

population estimate has been produced. Furthermore, extremely little is known about the status and ecology of gray foxes outside of the USA and Canada. The effects of gray foxes on populations of smaller vertebrates, especially in urban and suburban settings without larger predators, may be important.

Core literature

Fritzell 1987; Fritzell and Haroldson 1982; Hall 1981; Harrison 1997; Lord 1961; Trapp and Hallberg 1975.

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4.4 Island fox

***Urocyon littoralis* (Baird, 1858)**
Critically Endangered – CR:A2be+3e (2004)

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Other names

English: island gray fox, Channel Islands fox, California Channel Island fox.

Taxonomy

Vulpes littoralis Baird, 1858:143. Type locality: San Miguel Island, Santa Barbara County, California, USA [34°02'N, 120°22'W].

Urocyon is currently considered a basal genus within the Canidae and has only two surviving members, the gray fox (*U. cinereoargenteus*) and the island fox (*U. littoralis*) (Wayne *et al.* 1997). The island fox is believed to be a direct descendant of the gray fox, having reached the Channel Islands either by chance over-water dispersal or human-assisted dispersal (Collins 1991a, b). Each island population differs in genetic structure and of the five mtDNA haplotypes found in island foxes, none are shared with a nearby mainland sample of gray foxes. However, all island fox populations share a unique restriction enzyme site, clustering the populations into a single monophyletic clade (Wayne *et al.* 1991b). Population specific restriction-fragment profiles have been identified from minisatellite DNA (Gilbert *et al.* 1990), and multilocus genotypes from hypervariable microsatellite DNA were used to correctly classify 99% of 183 island/gray fox samples to their population of origin (Goldstein *et al.* 1999). The two misclassifications occurred between nearby island populations. These data clearly justify the current classification of island foxes as a separate species (Wozencraft 1993) and the subspecific classifications of the six island populations (Hall 1981; Moore and Collins 1995).

Chromosome number is identical to *U. cinereoargenteus* with 2n=66; 62 acrocentric chromosomes, a submetacentric pair and two sex chromosomes (Wayne *et al.* 1991b).

Description

Island foxes are the smallest North American canid. Males are significantly heavier than females (Moore and Collins 1995) (Table 4.4.1). The head is grey with black patches on the lateral sides of the muzzle in the vicinity of the vibrissae, with black outlining the lips of both jaws. White patches

Table 4.4.1. Body measurements for the Island fox. Measures of adult foxes were taken in 1988 for all subspecies except for San Clemente (R. Wayne unpubl.). Weight for San Clemente foxes was measured in 1988 (D. Garcelon and G. Roemer unpubl.), other measures for San Clemente foxes are from Moore and Collins (1995).

	Northern Channel Islands	Southern Channel Islands
HB male	536mm (470–585) n=44	548mm (513–590) n=28
HB female	528mm (456–578) n=50	538mm (475–634) n=30
T male	213mm (145–255) n=44	272mm (230–310) n=51
T female	202mm (115–265) n=50	248mm (180–295) n=46
HF male	111mm (94–124) n=44	112mm (104–120) n=51
HF female	107mm (95–122) n=50	107mm (92–115) n=46
E male	60mm (53–68) n=44	63mm (55–72) n=51
E female	60mm (54–67) n=50	62mm (59–67) n=46
WT male	2.0kg (1.4–2.5) n=44	2.0kg (1.4–2.5) n=51
WT female	1.8kg (1.5–2.3) n=50	1.8kg (1.3–2.4) n=46

Adult female island fox, San Miguel Island, California, USA, 1994.



Timothy J. Coonan

on the muzzle extend behind the lateral black patches to the cheek and blend into the ventral surface of the neck which is mostly white and bordered by rufous dorsally. Small white patches are present lateral to the nose. Variable degrees of white and rufous colour the chest and extend throughout the belly. The body and tail are mostly grey, with the latter having a conspicuous black stripe on the dorsal surface ending in a black tip. The grey of the body extends partially down the legs giving way to mostly rufous, both in the middle and towards the rear. On both San Clemente and San Nicolas Islands, a brown phase coat colour occurs in which the grey and black of the body are largely replaced with a sandy brown and deeper brown, respectively. It is unclear if the brown phase is a true coat colour morph, a change that occurs with age or possibly a change that occurs because of an interaction with *Opuntia* spines that get imbedded within the pelt (Sheldon 1990). Pelage is relatively short (20–40mm deep) with a single moult resulting in a thin summer coat and a dense winter coat. Eight mammae are present. Dental formula is 3/3-1/1-4/4-2/3=42. Island foxes typically have fewer caudal vertebrae, 15–22 (n=47), than the gray fox, 21–22 (n=31) (Moore and Collins 1995).

Subspecies Six subspecies are currently recognised (Moore and Collins 1995):

Northern Channel Islands

- *U. l. littoralis* (San Miguel Island, 34°02'N, 120°22'W)
- *U. l. santarosae* (Santa Rosa Island, 33°57'N, 120°10'W)
- *U. l. santacruzae* (Santa Cruz Island, 33°57'N, 119°45'W)

Southern Channel Islands

- *U. l. dickeyi* (San Nicolas Island, 33°14'N, 119°30'W)
- *U. l. clementae* (San Clemente Island, 32°52'N, 118°27'W)
- *U. l. catalinae* (Santa Catalina Island, 33°24'N, 118°24'W)

Similar species Gray fox (*Urocyon cinereoargenteus*): coloration very similar with a similar dark longitudinal stripe on top of a black-tipped tail. The gray fox also has dark and white markings on its face, and a conspicuous cinnamon-rusty colour on its neck, sides and limbs. There is also white on the gray fox's ears, throat, chest, belly and hind limbs, while the undercoat is mostly buff and grey. The gray fox is at least 30% larger than the island fox (Fritzell and Haroldson 1982).

