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A Survey of the Parasites of Coyotes (*Canis latrans*) in New York based on Fecal Analysis

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ABSTRACT: Coyotes (*Canis latrans*) have colonized northeastern North America only within the past 10–80 yr. We examined feces of coyotes in 2000–01 at three sites in New York (USA) to survey parasites in the region. Two cestodes, nine nematodes, five protozoa, one trematode, and two arthropods were identified from 145 coyote fecal samples. Parasite component community diversity was higher ($n=16$ species) in southern New York than in middle and northern sites (nine species each) and infracommunity species richness was greater in southern New York than at the other sites. These differences may reflect the variable diets of coyotes, as well as recent colonization of the region and the mixing of component communities from expanding coyote populations.

Key words: *Canis latrans,* coyotes, parasites, New York, survey.

Coyotes (*Canis latrans*) first colonized northeastern North America in the 1940s when animals moved from Québec (Canada) into northern New York (USA), and then steadily expanded into surrounding states and provinces such that by the late 1990s the species was virtually ubiquitous throughout the northeast (Parker, 1995; Fener, 2001; Gompper, 2002a). While heartworms, sarcoptic mange mites, canine distemper virus, and rabies virus are known to infect and cause clinical disease and mortality in coyotes in the northeast (Agostine and Jones, 1982; Okoniewski and Stone, 1983) no broad examination of occurrence of enteric parasites of coyotes in the northeast has been published (Gompper, 2002b). Such information is important for understanding coyote population limitation and understanding potential risks that coyote range expansion represent to humans, domestic animals, and wildlife of the region.

Much of what we know about parasites of coyotes comes from the western and southeastern United States (Custer and Pence, 1981a, b; Pence and Custer, 1981; Van Den Bussche et al., 1987). In the eastern United States the most northern examination of coyote parasites was a small ($n=16$ fecal sample) study in southern Pennsylvania (USA; Bixel, 1995). It is unclear how transferable these findings are to the very different environment of the northeast, especially given previous findings demonstrating substantial dissimilarity of coyote parasite faunas from across geographic regions (Custer and Pence, 1981a).

The goal of this study was to survey the parasites of coyotes from New York, based on fecal samples collected from a series of transects at three sites (Fig. 1): the northern Adirondacks (ADK) across a large area in Franklin, Essex, and Clinton counties (44°09′N, 74°18′W); the 12 km^2 Albany Pine Bush Preserve (PBP) between the cities of Albany and Schenectady (42°42′N, 73°52′W); and the 15 km^2 Black Rock Forest (BRF) in the Hudson Highlands of southern New York between the towns of Cornwall and West Point (41°45′N, 74°01′W). Coyotes have inhabited these sites for approximately 60, 40, and 20 yr, respectively (Fener, 2001). Although all transects were located in forested sites, the landscapes in which they

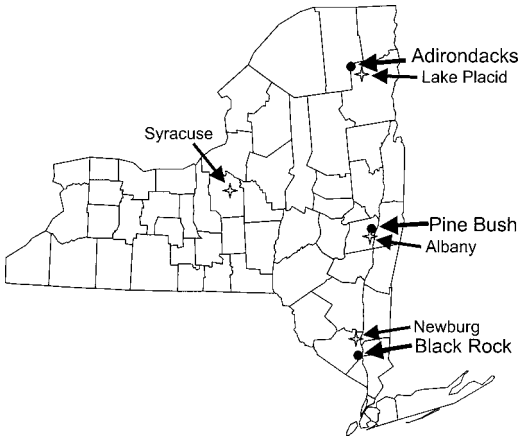

FIGURE 1. Map of New York showing the three study sites.

were situated covered a wide spectrum in housing density and general human development, with ADK the least developed, PBP situated in a suburban setting, and BRF situated in a rural region 80 km north of New York City.

During 2000 and 2001, fecal samples were collected at all three sites by walking transects of variable lengths (5–40 km) on unpaved roads and hiking trails in each region. Fresh feces (estimated ≤4 days old) were collected and preserved in 10% formalin acetate within 12 hr and stored at room temperature until analysis. Species origin of the sample was determined by size, shape, and a detailed knowledge of the fauna of each site based on extensive use of motion detection cameras (M. Gompper, R. Kays, and J. Ray, unpubl. data). To avoid confusion between fox (*Vulpes vulpes*) and coyote feces, we only selected large samples (>2 cm diameter) for analysis.

