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A SEROLOGIC SURVEY OF THE ISLAND FOX (*UROCYON LITTORALIS*) ON THE CHANNEL ISLANDS, CALIFORNIA

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ABSTRACT: The island fox is listed as a threatened species in California. A serologic survey of 194 island foxes (*Urocyon littoralis*) was conducted over the entire range of the species on the Channel Islands (California, USA). Antibody prevalence against canine adenovirus and canine parvovirus reached 97% and 59%, respectively, in some populations sampled. Antibody prevalence of canine herpesvirus, canine coronavirus, leptospirosis and toxoplasmosis were low. Antibodies against canine distemper virus were not detected.
Key words: Island fox, *Urocyon littoralis*, canine distemper virus, canine herpesvirus, canine adenovirus, canine coronavirus, canine parvovirus, leptospirosis, toxoplasmosis.

INTRODUCTION

The island fox (*Urocyon littoralis*) is a diminutive relative of the gray fox (*Urocyon cinereoargenteus*) and is restricted in its range to the six largest of the eight California Channel Islands (USA). The island fox has been classified as threatened by the California Department of Fish and Game (California Department of Fish and Game, 1987) due to its isolated distribution, habitat degradation by introduced feral animals, and possible competition from feral cats (*Felis catus*). Other than spotted skunks (*Spilogale gracilis*), which occur on Santa Cruz and Santa Rosa Islands, the island fox is the only native terrestrial carnivore present on the Channel Islands.

The general life history (Laughrin, 1977) and diel movements (Fausett, 1982) of the island fox have been studied on Santa Cruz Island. The origin, morphological differentiation and genetic relationships between island populations have also been investigated (Collins, 1982; Gilbert et al., 1990). The prevalence of antibodies against calicivirus in island foxes has been investigated (Prato et al., 1977).

Because the island fox is distributed on small islands it is more subject to the effects of environmental perturbations than species occurring on the mainland. Introduction of canine infectious diseases could pose a significant threat to an island fox population which has no acquired immunity. Domestic dogs (*Canis familiaris*) and cats are currently or have historically occurred on most of the Channel Islands and could be a vehicle for introduction of disease into fox populations.

The purpose of this serologic survey was to determine which common canine disease agents occurred in each of the island fox populations. As a result of this serologic survey, potential disease threats to the conservation of this species could be evaluated.

STUDY AREA

The California Channel Islands are located off the coast of Southern California between Point Conception and San Diego (34°00′N, 119°40′W). The six islands supporting fox populations range in their distance to the mainland from 30 km to 98 km, and range in area from 37 km^2 to 249 km^2 (Philbrick, 1967). Major habitat types on the islands include coastal sage scrub, grassland, woodlands and sand dune communities (Johnson, 1980; Minnich, 1980).

MATERIALS AND METHODS

Each of the six Channel Islands supporting island fox populations were visited between February and July 1988. Foxes were live captured in box traps (Tomahawk Live Trap Co., Tomahawk, Wisconsin 54487, USA) and 3 ml of blood was drawn from the femoral vein of unanesthetized individuals. Kits were not sampled and no distinction was made between age classes of adults. Serum was separated from the cellular fraction by centrifugation, removed, and then frozen. Sera were tested for antibodies against canine distemper virus (CDV), canine parvovirus (CPV), canine adenovirus (CAV), canine coronavirus (CCV), canine herpesvirus (CHV), *Toxoplasma gondii* (TOX), *Leptospira interrogans* serovar *canicola* (LVC) and serovar *icterohaemorrhagiae* (LVI). Serologic tests were conducted at the Washington Animal Disease Diagnostic Laboratory (Washington State University, Pullman, Washington 99164, USA). Antibodies to parvovirus and coronavirus were detected by the indirect fluorescent antibody method described by Helfer-Baker et al. (1980) with titers of ≥1:15 considered indicative of previous exposure. Viral neutralization (Appel and Robson, 1973) was used to determine antibody titers against canine distemper virus, herpesvirus, and adenovirus. Antibody titers of ≥1:5 were considered to provide evidence of prior exposure for these agents. Antibodies to *T. gondii* were determined with indirect hemagglutination (Wample Labs, Cranbury, New Jersey 08512, USA) with titers ≥1:64 considered indicative of previous infection. Antibodies to the 2 serovars of *L. interrogans* were detected with a modification of the technique described by Cole et al. (1973), and titers ≥1:100 were considered indicative of previous infection. Specimens which met or exceeded levels will be referred to as "positive."

