LAND-USE EFFECTS ON PREVALENCE OF RACCOON ROUNDWORM (BAYLISASCARIS PROCYONIS)

Authors: Page, L. Kristen, Gehrt, Stanley D., and Robinson, Nathaniel P.

Source: Journal of Wildlife Diseases, 44(3) : 594-599

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-44.3.594

Journal of Wildlife Diseases, 44(3), 2008, pp. 594–599

LAND-USE EFFECTS ON PREVALENCE OF RACCOON ROUNDWORM (*BAYLISASCARIS PROCYONIS*)

L. Kristen Page,[1,5] Stanley D. Gehrt,[2,3] and Nathaniel P. Robinson[1,4]

[1] 501 College Ave., Biology Department, Wheaton College, Wheaton, Illinois 60187, USA
[2] School of Natural Resources, Ohio State University, 2021 Coffey Road, Columbus, Ohio 43210, USA
[3] Max McGraw Wildlife Foundation, PO Box 9, Dundee, Illinois 60188, USA
[4] Department of Environmental Studies, University of Montana, Missoula, Montana 59812, USA
[5] Corresponding author (email: Kristen.page@wheaton.edu)

ABSTRACT: The raccoon (*Procyon lotor*) is the definitive host of *Baylisascaris procyonis*, a large intestinal roundworm that is zoonotic and can result in fatal or severe central nervous system disease in young children. Prevalence of infection among raccoon populations often is high, and in the midwestern United States, *B. procyonis* has been reported in 68–82% of raccoons. Raccoon populations have increased in response to changes in human land use, and often reach higher densities in urban and suburban landscapes than rural landscapes. However, shifts in foraging behavior among urban raccoons could impact the transmission of *B. procyonis* if small vertebrate intermediate hosts are not a significant part of the raccoon diet. The objective of this study was to compare prevalence of *B. procyonis* infection between urban and rural raccoon populations on a regional scale. Necropsy was done on 204 raccoons collected from September through February during 2000–2005 from seven states across the Midwest (regional sample). *Baylisascaris procyonis* was found in 54% of examined raccoons. Prevalence differed between land-use types (χ^2=11.56, df=1, P=0.0007), and was higher among animals collected from rural locations (65%) than those collected in urban locations (41%). Intensity of infection also differed (F=5.52, df=1, P=0.02), with rural raccoons having greater worm burdens ($\bar{x}$=29.63±36.42) than urban raccoons ($\bar{x}$=13.85±18.47). Despite high densities of raccoons in urban landscapes, fewer urban raccoons were infected with *B. procyonis*, suggesting decreased dependence on intermediate hosts as a food source. This possible explanation was supported by a similar trend in prevalence among subsamples of raccoons collected from three Chicago-area populations (local samples) with differing levels of urbanization, population densities, and foraging behavior that had been intensively monitored during 1995–2002. Decreased transmission of *B. procyonis* in urban landscapes may be due to decreased predation of intermediate hosts, and contact of juvenile raccoons with *B. procyonis* eggs may be an important factor in maintaining infections within such populations.
Key words: *Baylisascaris procyonis*, land use, nematode, prevalence, *Procyon lotor*, raccoon.

INTRODUCTION

As human populations increase, landscapes are dramatically altered through the process of urbanization and shifts in predominant land use (Heimlich and Anderson, 2001; DeStefano and DeGraaf, 2003; Radeloff et al., 2005). Landscapes altered by urban and suburban development are characterized by increased local extinction rates (Czech et al., 2000), replacement of native species with nonnative species (McKinney, 2002), and changes in the abundances, behaviors, and interactions of native wildlife populations (Dickman, 1987; Soule et al., 1988; Crooks and Soulé, 1999; Cam et al., 2000). How wildlife populations respond to urbanization may also affect host-parasite dynamics, especially if those populations are altered in dramatic ways.

