

Ectoparasites of a Threatened Insular Endemic Mammalian Carnivore: The Island Spotted Skunk

KEVIN R. CROOKS¹, DAVID K. GARCELON², CHERYL A. SCOTT³,
JOHN E. DEPUE², JEFFERY T. WILCOX⁴, ROBERT B. KIMSEY⁵
AND DIRK H. VAN VUREN⁶

¹Department of Fishery and Wildlife Biology, Colorado State University Ft. Collins 80523,

²Institute for Wildlife Studies, P.O. Box 1104, Arcata, California 95518

³P.O. Box 73842, Davis, California 95617

⁴1474 Rose St, Berkeley, California 94702

⁵Department of Entomology, University of California, Davis 95616

⁶Department of Wildlife, Fish, and Conservation Biology, University of California, Davis 95616

ABSTRACT.—Parasites have been identified as potential threats to mammalian carnivores, particularly insular species. We evaluated external parasites on island spotted skunks (*Spilogale gracilis amphiala*), a threatened insular endemic carnivore on Santa Cruz and Santa Rosa Islands of the California Channel Islands (USA). We identified fleas (*Pulex irritans*, *Nosopsyllus fasciatus*), lice (*Neotrichodectes mephitidis*) and ticks (*Ixodes pacificus*, *I. kingi*). Results suggest potential host-switching by ectoparasites among the native and introduced fauna on the islands, possibly due to the paucity of both potential hosts and ectoparasite species. Sharing of ectoparasites enhances the possibility of disease transmission between carnivores via ectoparasite vectors.

INTRODUCTION

The island spotted skunk (*Spilogale gracilis amphiala*), a subspecies of the western spotted skunk, is an insular endemic carnivore that is restricted to Santa Cruz Island and Santa Rosa Island, the two largest of the eight California Channel Islands (USA). Although recent evidence suggests that populations on Santa Cruz Island may be increasing (Crooks and Van Vuren, 2000; Roemer *et al.*, 2002), island spotted skunks are still considered rare, restricted in distribution, specialized in resource use and particularly sensitive to environmental perturbations (Crooks, 1994a, b; Crooks and Van Vuren, 1994, 1995, 2000). As such, the continued existence of island spotted skunks is precarious. They are listed as a subspecies of special concern by the State of California, and further monitoring of their populations is essential (Crooks, 1994a; Crooks and Van Vuren, 1994, 2000).

Diseases can pose serious threats to rare species (McCallum and Dobson, 1995; Woodroffe, 1999), and disease epizootics in mammalian carnivores have heightened concern about the threat of disease to carnivore species worldwide (Macdonald, 1996; Funk *et al.*, 2001). Carnivores on islands may be especially susceptible. Because insular endemic species often lack natural enemies, they may be relatively defenseless when exotic parasites or predators are introduced (Van Riper *et al.*, 1986; Case *et al.*, 1992; Bowen and Van Vuren, 1997; Primack, 2002). Indeed, parasites and diseases have been identified as a potential threat to the island fox (*Urocyon littoralis*), the other endemic carnivore on the California Channel Islands (Garcelon *et al.*, 1992; Crooks *et al.*, 2001a, b). The role of disease in regulating carnivore populations, however, is poorly understood due to lack of data on disease organisms and their vectors in wild predators (Addison *et al.*, 1987; Patrick and

¹ Department of Fishery and Wildlife Biology, Colorado State University, Ft. Collins 80523; e-mail: kcrooks@cnr.colostate.edu

Harrison, 1995; Crooks *et al.*, 2001a; Funk *et al.*, 2001). The prevalence and intensity of external parasites have not been quantified for the island spotted skunk. The objective of this study therefore was to determine ectoparasite intensities for island spotted skunks on Santa Cruz Island and Santa Rosa Island, California.

