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Ectoparasites of the Island Fox on Santa Cruz Island

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ABSTRACT: The ectoparasite fauna for island foxes (*Urocyon littoralis*) on Santa Cruz Island (California, USA) in April (wet season) and September (dry season) 1998 was evaluated. Three taxa of ectoparasites were identified. These were fleas (*Pulex irritans*), lice (*Neotrichodectes mephitidis*), and ticks (*Ixodes pacificus*). Ectoparasite abundances varied seasonally. Typical of insular endemic species, island foxes may be especially vulnerable to the introduction of novel disease organisms and their vectors.

Key words: ectoparasite, flea, island fox, lice, tick, survey, *Urocyon littoralis.*

The island fox (*Urocyon littoralis*), an insular endemic relative of the mainland gray fox (*U. cinereoargenteus*), occurs on only the six largest of the eight California Channel Islands (USA). This species is listed as threatened by the state of California due to its restricted distribution and small population sizes. Diseases and parasites have been identified as a primary threat to island fox populations (Garcelon et al., 1992). The role of disease in regulating carnivore populations, however, is poorly understood due to lack of data on the prevalence and intensity of disease organisms and their vectors in wild predators (Addison et al., 1987; Patrick and Harrison, 1995). The prevalence and intensity of external parasites have not been quantified for the island fox. The objectives of this study were to determine ectoparasite intensities for the island fox on Santa Cruz Island (California, USA), and to evaluate the effect of season and host sex on ectoparasite abundances.

Santa Cruz Island (California, USA; 34°0′N, 119°45′W), located 40 km south of Santa Barbara (California), is 39 km long and 3 to 11 km wide (250 km^2) and is the largest of the California Channel Islands. The island has a system of interior valleys, including the large Central Valley, oriented in an east-west direction and bounded by mountain ranges on the north (maximum elevation 750 m) and the south (465 m). Although 10 plant communities have been described (Junak et al., 1995), most of the island supports grassland, chaparral, and coastal sage scrub communities (Minnich, 1980). The climate is maritime and Mediterranean, with hot dry summers and cool wet winters.

From 9–13 April (wet season) and 2–5 September (dry season) 1998, we sampled foxes along road transects that totaled about 30 km in length throughout the central portion of the island. Foxes were live-trapped in single-door box-traps set every 250 to 500 m and baited with commercial canned cat food (Whiskas, Kal Kan Foods, Inc., Vernon, California, USA), dry cat food (Purina Cat Chow, Ralston Purina Company, St. Louis, Missouri, USA), and fruit paste baits (Nick Wyshinski, Berwick, Pennsylvania, USA). Each road transect was sampled for no more than two consecutive nights, then the traps were relocated to a new transect. Foxes were docile and could be manually restrained during processing without the use of anesthesia. During processing, tooth wear (Crooks et al., 2000) and other distinguishing characteristics for each fox were recorded, and each fox was marked with a permanent marker and hair clipping; recaptured animals were released without re-sampling for ectoparasites.

We collected ectoparasites by spraying

TABLE 1. Ectoparasite abundances on island foxes on Santa Cruz Island (California, USA) in 1998.

	Dry Season						Wet Season					
	Female (n = 11)			Male (n = 12)			Female (n = 14)			Male (n = 11)		
	Mean	SE	Range	Mean	SE	Range	Mean	SE	Range	Mean	SE	Range
Pulex irritans	16.55	5.62	2–64	14.92	3.91	2–44	5.30	1.60	0–21	8.80	1.76	1–23
Neotrichodectes mephitidis	0.82	0.38	0–3	3.08	1.01	0–11	4.40	1.80	0–24	9.10	4.23	0–43
Ixodes pacificus	0.00	0.00	0–0	0.00	0.00	0–0	1.73	0.50	0–5	2.40	0.43	1–5

each fox with 50–60 ml of pyrethrin (Adams Flea and Tick Mist, Adams Pet Supplies, Jacksonville, Florida, USA) over the entire body below the neck, and then thoroughly combing the animal for 2 min with a flea comb (Adams Pet Supplies, Jacksonville, California, USA) over a white cloth sheet. Ectoparasites were stored in 70% ethanol for later identification. Ectoparasites were identified by one of us (RBK: with the aid of Kellog and Ferris, 1915; Emerson, 1972; Furman and Loomis, 1984; Emerson and Price, 1987; Lewis et al., 1988) and voucher specimens (#99001–99026) were deposited in the Bohart Museum of Entomology (University of California, Davis, California, USA). We calculated the mean, standard error, and range for parasite intensity of each taxon, and conducted two-way ANOVA to test for the effects of season (wet and dry), sex, and season-sex interactions on ectoparasite intensity (Statistica Version 5.1, StatSoft Inc., Tulsa, Oklahoma, USA). To help meet assumptions of normality, ectoparasite abundances were log 10-transformed for statistical analyses; the value of 1 was added to the number of ectoparasites for computational purposes.