RESULTS AND DISCUSSION

Antibody prevalence of foxes varied among islands (Table 1). Foxes on San Miguel Island, the smallest of the islands, had serologic evidence of only two infectious agents; those on Santa Cruz Island, the largest and closest to the mainland, had evidence of five infectious agents, the most of any of the fox populations surveyed.

Canine distemper virus (CDV)

The absence of antibodies to CDV in any of the fox populations suggests either CDV has never been introduced onto the islands, or the species is highly susceptible to infection and few animals survive. In an epizootic of canine distemper in Alaskan sled dogs with no immunity, 50% died or were rendered helpless by neuropathic sequellae (Reinhard et al., 1955). Antibodies against CDV have been found in other free-ranging canids (Guo et al., 1986; Stephenson et al., 1982). Gray foxes are highly susceptible to canine distemper (Parker et al., 1961; Hoff et al., 1974; Halbrooks et al., 1981; Nicholson and Hill, 1984), with mortality rates as high as 36% (Hoff et al., 1974; Nicholson and Hill, 1984). While island foxes are genetically distinct from gray foxes (Gilbert et al., 1990), they are similar enough that we suspect island foxes also would be very susceptible to infection.

Canine parvovirus (CPV)

Antibodies against CPV were found in foxes on all of the islands (Table 1). Canine parvovirus antibodies have been found in other free-ranging canids including wolves (Goyal et al., 1986; Mech et al., 1986), red foxes (*Vulpes vulpes*) (Barker et al., 1983), kit foxes (*Vulpes macrotis*) (McCue and O'Farrell, 1988), and in South American canids (Mann et al., 1980). The disease is likely spread to wild canids from domestic dogs (Montali et al., 1987). In captive canids CPV appears to be most common in juveniles. Ten of 12 captive wolf (*Canis lupus*) pups died after developing clinical signs of CPV infection in one study (Mech et al., 1986), and a 43% mortality rate (19 of 44) among captive coyote (*Canis latrans*) pups occurred from CPV or a combination of CPV and CCV (Evermann et al., 1980). Antibody prevalence in free-ranging coyotes was >70% (Thomas et al., 1984). While the antibody prevalence in island foxes was lower than found in coyotes, the value may be significant if it reflects a high kit mortality. Assessing kit mortality in a denning species like the island fox would prove difficult since kits may die before venturing from the den.

Canine adenovirus (CAV)

Antibodies against CAV in foxes occurred on all islands except Santa Cruz and Santa Catalina (Table 1). Canine adenovirus, like CPV, appears to have its greatest effect on pups. Mortality rates in individuals <6 months old have been reported to

TABLE 1. Prevalence of serum antibodies in island fox (*Urocyon littoralis*) of the Channel Islands, California 1988.

Island	N	Pathogen[a]							
		CDV	CHV	CAV	CCV	CPV	LVC	LVI	TOX
San Miguel	23	0[b]	0	96	0	30	0	0	0
Santa Rosa	34	0	12	97	0	35	0	0	12
Santa Cruz	29	0	10	0	7	59	0	14	3
San Nicolas	46	0	0	72	0	7	0	0	7
San Clemente	42	0	2	88	0	50	0	0	26
Santa Catalina	20	0	0	0	60	5	0	0	10
Total	194								

[a] CDV, canine distemper virus; CHV, canine herpesvirus; CAV, canine adenovirus; CCV, canine coronavirus; CPV, canine parvovirus; LVC, *Leptospira interogans* serovar *canicola*; LVI, *Leptospira interogans* serovar *interohaemorrhagiae*; TOX, *Toxoplasma gondii*.

[b] Prevalence = (Number of positive samples/total number of samples tested) × 100.

be as high as 80% in fox farm epizootics (Cabasso, 1981). Among free-ranging wolves the prevalence of CAV antibodies were 95% and 13%, in Alaska and Canada, respectively (Stephenson et al., 1982; Choquette and Kuyt, 1974). Kit foxes collected in California had a prevalence of 16% (McCue and O'Farrell, 1988).

Domestic dogs have not been resident on San Clemente, San Nicolas, or San Miguel Islands for several years. Therefore, the high serologic prevalence of CAV in foxes suggests that either CAV is enzootic or there is another source of the virus in those populations.

Canine coronavirus (CCV)

Antibodies against CCV were found on only two of the islands (Table 1). Antibodies against CCV have been found in both free-ranging (5% prevalence) and captive (30% prevalence) coyotes (Green et al., 1984; Foreyt and Evermann, 1985). Green et al. (1984) discussed dual infection of CCV and CPV; five of 66 pups died after exhibiting bloody diarrhea, emaciation and dehydration. Disease associated with CCV alone has not been reported in wild carnivores (Bartz and Montali, 1987). Green et al. (1984) believed that the virus is probably not an important cause of mortality in adult coyotes; however, Foreyt and Evermann (1985) suggested that the virus may be an important cause of enteric disease in coyote pups, either directly or in conjunction with other intestinal pathogens.

