaho. Univ. Calif. Publ. Zool. 40:235-276.