

# Altered prevalence of raccoon roundworm (*Baylisascaris procyonis*) owing to manipulated contact rates of hosts

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## Abstract

*Baylisascaris procyonis* is a common parasitic nematode of the raccoon *Procyon lotor*. In intermediate or accidental hosts, including humans, *B. procyonis* can cause severe disease and mortality, and the parasite is increasingly viewed as an important wildlife conservation and public health concern. The prevalence of *B. procyonis* was assessed over a 4-year period in a population of raccoons in a forested region of lower New York. Prevalence ranged from 0% (undetected) to 21%, which was relatively low compared to values reported in other studies from the north-east. During year three of the study, a subset of the raccoon population was experimentally manipulated through altered resource distribution to enhance the contact of individuals. Within the manipulated subpopulation, prevalence of *B. procyonis* increased to 54% which was significantly greater than prevalence in the same subpopulation before perturbation or than prevalence among raccoons that were not subject to increased intraspecific contact. These observations suggest that altered resource distributions that directly influence raccoon behaviour may indirectly play a role in the ecology of *B. procyonis*.

**Key words:** raccoon, *Procyon lotor*, *Baylisascaris*, parasites, contact rate, behavioural ecology

## INTRODUCTION

Raccoon roundworm *Baylisascaris procyonis* is an endoparasitic nematode whose primary host is the raccoon *Procyon lotor*. The species is common in raccoons, where prevalence levels in some populations may be > 80%, but except for extreme worm burdens in adults, impact on primary hosts is probably relatively minor (Kazacos, 2001). A principal concern regarding *B. procyonis* is its transmission to accidental hosts. Adult *B. procyonis* produce copious eggs/day, such that infected raccoons, who usually carry multiple adult worms, may produce > 20 000 eggs/g faeces (Snyder & Fitzgerald, 1987; Kazacos, 2001; Evans, 2002a). Eggs ingested by raccoons hatch and grow to adult stages in the intestinal tract, but those ingested by accidental or intermediate hosts hatch into active larvae that migrate in the tissues and organs of the host. Larva migrans may produce extensive tissue damage leading to diverse clinical disease, behavioural abnormalities and possibly death (Kazacos, 2001).

Raccoons are among the most common members of the order Carnivora in North America, and the species is also common in Europe, Russia, and Japan owing to introductions (Lotze & Anderson, 1979; Gehrt, 2003).

Raccoons may therefore act as a reservoir for many parasitic organisms with the potential for these organisms to spill over into populations of other vertebrate species, including those of conservation concern. The range of species in which *B. procyonis* may cause larva migrans and thus disease is broad (Evans, 2002b), and the species has the potential to be an important concern in the wildlife and conservation arena (Logiudice, 2001). *Baylisascaris procyonis* also infects humans by faecal–oral transmission and is capable of causing ocular and severe neurologic sequelae as well as death in humans. As such it is viewed by some as an emerging zoonosis and a serious public health problem (Kazacos, 2001; Sorvillo *et al.*, 2002).

Much previous work on *B. procyonis* has focused on populations inhabiting agricultural areas or areas with high human densities (e.g. suburban communities), and within these settings a primary focus has been the latrine use by raccoons and the potential for this behaviour to facilitate spill-over of *B. procyonis* into intermediate or accidental hosts (Page, Swihart & Kazacos, 1998, 1999; Evans, 2002a,b). Less understood are the prevalence rates in host populations from forested ecosystems, and especially sites where the use of latrines is less common. In this study, a 4-year dataset on prevalence of *B. procyonis* in a rural, southern New York host population was examined. In addition to monitoring prevalence under normal conditions in which contact rates of hosts are low, a

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subset of the raccoon population was also manipulated to cause increased contact rates, allowing us to gain preliminary insights into whether and how host contact rate may influence the prevalence of *B. procyonis*. We hypothesized that the direct transmission portion of the *B. procyonis* life cycle would result in an increase in prevalence rates among hosts whose contact rates were increased. The raccoon population examined here was of particular interest because: (1) it occurred in a forested region lacking human habitations; (2) raccoon faecal latrines rarely occurred in the population; (3) with the exception of mothers and offspring and of occasional communal denning events in winter, raccoons at the study site rarely reused dens (Wright, 2002). Thus contact with contaminated faeces at latrines or at commonly reused den sites is unlikely to drive *B. procyonis* prevalence in this population.