METHODS

Santa Cruz Island and Santa Rosa Island, located about 40 km south of Santa Barbara, California, are adjacent islands separated by about 10 km. The climate on the islands is maritime and Mediterranean with a pronounced dry season (June–November) and wet season (December–April). We sampled island spotted skunks in August 2000 and January 2001 on Santa Cruz Island, and from February to April 2001 on Santa Rosa Island. Skunks were live-trapped in single-door box-traps baited with fruit-paste baits (Nick Wyshinski, Berwick, Pennsylvania, USA) and commercial canned and dry cat food. On Santa Rosa Island, to facilitate processing, captured skunks were chemically restrained with an intramuscular injection of a combination of a general anesthetic (ketamine hydrochloride: 28 mg/kg) and a sedative (acepromazine: 0.3 mg/kg). On Santa Cruz Island, skunks were manually restrained during processing without the use of anesthesia. Captured animals were temporarily or permanently marked to allow individual identification. Based on date of capture, typical late spring litter production (Howard and Marsh, 1982), typical age-specific weights (Crabb, 1944; Crooks, 1994a), and tooth wear, captured skunks were likely young adults or adults. All captured skunks appeared healthy based on a brief physical exam.

Ectoparasites were collected by combing the animal thoroughly for about two min with a flea comb over a white cloth sheet. On Santa Cruz Island, each skunk also was sprayed with 50–60 ml of pyrethrin (Adams Flea and Tick Mist, Adams Pet Supplies, Jacksonville, Florida, USA) over the entire body below the neck before combing. 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 (202001–202024) 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. Because of relatively low sample sizes and differences in restraint and sampling methodology, we did not directly compare parasite intensities between islands.

RESULTS

Five taxa of ectoparasites were identified from 23 skunks on Santa Cruz Island and 17 skunks on Santa Rosa Island. The flea *Pulex irritans* was the most common ectoparasite on island spotted skunks, found on all sampled skunks on Santa Cruz Island and 88% of skunks on Santa Rosa Island (Table 1). A total of 315 *P. irritans* was collected, with as many as 50 fleas per skunk. Another flea species, *Nosopsyllus fasciatus*, was found on one skunk on Santa Cruz Island and two skunks on Santa Rosa Island, with one flea collected per individual (Table 1).

Four lice were collected and were identified as *Neotrichodectes mephitidis*. Lice were collected from two skunks from Santa Cruz Island and two skunks from Santa Rosa Island, with one louse per skunk (Table 1).

Two tick species, *Ixodes pacificus* and *I. kingi*, were collected from island spotted skunks. *Ixodes pacificus* was only found on Santa Cruz Island, with a total of 12 ticks collected and up to 7 ticks per skunk (Table 1). A total of 15 *I. kingi* was collected, 4 on Santa Cruz Island and 11 on Santa Rosa Island.

TABLE 1.—Ectoparasite prevalence and intensity of island spotted skunks on Santa Cruz Island and Santa Rosa Island, California, USA

	Santa Cruz Island (n = 23)				Santa Cruz Island (n = 17)			
	Prevalence (%)	Abundance			Prevalence (%)	Abundance		
		Mean	SE	Range		Mean	SE	Range
Fleas								
<i>Pulex irritans</i>	100	11.96	2.49	1–50	88.2	2.35	0.45	0–7
<i>Nosopsyllus fasciatus</i>	4.3	0.04	0.04	0–1	11.8	0.12	0.08	0–1
Ticks								
<i>Ixodes pacificus</i>	13	0.52	0.33	0–7	0	0	0	0
<i>Ixodes kingi</i>	17.4	0.17	0.08	0–1	35.3	0.65	0.26	0–3
Lice								
<i>Neotrichodectes mephitidis</i>	8.7	0.09	0.06	0–1	11.8	0.12	0.08	0–1

DISCUSSION

Island spotted skunks were host to one common and four uncommon ectoparasites. The origins of these ectoparasites on island spotted skunks are unknown. Some parasites could have arrived when skunks colonized the California Channel Islands. Although the date of origin of spotted skunks on the islands is unknown, skunk remains in Native American Chumash archeological sites on Santa Cruz Island suggest that skunks may at least pre-date the arrival of Europeans over 400 y ago (Crooks and Van Vuren, 1994). Parasites also may have arrived via other native species on Santa Cruz and Santa Rosa Islands, or recently via exotic species introduced to the islands (Crooks *et al.*, 2001a).