Ectoparasites from three taxa were identified from the 48 foxes examined (Table 1). Five hundred twenty-nine fleas were collected and were confirmed as *Pulex irritans,* a species difficult to distinguish from *P. simulans* (Smit, 1958; Patrick and Harrison, 1995). Fleas were collected on all but one fox (98%, n = 48 foxes), with as many as 64 fleas per fox. Mean number of fleas did not differ with sex of foxes (P = 0.233), but this did vary with season (P = 0.013); there were more fleas in the dry versus the wet season.

Two hundred five lice were collected and were identified as *Neotrichodectes mephitidis,* the chewing louse commonly found on striped skunks (*Mephitis mephitis*) (Emerson and Price, 1987). Lice were collected from 60% of the foxes (n = 48 foxes), with as many as 43 lice per fox. Mean number of lice was higher for males (P = 0.056) and in the wet season (P = 0.037).

Fifty ticks were collected. All ticks were adults of one species, *Ixodes pacificus.* Ticks were collected from 80% of foxes in the wet season (n = 25) but from no foxes in the dry season (n = 23). Mean number of ticks did not vary with sex (P = 0.140) but did vary with season ($P < 0.001$).

Mainland gray foxes host at least 15 species of fleas, two species of lice, and nine species of ticks (Fritzell, 1987). Like island foxes, gray foxes are often infected with *Pulex* spp. and adult *Ixodes* spp. (Eads and Menzies, 1950; Coultrip et al., 1973; Whitaker and Goff, 1979; Furman and Loomis, 1984; Bloemer and Zimmerman, 1988; Davidson et al., 1992a; Patrick and Harrison, 1995). Although *N. mephitidis* is known primarily from the striped skunk, Emerson and Price (1987) also reported this louse species on island foxes and on mainland gray foxes in Santa Barbara County in southern California; their figures of the male genitalia of *N. mephitidis* correspond almost exactly to that of the lice collected by us.

The origins of the ectoparasites on foxes

on Santa Cruz Island are unknown. If parasites arrived when foxes colonized the island around 16,000 yr ago (Wayne et al., 1991), then, like their host, they may now be endemic to the island. Parasites may have also colonized via other native species on Santa Cruz Island; for example, immature *I. pacificus* infect small vertebrates, including birds (Furman and Loomis 1984), which could have transported ticks to the island. It is not known how the striped skunk louse, *N. mephitidis*, became established on island foxes rather than *Suricatoecus* sp. that are more frequently reported on foxes (Emerson and Price, 1987). Striped skunks do not occur on the California Channel Islands, but spotted skunks (*Spilogale gracilis amphiala*) are endemic to Santa Cruz Island and may also harbor *Neotrichodectes*; *Neotrichodectes osborni* has been recorded on spotted skunks on the mainland (Price and Graham, 1997).

Exotic species introduced to Santa Cruz Island are also likely vehicles of transmission of ectoparasites to Santa Cruz Island. For example, *Pulex irritans* is a cosmopolitan human flea that attacks a wide range of hosts, including swine, humans, and dogs, and *I. pacificus* infects numerous animals, including humans, dogs, cattle, and swine (Wall and Shearer, 1997). Any of these hosts may have transmitted parasites to foxes on Santa Cruz Island. Humans colonized the island about 10,000 yr ago (Wayne et al., 1991), and cattle, horses, pigs and sheep were introduced by the mid-1800's (Brumbaugh, 1980). Domestic dogs, which are known to transmit infectious diseases to wild carnivores (Macdonald, 1996), frequently visit island beaches as pets of recreational boaters (Garcelon et al., 1992).

Parasites may affect fitness by directly causing death or negatively affecting reproduction, growth, physical condition, and behavior (Van Vuren, 1996). Chewing lice are active ectoparasites that can produce intense irritation with secondary bacterial infection (Wall and Shearer, 1997). *Pulex irritans* is a vector of *Yersinia pestis*, the causative agent of plague, and of a canine tapeworm, *Dipylidium caninum* (Patrick and Harrison, 1995). Ticks are known to cause tick paralysis in gray foxes (Jessup, 1979; Davidson et al., 1992b), and *Ixodes* spp. harbor Lyme disease spirochaetes (Isogai et al., 1994) that can cause lethargy, anorexia, and arthritis in canids (Wall and Shearer, 1997). Therefore, ectoparasites we detected on island foxes are possible vectors for dangerous diseases that may reach Santa Cruz Island in the future.

Island fox populations may be especially vulnerable to the introduction of novel disease organisms and their vectors. Insular populations often have depauperate parasite faunas (Dobson, 1988), and island foxes are no exception; a previous serological survey revealed little to no exposure to several common canine infectious diseases (Garcelon et al., 1992). Evolution in the absence of parasites can lead to compromised disease resistance, with disastrous consequences when exotic diseases are introduced (Van Riper et al., 1986; Dobson, 1988). Further, low genetic variability (Wayne et al., 1991) and high densities (Crooks, 1994) in island foxes, features characteristic of insular populations (MacArthur et al., 1972; Berry, 1986), may lead to higher transmission efficiency and infection rates than in mainland hosts (Dobson, 1988). The vulnerability of island foxes highlights the need to monitor their populations and enact management and conservation plans accordingly.

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