All fecal samples were processed using standard sugar and zinc sulfate centrifugation concentration flotation techniques (Bowman, 1999). Ova, oocysts, and larvae were identified by morphologic characteristics and linear measurements. A subset of samples was tested for *Giardia* spp. using an enzyme-linked immunosorbent assay (ELISA; ProSpecT Giardia Microplate Assay, Alexon-Trend, Ramsey, Minnesota, USA). Prevalence was calculated as the ratio of the number of fecal samples infected to the total number examined. Species accumulation curves and the non-parametric Chao2 estimator were used to calculate species richness of parasite component communities (the community of parasites associated with a regional subset of hosts; Bush et al., 1997). The Chao2 estimator has been shown to have excellent predictive power when data are in the form of presence-absence and sample sizes are small (Colwell and Coddington, 1994). Calculations were performed using EstimateS version 6.0b1 (Colwell, 2001). Sample order was randomized 100 times without replacement and mean (±SD) species richness estimated for each sample accumulation level.

Nineteen species of parasites were identified from 145 coyote fecal samples (Table 1). All observed species have previously been reported from coyotes elsewhere in their range. Forty-four percent (n=64) of the samples contained no parasite species of coyotes. While it is typical for a significant percent of the population to be unparasitized, it is also possible that some of our samples may have suffered from degradation. However, 13% of these did contain eggs or cysts of prey species eaten by coyotes, suggesting that degradation of the samples does not explain the absence of coyote parasites in all fecal samples.

Ova of nine species of nematodes were observed, including *Capillaria aerophila* and *C. putorii*, at all three sites, and *C. plica* at ADK. Prevalence of *C. aerophilia* was relatively high in ADK (35%), but lower in PBP and BRF (13–14%). If the rate of occurrence observed in these three sites is representative of the true prevalence in the Northeast, it is unlikely that *Capillaria* infection is a significant morbidity or mortality risk to coyotes in southern New York, but it may be important in northern New York.

Uncinaria stenocephala was found in over a third of BRF samples, but was rare elsewhere. Samuel et al. (1978) reported

TABLE 1. Endoparasites of coyote fecal samples from three sites in New York. Values are prevalence estimates excluding samples for which no parasites of coyotes were observed, suggesting degradation. Values in parentheses are prevalence estimates including all samples. For *Giardia,* values represent ELISA-based prevalence with number of samples tested in parentheses.

	Northern Adirondacks (n = 54)	Pine Bush, Albany (n = 68)	Black Rock Forest, Cornwall (n = 23)	Total (n = 145)
Arthropods				
Trichodectes canis			6.3 (4.4)	1.1 (0.7)
Demodex sp.		6.8 (4.4)	6.3 (4.4)	4.5 (2.8)
Cestodes				
Spirometra sp.	10.3 (5.6)			3.4 (2.1
Taenia sp.	41.4 (22.2)	6.8 (4.4)	6.3 (4.4)	18.0 (11.0)
Nematodes				
Capillaria aerophila	34.5 (18.5)	13.6 (8.8)	12.5 (8.2)	20.2 (12.4)
Capillaria putorii	3.5 (1.9)	2.3 (1.5)	12.5 (8.2)	4.5 (2.8)
Capillaria plica	3.5 (1.9)			1.1 (0.7)
Crenosoma sp.	10.3 (5.6)	2.3 (1.5)	6.3 (4.4)	5.6 (3.5)
Physaloptera sp.			6.3 (4.4)	1.1 (0.7)
Spirurida			6.3 (4.4)	1.1 (0.7)
Toxascaris leonina			12.5 (8.7)	2.3 (1.4)
Toxocara canis			12.5 (8.7)	2.3 (1.4)
Uncinaria stenocephala	3.5 (1.9)	2.3 (1.5)	37.5 (26.1)	9.0 (5.5)
Protozoans				
Giardia spp.	15.2 (46)	13.3 (30)	16.6 (18)	14.9 (94)
Isospora canis			6.3 (4.4)	1.1 (0.7)
Isospora (*Hammondia*) *heydorni*			18.8 (13.0)	3.4 (2.0)
Isospora ohioensis			25.0 (17.4)	4.5 (2.8)
Sarcocystis sp.	6.9 (3.7)	45.5 (29.4)	12.5 (8.7)	27.0 (16.6)
Trematodes				
Digenea		18.2 (11.8)		9.0 (5.5)