Two of the ectoparasites, *Pulex irritans* and *Ixodes pacificus*, are general external parasites whose presence on island spotted skunks was expected. *Pulex irritans*, the most common ectoparasite on island spotted skunks, is also found on the island fox on Santa Cruz Island (Crooks *et al.*, 2001a). *Pulex irritans* is a widespread human flea that attacks a wide range of hosts, including domestic animals such as cattle, swine and dogs, all of which have occurred on Santa Cruz and Santa Rosa Islands and may have transmitted parasites to the native carnivores (Crooks *et al.*, 2001a). Spotted skunks in the Sacramento Valley of mainland California harbored fleas that Mead (1963) identified as *P. simulans*, although this species is closely related to and difficult to distinguish from *P. irritans* (Smit, 1958; Patrick and Harrison, 1995) and Mead (1963) acknowledged that some of the fleas may have been *P. irritans*.

Ixodes pacificus, recorded on island spotted skunks only on Santa Cruz Island, also occurs on island foxes on that island (Crooks *et al.*, 2001a). *Ixodes pacificus* is a common parasite of a wide range of animals along the temperate west coast of North America (Wall and Shearer, 1987; Samuel *et al.*, 2001) and is the most commonly encountered *Ixodes* species in California (Furman and Loomis, 1984). Immature *I. pacificus* infect a variety of small vertebrates, including birds (Furman and Loomis, 1984), which may have transported ticks to the California Channel Islands.

The presence of the other ectoparasites on island spotted skunks was somewhat surprising. *Neotrichodectes mephitidis*, recorded on island spotted skunks from both Santa Cruz Island and Santa Rosa Island, is a chewing louse normally associated with the striped skunk (*Mephitis mephitis*) (Emerson and Price, 1987; Samuel *et al.*, 2001). A congeneric species, *N. osborni*, is listed as the typical chewing louse parasitic on mainland spotted skunks (Price and Graham, 1997; Samuel *et al.*, 2001), although Mead (1963) recorded *N. mephitidis* on 29% of

14 spotted skunks examined in mainland California and recorded no *N. osborni*. Interestingly, *N. mephitidis* also occurs on the island fox (Crooks *et al.*, 2001a), rather than the *Suricataeacus* sp. that are more frequently reported on foxes in the mainland (Emerson and Price, 1987), perhaps suggesting that island foxes became infected with *N. mephitidis* via island spotted skunks.

Ixodes kingi, detected on spotted skunks on both islands, is widespread in the United States (Furman and Loomis, 1984; Samuel *et al.*, 2001), but is seldom reported in California (R. B. Kimsey, pers. obs.). Although spotted skunks are listed as a host species for *I. kingi* (Samuel *et al.*, 2001), no *Ixodes* ticks were recorded on 14 mainland spotted skunks in the Sacramento Valley of California (Mead, 1963). Primary hosts of *I. kingi* include pocket gophers, kangaroo rats and sigmodontine mice west of the Rocky Mountains, and carnivores, ground squirrels and prairie dogs east of the Rocky Mountains (Furman and Loomis, 1984; Samuel *et al.*, 2001).

