Determining the Prevalence of Patent Parasite Infections in Raccoons from West-Central Illinois

Mark A. Mitchell, DVM, MS, PhD[1]
Laura Hungerford, DVM, MPH, PhD[2]
Charles M. Nixon, MS[3]
Terry Esker, BS[4]
Joseph B. Sullivan, BS[3]
Robert Koerkenmeier, BS[3]

[1]International Aquatic and Terrestrial Conservation Medicine and Biotelemetrics Research Laboratory, Department of Veterinary Clinical Science, School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA 70803
[2]Department of Epidemiology and Preventive Medicine, School of Medicine, University of Maryland, Baltimore, MD 21201
[3]Illinois Natural History Survey, Champaign, IL 61820
[4]Illinois Division of Natural Resources, Division of Natural Heritage, Newton, IL 62448

Introduction

The raccoon (*Procyon lotor*) is an omnivorous mammal that is widely distributed throughout North America (Kaufman 1982). This omnivorous diet exposes the raccoon to a broad spectrum of intestinal parasites. Because the raccoon is highly adapted to both urban and rural environments, and raccoon densities are increasing in both types of areas (Hoffman and Gottschang 1977), there is increased contact between humans and raccoons. Greater contact with raccoons creates a potential for human and domestic animal exposure to parasites normally harbored by raccoons.

Intestinal parasitism can cause serious consequences for the vertebrate host, including weight loss, poor pelt, anemia, and death (Hanson 1933; Soulsby 1982). Intestinal parasitism in the raccoon has been studied extensively, especially in the Midwest and Southeast (Cole and Shoop 1987; Schaffer et al. 1981; Smith et al. 1985; Snyder and Fitzgerald 1985a). Several studies in different geographic locations have characterized age, gender, season, and/or location patterns for *Baylisascaris procyonis* (Kidder et al. 1989; Snyder and Fitzgerald 1985b); however, no study has evaluated the combination of these factors for *B. procyonis* and/or other intestinal parasites

simultaneously.

The objectives of this study were to (1) determine the prevalence of patent intestinal nematode and protozoal infections in raccoons; (2) compare prevalence of shedding between age and gender groups; and (3) compare prevalence of shedding between raccoons captured in different sites or seasons.

Materials and Methods

The study was conducted from September 1989 to October 1993 in west-central Illinois. Trapping seasons were divided into spring (March to June) and fall (August to October). Two neighboring but distinct study areas were used; a state recreational facility (Park) and privately owned, farming property (Farm). The park study area was a 644 ha* state park (39E 53'N, 90E 56'W), with a raccoon population estimated to be at least 13.5 raccoons/km (Nixon et al. 1994). The park had approximately 205,000 visitors annually, and the potential for human-raccoon contact was high. Visitors reported that raccoons would enter campsites, eat leftover food, garbage, and destroy property. Raccoons also had potential contact with domestic animals, as some visitors brought dogs and cats as traveling companions and a section of

Dr. Mitchell is Assistant Professor of Zoological Medicine and Director of the Wildlife Hospital of Louisiana at the Louisiana State University in Baton Rouge, LA.

*Hectare: one hectare is equal to 2.47 acres.

the park was designated for individuals to camp and trailer horses. The farm study area was a 2,310 ha forested/extensively farmed area (39E 57'N, 90E 53'W), with a raccoon population estimated to be at least 4.5 raccoons/km (Nixon et al. 1994). Human contact occurred as a result of removing nuisance raccoons, hunting, and trapping. Various species of livestock (cattle, horses, swine, and sheep) were maintained within the farm study area.

Box traps (wood and mesh, drop-door style) baited with canned sardines in mustard sauce were placed in suitable raccoon habitat, left overnight, and checked for captures the following morning. Most traps were placed on stream banks or along drainage areas. Each raccoon was removed from the trap into a wire cone, weighed, and sedated using Telazol® (Fort Dodge Laboratories, Inc., Fort Dodge, Iowa) at 5 mg/kg.