similarly high *Uncinaria* prevalence (28%) in southwestern Manitoba. Hookworm infection can cause varying severity of disease, from unapparent infection or mild anemia to fatal exsanguination, depending on virulence of the parasitic species, the age and health of the host, and acquired immunity of the host. *Uncinaria* infects the small intestines of carnivores and is less pathogenic than the common canid hookworm, *Ancylostoma caninum* (Bowman, 1999), which was not observed in this survey. Both species have been observed in eastern coyotes as far north as southern Pennsylvania (Bixel, 1995). While disease due to *U. stenocephala* is perhaps less severe than that due to *A. caninum,* the high prevalence of *U. stenocephala* suggests it could be an important stressor on the BRF population, especially among young individuals with lower levels of immunity. Similarly, the common canid parasites, *Toxascaris leonina* and *Toxocara canis* were only identified at BRF. The later species can be quite pathogenic to domestic puppies (Bowman, 1999).

Two parasites of domestic cats were identified. Ova of *T. cati* in one sample from PBP and *Aelurostrongylus* larvae in one sample from BRF. Both are likely spurious prey parasites gained from ingesting a domestic cat, as the sample from which *T. cati* was identified also contained the remains of a domestic cat. Coyote predation on domestic cats is not unusual, and domestic cat hair has been found in coyote feces collected from all three study sites (M. Gompper and R. Kays, unpubl. data).

Two cestodes were identified; *Spirometra* sp. was observed from ADK and *Taenia* sp. was identified at all three sites, although prevalence was higher at ADK. Taeniids generally cannot be identified to species based on ova alone (Bowman, 1999), and at least nine species of *Taenia* have been reported in necropsies of coyotes (Custer and Pence, 1981b). In February 2001 we necropsied four adult ADK coyotes killed by a trapper ca. 20 km NW of Paul Smiths and found adult *T. pisiformis* in the intestines of two coyote. Previous studies of coyotes have found this species ubiquitous (Custer and Pence, 1981b).

Five species of protozoa were identified. *Giardia* sp. and *Sarcocystis* sp. occurred at all three sites, while three *Isospora* spp. occurred only at BRF where the genus occurred in 35% of samples. No sample, however, had >1 *Isospora* species. Prevalence of *Sarcocystis,* for which coyotes are definitive hosts (Dubey et al., 1989), was high (46%) in PBP but far lower at the other sites. *Sarcocystis* has been previously reported in coyotes from the western and southeastern United States (Conder and Loveless, 1978; Davidson et al., 1992; Holzman et al., 1992).

Species accumulation curves and estimates of species richness indicate a maximal sampled parasite community of approximately 18 species, based on fecal flotations and excluding ectoparasites (Fig. 2). The number of observed species (16) and the mean Chao2 estimate for all 145 samples (18.2±5.3) suggest that this survey has identified most of the fecal parasites in these regions, and that the analysis of additional samples would not greatly increase estimates of species richness. The BRF component community appears to be well sampled, with the observed species richness (13) and estimated species richness (14.7±3.0 for all samples) curves meeting. However, the richness of the component communities of ADK, and especially PBP, remain inexact. The Chao2 estimator indicates a species richness of

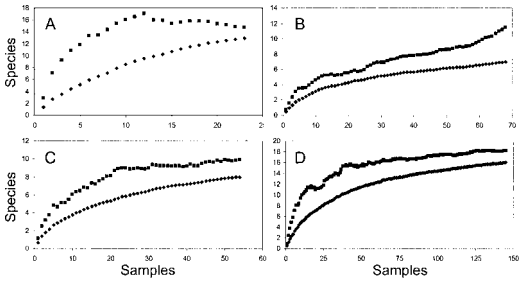

FIGURE 2. Species accumulation curves for parasite component communities (excluding *Giardia* and ectoparasites) in A) Black Rock Forest, B) Pine Bush Preserve, C) Northern Adirondacks, and D) all sites combined. Lower curve is based on observed data. Upper curve is the results of the Chao2 non-parametric estimator of species richness based on successively greater numbers of samples from the data set. For both curves each point represents the mean of 100 estimates using randomized accumulation order of fecal samples.

9.9 and 11.5 species for ADK and PBP, respectively. However the shape of the curve for PBP, and the large standard deviation (±7.2) for ADK indicate that an exact estimate for these sites necessitates additional sampling.