## METHODS

Field work took place at Black Rock Forest in the Hudson Highlands of southern New York (41°45'N, 74°01'W). This 1500-ha reserve has been managed for forestry and environmental research since 1928, and protected as a natural area since 1989. The site is contiguous with Palisades Interstate Park lands of New York and New Jersey as well as federal lands managed by the United States Military Academy at West Point. The primary habitat is second growth mixed-hardwood deciduous forest, dominated by oaks *Quercus* spp., maples *Acer* spp., beech *Fagus grandifolia*, and birch *Betula* spp. Abundant water is present year-round in the form of streams, ponds, lakes, bogs, and wetlands; therefore water is probably not a limiting resource as has been observed for raccoon populations in other sites (Gehrt, 2003). No trapping or hunting of raccoons occurs at the study site or in the surrounding public lands.

Raccoons inhabited 2 adjacent sites (western and south-eastern) delineated by watershed boundaries, reservoirs, and rocky outcrops; there was no evidence from either trapping or telemetry data of raccoons travelling between the 2 sites during the study. Raccoons at the study site are relatively inactive in cold weather, and thus trapping of raccoons and collection of faeces occurred primarily between May and November. Trapping occurred twice yearly (summer and autumn) per site. A rough assessment for differences in the relative population size at the 2 sites was made by quantifying the number of different raccoons captured per season corrected for trapping effort (number of trap-nights). Under an assumption of no large differences in the populations, these measures of relative population size should not differ significantly (Wilcoxon signed-rank tests) and should be closely correlated over time.

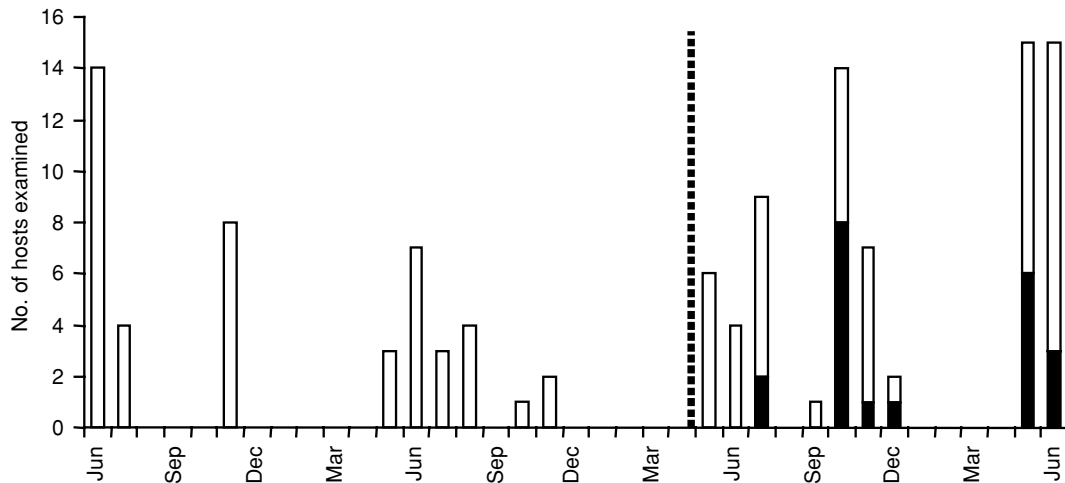
Raccoons were anaesthetized with ketamine hydrochloride (10 mg/kg) and xylazine (0.1 mg/kg), after which they were ear-tagged and basic morphological measures taken. Faecal samples were collected from the trap or for a small number of animals ( $n = 3$  samples from 2 individuals who were also sampled on additional occasions),

by faecal loop. Age was approximated as juvenile (0–12 months), sub-adult (13–21 months), or adult (> 21 months) from tooth wear, body size, reproductive status, and recapture history. Thirty-eight adult raccoons were radio-collared and tracked during the study (Wright, 2002), allowing den sites of known individuals to be located where fresh (< 12 h) faecal samples of these individuals were collected. All work was approved by the Columbia University Institutional Animal Care and Use Committee.