Age was estimated in the field by evaluation of facial and body features, tooth eruption, and body weight (Nixon et al. 1994). Raccoons were categorized as juveniles, yearlings, or adults. Juveniles were raccoons born in the spring of the current trapping year or entering their first fall. Raccoons were classified as yearlings during the subsequent spring and fall seasons (12 to 24 months). Animals became adults the second spring after their birth (>24 months). A first premolar was extracted from yearling and adult raccoons and cementum annuli were used to confirm field age (Grau et al. 1970).

Fecal samples were collected from the rectum of sedated raccoons. Fecal material was placed in a 2.5 percent potassium dichromate solution in the field and samples returned to the University of Illinois, College of Veterinary Medicine, Urbana, Illinois, for parasitologic testing. Fecal material was forced through a tea-strainer to thoroughly mix the sample. The fecal solution was then placed in a centrifuge tube and centrifuged at 1,500 rpm for five minutes. The supernatant was removed from the sample and the fecal pellet was re-suspended with Sheather's sugar solution. A cover slip was placed on the centrifuge tube and the sample was centrifuged at 1,200 rpm for 10 minutes. The cover slip was removed, placed on a slide and reviewed under light microscopy.

Parasites were identified to the generic level for all ova except *B. procyonis*. Characterization to species was not performed because adult worms were not used. The mean *B. procyonis* egg size was 68 x 55 μ. The eggs were golden-brown in color, ellipsoidal, and had a granular texture. *Strongyloides* sp. larvae were elongate, colorless, and had a tapered posterior. *Capillaria* sp. eggs were 60 to 72 μ in length. The eggs were elongate, brown, and bipolar. *Eimeria* sp. oocysts were 17

to 25 x 16 to 20 μ and had four sporocysts. Parasite quantification was not performed due to variation in fecal collection weights.

Data Analyses

The 95 percent binomial confidence intervals (CI) were calculated for each parasite. Mantel-Haenszel chi-square tests and odds ratios (OR) were used to evaluate year of capture, age class, and season for each of the major parasites identified (ProcFreq, SAS 1989a). Mantel-Haenszel (MH) and adjusted OR were then used to evaluate gender, site, and season, while controlling for age class. Mantel-Haenszel and adjusted OR were also used to evaluate the effects of age class and gender for different seasons. The Breslow-Day Test (B-D) for Homogeneity was used to evaluate homogeneity of OR's across strata. A B-D statistic with a p< 0.05 was considered statistically significant and suggested that the strata were heterogeneous. A summary odds ratio (Cochran-Mantel-Haenszel) was calculated for each (adjusted) comparison with homogeneous strata. Adjusted and crude odds ratios were compared to assess confounding. A 10 percent change in OR was selected as the criteria for detecting confounding. Variables with p< 0.05 were considered statistically significant.

Separate logistic regression analyses were used to model risk for each major parasite identified. Age class, gender, site, and season of capture were all included in initial models (Proc Logistic, SAS 1989b). Year of study and body condition were also included if they were significant at the univariate level, but removed first if they did not affect the magnitude of the coefficients (> 20%) of the other variables. Main effect variables were removed individually from full models to assess effects on model likelihood ratio statistics, magnitude of coefficients for other variables, and Hosmer and Lemeshow goodness-of-fit statistics (Hosmer and Lemeshow 1989). For models where there was a seasonal effect, juveniles were removed from the comparison and the logistic regression model re-evaluated. This was done to determine if age was confounded by season. The model without juveniles was compared to the full model and if the model likelihood ratio statistics, magnitude of coefficients, or the H-L goodness of fit statistic were significantly altered, the unrestricted model was used. Biologically relevant interactions of main effect variables were also evaluated.

Results

In the farm area, fecal samples were collected from

228 raccoons, of which 121 (53%) were captured in the spring and 107 (47%) in the fall. There were 137 (60%) males and 91 (40%) females composed of 47 (20%) juveniles, 79 (35%) yearlings and 102 (45%) adults. In the park area, 164 fecal samples were examined, of which 51 (31%) were collected in the spring and 113 (69%) in the fall. There were 68 (41%) males and 96 (59%) females composed of 35 (21%) juveniles, 34 (21%) yearlings and 95 (58%) adults.