Of the 145 fecal samples, 44.1% contained one species, 9.0% contained two species, 1.4% contained three species, and 1.4% contained five species (Fig. 3). The overall distribution of number of parasitic species per fecal sample showed a negative binomial distribution, although the distribution pattern for the individual sites varied. There were significant differences in the size of the infracommunities (the parasite community within a particular host; Bush et al., 1997) at the three sites (Kruskal-Wallis One-Way ANOVA; $P=0.049$) due to the higher species richness of BRF infracommunities. Samples from ADK and PBP had similar means of 0.61 (range 0–2) and 0.59 (0–3) species per sample, respectively. In contrast, BRF had a mean of 1.30 (0–5) species per sample, with 13% of samples containing ≥three species, despite a small sample size relative to ADK and PBP. Across the three sites, mean infracommunity richness was 0.71 species.

The parasite component community of

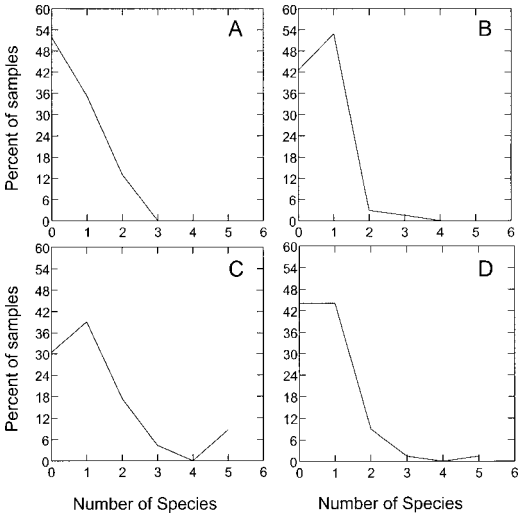

FIGURE 3. Distribution of the number of parasite species identified per sample. A. Northern Adirondacks (n=54). B. Pine Bush Preserve (n=68). C. Black Rock Forest (n=23). D. All sites combined (n=145).

BRF differed from that of PBP and ADK. Two species of parasites were found only in ADK and one only in PBP. In contrast, nine species were unique to BRF. These differences may reflect sampling error, as sample sizes were relatively small and sample collection was opportunistic. In addition, seasonal variation in worm burden, egg output, rates of hatching, and rates of degradation of parasite ova were unaccounted for. Nonetheless, the BRF parasite component community stands out in its higher parasite richness (14 endoparasite species versus nine at ADK and eight at PBP) which was detected in a relatively small sampling effort. Seven parasite species were common to all three sites. Including these species, overlap in community composition was 39–47% between both BRF and the other sites. In contrast, overlap in the ADK and PBP communities was 64% (Table 2).

While this survey has likely identified the majority of gastrointestinal parasites present in coyotes in the Northeast, there were significant differences in the parasite communities of the three study sites. The basis for these differences in infracommunity and component community structure, especially in southern New York, are unclear. The differences could be due to dietary variation among the hosts or to environmental differences between the sites, perhaps including differences in the ecology of domestic dogs in and near the sites. In addition the pattern and process of colonization of the northeast by coyotes may also have played a role in structuring the parasite community. Coyotes only arrived in the southern New York region within the past two decades, and the colonizing animals may have entered from multiple fronts, including not only northern New York but also northeastern Pennsylvania and northwestern New Jersey (USA) (which represent separate colonization fronts from the New York front; Parker, 1995). The current southern New York coyote population and its parasite component community may therefore represent an interface between that found in upstate New York and that found in more southern regions. Indeed, of the five species of parasites identified by Bixel (1995) in Pennsylvania, only one (an *Ancylostoma* species) is absent from the southern New

TABLE 2. Overlap in the parasite component communities of three study sites in New York. Values above the diagonal represent absolute number of species shared between the sites. Values below the diagonal represent the proportion (%) of total number of identified species (n) shared among the two sites.

	Northern Adirondacks	Pine Bush, Albany	Black Rock Forest, Cornwall
Northern Adirondacks	n/a	7	7
Pine Bush, Albany	63.6% (n = 11)	n/a	8
Black Rock Forest, Cornwall	38.9% (n = 18)	47.1% (n = 17)	n/a

York site examined in this study, while three are absent from the central and northern New York sites. These preliminary findings suggest further study for the idea of mixing parasite fronts is warranted.

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