Raccoon (*Procyon lotor*) populations have increased in response to changes in human land use. They are abundant in heterogeneous landscapes, especially in those dominated by humans (Riley et al., 1998; Gehrt, 2003), and often are the source of wildlife-human conflict characterized by nuisance, property damage (de Almeida, 1987; DeStefano and DeGraaf, 2003), and disease transmission (Kazacos, 2000). Raccoon population densities attain extremely high levels in urbanized landscapes, with some reported densities greater than 100 raccoons per square kilometer (Riley et al., 1998; Prange et al., 2003).

Raccoons are the definitive hosts of

Baylisascaris procyonis, a large intestinal roundworm recognized for its zoonotic potential (Sorvillo et al., 2002; Murray and Kazacos, 2004). The prevalence of infection among raccoon populations often is high, and in the midwestern United States, *B. procyonis* has been documented in 68–82% of raccoons (Kazacos and Boyce, 1989). Prevalence is highest among juvenile raccoons (≥90%) because they can develop patent infections following exposure to larvated eggs (Kazacos, 2001). Adult raccoons are not susceptible to infection via ingestion of larvated eggs, and only develop patent infections via ingestion of infected intermediate hosts such as rodents (Kazacos, 2001). The transmission of *B. procyonis* to intermediate hosts has been shown to occur at raccoon latrines (Page et al., 1999). Because millions of eggs can accumulate at these locations, latrines also are a source of zoonotic infection (Kazacos, 2001; Roussere et al., 2003). Human infections are most common among young children because of the fecal-oral transmission route (Kazacos, 2001), and severe or fatal central nervous system disease can result (Murray and Kazacos, 2004). The transmission dynamics of the parasite differ as a function of predominant land use (Page et al., 2001), presumably as a result of differences in latrine densities, host densities, and raccoon behavior. Prevalence of infection among raccoons is highest where raccoons and intermediate hosts of *B. procyonis* are at high densities (Page et al., 2001). Given the relatively high densities of urban populations of raccoons, one might predict that prevalence of *B. procyonis* would also be high. Indeed, prevalence of *B. procyonis* has been reported to be as high as 72% in urban raccoon populations that were apparently at high densities (Evans, 2001); however, estimates of host population densities have rarely been reported in studies of *B. procyonis*.

Given that raccoon populations typically occur at high densities in urban systems, it seems intuitive that prevalence rates for *B. procyonis* in urban systems would follow the same pattern. However, the anthropogenic factors that contribute to high raccoon densities may also complicate the linkage between host density and parasite infection. Raccoons in Midwestern urban landscapes have been shown to have altered foraging behaviors that focus on anthropogenic resources rather than more natural items (Prange and Gehrt, 2004). This habituation to human-related foods could reduce transmission of *B. procyonis* if intermediate hosts were not a common part of raccoon diets. Understanding the dynamics of *B. procyonis* in midwestern urban landscapes has important implications for public health because of the large numbers of raccoons and people that coexist in many urban areas. The objective of this study was to compare prevalence of *B. procyonis* infection between urban and rural raccoon populations in the midwestern United States (regional scale). In addition, we examined differences in prevalence among a subsample of raccoons from local populations in northeastern Illinois that had been intensively monitored with live trapping and radiotelemetry.

METHODS

We obtained 204 gastrointestinal tracts from trapped, hunter-killed, or road-killed raccoons collected from September through February during 2000–2005 from Illinois ($n=100$), Indiana ($n=14$), Kansas ($n=3$), Michigan ($n=15$), Minnesota ($n=37$), Missouri ($n=5$), and Wisconsin, USA ($n=30$). For each raccoon, we recorded the date of collection, gender and predominant land use (rural or urban). Animals were classified as originating from a rural area if they were trapped in a rural area or were collected by us as vehicle-killed animals on rural roads. Urban raccoons included trapped nuisance raccoons and those that were killed by vehicles in urban areas. Stomach and intestinal tract were removed and placed in individual marked bags, and stored at −20 C until examination. The stomach and intestines, including the lumen, mucous, and ingesta were examined for *B. procyonis*. Voucher specimens were stored in 95% ethanol. Prevalence was determined as the proportion of infected individuals from the entire sample. Differences in prevalence estimates were tested as a function of land use with the use of chi-square analysis (JMP7, 2007). Counts of *B. procyonis* were made from 91 raccoons. Analysis of variance was used to determine differences in intensity of infection (burden size) as a function of predominant land use (JMP7, 2007). In all cases, raccoon samples were obtained opportunistically.