Faeces were stored in 10% formalin before laboratory analyses using standard sugar and zinc sulphate centrifugation–concentration–flotation techniques (Bowman, 1999). Laboratory analyses were carried out at the Cornell University Veterinary Diagnostic Laboratory (Ithaca, NY), and *B. procyonis* identification from ova was based on the criteria of Averbeck *et al.* (1995). Prevalence was estimated as the number of individuals identified as positive for *B. procyonis* eggs divided by the number of individuals examined (Bush *et al.*, 1997). Because *B. procyonis* infection is assessed based on presence or absence of eggs rather than worms (the later was not possible in the context of this study), the repeatability of *B. procyonis* infection diagnoses was examined for all individuals for which  $n \geq 2$  faecal samples were collected. Two-tailed Fisher's exact tests were used to test for statistical differences in prevalence among individuals lumped by age, sex, time of sampling (pre- or post-perturbation for the south-eastern subpopulation manipulated to increase contact), and site of sampling (low-contact or high-contact subpopulations during 2001–2).

From summer 1999 to summer 2002 animals from both subpopulations were trapped, sampled, and monitored using radio-telemetry. In May 2001, an experimental manipulation commenced. The south-eastern subpopulation was provisioned with clumped food resources while the western subpopulation received equal quantities of dispersed food. This allowed for 2 comparisons: temporal (before and after the start of resource addition), and spatial (low-contact western and high-contact south-eastern subpopulations). Two feeding stations of cracked corn (*c.* 11 kg per station, replenished weekly) were maintained in the south-eastern site, resulting in aggregations of raccoons. The western subpopulation received equal amounts of corn subdivided into *c.* 0.5 kg quantities placed weekly at multiple, randomly selected locations each week.

Raccoon aggregations were monitored by remote photography at feeding stations, and by telemetry to identify possible communal denning. The group size and telemetry data are reported elsewhere (Wright, 2002; Wright & Gompper, 2005), but are summarized here. In brief, adult raccoons in the western subpopulation remained solitary, while in the south-eastern subpopulation the range in numbers of adults was 0–5 (mean  $\pm$  SE =  $1.44 \pm 0.03$ ) after feeding stations were created. Including juveniles, aggregation sizes in the south-eastern subpopulation were 1–8 (mean  $\pm$  SE =  $1.85 \pm 0.06$ ). At the feeding stations, cross-site differences in instantaneous contact rates may be assessed by quantifying the percentage of independent observations (photos) in which  $\geq 2$  raccoons occurred, thereby creating a



**Fig. 1.** Number of known raccoons *Procyon lotor* examined per month of the study (June 1999–June 2002). Filled bars, individuals positive for *Baylisascaris procyonis*; open bars, individuals negative for *Baylisascaris procyonis*. Data from both subpopulations are included; virtually all positive infections were from the high-contact subpopulation. Dashed line, start of resource perturbation, at which point raccoons in the high-contact subpopulation formed aggregations.

categorical variable for short-term contact while at the feeding station of 0 (no contact within the *c.* 16 m<sup>2</sup> camera range) or 1 (contact with conspecifics within the range). Instantaneous contact rates for adults were 0% (3% for adults + cubs) in the western subpopulation and 34% (42% for adults + cubs) in the south-eastern subpopulation. Animals denned solitarily with the exception of mothers with cubs, and some communal denning that occurred primarily in winter. A total of 162 dens were located, with 149 containing only 1 radio-collared animal. Communal dens were occasionally found in both sites, primarily during winter, and there was no apparent difference in rates of communal denning in the high-contact south-eastern population relative to the low-contact population, or any apparent increase in communal denning in the south-eastern population after resource addition and increased contact rates at feeding stations occurred. Thus periods of high contact were apparently spatially localized to the feeding station.