The rat flea, *Nosopsyllus fasciatus*, was detected on island spotted skunks on both islands. This flea is endemic to Europe and the British Isles and has a worldwide distribution due to its association with commensal rodents (Schwan, 1984). The flea is typically associated with rats (*Rattus* spp.), but can occasionally cross-transfer to other murine rodents (Hubbard, 1947; Schwan, 1984; Roberts, 1991), as well as a variety of other vertebrates including mustelid carnivores (Fox, 1940; Debrot and Mermod, 1982; King and Moody, 1982). Although it is possible that rat fleas may "hitchhike" to islands via other mammalian hosts, the presence of *N. fasciatus* on insular fauna has been used as possible parasitological evidence of past or current introduction of rats onto Pacific islands (Schwan, 1984; Roberts, 1991). No rats are currently known to live on Santa Cruz Island or Santa Rosa Island, but black rats (*Rattus rattus*) do occur on neighboring Anacapa Island and San Miguel Island (Erickson and Halvorson, 1990). It is possible that some rats escaped onto Santa Cruz and Santa Rosa Islands from visiting ships in the past and lived long enough to transmit fleas to skunks or other mammalian hosts, such as the native deer mouse (*Peromyscus maniculatus*) or harvest mouse (*Reithrodontomys megalotis*). Island spotted skunks are known predators of small mammals (Crooks and Van Vuren, 1995) and, as has been suggested for other mustelids (King and Moody, 1982), may have acquired *N. fasciatus* directly from the bodies of prey animals being eaten or indirectly from prey nests in which they have hunted or slept. *Nosopsyllus fasciatus* certainly has the ability to invade islands offshore of California by hitchhiking or other means. The flea parasitizes house mice (*Mus musculus*) on Southeast Farallon Island off the coast of San Francisco and deer mice (and presumably black rats) on San Miguel Island (Schwan, 1984).

In all, these results suggest potential host-switching by ectoparasites among the native and introduced fauna on Santa Cruz and Santa Rosa Islands, demonstrating the possibility for disease transmission among species via ectoparasite vectors. Insular populations are often exposed to relatively few parasites compared to mainland counterparts (Dobson, 1998; King and Moody, 1982), and such may be the case with the island spotted skunk as well as the island fox. For example, we examined 40 island spotted skunks and recorded two species of flea, whereas Mead (1963) examined only 14 spotted skunks on mainland California yet found six species of flea. In addition, serological surveys suggest that island foxes (Garcelon *et al.*, 1992) and island spotted skunks (Crooks *et al.*, unpubl. data) have experienced relatively little exposure to several common infectious diseases. Evolution in the absence of parasites can lead to compromised disease resistance, with potentially severe consequences when exotic diseases are introduced (Van Riper *et al.*, 1986; Dobson, 1988; Primack, 1998; Crooks *et al.*, 2001a, b).

As is characteristic of oceanic islands (Lawlor, 1986), Santa Cruz Island and Santa Rosa

Island also support depauperate vertebrate faunas (Wenner and Johnson, 1980). For example, in addition to the island fox and island spotted skunk, the two islands support only two other native species of terrestrial mammals, the deer mouse, which occurs on both islands, and the harvest mouse, only occurring on Santa Cruz Island (von Bloeker, 1967). Few potential host species, and few parasite taxa to infect them, raises the possibility that island foxes and island spotted skunks may share more ectoparasite species than do their counterparts on the mainland. Indeed, all three ectoparasites found on island foxes (*Pulex irritans*, *Ixodes pacificus*, and *Nosopsyllus mephitidis*; Crooks, 2001a) are found on island spotted skunks. In comparison, mainland gray foxes host at least 15 species of fleas, two species of lice and nine species of ticks (Fritzell, 1987), an ectoparasite assemblage that only partially overlaps the similarly diverse ectoparasite fauna hosted by mainland spotted skunks (Mead, 1963; Howard and Marsh, 1982; Rosatte, 1987; Kinlaw, 1995; Verts *et al.*, 2001). It remains uncertain if increased overlap of ectoparasite fauna between insular endemic carnivores would result in increased disease transmission compared to the mainland. Nevertheless, island spotted skunks and island foxes do share some ectoparasites, so the possibility of disease transmission exists. We recommend continued monitoring of diseases and their vectors in these endemic carnivores.

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