Current distribution

The current distribution is thought to be a consequence of waif dispersal to the northern Channel Islands during the late Pleistocene, followed by Native American assisted dispersal to the southern Channel Islands (Collins 1982, 1991a, b, 1993; Wayne *et al.* 1991b; Goldstein *et al.* 1999; see also Historical perspective). The species is now

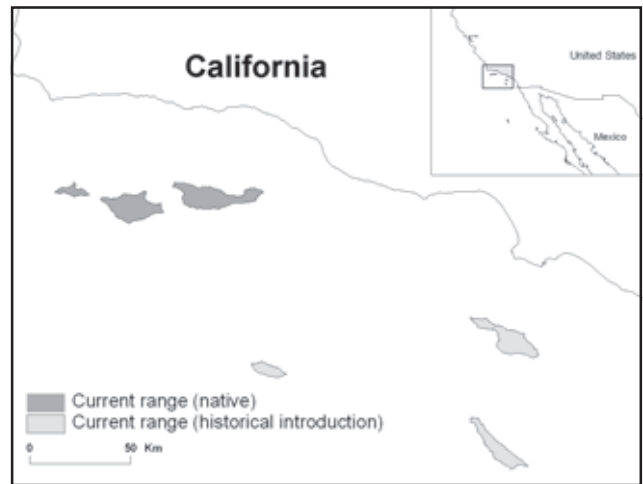


Figure 4.4.1. Current distribution of the island fox.

geographically restricted to the six largest of the eight California Channel Islands located off the coast of southern California, USA (Figure 4.4.1).

Range countries United States (Moore and Collins 1995).

Relative abundance

Island foxes exhibit substantial variability in abundance, both spatially and temporally.

Estimated population size, relative abundance and population trends Total island fox numbers have fallen from approximately 6,000 individuals (Roemer *et al.* 1994)

Figure 4.4.2. Trend in fox population size on San Clemente (SCL), Santa Cruz (SCR) and San Miguel (SMI) Islands.

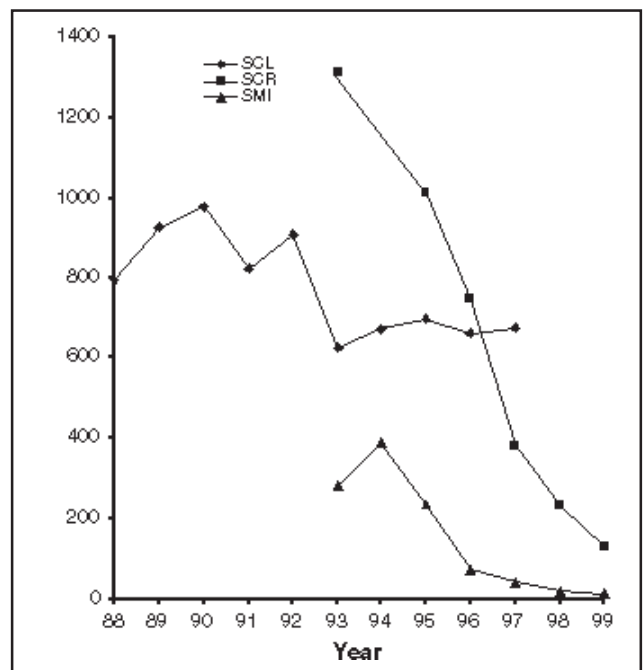


Table 4.4.2. Status of island foxes in the Channel Islands (Trend: S=stable, D=decreasing).

Island	Initial Population ¹	Protected areas		Other areas		Total	
		Population	Trend	Population	Trend	Population	Trend
San Miguel	450	28	D			28	D
Santa Rosa	?	45	D			45	D
Santa Cruz	1,312	17	D	60–80		77–97	D
San Nicolas	520			435–734	S	435–734	S
Santa Catalina	1,342	24		200	D	224	D
San Clemente	825			410	D	410	D

¹ Initial population sizes (N_0) were estimated from data collected in the mid- to late 1980s or early 1990s using a capture-recapture approach (Kovach and Dow 1981; Roemer *et al.* 1994; Garcelon 1999; Roemer 1999; Coonan *et al.* 2000). Current population sizes (N) are the best estimates for 2002 (Garcelon 1999; Roemer 1999; Coonan 2002, 2003; Coonan *et al.* 2000; Timm *et al.* 2000; Roemer and Wayne 2003; G. Smith unpubl.).

