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Prevalence of *Baylisascaris procyonis* in Habitat Associated with Allegheny Woodrat (*Neotoma magister*) Populations in Indiana

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ABSTRACT: Allegheny woodrat (*Neotoma magister*) populations have been in decline across their range since the late 1970s. Hypotheses proposed to explain these declines include habitat fragmentation and loss, decreased food availability, and increased mortality from infection with *Baylisascaris procyonis*. We investigated the prevalence of *B. procyonis* at raccoon (*Procyon lotor*) latrines in woodrat cliff habitats ($n=18$) along the Ohio River in southern Indiana in 1995. We located 275 latrines (mean=15.3/site; range, 6–34) and found *B. procyonis* in 13 (4.7%) latrines across all sites. When present at a site, *B. procyonis* occurred, on average, at 11.1% of latrines (range, 3–36%). Woodrat abundance, determined through a concurrent live-trapping program, was significantly higher ($\chi^2=5.12$, df=1, $P=0.024$) at sites where *B. procyonis* was not found (9.5±2.52) than at sites with *B. procyonis* (3.7±2.2). Our analyses support the hypothesis that this parasite could contribute to declines in woodrat abundance. Because woodrats cache nonfood items, including raccoon feces, and are highly susceptible to the parasite, they are at increased risk for *B. procyonis* infection, which could be deleterious, especially to small populations.

Key words: *Baylisascaris procyonis*, endangered species, nematode, *Neotoma magister*, *Procyon lotor*, raccoon, woodrat.

The raccoon roundworm (*Baylisascaris procyonis*) is a ubiquitous parasite of the raccoon (*Procyon lotor*) in the United States (Kazacos, 2001). Infected raccoons can shed millions of *B. procyonis* eggs daily, which accumulate at raccoon latrines and remain infective for years (Kazacos, 2001). Transmission of *B. procyonis* to various paratenic hosts occurs primarily at latrines, when small vertebrates foraging for seeds in feces accidentally ingest infective eggs (Page et al., 2001). Migrating larvae entering the brain of small paratenic hosts often produce neurologic disease and death (Kazacos, 2001). *Baylisascaris procyonis* has caused fatal or severe neurologic disease (neural larva migrans, NLM) in more than 130 species of mammals and birds (Kazacos, unpubl.).

The Allegheny woodrat (*Neotoma magister*) historically ranged throughout the Appalachian Mountains from southern New York to northern Alabama (Wright, 2008). They occupy rocky talus slopes, boulder piles, outcrops, cliff faces, and caves or abandoned mines within deciduous forests (Castleberry, 2008). Woodrat populations have been declining in portions of this range since the late 1970s (Wright, 2008), have been extirpated from several states, and are of conservation concern in several others (LoGiudice, 2006), including Indiana.

Hypotheses proposed to explain these declines in woodrat populations include habitat fragmentation and destruction, decreased food availability, and increased mortality from *B. procyonis* (McGowan, 1993; LoGiudice, 2008). Allegheny woodrats are highly susceptible to *B. procyonis* NLM and readily develop neurologic disease after infection (Kazacos, unpubl.). They are likely to become infected because the rocky habitats they favor often are used by raccoons for den and latrine sites (Page et al., 1998). Woodrats routinely collect and cache food and nonfood items, including the feces of other animals. This increases their risk of ingesting infective *B. procyonis* eggs present in raccoon feces (Castleberry and Castleberry, 2008). Two studies conducted in *B. procyonis*–contaminated habitats support the parasite hypothesis (McGowan, 1993; LoGiudice, 2003). Uninfected woodrats translocated to formerly occupied sites in New York experienced high mortality attributed to *B. procyonis* infection. *Baylisascaris procyonis* larvae were recovered from the brains of 10 of 11 woodrats available for necropsy, and the 11th had compatible histopathologic lesions of NLM; four woodrats were exhibiting abnormal behavior when live-trapped (McGowan, 1993). In New Jersey, LoGiudice (2003) found that woodrats released in areas with low levels of *B. procyonis* eggs survived longer than those in highly contaminated areas. *Baylisascaris* NLM also was identified in Allegheny woodrats in south-central Pennsylvania and southern Indiana (Kazacos, 2001).