One hundred and forty-nine (38%, 95% CI: 33-43) of 392 raccoons were found to be actively shedding *B. procyonis* eggs. There were no significant differences between study years, although prevalence was slightly higher in 1990 (43%) and 1991 (39%) than in 1992 (29%) and 1993 (34%). Juvenile raccoons were more likely to be shedding *B. procyonis* eggs (70%, OR: 5.4, 95% CI: 2.9-10.0, p=0.0001) than were yearlings (31%) and adults (28%). Among adults, there were no differences in the prevalence of patent infections as age increased (p=0.20).

The effects of gender, site, and season on egg shedding were evaluated after adjusting for age. Male raccoons were more likely to be shedding *B. procyonis* eggs (45%, OR: 2.0, 95% CI: 1.3-3.1, p=0.003) than were females (30%). Raccoons in the park area were less likely to have patent infection (26%, OR: 0.4, 95% CI: 0.2-0.6, p=0.001) than those in the farm area (46%). Raccoons captured in the spring were less likely to be shedding *B. procyonis* eggs (34%, OR: 0.60, 95% CI: 0.4-0.97, p=0.01) than those in the fall (41%). There were no significant changes in the OR when age was tested as a confounder. However, when juveniles were excluded from the comparison, because there were no samples collected from this age group in the spring, shedding of *B. procyonis* was lower in the fall (23%, OR: 0.60, 95% CI: 0.4-0.98) than the spring (34%). The effects of gender, site, and age on egg shedding were also evaluated after stratifying for season. Egg shedding was less for adult males (31%) and females (16%) in the fall than in the spring (males: 41%, females: 25%), but the differences were not significant (p=0.25). The prevalence of shedding in yearling females did not vary between the spring (24%) and fall (23%) trapping seasons, while there was a difference between spring (26%) and the fall (13%) in adult females although it was not significant (p=0.10). There were no significant changes in the OR when season was tested as a confounder.

In the final regression model, juvenile raccoons were more likely to be shedding *B. procyonis* eggs (OR: 6.6, 95% CI: 1.4–10.5, p<0.05), relative to yearlings and adults. Female raccoons were also less likely to be shedding *B. procyonis* eggs (OR: 0.6, 95% CI: 0.3–0.9,

p< 0.05), while raccoons captured in the farm area were more likely to be shedding eggs (OR: 2.5, 95% CI: 1.5–4.0, p<0.05). The Hosmer and Lemeshow goodness-of-fit statistic was 0.85. There were no significant interaction terms.

Fifty-nine (15%, 95% CI: 12–18) of 392 raccoons were found to be shedding *Strongyloides* sp. larvae. Raccoons captured in 1990 (22%) and 1992 (19%) were more likely to be shedding *Strongyloides* sp. than those raccoons captured in 1991 (1%) and 1993 (7%) (p<0.05). The prevalence of egg shedding was lower in juveniles (4%) than in yearlings (18%) and adults (19%) (p<0.05).

The effect of gender, site, and season on *Strongyloides* sp. shedding was evaluated after adjusting for age. There was no difference in *Strongyloides* sp. shedding between males (16%) and females (13%) (p>0.05). Raccoons in the park area were less likely to be shedding *Strongyloides* sp. (7%, OR: 0.3, 95% CI: 0.1-0.5, p=0.001) than those captured in the farm area (21%). Raccoons trapped in the fall were less likely to be shedding *Strongyloides* sp. (5%, OR: 0.2 95% CI: 0.1–0.4, p=0.001) than those in the spring (27%). This association remained after juveniles were excluded from the analyses. The effect of gender, site, and age on egg shedding was also evaluated after stratifying for season. There were no significant changes in the OR when age and season were tested as confounders.

In the final regression model, raccoons captured in the spring were more likely to be shedding *Strongyloides* spp. (OR: 5.6, 95% CI: 2.8–11.0, p<0.05) than those captured in the fall. Raccoons captured in the farm area were more likely to be shedding *Strongyloides* spp. (OR: 2.4, 95% CI: 1.2–4.8, p<0.05), relative to those captured in the park area. The Hosmer and Lemeshow goodness-of-fit statistic for the regression model was 0.93. There were no significant interaction terms.