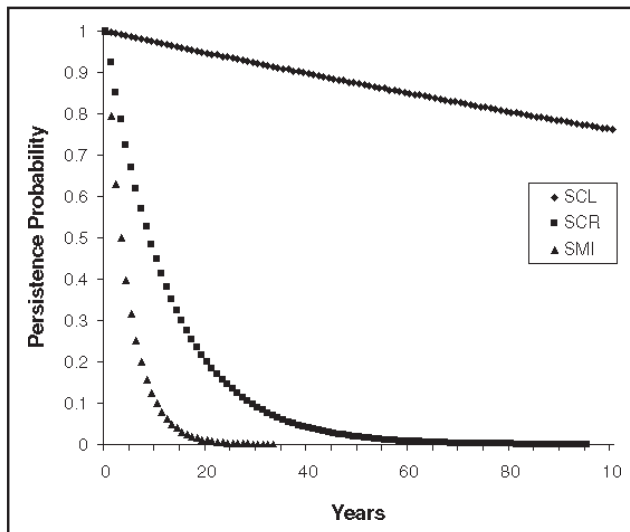


Figure 4.4.3. The probability of population persistence for each of three island fox populations: San Clemente (SCL), Santa Cruz (SCR) and San Miguel (SMI). The estimates of $T_e(n_0)$ used to generate the population persistence probabilities are 381, 5 and 13 years, respectively (G. Roemer *et al.* unpubl.).

to less than 1,500 in 2002 (Table 4.4.2). Four of the six island fox subspecies have experienced precipitous declines in the last four years. Fox populations on both San Miguel and Santa Cruz Islands declined by >90% between 1995 and 2000 (Figure 4.4.2). Similar declines also occurred on Santa Rosa and Santa Catalina Islands (Roemer 1999; Timm *et al.* 2000; Roemer *et al.* 2001a, 2002; Coonan 2003). Only 28 foxes are left on San Miguel and 45 foxes on Santa Rosa, and all are in captivity (Coonan 2002, 2003). The Santa Cruz population has dropped from an estimated 1,312 foxes in 1993 to 133 foxes in 1999 (Roemer 1999; Roemer *et al.* 2001a). Estimates for 2001 suggest that this population may have declined to as low as 60–80 individuals in the wild (Coonan 2002). A captive-breeding facility was initiated on Santa Cruz Island in 2002 when three adult pairs were brought into captivity; one pair had

five pups in the spring (Coonan 2002). The subspecies on all three northern Channel Islands are in imminent danger of extinction (Figure 4.4.3). Fox populations on San Miguel and Santa Cruz Islands have an estimated 50% chance of persistence over the next decade, are in need of immediate conservation action (Roemer 1999; Roemer *et al.* 2001a, 2002; Coonan 2003). On Santa Catalina, island foxes are now rare on the larger eastern portion of the island as a result of a canine distemper outbreak that swept through the population in 1999 (Timm *et al.* 2000). The San Clemente population could be as low as 410 adult foxes, down from a high of 800–900 foxes. The causes of this decline are not yet clear (Garcelon 1999; Roemer 1999); however, it has been suggested that management actions aimed at protecting the threatened San Clemente loggerhead shrike (*Lanius ludovicianus mearnsi*) may be a major factor in this decline (Cooper *et al.* 2001; Schmidt *et al.* 2002; Roemer and Wayne 2003). The San Nicolas population appears to be at high density (5.6–16.4 foxes/km²) and currently harbours one of the largest populations (estimate=734 foxes, Roemer *et al.* 2001b). However, this estimate may be positively biased and the actual population size may be closer to 435 foxes (G. Smith pers. comm.).

All of the current estimates of density and population size in island foxes have been conducted using modifications of a capture-recapture approach (Roemer *et al.* 1994). In its simplest application, population size is determined by multiplying average density among sampling sites times island area. Population estimates could be improved by first determining habitat-specific estimates of density and multiplying these densities times the area covered by the specific habitat (Roemer *et al.* 1994), an approach amenable to analysis with geographical information systems. However, density estimates made from aggregating home ranges suggest that the use of capture-recapture data may also overestimate density. For example, fox density estimated at Fraser Point, Santa Cruz Island using the capture-recapture approach was 7.0 foxes/km² (Roemer *et al.* 1994). A simultaneous estimate

of density based on the distribution of home ranges for 14 radio-collared foxes with overlapping home ranges was approximately 31% lower (4.8 foxes/km²) (Roemer 1999). Thus, the size of island fox populations may be lower than current capture-recapture analyses suggest.

Habitat

Island foxes occur in all habitats on the islands including native perennial and exotic European grassland, coastal sage scrub, maritime desert scrub, *Coreopsis* scrub, *Isocoma* scrub, chaparral, oak woodland, pine woodland, riparian, and inland and coastal dune.

Although fox density varies by habitat, there is no clear habitat-specific pattern. When fox populations were dense, foxes could be trapped or observed in almost any of the island habitats, except for those that were highly degraded owing to human disturbance or overgrazing by introduced herbivores. More recently, foxes have become scarce owing to precipitous population declines. On the northern Channel Islands where the declines are principally a consequence of hyperpredation by golden eagles (*Aquila chrysaetos*) (Roemer *et al.* 2001a, 2002), foxes are more numerous in habitats with dense cover, including chaparral and introduced stands of fennel (*Foeniculum vulgare*) (G. Roemer pers. obs.).