In addition to the regional aspect of our sample collection, we examined trends in prevalence from a subsample of raccoons collected from three populations in northeastern Illinois representing different levels of urbanization and anthropogenic resources. These populations were intensively monitored by radiotelemetry during associated research of raccoon ecology during 1995–2002 (Prange et al., 2003; Gehrt, 2004; Prange and Gehrt, 2004), thereby providing information on demographics and foraging behavior. This arrangement also afforded us the opportunity to determine the relationships between urbanization, raccoon behavior, and parasite dynamics at the local scale. The three study sites were comprised of an urban, suburban, and rural site. The urban site was represented by the Ned Brown Forest Preserve (42°01′55.05″N, 88°00′00.62″W, Cook County), a 1,499-ha park located 20 km from Chicago near O'Hare International Airport. The site is surrounded by intense development, with a human population density of 3,420/km^2 immediately adjacent to the park, and heavily used roads with a traffic volume of >300,000 vehicles/24 hr (Prange et al., 2003). Although the habitat within the park is largely second-growth mature forests and wetlands, there is an extensive interior road and parking system (0.94 km of road per km^2), with a series of garbage cans or dumpsters placed along the roads at an estimated density of one can for every 23 m (Gehrt, unpublished data). Anthropogenic resources were plentiful during most of the year as the park receives 1–3 million human visitors annually; picnicking is the primary recreational activity. These highly clumped food resources were easily accessed by raccoons, as cans did not have lids and the park was closed to people during the night.

In contrast to the urban site, the Max McGraw Wildlife Foundation located in Kane County representing the suburban site, and the rural site, Glacial Park located in McHenry County, had less adjacent urbanization as well as less human use within the sites. The 495-ha suburban site was privately owned with limited human use and no picnic areas. The rural site (1,052 ha) was a public conservation area with little interior access and a road density of only 0.24 km of road/km^2, with no garbage receptacles or shoulders along the roads. These study areas are described in more detail in Prange et al. (2003, 2004), and Bozek et al. (2007).

Raccoon populations from the three sites differed in density and movement patterns, apparently in response to the different levels of human influence. Population densities during spring ranged from 33 to 42 raccoons/km^2 at the urban site, which were three to four times higher than densities for a rural population at Glacial Park (8–13 raccoons/km^2; Prange et al., 2003). Raccoon density was manipulated for unrelated research at the suburban site, so the density estimates by 2002 were intermediate between the urban and rural populations (Gehrt, 2002). Based on radiotelemetry results, home range size was smaller, and more spatially aggregated, for urban and suburban populations relative to the rural population (Prange et al., 2004), and the urban population focused nocturnal foraging near garbage areas despite abundant natural habitat (Gehrt, 2004; Bozek et al.,

TABLE 1. Relationships between population characteristics and prevalence of *Baylisascaris procyonis* for three raccoon populations in northeastern Illinois.

	Urban	Suburban	Rural	Source
Raccoon density[a]	40	37	11	Gehrt (2002)
Home range (ha)[b]	25–53	29–37	71–182	Prange et al. (2004)
Habitat selection rankings for anthropogenic habitat[c]	1	3	4	Bozek et al. (2007)
Prevalence	57%	50%	42%	This study

[a] Number of raccoons/square kilometer during spring.
[b] Range among seasons.
[c] Selection rankings for human-related habitat associated with anthropogenic foods during raccoon foraging bouts. Out of five possible habitat types available to raccoons, a '1' represents the top-ranked habitat type selected by raccoons and a '5' is the lowest.

