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HELMINTHS OF SYMPATRIC STRIPED, HOG-NOSED, AND SPOTTED SKUNKS IN WEST-CENTRAL TEXAS

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ABSTRACT: Twenty-eight hog-nosed skunks (*Conepatus leuconotus*), 23 striped skunks (*Mephitis mephitis*), and nine spotted skunks (*Spilogale gracilis*) from an area of sympatry in west-central Texas were examined for helminth parasites. Shared helminth species among all three host species were one nematode (*Physaloptera maxillaris*), two acanthocephalans (*Pachysentis canicola*, *Macracanthorhynchus ingens*), and one cestode (*Mathevotaenia mephitis*). Two nematodes (*Gongylonema* sp. and *Filaria taxidaea*) occurred in both the striped and hog-nosed skunks. One nematode (*Filaroides milksi*) and one acanthocephalan (*Oncicola canis*) were collected only from *C. leuconotus*. The most common helminth infections for striped and hog-nosed skunks were *P. maxillaris* and *P. canicola*. Helminth species richness was highest in hog-nosed skunks, but striped skunks had the highest prevalences and intensities of all the common helminth species. The helminth fauna of spotted skunks was markedly depauperate in terms of species richness and helminth abundance compared to the other two host species. Differences in helminth communities across these three sympatric skunks may be related to differences in their relative abundance, behavior, food habits, and geographic range.

Key words: *Conepatus leuconotus*, helminth survey, hog-nosed skunk, *Mephitis mephitis*, *Spilogale gracilis*, spotted skunk, striped skunk, sympatric skunks.

INTRODUCTION

Hog-nosed skunks occur throughout much of Central and South America with only one species, *Conepatus leuconotus*, reaching into the southwestern US (Dragoo et al., 2003). In contrast, striped and hooded skunks (*Mephitis* spp.) and spotted skunks (*Spilogale* spp.) are primarily North American, occurring from Canada throughout the USA and into Central America. A single species from each of these genera, *C. leuconotus*, *Spilogale gracilis*, and *Mephitis mephitis*, are sympatric across central and west Texas (Schmidly, 2004). Of these, *C. leuconotus* and *S. gracilis* are near the extremities of their geographic range in west-central Texas.

Helminth parasites of striped and spotted skunks are well documented throughout North America (Tiner, 1946; Verts, 1967; Dyer, 1969; Dyer et al., 1974; Patton, 1974), while helminth data from *C. leuconotus* are deficient (Tiner, 1946; Patton, 1974). Tiner (1946) examined endoparasites of skunks in central Texas but listed only the collective parasite species and their prevalences for the three skunk genera (*Mephitis*, *Conepatus*, and *Spilogale*) without distinguishing among host species. Patton (1974) differentiated between species of skunks in west Texas but examined only the gastrointestinal tract for helminths.

As part of a larger ecological research project on skunks in west-central Texas we examined their helminth faunas. Specifically, our objectives for this study were to (1) document the helminth faunas of three sympatric skunk species, *M. mephitis, S. gracilis*, and *C. leuconotus*; (2) compare the three host species in terms of helminth occurrence and abundance; and (3) relate the findings to the ecology of these hosts.

MATERIALS AND METHODS

Sixty skunks were collected between December 1993 and October 2004. Most skunks ($n=40$) were road-killed carcasses. An additional 20 specimens were live trapped in Tomahawk traps (Tomahawk Live Trap, Tomahawk, Wisconsin, USA) and euthanized with chloroform. Our fieldwork was conducted in accordance with animal care and use guidelines set forth by the American Society of Mammalogists (Animal Care and Use Committee, 1998). All collected animals were frozen for later necropsy. Necropsy techniques followed Radomski et al. (1991). Subcutaneous tissues were examined for filariids. The nares, sinuses, and skull were examined for nasal metastrongyloid nematodes. In addition, all skunk skulls in the Angelo State Natural History Collection (ASNHC; Angelo State University, San Angelo, Texas, USA) were examined for pathology associated with these nematodes. Techniques used in the collection, preservation, preparation, examination, and measurement of helminths followed those outlined in Waid and Pence (1988). Tongues from 15 and 18 striped and hog-nosed skunks were examined for *Trichinella* spp., respectively, as previously described (Posio et al., 2001). Helminths were identified by comparison with voucher specimens collected from carnivores in Texas by the junior author (D.B.P.) during previous studies and from the original descriptions and keys in Morgan (1944), Erickson (1946), Self and McKnight (1950), Yamaguti (1959–63), Pence (1978), and Schmidt (1986). Collection of all helminths from the viscera and other tissues was attempted. Nematodes were fixed in glacial acetic acid, preserved in 70% ethyl alcohol with 7% glycerine, and examined in glycerine wet mounts following slow evaporation of the alcohol. All other helminths were relaxed in cold water and preserved in 70% ethyl alcohol. Cestodes and acanthocephalans were stained in Semicohn's acetocarmine, dehydrated in a graded series of ethyl alcohol solutions, cleared in methyl salicylate, and mounted in Canada balsam. Representative specimens of helminth species from skunk host species are deposited in the U.S. National Parasite Collection (Beltsville, Maryland, USA; hog-nosed skunk helminth accession numbers 094919.00–094927.00; striped skunk helminth accession numbers 094928.00–094933.00; spotted skunk helminth accession numbers 095655.00–095658.00). Host vouchers are deposited in the ASNHC.