Food and foraging behaviour

Food Island foxes are omnivorous and feed on a wide variety of insects, vertebrates, fruits, terrestrial molluscs and even near-shore invertebrates (Laughrin 1973, 1977; Collins 1980; Kovach and Dow 1981; Crooks and van Vuren 1995; Moore and Collins 1995; Roemer *et al.* 2001b). The relative abundance of insects, mammals and plant material in the fox diet has been found to differ by habitat type (Laughrin 1977; Crooks and van Vuren 1995; Roemer *et al.* 2001b), and by island, depending upon availability of food items (Laughrin 1973; Collins and Laughrin 1979). For example, on San Miguel Island where deer mouse (*Peromyscus maniculatus*) densities are high, they form a large proportion of the diet of the island fox (Collins 1980). On Santa Cruz Island, Jerusalem crickets (*Stenopelmatus fuscus*) are a principal prey whereas on San Clemente Island, Jerusalem crickets are absent from the fauna and therefore unavailable. In contrast, the fruits of the coastal prickly pear cactus (*Opuntia littoralis*) are a principal food on San Clemente Island, especially during winter, but the cactus was nearly eradicated from Santa Cruz Island (Goeden *et al.* 1967) and thus comprises only a small portion of the fox diet there. The frequency of bird remains in the scat of island foxes is usually low (3–6%) but on San Miguel Island bird remains were found in 22% of scats (n=208) examined (Laughrin 1977; Collins and Laughrin 1979; Crooks and van Vuren 1995). For an exhaustive list of foods consumed by island foxes and the inter-habitat and inter-island variability see Laughrin

(1973, 1977), Collins and Laughrin (1979) and Moore and Collins (1995).

Foraging behaviour Island foxes primarily forage alone, mostly at night, but they are also active during the day (Laughrin 1977; Fausett 1982; Crooks and van Vuren 1995). Dependent young accompany adults on forays and adult foxes may also forage together on occasion (G. Roemer pers. obs.). Foxes forage by coursing back and forth through suitable habitat patches and then moving, rather directly, through little-used habitats to other suitable habitat patches. Foxes are unable to extract prey as easily from the denser habitat and thus forage in more open habitats where prey availability, but perhaps not abundance, is greater (Roemer and Wayne 2003).

Damage to livestock or game Island foxes are not known to prey on livestock, but the introduced chukar (*Alectoris chukar*), occurs in the diet (Moore and Collins 1995), and it is probable that foxes feed on California quail (*Callipepla californica*), which are found on both Santa Catalina and Santa Cruz Islands.

Adaptations

Island foxes are a dwarf form of the mainland gray fox and this reduction in body size may be a consequence of an insular existence (Collins 1982). Reduced interspecific competition, reduced predation and lack of large prey may have contributed to their smaller body size.

Social behaviour

Island foxes typically exist as socially monogamous pairs that occupy discrete territories (Crooks and van Vuren 1996; Roemer *et al.* 2001b). It is not uncommon for full-grown young to remain within their natal range into their second year or for independent, territory-holding offspring to visit their parents in their former natal range (Roemer *et al.* 2001b).

The home range size of the island fox is one of the smallest recorded for any canid. On Santa Cruz Island, fox home ranges varied by season and habitat type, generally ranging between 0.15 and 0.87km² (Crooks and van Vuren 1996; Roemer *et al.* 2001b). Mean annual home range on Santa Cruz Island was 0.55km² (n=14, Roemer *et al.* 2001b). On San Clemente Island, mean home range size was larger (0.77km², n=11), perhaps due to the lower productivity of this more southerly island (Thompson *et al.* 1998). On Santa Cruz Island, fox home ranges expanded when territorial neighbours were killed by golden eagles, suggesting that density of foxes and the spatial distribution of neighbours may influence territory size (Roemer *et al.* 2001b).

Foxes communicate using visual, auditory and olfactory cues. Both submissive and aggressive behaviours have been observed and are similar to those described for the

gray fox (Laughrin 1977; Fausett 1982; Moore and Collins 1995). Males have been observed chasing other male foxes and have also been observed fighting. Bite wounds were noted in 4 of 1,141 captures of foxes on Santa Cruz Island but were observed only in males and only during the breeding season (Roemer 1999). Foxes demarcate territory boundaries with latrine sites and have been observed urinating as frequently as every 6–9m (Laughrin 1977).

Reproduction and denning behaviour

Foxes breed once a year with parturition usually occurring in early April. Recent research suggests this canid may have induced ovulation (C. Asa pers. comm.), a physiological character that may allow for plasticity in the timing of reproduction. Pups have been born in early February on San Clemente Island and as late as 27 May on Santa Catalina Island (Schmidt *et al.* 2002; Timm *et al.* 2002). Of 35 foxes captured and killed in the month of February 1928 on Santa Cruz Island, 11 (46%) were pregnant (Sheldon 1990). An increase in territory vigilance by males occurs as early as January with actual copulations in captivity typically observed in early March (Coonan and Rutz 2000; Roemer *et al.* 2001b).

Length of gestation is unknown but has been estimated at 50–53 days (Moore and Collins 1995). Litter size varies from one to five but most litters are smaller, from one to three. Of 24 dens located on Santa Cruz Island, average litter size was 2.17 (Laughrin 1977). Average litter size for two captive breeding facilities on the northern islands was 2.6 (n=5, Coonan and Rutz 2000). In 2002, one captive pair on Santa Cruz Island produced a litter of five pups (Coonan 2002). Weaning is complete by mid- to late June and pups reach adult weight and become independent by September (Garcelon *et al.* 1999). Although most foxes are typically monogamous, extra-pair fertilisation has

been recorded. Of 16 pups whose paternity was determined by genetic analysis, 25% were the result of extra-pair fertilisations (Roemer *et al.* 2001b). Dens used include rock piles, dense brush and naturally occurring cavities in the ground or under tree trunks.