2007). Carcasses were collected opportunistically on roads immediately adjacent to and within study sites.

RESULTS

Baylisascaris procyonis was found in 54% of 204 raccoons. Significantly more (χ^2=11.56, df=1, P=0.0007) individuals collected from rural locations (n=114) were infected (65%) than those collected in urban locations (41%; n=90). Intensity of infection differed between predominant land-uses (F=5.52, df=1, P=0.02), with rural raccoons (n=57) having greater worm burdens ($\bar{x}$=29.63±36.42) than urban raccoons ($\bar{x}$=13.85±18.47, n=34).

Our subsamples followed the regional prevalence pattern; the urban raccoon population had a lower prevalence rate (42%, n=12) compared to the suburban (50%, n=12) and rural (57%, n=7) study sites. During 1995–2002, raccoon density estimates that were three to four times greater on the urban site when compared the rural population. Although the trend in prevalence followed an inverse relationship with urbanization and density, these differences were not statistically different (χ^2=0.446, df=2, P=0.80; Table 1).

DISCUSSION

Previous studies suggest that prevalence of *B. procyonis* increases as a function of raccoon density (Page et al., 2001; LoGiudice, 2003; Wright and Gompper, 2005). Although very high prevalence rates have been reported from California raccoon populations where densities were assumed to be high, density estimates are not reported in these studies (Evans, 2001; Roussere et al., 2003). In the present study, the lowest prevalence and intensity estimates for *B. procyonis* were detected in raccoons sampled in urban landscapes, and this relationship was observed on one area with a high raccoon density (Prange et al., 2003). The lower prevalence in urban and high-density raccoon populations may be a function of decreased contact with *B. procyonis*.

Raccoons are generalists, and population-level responses to anthropogenic food sources in urban landscapes have been previously demonstrated (Prange et al., 2003; Prange et al., 2004). Raccoons in urbanized areas can become habituated to human-related food, which alters their foraging patterns (Gehrt, 2004). Dependence on artificial concentrations of food can result in decreased predation by raccoons on small vertebrates (Prange et al., 2004), the intermediate hosts of *B. procyonis*. Transmission of *B. procyonis* to raccoons differs as a function of age. Juvenile raccoons are susceptible to infection via ingestion of larvated eggs and infected intermediate hosts (Kazacos, 2001). However, transmission to adult raccoons requires ingestion of intermediate hosts; therefore, decreased predation by raccoons should result in decreased transmission rates and lowered prevalence among raccoon populations dependent on anthropogenic resources. We did not have access to age data for many of the individuals included in this study; however, most individuals had attained adult body size. Changes in prevalence among adult raccoons ultimately would alter the levels of eggs at latrines, and thus decrease exposure of juvenile raccoons to infective eggs. In this study, observed decreases in prevalence among urban raccoons suggests decreased contact with infective stages; one likely point of transmission that is affected is transmission to adults via predation. Therefore, the results of this study are consistent with evidence that foraging by urban raccoons is strongly influenced by anthropogenic resources (Prange et al., 2004).

Radiotracking of raccoons in our three local study areas revealed different movement and spatial patterns in response to anthropogenic resources within their home ranges (Gehrt, 2004; Prange et al., 2004; Bozek et al., 2007). Urban raccoons had smaller home ranges that were spatially aggregated compared to the rural population (Prange et al., 2004). Foraging patterns by the urban raccoons during summer strongly suggested that they focused their activity on areas with refuse and used habitats differently than rural raccoons (Bozek et al., 2007). The present study includes a subsample of individuals removed from populations included in the radiotelemetry studies of Gehrt (2004), Prange et al. (2004), and Bozek et al. (2007). Although no significant differences were observed, decreased prevalence among the urban and suburban individuals from this small subset of data ($n=31$) suggests that the fine-scale habitat selection for anthropomorphic resources may have an impact on *B. procyonis* transmission (Table 1), and further studies should investigate foraging patterns and infection status concurrently.