Herein, the terms prevalence, intensity, and abundance are used according to definitions outlined in Bush et al. (1997). Prevalence of a parasite species is the percentage of hosts infected with that species/total number of hosts examined. Intensity is the total number of individuals of a species of parasite/the number of hosts infected with that parasite species. Abundance is defined as the total number of individuals of a parasite species/the total number of hosts examined. Both intensity and abundance values are reported as a mean±standard error ($\bar{X}\pm SE$). Host refers to the vertebrate animal in which the helminth occurs. Site is defined as the specific anatomical locality where a parasite is found within the host. Those helminth species occurring in ≥18% of these hosts were considered as common species, while those with lower prevalences were considered uncommon to rare.

Statistical analyses on helminth prevalence and intensity data were performed using SYSTAT (2002 edition; SPSS Science, Inc., Chicago, Illinois, USA). The frequency distribution was determined with a one-sample Kolmogorov-Smirnov test on each of the common helminth species. Parasites displayed an aggregated (nonnormal) distribution pattern, and therefore data on intensity and abundance were ranked prior to analysis. Intensity was analyzed for each of the common parasites using analysis of variance (ANOVA). Prevalence was analyzed for goodness-of-fit using chi-squared tests to determine if the number of hosts infected varied between the host species. The level of significance was set at $\alpha=0.05$.

Twenty-eight *C. leuconotus*, 23 *M. mephitis*, and nine *S. gracilis* were collected from 13 counties comprising an area bounded by coordinates 32.7 and 30.4 N by 98.1 and 102.0 W in west-central Texas during the period 1993–2004. Of the hog-nosed skunks, 15 were from Tom Green County, three from Concho County, and one each was from Glasscock, Sterling, Val Verde, Coke, Howard, Taylor, Llano, Schleicher, Runnels, and Irion counties. Twenty-two of the striped skunks were from Tom Green County (gastrointestinal tract only for one specimen), and one was collected from Brown County. Eight of the spotted skunks came from animals collected by city of San Angelo Animal Services, and one was collected from elsewhere in Tom Green County. Although the interface with the eastern spotted skunk (*Spilogale putorius*) is near our collection localities, all specimens of the genus *Spilogale* that we collected were identified as the western spotted skunk, *S. gracilis*.

West-central Texas is composed of the Edwards plateau ecological region. This area is 700–1,000 m in elevation with a gently sloping landscape (Wiedenfeld and Flores, 1976). Average annual rainfall is approximately 38 cm. Average annual temperature is approximately 19 C (Fowler and Dunlap, 1986). Vegetation is primarily desert scrub with mesquite (*Prosopis glandulosa*) and prickly pear (*Opuntia* spp.) as the predominant plants in the study area (Smeins et al., 1976).

RESULTS

Nine species of helminths were identified from *C. leuconotus*, seven were found in *M. mephitis*, and four were collected from *S. gracilis*. Skunks were infected with none to five species of helminths; $\bar{X}\pm SE$ for *M. mephitis*, *C. leuconotus*, and *S. gracilis* was 3.0 ± 1.0, 2.2 ± 1.0, and 1.7 ± 0.4 species/host, respectively. Prevalence, intensity, abundance, and site data for the helminths collected from these three sympatric skunks are summarized in Table 1. Common helminth species in hog-nosed, striped, and spotted skunks included numerous unidentifiable larvae and immature *Physaloptera* spp., and adults and larvae of *Pachysentis canicola* and *Macracanthorhynchus ingens*. In addition to these, other common helminth species were adult *Physaloptera rara* and *Physaloptera maxillaris* shared by hog-nosed and striped skunks, mature strobilae of *Mathevotaenia mephitis* found in both striped and spotted skunks, and adult *Filaria taxidaea* in the hog-nosed skunk. Of the four helminth species found in the spotted skunk, only the nematode *P. maxillaris* (represented by a single female) and cestode *M. mephitis* occurred as adults in this host.