Competition

The only known competitors of island foxes are island spotted skunks (*Spilogale gracilis amphiala*) on Santa Cruz and Santa Rosa Islands (von Bloeker 1967; Laughrin 1977; Crooks and van Vuren 1995; Roemer *et al.* 2002) and feral cats on all three southern Channel Islands (Laughrin 1977; Kovach and Dow 1981).

Mortality and pathogens

Natural sources of mortality Hyperpredation by golden eagles has been identified as a primary mortality factor for island foxes on the northern Channel Islands, and is likely responsible for the recent catastrophic population declines of those three subspecies (Roemer 1999; Roemer *et al.* 2001a, 2002.). The presence of an exotic omnivore, the feral pig (*Sus scrofa*), enabled eagles to colonise the islands, increase in population size, and overexploit the fox. Evidence from 28 fox carcasses from Santa Cruz and San Miguel Islands implicated eagles in nearly 90% of the mortalities, and a logistic model of hyperpredation showed that pigs would have been necessary to support a large, resident eagle population (Figure 4.4.4) (Roemer 1999; Roemer *et al.* 2001a, 2002). Further, the prevalence of other potential mortality factors, such as disease and parasites, were found to be incongruent with the pattern of fox population declines (Roemer *et al.* 2000a, 2001a). Red-tailed hawks (*Buteo jamaicensis*) may kill kits (Laughrin 1977). Interspecific aggression is another source of natural mortality.

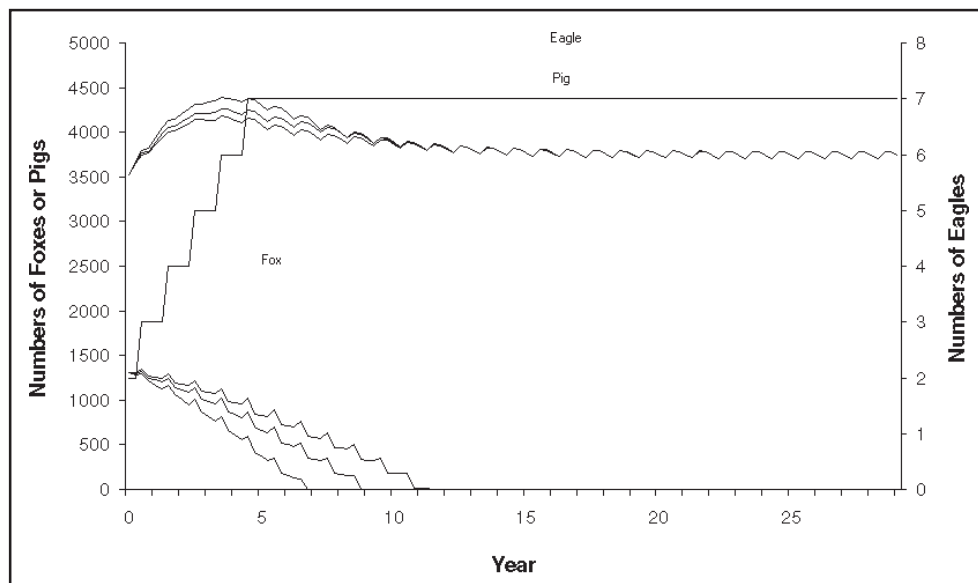


Figure 4.4.4. Trend in the fox, pig and eagle populations on Santa Cruz Island predicted from a logistic model of hyperpredation. Our time unit is a day and we plotted population size every 90 days. The regular peaks in fox population size are due to modelling growth as a single pulse each year. The three trajectories for each of the prey populations are due to differences in predator preference for the prey (pigs: foxes). The preference ratios modelled are 3, 1, and 0.33. Time to extinction for the fox populations given these preferences was 11.5 years, 8.7 years, and 6.7 years, respectively.

Persecution Island foxes are not persecuted except for the predator control programme currently being instituted by the U.S. Navy to protect the San Clemente loggerhead shrike.

Hunting and trapping for fur Island foxes are not currently hunted or trapped for their fur, but may have been historically. Sheldon (1990) took 155 foxes in the winter of 1927–1928 during 20 days of trapping with the intent of selling the pelts. It is not known if a market for fox pelts was established. Native Americans used fox pelts to create ceremonial headdresses, arrow-quivers, capes and blankets (Collins 1991b).

Road kills On San Clemente, Santa Catalina and San Nicolas Islands, trauma from automobiles is a significant source of mortality (Garcelon 1999; G. Smith pers. comm.).

Pathogens and parasites Canine diseases are considered important potential mortality sources for island foxes (Garcelon *et al.* 1992). This is underscored by the epidemic of canine distemper virus (CDV) that decimated the Santa Catalina Island fox population in 1998 to 2000 (Timm *et al.* 2000). CDV was apparently introduced sometime between late 1998 to mid-1999 and has caused an estimated 95% reduction in the fox population on the eastern 87% of Catalina Island. Human settlement on a narrow isthmus likely formed a barrier to fox dispersal and the spread of the disease to the western portion of the island. A total of 148 foxes have been captured in 2000 to 2001 on the western 13% of Santa Catalina Island supporting the contention that foxes there were not exposed to CDV (S. Timm pers. comm.). Antibodies to CDV were recently detected in foxes from San Nicolas Island but the titre levels observed may represent false positives (Coonan 2002; S. Timm pers. comm.).