## RESULTS

Eighty-four raccoons were trapped and processed during 2082 trap-nights between summer 1999 and summer 2002. During this period there were no differences in the relative sizes of the western and south-eastern subpopulations (summer only:  $Z = -1.095$ ,  $P = 0.273$ ; summer and autumn:  $Z = -0.845$ ,  $P = 0.398$ ). While capture success increased over the course of the study for both the summer trapping efforts (mean capture rate of novel individuals: 1999 = 0.05, 2000 = 0.03, 2001 = 0.14, 2002 = 0.14) and autumn trapping efforts (1999 = 0.04, 2000 = 0.05, 2001 = 0.13) suggesting that the population size may have been increasing, the two subpopulations covaried (summer:  $r = 0.97$ ; autumn:  $r = 0.91$ ) and there was no evidence for fundamental differences in subpopulation sizes between sites within a year. The apparent increase in population density may have been partially a result of

an acorn masting event which occurred in 2001. Acorn production increased from < 2000 acorns/ha in 2000, to > 30 000 acorns/ha in 2001 (Brady, 2002).

Faecal samples ( $n = 152$ ) were examined from 62 known individuals, six juveniles of unknown sex, and eight animals for which reduced information exists. Mean ( $\pm$  SE) number of faecal samples collected per known raccoon was  $2.23 \pm 0.32$  (range 1–15). Repeatability of *B. procyonis* identification from faeces was high; of known animals for which > 1 faecal sample was collected ( $n = 28$ ; mean number of faecal samples =  $3.7 \pm 0.6$ ), 75% of individuals had identical patterns of *B. procyonis* infection for the multiple samples, and an additional 14.3% varied in infection status only when samples collected over extended periods were compared. For the later samples, the lack of repeatability may indicate a change in infection status of the individuals. Samples from three individuals with both positive and negative diagnoses were collected within < 7-day periods. These animals were thus deemed *B. procyonis* positive.

In the 2 years before resource augmentation, 62 faecal samples from 31 individuals ( $n = 15$  males, 11 females, five unknown sex; 22 adults, four sub-adults, five juveniles) of both sites ( $n = 16$  at experimental site, 15 at control site) were examined for *B. procyonis*. All samples were negative (prevalence 0%). Lack of *B. procyonis* was not the result of handling or degradation as analyses did identify 11 other species from these samples (Wright, 2002; Wright & Gompper 2005). Lack of *B. procyonis* was also not owing to the time of sample collection, which occurred primarily from May to November (Fig. 1) when *B. procyonis* prevalence peaks (Kidder *et al.*, 1989; Kazacos, 2001).

Following the start of resource perturbation, 90 faecal samples from 43 known ( $n = 20$  males, 22 females, and one uncertain sex juvenile; 24 adults, 17 sub-adults, two juveniles) and seven unknown individuals (probably adults) were collected ( $n = 31$  from south-eastern high-contact subpopulation, 19 at western low-contact

**Table 1.** Prevalence (%) of *Baylisascaris procyonis* among known raccoons *Procyon lotor* of different age and sex classes in the high-contact and low-contact subpopulations following the onset of resource perturbation. Prevalence before perturbation was 0% in both subpopulations (see text). Sub-adults include all individuals  $\leq 21$  months of age. Significance values are for Fisher's exact tests