The highest prevalence of antibodies against CCV was on Santa Catalina Island (60%) which has a dense but relatively confined domestic dog population. Domestic dogs may have been the original source of infection and may serve as a reservoir for the virus; however, the virus may now be endemic in the fox population. With little information on the effects of CCV on wild carnivores it is difficult to evaluate the threat of this disease to the fox population.

Canine herpesvirus (CHV)

Antibodies for CHV were found on three of the six islands (Table 1). Jamison et al. (1973) found no evidence of CHV exposure in skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), oppossums (*Didelphis marsupialis*), or woodchucks (*Marmota monax*) in Maryland. Canine herpesvirus has caused high mortality in captive coyote pups (Evermann et al., 1984) and domestic dogs (Appel, 1987).

Toxoplasmosis

Antibodies against *Toxoplasma gondii* were found in all but the San Miguel Island fox population (Table 1). Toxoplasmosis is a common disease in many species (Dubey and Beattie, 1988). *Toxoplasma* antibodies were found in 6% of kit foxes sampled in California (McCue and O'Farrell, 1988). In red foxes, infections are generally subclinical (Dubey, 1983), but can become severe (Dubey et al., 1990). Antibodies to this agent have been found in coyotes and gray foxes (Marchiondo et al., 1976; Riemann et al., 1978). Toxoplasmosis requires a member of the Felidae to form the infectious oocysts. Unless cysts are being transported to the islands in the bodies of migrating birds or marine mammals, only foxes on those islands with feral cats should have evidence of exposure. Because Santa Cruz Island is not known to have a population of feral cats, the small number of foxes found to be positive may represent false positive laboratory results.

Leptospirosis

Serologic evidence for the infection was found only in the Santa Cruz Island fox population. The 14% prevalence was similar to rates reported for coyotes in Kansas (10%) (Marler et al., 1979) and red foxes in Ontario (12%) (Kingscote, 1986). Leptospirosis has a wide distribution among mammalian taxa with at least 184 serovars identified (Shotts, 1981). No antibodies to the *canicola* serovar were found in this survey. Among canids, evidence of exposure has been found in gray foxes (Amundson and Yuill, 1981), red foxes (Amundson and Yuill, 1981; Kingscote, 1986), coyotes (Trainer and Knowlton, 1968; Marler et al., 1979; Drewek et al., 1981) and wolves (Zarnke and Ballard, 1987). Antibodies were not found among 23 kit foxes sampled from California (McCue and O'Farrell, 1988).

Leptospirosis typically is considered self-limiting in wildlife. Most animals recover from infection and may then remain carriers (Shotts, 1981). Because of the variety of serovars that infect gray and red foxes (Shotts, 1981) future serologic studies on island foxes should include a wider spectrum of these serovars.

CONCLUSIONS

Positive serologic test results do not indicate the effect of a disease on a population. Such results only suggest previous exposure to an infectious agent or parental acquired immunity. Likewise, negative test results do not necessarily indicate lack of previous exposure to infection, because individuals may not maintain detectable levels of antibodies for long periods after infection (Scott, 1988). Occurrence of a positive result for an infection in only a few members of a population may be an artifact of laboratory testing rather than a reflection of low prevalence. Additional sampling may be required to better determine the occurrence of antibodies for certain infections in the fox populations.

Apparently healthy island fox populations on San Clemente and Santa Catalina Islands seem to recruit relatively few kits into the adult population (D. K. Garcelon, unpubl. data). While this may be explained by density dependent factors, such as competition for food or den sites, the influence of CPV, CAV and CCV on fox population dynamics should be further investigated.

The probable high susceptibility of island foxes, coupled with lack of evidence of acquired immunity in these populations, suggests a high risk for an epizootic if CDV were introduced onto these islands. This highly contagious disease caused a catastrophic decline in a population of the endangered black-footed ferret (*Mustela nigripes*) (Thorne and Williams, 1988). Two of the islands have resident domestic dogs, and recreational boaters that visit all of the islands may bring pets onshore. These domestic dogs could be a potential source for the transmission of CDV and other canine diseases to island fox populations. Because island fox population sizes are small and immigration among populations unlikely, effects of an epizootic such as CDV may not leave sufficient animals to allow for population recovery. We recommend that islands on which pets or working dogs are allowed should adopt strict pet vaccination policies to help prevent the transmission of disease to island foxes.

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