Exposure to other various canine pathogens has been confirmed but morbidity or mortality has not been substantiated (Timm *et al.* 2000; L. Munson unpubl.). Positive antibody titres have been detected for canine parvovirus, canine adenovirus, canine herpesvirus, canine coronavirus, leptospirosis, toxoplasmosis and for heartworm (*Dirofilaria immitis*) (Garcelon *et al.* 1992; Roemer 1999; Roemer *et al.* 2000a, 2001a; Crooks *et al.* 2001). In addition a number of intestinal pathogens have been identified including *Ancylostoma*, *Toxascaris*, *Mesocestoides*, *Isospora*, *Sarcocystis*, and *Neospora* (Roemer *et al.* 2001a). Island foxes from San Miguel are infested with three pathogenic parasites, *Uncinaria*, *Angiocaulus* and an as yet unidentified spirurid that causes granulomas in the intestinal tract and mesentery (L. Munson unpubl.). These parasitic granulomas are likely the cause of the rectal prolapses that were observed in two wild foxes, one of which later died (G. Roemer pers. obs.) and in two captive foxes that recovered after reinsertion

(K. Rutz pers. comm.). Other sources of mortality include trauma as a result of injury and aspiration pneumonia. A captive fox on Santa Rosa recently died from an aggressive oral cavity cancer (M. Willett and L. Munson unpubl.) and cancer of the ear canal (ceruminous gland carcinomas) has been observed in three foxes from Santa Catalina Island (L. Munson unpubl.).

Foxes on all islands also have thyroid atrophy, hepatic fibrosis and amyloidosis, and recently foxes from San Clemente Island have shown evidence of Quintox poisoning (L. Munson unpubl.), an anti-coagulant rodenticide used to control rodents as part of the San Clemente Loggerhead Shrike Recovery Program (Cooper *et al.* 2001).

Longevity Foxes as old as 10 years of age have been captured on San Miguel Island (Coonan *et al.* 1998).

Historical perspective

Island foxes played a spiritual role in earlier Native American societies on the Channel Islands (Collins 1991b). Native Americans of the Channel Islands harvested foxes to make arrow-quivers, capes and headdresses from their pelts, they ceremonially buried foxes, conducted an Island Fox Dance and most likely kept foxes as pets or semi-domesticates (Collins 1991b). Their current distribution is a direct consequence of historical interaction with humans (Collins 1991a, b; Wayne *et al.* 1991b; Goldstein *et al.* 1999). Fossil evidence dates the arrival of foxes to the northern Channel Islands (Santa Cruz, Santa Rosa and San Miguel) from 10,400–16,000 ybp (years before present) (Orr 1968). Their actual colonisation probably occurred between 18,000 and 40,000 years ago, when these northern islands were joined into one large island known as “Santarosae” (Collins 1982, 1993). At its closest, Santarosae was a mere 6km from the North American continent, having reached its maximum size 18,000–24,000 ybp. It is hypothesised that sometime during this period, mainland gray foxes, the progenitor of the island fox, colonised Santarosae by chance over-water dispersal, by either swimming or by rafting on floating debris (Collins 1982, 1993). As glaciers retreated and sea levels rose, Santarosae was subdivided into separate islands. Santa Cruz Island was formed first, some 11,500 ybp. Sea levels continued to rise separating the remaining land mass once again, approximately 9,500 ybp, to form Santa Rosa and San Miguel Islands. Native Americans then colonised the Channel Islands 9,000–10,000 ybp, and after establishment of an extensive trade route, transported foxes to the southern islands. The southern islands were thought to have been colonised by foxes between 2,200 and 5,200 ybp (Collins 1991a, b, 1993; Wayne *et al.* 1991b; Vellanoweth 1998).

Island foxes also represent a significant scientific resource. Their geographic distribution and resulting isolation has created a set of model populations that has

extended our knowledge regarding the effects of insularity on mammalian social organisation (Roemer *et al.* 2001b), has contributed to an understanding of the molecular evolution of highly variable gene regions (Gilbert *et al.* 1990; Goldstein *et al.* 1999) and their recent decline is a clear example of the potential impact that invasive species can have on insular systems (Roemer *et al.* 2001a, 2002).

Conservation status

Threats The current primary threats to the species include golden eagle predation on the northern Channel Islands (Roemer 1999; Roemer *et al.* 2001a, 2002) and the possible introduction of canine diseases, especially CDV, to all populations (Garcelon *et al.* 1992; Roemer 1999; Timm *et al.* 2000). All populations are small, several critically so, and are threatened by demographic stochasticity and environmental variability. The small populations are especially vulnerable to any catastrophic mortality source, be it predation, canine disease, or environmental extremes (Roemer *et al.* 2000b).

Recently, there has also been a management conflict between island foxes and the San Clemente Island loggerhead shrike (Roemer and Wayne 2003). Island foxes were euthanised on San Clemente Island in 1998 as part of a programme to protect nesting shrikes (Elliot and Popper 1999; Cooper *et al.* 2001). Although euthanasia of foxes has stopped, a number of foxes are now retained in captivity each year, during the nesting and fledging stage of the shrike, and subsequently released back into the environment. The impact to fox reproduction and the potential disruption of the social system are unknown, but may be significant. These actions may have contributed to a 60% decline in the fox population on San Clemente Island (Cooper *et al.* 2001; Schmidt *et al.* 2002; Roemer and Wayne 2003). Considering the precipitous declines in foxes on four of six islands and the continued decline in the San Clemente population, this current management practice needs further scrutiny.