Age or sex class	High-contact (%; n)	Low-contact (%; n)	P
All raccoons	54.2; 24	21.1; 19	< 0.05
Adults	27.3; 11	30.8; 13	NS
Adult males	60.0; 5	28.6; 7	NS
Adult females	0; 6	33.3; 6	NS
Sub-adults	76.9; 13	0; 6	< 0.005
Sub-adults males	71.4; 7	0; 1	NS
Sub-adults females	80.0; 5	0; 5	< 0.05

subpopulation). Overall prevalence of *B. procyonis* in faecal samples was 26.7%, and prevalence among known individuals was 39.5% (36% including unknown individuals). Prevalence was significantly greater (Fisher's exact test,  $P = 0.034$ ) in the high-contact subpopulation than the low-contact subpopulation following the perturbation (Table 1). Prevalence in the low-contact subpopulation increased non-significantly ( $P = 0.113$ ) from 0% to 21.1%, owing to identification in four adults (two male, two female) of 19 examined animals. One of these males was a recapture of a long-term resident that had become positive, while the other three were new captures, and therefore possibly immigrants into the population. Combining all data from the western low-contact subpopulation ( $n = 34$  known individuals; 1999–2002), prevalence was 11.8%. In the south-eastern subpopulation, prevalence among known individuals increased from 0% before resource augmentation to 54.2% ( $P < 0.001$ ) when contact rates increased. If unknown individuals are included, prevalence increased to 45.2% ( $P = 0.002$ ).

Initial observations of *B. procyonis* positive individuals occurred 3 months after the start of resource addition (Fig. 1) owing to two positive adults (one on each site). These individuals had not been previously captured and may have been immigrants. Peak prevalence occurred in October 2001, when 63% ( $n = 11$ ) of raccoons sampled for the first time from the south-eastern high-contact site were positive for *B. procyonis*. Positive individuals were all sub-adults (see below), of which three were known to have been born in the population. The other sub-adults were probably also born in the south-eastern population, but it is also possible that several may have immigrated during autumn 2001. Cumulative prevalence in the experimental population following the start of resource perturbation reached 53% ( $n = 17$ ) in October 2001 and remained at c. 50% ( $n = 24$ ) to the end of the study.

Post-perturbation differences were a function of differences among sub-adult hosts (Table 1). Prevalence among adult raccoons of both sexes did not differ significantly between subpopulations after the onset of resource addition, and no adult trapped in the south-eastern site before perturbation when prevalence was 0% became positive for *B. procyonis* following perturbation of the site. In contrast, sub-adult raccoons from the

high-contact subpopulation had prevalence levels of 70–80%, while those examined from the control site lacked infection by *B. procyonis*. Within the entire post-perturbation high-contact subpopulation, there was no relationship between prevalence and sex ( $P = 0.220$ ). There was, however a weak relationship among adults; prevalence in males was higher than that of females ( $P = 0.061$ ). This pattern was not detected among sub-adults of the high-contact subpopulation ( $P = 1.000$ ). Note, however, that sample sizes for some age and sex classes are small (Table 1).

## DISCUSSION

The prevalence of *B. procyonis* (11.8%, including 2 years during which *B. procyonis* was not detected) based on data collected from both subpopulations before resource augmentation plus the low-contact subpopulation surveyed after resource augmentation, is low relative to elsewhere in north-eastern North America (Kazacos, 2001). While studies suggest geographic and landscape-level clines in prevalence, and seasonality, host age, and host sex class relationships in parasitism by *B. procyonis* (Snyder & Fitzgerald, 1985; Kidder *et al.*, 1989; Kazacos, 2001; Evans, 2002a), how the contact rates of raccoons might influence prevalence of *B. procyonis* in the host population has not been assessed. Our observations suggest that prevalence of *B. procyonis* in a raccoon population may be a function of host contact rates. Prevalence went from undetected and putatively absent before the perturbation to > 50% prevalence among the post-perturbation high-contact raccoons. This increased prevalence occurred at a site whose overall host density did not differ from that of the low-contact subpopulation. The mechanism of infection implicated by these spatial and temporal changes is direct transmission by ingestion of embryonated eggs. That is, the increased contact rates that resulted from raccoons congregating at clumped resources in the south-eastern population resulted in the transmission of eggs from contact with infected materials or sites, or from direct contact among hosts. Photographs of raccoons allogrooming at the feeding station were taken, but the full contexts of these events were unclear.