Intensity of infection also was significantly reduced among urban raccoons suggesting decreased contact with *B. procyonis*. Transmission of *B. procyonis* to adult raccoons requires predation of intermediate hosts; however, transmission to juveniles requires only ingestion of larvated *B. procyonis* eggs (Kazacos, 2001). This mode of transmission is seemingly important in maintaining low-level *B. procyonis* infections in urban areas due to an increased dependence of raccoons on anthropogenic food sources (Prange et al., 2004). Because raccoon foraging behaviors change in response to anthropogenic food sources, models of *B. procyonis* transmission assuming a correlation between raccoon density and prevalence may not always be valid, and subsequent predictions of risk of zoonoses must consider predominant human land use and associated raccoon behavior.

ACKNOWLEDGMENTS

The authors would like to acknowledge C. Anchor and the Cook County Forest Preserve district, and numerous trappers from Indiana, Kansas, Michigan, Minnesota, Missouri, and Wisconsin for providing samples for this study. We would also like to thank K. Titcombe, A. Cascione, E. Walter, and K. Kellner for laboratory and field assistance. Kevin Kazacos provided helpful comments on this manuscript. In addition, we appreciate the support of the Wheaton College Alumni Association and the Science Division. This study was further supported by the Max McGraw Wildlife Foundation, the Forest Preserve District of Cook County, the Rice Foundation, and the Furbearer Fund of the Illinois Department of Natural Resources.

LITERATURE CITED

Bozek, C. K., S. Prange, and S. D. Gehrt. 2007. The influence of anthropogenic resources on multiscale habitat selection by raccoons. Urban Ecosystems 10: 413–425.

Cam, E., J. D. Nichols, J. R. Sauer, J. E. Hines, and C. H. Flather. 2000. Relative species richness and community completeness: Birds and urbanization in the mid-Atlantic states. Ecological Applications 10: 1196–1210.

Crooks, K. R., and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature 400: 566.

CZECH, B., P. R. KRAUSMAN, AND P. K. DEVERS. 2000. Economic associations among causes of species endangerment in the United States. Bioscience 50: 593–601.

DE ALMEIDA, M. H. 1987. Nuisance furbearer damage control in urban and suburban areas. *In* Wild furbearer management and conservation in North America, M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch (eds.). Ontario Trappers Association, North Bay, Canada, pp. 996–1006.

DESTEFANO, S., AND R. M. DEGRAAF. 2003. Exploring the ecology of suburban wildlife. Frontiers in Ecology and the Environment 1: 95–101.

DICKMAN, C. R. 1987. Habitat fragmentation and vertebrate species richness in an urban environment. Journal of Applied Ecology 24: 337–351.

EVANS, R. H. 2001. *Baylisascaris procyonis* (Nematoda: Ascaridae) in raccoons (*Procyon lotor*) in Orange County, California. Vector Borne Zoonotic Diseases 1: 239–242.

GEHRT, S. D. 2002. Evaluation of spotlight and road-kill surveys as indicators of local raccoon abundance. Wildlife Society Bulletin 30: 449–556.

———. 2003. Raccoons *Procyon lotor* and allies. *In* Wild mammals of North America: Biology, management, and conservation. 2nd Edition. G. A. Feldhamer, B. C. Thompson, and J. A. Chapman (eds.). Johns Hopkins University Press, Baltimore, Maryland, pp. 611–634.

———. 2004. Ecology and management of striped skunks, raccoons, and coyotes in urban landscapes. *In* People and predators: From conflict to conservation, Nina Fascione, Aimee Delach, and Martin Smith (eds.). Island Press, Washington, D.C., pp. 81–104.