Commercial use There is no commercial use of island foxes.

Occurrence in protected areas The three subspecies on the northern Channel Islands occur within the Channel Islands National Park. Approximately two-thirds of Santa Cruz Island is owned by The Nature Conservancy (TNC), and managed as the Santa Cruz Island Preserve. The Preserve is within the boundaries of the Channel Islands National Park, and the TNC and NPS (National Parks Service), co-manage natural resources together under a cooperative agreement. Approximately 87% of Santa Catalina Island is owned by the Santa Catalina Island Conservancy, a non-profit conservation organisation, and both San Clemente and San Nicolas Islands are owned and managed by the U.S. Navy.

Protection status CITES – not listed.

Current legal protection The species was formerly a category II candidate for federal listing, but is not currently listed by the U.S. Fish and Wildlife Service (USFWS) as ‘threatened’ or ‘endangered’ under the Federal Endangered Species Act. The species is listed by the state of California as a ‘threatened’ species (California Department of Fish and Game 1987). The current legal status has not been sufficient to prevent recent catastrophic population declines. In June 2000, the USFWS was petitioned to list the populations on the three northern Channel Islands and Santa Catalina Island as ‘endangered’ (Suckling and Garcelon 2000). The USFWS recently proposed to list these four subspecies as ‘endangered’ (USDI 2001).

Conservation measures taken Based upon recommendations from an *ad hoc* recovery team, the Island Fox Conservation Working Group, the National Park Service (NPS) began initiating emergency actions in 1999, with the objectives being to remove the primary mortality factor currently affecting island foxes (golden eagle predation), and to recover populations to viable levels via captive breeding. Between November 1999 and June 2002, 22 eagles were removed from Santa Cruz Island and relocated to north-eastern California. In 1999, the NPS established an island fox captive breeding facility on San Miguel Island, added a second facility on Santa Rosa in 2000 and a third on Santa Cruz Island in 2002 (Coonan 2002, 2003; Coonan and Rutz 2000, 2002). Fourteen foxes were originally brought into captivity on San Miguel; current captive population is now 28. There are currently 45 foxes in captivity on Santa Rosa, and 12 adult foxes in the Santa Cruz facility that produced a single litter of five pups (Coonan 2002, 2003).

The NPS has prepared an island fox recovery plan for the northern Channel Islands (Coonan 2001) and an island-wide restoration plan for Santa Cruz Island (USDI 2002). The measures taken thus far on the northern Channel Islands (golden eagle removal and captive breeding) will form the basis for long-term recovery for the subspecies on the northern Channel Islands. In addition, the reintroduction of bald eagles (*Haliaeetus leucocephalus*), the eradication of feral pigs, and the removal of exotic plants have been recommended and are being implemented (Roemer *et al.* 2001a; USDI 2002). Demographic modelling indicates that recovery to viable population levels could take up to a decade (Roemer *et al.* 2000b).

On Santa Catalina Island, The Santa Catalina Island Conservancy has taken a series of measures to mitigate the effects of canine distemper virus on that subspecies. Close to 150 foxes from the west end have been field-vaccinated for CDV, and both translocation and captive breeding

programmes have been established to aid in recolonising the eastern portion of the island (Timm *et al.* 2000, 2002).

Although the Island Fox Conservation Working Group recognised the need for a species-wide recovery plan, there is currently no formal vehicle to accomplish such a planning effort, because the species is not listed under the Federal Endangered Species Act. Nonetheless, the Working Group recognised that the following actions need to be implemented in order to ensure recovery of island fox populations to viable levels (Coonan 2002, 2003):

- Complete removal of golden eagles from northern Channel Islands.
- Implement monitoring/response programme for future golden eagles.
- Remove feral pigs from Santa Cruz Island.
- Reintroduce bald eagles to the northern Channel Islands.
- Eliminate canine distemper as a mortality factor on Santa Catalina Island.
- Vaccinate wild foxes against canine distemper virus, as needed.
- Monitor populations for diseases causing morbidity and mortality through necropsy and faecal and blood testing.
- Enforce no-dog policy on islands, and vaccinate working dogs.
- Educate the public about potential disease transmission from domestic dogs.
- Establish and maintain captive breeding facilities on San Miguel, Santa Rosa, Santa Cruz and Santa Catalina Islands.
- Supplement wild populations with captive-reared foxes.
- Implement annual population monitoring of each subspecies/population.
- Halt management actions to protect the San Clemente loggerhead shrike that are adversely affecting the San Clemente island fox.
- Develop adaptive management programme.

Occurrence in captivity

Island foxes currently are kept in captivity on four islands. The National Park Service's captive breeding programme maintains facilities on San Miguel, Santa Rosa and Santa Cruz Islands, in which there are currently 28, 45 and 17 island foxes, respectively. The Santa Catalina Island Conservancy and the Institute for Wildlife Studies have established a captive breeding facility on that island, and there are currently 12 adult pairs of foxes there (Timm *et al.* 2002). Small numbers (1–4) of San Clemente Island foxes are kept in a total of four zoos on the mainland with a variable number of foxes held in captivity each year on that island (Cooper *et al.* 2001).