Increased prevalence was primarily a function of changes among young raccoons rather than adults. Prevalence among sub-adults and juveniles in the low-contact subpopulation remained 0%, while prevalence in the south-eastern subpopulation increased to 70–80% when contact rates increased. Sex-class patterns were less clear, although there was a weak pattern of adult males having greater prevalence than adult females. These age and sex-class patterns generally support the findings of other studies (Snyder & Fitzgerald, 1985, 1987; Cole & Shoop, 1987; Kidder *et al.*, 1989; Robel, Barnes & Upton, 1989). Since sub-adults may have higher worm intensities than adults, and since sub-adults often congregate in family groups as well as at resource aggregation sites, rapid increases in prevalence in sub-adults may drive the zoonotic potential of *B. procyonis* in a population (Snyder & Fitzgerald, 1987).

The implications of this study are limited by the small sample size, the focus on a single site, an ova-based survey rather than an examination of the intensity of worm burdens, and the lack of a true control population in which no resource augmentation took place. It is also plausible that a change at the south-eastern, high-contact site unrelated to enhanced host contact may partially underlie the changes in *B. procyonis* prevalence observed in this study. In particular, migration into the sites, coupled with a higher likelihood of immigrants remaining at the south-eastern site, might have occurred. While the capture history and ages of some infected animals indicates that they were born into the population, our knowledge of other sub-adults is less clear, and some sub-adults may have migrated into the population. If so, this suggests that the genesis of *B. procyonis* at the south-eastern site could be attributed, in part, to new infected individuals entering the population rather than the conversion of individuals born in the population from non-infected to infected status.

Independent of the mechanism causing the genesis of infection, however, this study identifies a need for further focus on the role of raccoon contact rate as a driver of *B. procyonis* prevalence. Raccoons can reach very high population densities in suburban–urban environments (Prange, Gehrt & Wiggers, 2003), and this high density is seen as a risk factor for *B. procyonis* transmission to humans (Evans, 2002a; Sorvillo *et al.*, 2002). Yet work contrasting prevalence of *B. procyonis* in suburban and rural raccoon populations has not identified clear clines of prevalence despite the higher presumed densities of raccoons in these suburban environments (Jacobson, Kazacos & Montague, 1982). This incongruence may stem from the assumption that raccoons in rural environments have low contact rates. Many rural environments represent landscapes with highly clumped resources and contact rates of raccoons may increase where limiting resources are clumped and animals congregate (Gehrt & Fritzell, 1998; Totton *et al.*, 2002; Wright, 2002). Often these resources are anthropogenic in origin, and therefore limiting the access of raccoons to these resources may reduce the likelihood of increased *B. procyonis* prevalence, and the associated risks to humans and wildlife.