Our objective was to determine the prevalence of *B. procyonis* eggs at raccoon latrines in currently and formerly occupied woodrat habitats in Indiana. These results are presented within the context of woodrat population data in an attempt to evaluate the effect of *B. procyonis* on woodrat populations in Indiana.

Our study was conducted in October 1995 at 18 bluff systems along a 74-km stretch of the Ohio River. These bluffs either supported extant woodrat populations (n=15), had old signs indicative of former occupancy (n=2), or suitable rock features for woodrat denning (n=1) (Cudmore, 1983; Johnson, 2002). To evaluate the potential effect of *B. procyonis* on woodrat populations, we determined woodrat abundance using a standardized live-trapping program (Johnson, 2002), twice before (1991, 1993) and once after (1996) our study.

Raccoon latrines are predictably found on horizontal substrates such as fallen logs and stumps (Page et al., 1998). Therefore, we searched all accessible substrates surrounding woodrat activity centers (i.e., woodrat caches and latrines) located on the rim and base of the cliff and any accessible tiers and outcrops. The number of fecal deposits at latrines varies, but a minimum of 2 g per fecal deposit was taken from each latrine and stored at −20 C until examination. We examined composite samples of all fecal deposits collected at a latrine (n=275) for *B. procyonis* eggs using fecal flotation in Sheather's sugar solution and identified eggs on the basis of size and morphology (Kazacos, 2001). Prevalence at each site was the proportion of positive samples. Random soil samples were not examined for eggs because latrines are not randomly distributed (Page et al., 1998). Woodrat abundance was the mean number of captures per 100 trap-nights in 1991–1992, 1993–1994, and 1996 (Johnson, 2002). A Wilcoxon Rank Sums test was used to determine differences in woodrat abundance between sites with and without *B. procyonis* (SAS, 2007).

We located 275 raccoon latrines at 18 sites (mean=15.3, SE=2.1; range, 6–34) and found *B. procyonis* eggs in 13 latrines (4.7%) at six sites (Table 1). Prevalence of *B. procyonis* across latrines at the six positive sites averaged 11.1% (range, 3% to 36%; Table 1). Woodrat abundance was significantly higher (χ^2=5.12, df=1, P=0.024) at sites with no *B. procyonis* (9.5±2.52) than at sites with *B. procyonis* (3.7±2.2).

Although *B. procyonis* has been implicated in population declines of Allegheny woodrats, estimates of its occurrence in woodrat habitat throughout the species' range are limited. Comparison of prevalences in raccoon populations is problematic because estimates vary with sample type, technique, season, and density or age structure of the population (Page et al., 2005). Nevertheless, intact woodrat populations tend to occur in areas with no evidence of *B. procyonis*, such as West Virginia (Owen et al., 2004), extant sites in Kentucky (Bommarito, 1999), and Ohio (J. Wright, pers. comm.). LoGiudice (2003), however, found that 22% of raccoon fecal samples and 29% of latrines contained *B. procyonis* eggs at four locations in New York and New Jersey where woodrats had declined. Additionally, relatively low

TABLE 1. Prevalence of *Baylisascaris procyonis* in raccoon (*Procyon lotor*) latrines and relative abundance of Allegheny woodrats at 18 cliff sites in Indiana, 1995.

Site	Woodrat population status		Raccoon latrines		Mean woodrat relative abundance[d,e]
	Initial[a]	At time of study[b]	*n*	*B. procyonis* prevalence[c]	
Mauckport cemetery	Old sign only	Old sign only	22	36	—
South Fredonia	Extant	Extirpated	8	12	0
North New Amsterdam	Unoccupied	Unoccupied	12	8	0
Mulzer #8	Extant	Unknown	28	4	—
Leavenworth	Extant	Extirpated	34	3	0
Overflow pond	Extant	Extant	34	3	3.2
Indian Hollow	Old sign only	Old sign only	6	0	—
Rabbit Hash Ridge—U	Extant	Extant	17	0	19.1
Rabbit Hash Ridge—C	Extant	Extant	17	0	12.6
Tobacco Landing	Extant	Extant	16	0	3.3
Bull's Point	Extant	Extant	13	0	31.4
Scenic view	Extant	Extirpated	13	0	0
Noes Park	Unknown	Extant	13	0	18.6
Narrows	Extant	Extant	10	0	5.8
Shelterhouse #2	Extant	Extant	9	0	36.6
Rabbit Hash Ridge—D	Extant	Extant	9	0	18.8
Lowe/Booth	Extant	Extirpated	8	0	0
South Nye	Extant	Extant	6	0	16.8 12.9
All			275	4.3	