In addition to the above hosts, 34, 53, and eight skulls of hog-nosed, striped, and spotted skunks in the ASNHC, respectively, were examined. Of these, one striped skunk and six spotted skunks had lesions or other signs of the invasive nasopharyngeal metastrongyloid nematode *Skrjabingylus chitwoodorum*. Neither lesions nor nematodes attributable to skrjabingylosis were observed in any of the 60 skunks necropsied in this study.

The absence of a helminth fauna was found in only two spotted skunks. In the remainder of the skunks, common helminths tended to exhibit a nonnormal distribution in certain hosts (*P. maxillaris*, $P<0.001$, *P. rara*, $P<0.001$, *P. canicola*, $P<0.001$, *M. ingens*, $P<0.001$, *M. mephitis*, $P<0.001$; Kolmogorov-Smirnov one-sample test). There was a significant difference among hosts in intensity of infection for two of the five common species of parasites. These were *P. maxillaris* ($F=24.505$, $P<0.001$, df=2) and *P. canicola* ($F=11.888$, $P<0.001$, df=2). Statistical differences were not detected among hosts in intensity for the other three common parasite species, *P. rara* ($F=2.934$, $P=0.107$, df=1), *M. ingens* ($F=0.757$, $P=0.49$, df=2), and *M. mephitis* ($F=1.62$, $P=0.242$, df=2); however, there were higher intensities of these helminths in *M. mephitis* compared to the other two host species (Table 1). There was a significant difference in prevalence among hosts for the two nematode species, *P. rara* ($\chi^2=3.96$, df=1, $P<0.05$) and *P. maxillaris* ($\chi^2=18.71$, df=2, $P<0.001$).

DISCUSSION

Previous records of helminths from skunks in Texas are incomplete and somewhat confounded by the recent taxonomic recognition of two spotted skunks, the eastern and western species (Mead, 1968a, b). Tiner (1946) reported that student workers found only 170 helminth infections in 400 (43%) formalin-preserved viscera of striped, spotted, and hog-nosed skunks. These were collected mostly from Kerr and Mason counties just south of our collection area in west-central Texas, and a few came from Brazos County in east-central Texas. *Physaloptera maxillaris* was the most common helminth occurring in 39% of these skunks. Two genera of cestodes, *Oochoristica* (=*Mathevotaenia*?) sp. and *Mesocestoides* sp., were found in 21% and 17% of the three species of skunks, respectively. Acanthocephalans were collected but not identified or quantified. *Filaria martes* (=*Filaria taxidae*?) occurred in the subcutaneous tissue of one

TABLE 1. Helminths of striped, hog-nosed, and spotted skunks in west-central Texas.

Helminth species[a]	Host[b]	Site[c]	Prevalence		Intensity		Abundance X̄±SE[h]	Total helminths[i]
			Infected/examined[d]	%[e]	X̄±SE[f]	Range[g]		
PR	1	S, SI	11/23[j]	48	10.2±2.8	1–32	4.9±1.7	112
	2	S, SI	6/28[j]	21	3.3±1.0	1–8	0.7±0.3	20
PM	1	S, SI	21/23[j]	91	21.2±3.3[j]	4–61	19.4±3.2	446
	2	S, SI	17/28[j]	61	3.9±0.8[j]	1–13	2.4±0.4	66
	3	S	1/9[j]	11	1.0±0[j]	1	0.1±0.1	1
Psp	1	S, SI	23/23	100	64.4±12.7	2–195	64.4±12.7	1694
	2	S, SI	27/28	96	34.0±7.1	3–123	31.7±6.9	945
	3	S	1/9	22	1.0±0	1	0.2±0.1	2
Gsp	1	E	2/23	9	1.0±0	1	0.1±0.1	2
	2	E	1/28	4	1.0±0	—	0.1±0.1	1
FM	2	L	2/28	7	1.0±0	1	0.1±0	2
FT	1	SC, B	2/22	9	1.5±0.4	1–2	0.1±0.1	3
	2	SC, B	7/28	25	6.3±0.7	1–12	2.8±1.1	44
PC	1	SI, B	18/23	78	23.2±6.9[j]	4–137	18.1±5.7	427
	2	SI, B	13/28	46	7.8±3.6[j]	1–49	4.3±1.9	101
	3	SI, B	6/9	66	4.0±2.2[j]	1–16	2.7±0.9	24
MI	1	SI	8/23	35	9.0±2.9	1–22	3.1±1.3	72
	2	SI	5/28	18	4.4±0.9	1–7	0.8±0.4	22
	3	SI	2/9	22	2.0±0.7	1–3	0.4±0.3	4
OC	2	SI	1/28	4	10.0±0	—	0.4±0.4	10
MM	1	SI	6/23	26	2.2±0.4	1–3	0.6±0.2	11
	2	SI	3/28	11	4.7±1.7	1–8	0.5±0.3	14
	3	SI	4/9	44	3.0±0.9	1–6	1.3±0.6	12