HEIMLICH, R. E., AND W. D. ANDERSON. 2001. Development at the urban fringe and beyond: Impacts on agriculture and rural land. Economic Research Service, U.S. Department of Agriculture Agricultural Economic Report No. 803.

JMP7 STATISTICAL SOFTWARE. 2007. SAS Institute, Cary, North Carolina.

KAZACOS, K. R. 2000. Protecting children from helminthic zoonoses. Contemporary Pediatrics 17(suppl): 1–24.

———. 2001. *Baylisascaris procyonis* and related species. *In* Parasitic diseases of wild mammals, W. M. Samuel, M. J. Pybus, and A. A. Kocan (eds.). Iowa State University Press, Ames, Iowa, pp. 301–341.

———, AND W. M. BOYCE. 1995. *Baylisascaris* larva migrans. Zoonosis updates from the Journal of American Veterinary Medical Association. 2nd Edition. American Veterinary Medical Association, Schaumburg, Illinois, pp. 20–30.

LOGIUDICE, K. 2003. Trophically transmitted parasites and the conservation of small populations: Raccoon roundworm and the imperiled Allegheny woodrat. Conservation Biology 17: 258–266.

MCKINNEY, M. L. 2002. Urbanization, biodiversity, and conservation. Bioscience 52: 883–890.

MURRAY, W. J., AND K. R. KAZACOS. 2004. Raccoon roundworm encephalitis. Clinical Infectious Diseases 39: 1484–1492.

PAGE, L. K., R. K. SWIHART, AND K. R. KAZACOS. 1999. Implications of raccoon latrines in the epizootiology of baylisascariasis. Journal of Wildlife Diseases 35: 474–480.

———, ———, AND ———. 2001. Changes in transmission of *Baylisascaris procyonis* to intermediate hosts as a function of spatial scale. Oikos 93: 213–220.

PRANGE, S., AND S. D. GEHRT. 2004. Changes in mesopredator-community structure in response to urbanization. Canadian Journal of Zoology 82: 1804–1817.

———, ———, AND E. P. WIGGERS. 2003. Demographic factors contributing to high raccoon densities in urban landscapes. Journal of Wildlife Management 67: 324–333.

———, ———, AND ———. 2004. Influences of anthropogenic resources on raccoon movements and spatial distribution in urbanized systems. Journal of Mammalogy 85: 483–490.

RADELOFF, V. C., R. B. HAMMER, S. I. STEWART, J. S. FRIED, S. S. HOLCOMB, AND J. F. MCKEEFRY. 2005. The wildland–urban interface in the United States. Ecological Applications 15: 799–805.

RILEY, S. P. D., J. HADIDIAN, AND D. A. MANSKI. 1998. Population density, survival, and rabies in raccoons in an urban national park. Canadian Journal of Zoology 76: 1153–1164.

ROUSSERE, G. P., W. J. MURRAY, C. B. RAUDENBUSH, M. J. KUTILEK, D. J. LEVEE, AND K. R. KAZACOS. 2003. Raccoon roundworm eggs near homes and risk for larva migrans disease, California communities. Emerging Infectious Diseases 9: 1516–1522.

SORVILLO, F., L. R. ASH, O. G. W. BERLIN, J. YATABE, C. DEGIORGIO, AND S. A. MORSE. 2002. *Baylisascaris procyonis*: An emerging helminthic zoonosis. Emerging Infectious Diseases 8: 355–359.

SOULE, M. E., D. T. BOLGER, A. C. ALBERTS, J. WRIGHT, M. SORRCE, AND S. HILL. 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. Conservation Biology 2: 75–92.

WRIGHT, A., AND M. E. GOMPER. 2005. Altered parasite assemblages in raccoons in response to availability. Oecologia 144: 148–156.

Received for publication 6 June 2007.