[a] Status in 1980–1983 (Cudmore, 1983).

[b] From Johnson (2002).

[c] Percentage of raccoon latrines containing *B. procyonis* eggs.

[d] Mean number of captures per 100 trap-nights during live-trapping sessions in 1991–1992, 1993–1994, and 1996.

[e] — = Site was not trapped.

levels of *B. procyonis* were found at sites occupied by woodrats in Maryland and Pennsylvania, as well as in Ohio where they had been extirpated (J. Wright, pers. comm.). Nevertheless, clinical NLM due to *B. procyonis* was noted in a woodrat from one site in Pennsylvania (J. Wright, unpubl.) and subsequently from one of our Indiana sites (Shelterhouse #2; K. Kazacos and S. Johnson, unpubl.) where no *B. procyonis* was found in the present study. In that animal, an adult female, eight larvae were recovered at necropsy, including four from the anterior carcass, three from the posterior carcass, and one from the brain (K. Kazacos, unpubl.).

Our study supports the hypothesis that *B. procyonis* is an important contributing factor in the decline of woodrat populations (LoGiudice, 2003). Our findings of *B. procyonis* eggs in ~5% of the raccoon latrines at 33% of sites sampled definitively established that *B. procyonis* was present in the woodrat habitat but suggested it was not common or widespread. We expected that the prevalence of *B. procyonis* would be highest at sites with low or extirpated woodrat populations and, although conclusive evidence supporting this hypothesis was lacking, general trends for it were present. We found *B. procyonis* at latrines in six of 18 sites examined, and at three of these locations, woodrat abundance was zero. We did not find *B. procyonis* at the nine study sites with the highest mean relative abundance of woodrats (Table 1). All of the 14 sites with extant woodrat populations in 1980–1983 (Cudmore, 1983) had evidence of raccoon use in 1995. Four of these sites contained raccoon latrines with *B. procyonis* eggs, and woodrats had been extirpated at three of these sites by 1996 (Johnson, 2002).

Conversely, only two of the 10 *B. procyonis*–negative sites that had active woodrat populations in 1980–1983 (Cudmore, 1983) were extirpated by 1996 (Johnson, 2002). Our results support LoGiudice's (2006) assertion that there likely exists a synergistic effect of habitat loss, changes in food availability, and *B. procyonis*.

Confounding factors probably played a part in or influenced our assessments. Because we only looked at latrines at one time, we are unsure of any changes that could have taken place over the 6 yr of woodrat assessment. Changes might have occurred in raccoon and latrine density, with possible effects of weather (e.g., heavy rains) or other actions (e.g., scattering by animals) on the integrity and thus recognition of raccoon latrines. Additionally, we simply could have missed some latrines, especially those in inaccessible (to humans) locations. We are also unsure of how our sample sizes as well as woodrat trapping data for particular sites might have affected our assessment of overall patterns. Most sites had small numbers of woodrats.

Sites where *B. procyonis* was detected had a wide variance in prevalence (3–36%), with most below the levels found in New York and New Jersey (LoGiudice, 2003). Despite our lower levels, *B. procyonis* cannot be excluded as an important mortality source. Infective feces can contain a large number of eggs, which can remain viable in the environment for years (Kazacos, 2001). Because woodrats can be seriously affected by a single larva in the brain, even in areas of low *B. procyonis* occurrence, woodrats with frequent contact with raccoon feces still would be at increased risk of infection and overall deleterious effect.

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