[a] FM = *Filaroides milksi*, FT = *Filaria taxidaea*, Gsp = *Gongylonema* sp., MI = *Macracanthorhynchus ingens*, MM = *Mathevotaenia mephitis*, OC = *Oncicola canis*, PC = *Pachysentis canicola*, PM = *Physaloptera maxillaris*, PR = *Physaloptera rara*, Psp = *Physaloptera* sp. larvae.

[b] Striped skunk, *Mephitis mephitis* = 1; hog-nosed skunk, *Conepatus leuconotus* = 2; spotted skunk, *Spilogale gracilis* = 3.

[c] B = body cavity, E = esophagus, L = lungs, S = stomach, SC = subcutaneous tissues, SI = small intestines.

[d] Prevalence = Number of hosts examined/number of hosts infected.

[e] Prevalence ratio expressed as a percentage.

[f] Intensity = Total number of all individuals of a helminth species collected/number of hosts infected; Expressed as mean±standard error.

[g] Range = Minimum to maximum number of helminth individuals found in all the respective infected hosts.

[h] Abundance = Total number of all individuals of a helminth species collected/total number of hosts examined; Expressed as mean±standard error.

[i] Total number of all individuals of each of the respective helminth species that were collected.

[j] Denotes significance at $P \leq 0.05$ for chi-squared test on prevalence and ANOVA on intensity.

hog-nosed and two striped skunks. In our opinion, collection and identification of helminths from formalin-preserved material is so difficult that results are always inconclusive in terms of host species richness and helminth abundance. Also, it should be noted that no distinction was made between the eastern and western species of spotted skunks in Tiner's (1946) study. Patton (1974) found that the most common parasite of both striped and hog-nosed skunks from the Trans Pecos of west Texas was *P. maxillaris* in 90% and 54% of 27 and 17 hosts, respectively. Cestodes were present in both hosts, but these were not identified. Acanthocephalans were reported but not identified in 48% of striped skunks; none were reported from the hog-nosed skunk. While Tiner (1946) noted that only spotted and striped skunks were infected with *S. chitwoodorum*, Patton (1974) reported this nematode in hog-nosed skunks from west Texas. Pence (1978) reported *Filaroides milksi* from one of six hog-nosed skunks examined from Concho County in west-central Texas.

Our results are similar to these previous studies. *Physaloptera* spp. occupied almost all of the available hosts, being present in all but one and three hog-nosed and striped skunks, respectively (Table 1). *Physaloptera maxillaris* was the most common parasite of all three host species, which is consistent with the findings of Tiner (1946) and Patton (1974). *Physaloptera maxillaris* has been reported as the most common endoparasite in striped skunks throughout North America (Dyer, 1974). The abundance of *F. taxidaea* for both hog-nosed and striped skunks is considerably higher than that reported (as *F. martes*) by Tiner (1946). Although Patton (1974) did not report acanthocephalans from hog-nosed skunks, our study demonstrates acanthocephalans to be an important part of the parasite component community in *C. leuconotus*. We collected three species of acanthocephalans from hog-nosed skunks, with *P. canicola* occurring in almost one-half of these hosts. *Macracanthorhynchus ingens* has been reported in striped skunks from across North America as well (Dyer, 1974). Both *P. maxillaris* and *M. ingens* appear to be important components of the helminth community of *M. mephitis*. This is the first report of *O. canis* and *Gongylonema* sp. in *C. leuconotus*. Trematodes were not found in any of the hosts we examined. West-central Texas is relatively arid and lacking in snails that serve as the intermediate hosts for trematodes. *Alaria taxideae* was the only trematode found in striped skunks from Illinois (Dyer et al., 1974). Several other species of trematodes have been reported from this host elsewhere (Dyer, 1969).