Current or planned research projects

M. Gray (UCLA, Los Angeles, California), G.W. Roemer

(New Mexico State University, Las Cruces, New Mexico) and E. Torres (California State University, Los Angeles, California) are currently conducting a genetic analysis of captive island foxes, assessing genetic relatedness to formulate captive breeding strategy and maintain genetic diversity of founders.

A. Aguilar and R.K. Wayne (UCLA, Los Angeles, California) are assessing variation at the major histocompatibility complex (Mhc) in the island fox.

C. Asa (St. Louis Zoo, Saint Louis, Missouri) is studying timing of the reproductive cycle via hormonal analysis of captive island foxes.

D.K. Garcelon (Institute for Wildlife Studies, Arcata, California) conducted transect trapping and radio-telemetry studies in 2001 which will be used to estimate basic population parameters for Santa Cruz Island foxes and determine mortality factors for this subspecies. Ongoing work will include annual population monitoring, and studies on spatial organisation and survival of island foxes on San Clemente Island using capture-recapture and radio-telemetry. This work will also include annual population monitoring on San Nicolas Island, using a grid-based, capture-recapture study for estimating density, survival and recruitment

S. Timm (Institute for Wildlife Studies, Arcata, California) is studying survival of translocated foxes on Santa Catalina Island.

L. Munson and D. Fritcher (University of California, Davis, California) are monitoring disease in the island fox. They aim to determine all diseases and parasites present in island foxes from all populations, both historically through archived frozen carcasses and presently through necropsy of dead foxes.

G.W. Roemer (New Mexico State University, Las Cruces, New Mexico) and P. Miller (IUCN Conservation Breeding Specialist Group) are undertaking a population viability analysis of the island fox with the aim to refine previous analyses of population viability and threat.

Gaps in knowledge

It is known that wild island fox pairs are unrelated and that extra-pair copulations occur (Roemer *et al.* 2001b), but little is known about how island foxes select mates and whether mate choice could play a role in improving the currently low reproduction characterising captive foxes (Coonan and Rutz 2002). Controlled mate-choice experiments are needed.

It has been suggested that intense predation by golden eagles could have altered island fox activity patterns and selected for greater nocturnal activity in those foxes that have survived predation (Roemer *et al.* 2002). The survival of the remaining wild island foxes on Santa Cruz Island is being monitored, but there has been no attempt to document daily activity levels (Dennis *et al.* 2001). The

pattern of daily activity of wild Santa Cruz Island foxes needs to be assessed, and compared to the activity of captive and captive-reared foxes that are released into the wild. If captive-reared foxes are more active during diurnal and crepuscular periods than their wild counterparts, it is probable that captive-reared foxes reintroduced into the wild will suffer higher mortality owing to golden eagle predation.

There has been only a single study that has examined dispersal in island foxes (Roemer *et al.* 2001b) and the number of dispersal events recorded was small (n=8). Additional information on island fox dispersal patterns on different islands and during periods of high and low density are needed.

Core literature

Collins 1991a,b, 1993; Crooks and van Vuren 1996; Laughrin 1977; Moore and Collins 1995; Roemer 1999; Roemer *et al.* 2001a,b, 2002; Roemer and Wayne 2003; Wayne *et al.* 1991b.

Reviewers: Lyndal Laughrin, David K. Garcelon, Paul Collins. **Editors:** Claudio Sillero-Zubiri, Deborah Randall, Michael Hoffmann.

4.5 Kit fox

***Vulpes macrotis* Merriam, 1888**
Least Concern (2004)

R. List and B.L. Cypher

Other names

English: desert fox; **German:** wüstenfuchs; **Spanish:** zorra del desierto, zorra norteña.

Taxonomy

Vulpes macrotis Merriam, 1888. Type locality: “Riverside, Riverside County, California“ [United States, c. 34°00’N, 117°15’E].

The kit fox has been considered conspecific with the swift fox, *V. velox*, based on morphometric similarities and protein-electrophoresis (Clutton-Brock *et al.* 1976; Hall 1981; Dragoo *et al.* 1990). Others have treated *V. macrotis* as a distinct species based on multivariate morphometric data (Stromberg and Boyce 1986) and more recently based on mitochondrial DNA (Mercure *et al.* 1993).

Chromosome number not known.

Description

The kit fox is one of the smallest foxes in the Americas (Table 4.5.1). The most conspicuous characteristic is the large ears. The fur is short, with yellowish to greyish head, back and sides; the shoulders and the outside of the legs are brown-yellow; the belly and the inner side of legs are white-yellowish; the tip of the tail is black. The neck, legs and belly may have buffy highlights. The hair is dense

Table 4.5.1 Body measurements for the kit fox from Janos, Chihuahua, Mexico (List and Jimenez Guzmán in press).

HB male	537mm (485–520) n=7
HB female	501mm (455–535) n=5
T male	308mm (280–340) n=8
T female	289mm (250–305) n=5
E male	82mm (71–95) n=8
E female	80mm (74–95) n=6
WT male	2.29kg (1.7–2.7) n=8
WT female	1.9kg (1.6–2.2) n=6



Adult kit fox, sex unknown, standing at the entrance of its burrow. Janos, Chihuahua, Mexico, 2001.

Rurik List