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### REFERENCES

- Averbeck, G. A., Vanek, J. A., Stromberg, B. E. & Laursen, J. R. (1995). Differentiation of *Baylisascaris* species, *Toxocara canis*, and *Toxocara leonina* infections in dogs. *Compend. Cont. Ed. Pract. Vet.* **17**: 475–478, 511.
- Bowman, D. D. (1999). *Georgis' parasitology for veterinarians*. 7th edn. Philadelphia: W. B. Saunders.
- Brady, J. F. (2002). *Acorn crop 2001* Unpublished report, Black Rock Forest, Cornwall, New York.
- Bush, A. O., Lafferty, K. D., Lotz, J. M. & Shostak, A. W. (1997). Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *J. Parasitol.* **83**: 575–583.
- Cole, R. A. & Shoop, W. L. (1987). Helminths of the raccoon (*Procyon lotor*) in western Kentucky. *J. Parasitol.* **73**: 762–768.
- Evans, R. H. (2002a). *Baylisascaris procyonis* (Nematoda: Ascaridoidea) eggs in raccoon (*Procyon lotor*) latrine scats in Orange County, California. *J. Parasitol.* **88**: 189–190.
- Evans, R. H. (2002b). *Baylisascaris procyonis* (Nematoda: Ascarididae) larva migrans in free-ranging wildlife in Orange County, California. *J. Parasitol.* **88**: 299–301.
- Gehrt S. D. (2003). Raccoon (*Procyon lotor* and allies). In *Wild mammals of North America*: 611–634. 2nd edn. Feldhamer, G. A., Thompson, B. C. & Chapman, J. A. (Eds). Baltimore: Johns Hopkins University Press.
- Gehrt, S. D. & Fritzell, E. K. (1998). Resource distribution, female home range dispersion and male spatial interactions: group structure in a solitary carnivore. *Anim. Behav.* **55**: 1121–1227.
- Jacobson, J. E., Kazacos, K. R. & Montague, F. H. Jr (1982). Prevalence of eggs of *Baylisascaris procyonis* (Nematoda: Ascaroidea) in raccoon scats from an urban and a rural community. *J. Wildl. Dis.* **18**: 461–464.
- Kazacos, K. R. (2001). *Baylisascaris procyonis* and related species. In *Parasitic diseases of wild mammals*: 301–341. 2nd edn. Samuel, W. M., Pybus, M. J. & Kocan, A. A. (Eds). Ames: Iowa State Press.
- Kidder, J. D., Wade, S. E., Richmond, M. E. & Schwager, S. J. (1989). Prevalence of patent *Baylisascaris procyonis* infection in raccoons (*Procyon lotor*) in Ithaca, New York. *J. Parasitol.* **75**: 870–874.
- Logiudice, K. (2001). Latrine foraging strategies of two small mammals: implications for the transmission of *Baylisascaris procyonis*. *Am. Midl. Nat.* **146**: 369–378.
- Lotze, J. -H. & Anderson, S. (1979). *Procyon lotor*. *Mamm. Species* **119**: 1–8.
- Page, L. K., Swihart, R. K. & Kazacos, K. R. (1998). Raccoon latrine structure and its potential role in transmission of *Baylisascaris procyonis* to vertebrates. *Am. Midl. Nat.* **140**: 180–185.
- Page, L. K., Swihart, R. K. & Kazacos, K. R. (1999). Implications of raccoon latrines in the epizootiology of *Baylisascaris*. *J. Wildl. Dis.* **35**: 474–480.
- Prange, S., Gehrt, S. D. & Wiggers, E. P. (2003). Demographic factors contributing to high raccoon densities in urban landscapes. *J. Wildl. Manage.* **67**: 324–333.
- Robel, R. J., Barnes, N. A. & Upton, S. J. (1989). Gastrointestinal helminths and protozoa from two raccoon populations in Kansas. *J. Parasitol.* **75**: 1000–1003.
- Snyder, D. E. & Fitzgerald, P. R. (1985). The relationship of *Baylisascaris procyonis* to Illinois raccoons. *J. Parasitol.* **71**: 596–598.
- Snyder, D. E. & Fitzgerald, P. R. (1987). Contaminative potential, egg prevalence and intensity of *Baylisascaris procyonis* infected raccoons (*Procyon lotor*) from Illinois, with a comparison to worm intensity. *Proc. Helminthol. Soc. Wash.* **54**: 141–45.
- Sorvillo, F., Ash, L. R., Berlin, O. G. W., Yatabe, J. A., Degiorgio, C. & Morse, S. A. (2002). *Baylisascaris procyonis*: an emerging helminthic zoonosis. *Emerg. Infect. Dis.* **8**: 355–359.
- Totton, S. C., Tinline, R. R., Rosatte, R. C. & Bigler, L. L. (2002). Contact rates of raccoons (*Procyon lotor*) at a communal feeding site in rural eastern Ontario. *J. Wildl. Dis.* **38**: 313–319.
- Wright, A. N. (2002). *Changes in raccoon (Procyon lotor) parasite communities in response to an experimental manipulation of resource availability*. MA thesis, Columbia University, New York.
- Wright, A. N. & Gompper, M. E. (2005). Altered parasite assemblages in raccoons in response to manipulated resource availability. *Oecologia* **143**: 000–000.