It appears that all three species of skunks from west-central Texas share at least four of the more common and important helminth species of skunks. Of these, *P. maxillaris, P. canicola*, and *M. mephitis* are usually reported as mostly skunk parasites, and *M. ingens* is usually found in raccoons, *Procyon lotor* (Yamaguti, 1959–63). Obviously skunks acquired these four helminth species through ingestion of their respective infected arthropod intermediate hosts. Arthropods are important components in the diets of all three skunk species, comprising 84%, 66%, and 58% of the diets of the striped, hog-nosed, and spotted skunks, respectively (Taylor, 1953a, b, c).

In terms of species richness and abundance, there were major differences in parasite communities across the three species of sympatric skunks. Prevalences and intensities of all the common helminth species were consistently highest in *M. mephitis*, persistent but lower in *C. leuconotus*, and depauperate in *S. gracilis* (Table 1). Kennedy et al. (1986) outlined five factors that influence the diversity of helminth communities: host vagility, broad host diet, host physiology/anatomy, selective feeding on intermediate hosts, and exposure of hosts to direct life cycle helminths through penetration. Some of these factors may be applicable to the helminth community in skunks. No helminths that infect through penetration were collected. Feeding generalists, such as *M. mephitis*, are thought to expose themselves to a greater number of potential infections from parasites because they use far more resources than do more specialized hosts, such as *C. leuconotus*. The greater propensity for the striped skunk to feed on arthropods (84% of dietary items) may partially account for the much higher abundances of helminths in this skunk species. The lower but persistent abundances of these helminths in the hog-nosed skunk is consistent with its still predominantly insectivorous food habits (66% of dietary items). But this skunk has more dependence on plants (14%) than the striped skunk (7%) (Taylor, 1953a, b). Likewise, the lowest helminth prevalences and abundances could be partly reflective of the spotted skunk's lesser dependence on insectivory (58%) than the other two species of skunks. The spotted skunk is the most carnivorous of the skunks, with 35% of its diet consisting of vertebrates (Taylor, 1953c).

Host vagility and physiology may play a part in the ability of helminths to successfully infect their hosts and may partially explain the differences in helminth community structure across similar host species. *Mephitis mephitis* is considered a habitat generalist, often thought of as one of the most common carnivores in North America (Verts, 1967). Thus, the high vagility of the striped skunk may subject it to more potential helminth infections when compared to a habitat specialist like the hog-nosed skunk that is typically found in rocky more arid areas. Although little is known regarding differences in physiology across skunk genera, this could account for susceptibility differences to helminth infections. The genus *Conepatus* is primarily a South American taxon and may represent new habitat to certain helminth parasites in North America. Likewise the western spotted skunk is of southern origin (Sonora Desert of Mexico) and is extending its range northward. The larger species of striped and hog-nosed skunks are much more abundant than the smaller more nocturnal spotted skunk (Taylor, 1953c). Even so, the hog-nosed skunk is relatively less abundant than the striped skunk in our study area. Previous studies have focused on the ability of parasites to adapt to the most common genotype in a host population and have shown that rare genotypes maintain an advantage (lower parasite abundances) over common ones within a single host species (Parker, 1985; Lively, 1989). If frequency-dependent selection can be extended to multiple closely related sympatric genera and species, it would follow that, all other factors being equal, more parasites would infect the most common species. Accordingly, we hypothesize that all genera and species of skunks may be susceptible to infection by the same parasites because of their close phylogeny. However, because *C. leuconotus* and *S. gracilis* represent rarer types in west-central Texas, they generally are less heavily parasitized than the more common and abundant *M. mephitis*.

There was no evidence of pathogenicity of helminth species even in adult striped skunks that were most heavily infected with *P. maxillaris* and/or *P. canicola*. However, neither neonate nor juvenile skunks were examined for helminths in this study. Massive infections of these and other helminth species that can occur in immunologically naïve juvenile hosts may have a more serious impact in certain other carnivore populations. For example, as high as 2/3 pup mortality in coyotes (*Canis latrans*) may result from infections with related nematode and acanthocephalan species in southern Texas (Pence, 1995).

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