One hundred and ninety (48%, 95% CI: 43–53) of 392 raccoons were actively shedding *Capillaria* sp. eggs. There were no significant differences between study years, although prevalence was slightly higher in 1990 (57%) than in 1991 (39%), 1992 (43%) or 1993 (45%) (p>0.05). There were no differences in the prevalence of shedding between juveniles (49%), yearlings (51%) and adults (47%) (p>0.05).

The effects of gender, site, and season on egg shedding were evaluated after stratifying for age. Male raccoons were more likely to be shedding *Capillaria* sp. (56%, OR: 1.9, 95% CI: 1.2–2.8, p=0.002) than were females (40%). Raccoons in the park area were less likely to be shedding eggs (41%, OR: 0.6, 95% CI: 0.4–0.9, p=0.01) than those in the farm area

(54%). Raccoons trapped in the fall were less likely to be shedding eggs (40%, OR: 0.4, 95% CI: 0.2-0.6, p=0.001) than those in the spring (59%). The effects of gender, site, and age on egg shedding were evaluated after adjusting for season. The prevalence of shedding eggs was higher in the spring for both yearlings (64%) and adults (55%) than in the fall (yearlings: 32%, adults: 37%). There were no significant changes in the OR when age and season were tested as confounders.

In the final regression model, female raccoons were less likely to be shedding *Capillaria* sp. (OR: 0.5, 95% CI: 0.4-0.8, p<0.05), relative to males. Raccoons captured in the spring were more likely to be shedding *Capillaria* sp. (OR: 2.0, 95% CI: 1.3-3.1, p<0.05). The Hosmer and Lemeshow goodness-of-fit statistic was 0.85. There were no significant interaction terms. An unrestricted model, removing juveniles from comparison, was evaluated to determine if age was confounded by season. There was no change in the restricted model, except the Hosmer-Lemeshow goodness-of-fit was lower (p=0.51). Therefore, the final model excluded juveniles.

Two hundred and twenty-two (57%, 95% CI: 52-62) of 392 raccoons were found to be actively shedding *Eimeria* sp. oocysts. Raccoons captured in 1990 (68%, OR: 4.7, 95% C.I.: 2.0-10.9) and 1991 (54%, OR: 2.6, 95% C.I.: 1.1-6.2) were more likely to be shedding oocysts than raccoons captured in 1993 (31%) (p<0.05). There were no differences in the prevalence of shedding oocysts between juveniles (60%), yearlings (57%) and adults (55%) (p>0.05).

The effect of gender, site, and season on oocyst shedding was evaluated after stratifying for age. Males (61%) had a slightly higher prevalence of shedding than females (52%), however the difference was not significant (p>0.05). Raccoons in the park area were more likely to be shedding oocysts (63%, OR: 1.6, 95% CI: 1.0-2.4, p<0.05) than those in the farm area (52%). In the farm area, adults older than 4 years old were all negative for *Eimeria* sp. (0/10). Animals trapped in the fall had a slightly higher prevalence of shedding (60%) than those in the spring (52%), however the difference was not significant (p=0.16). The effect of gender, site, and age on oocyst shedding was also evaluated after adjusting for season. The prevalence was higher in the fall for both yearlings (66%) and adults (57%) than in the spring (yearlings: 52%, adults: 52%), but the differences were not significant (p=0.10). There were no significant changes in the OR when age and season were tested as confounders.

In the final regression model, raccoons captured in the farm area were less likely to be shedding oocysts (OR: 0.6, 95% CI: 0.4-0.9, p<0.05). Raccoons captured in 1990 were more likely to be shedding *Eimeria* sp. oocysts relative to other years (OR: 2.3, 95% CI: 1.5-3.5, p<0.05). The Hosmer and Lemeshow goodness-of-fit statistic was 0.85. There were no significant interaction terms.

DISCUSSION

B. procyonis is the common roundworm of raccoons. Previous studies have reported prevalence levels of *B. procyonis* in raccoons ranging from 7.5 percent to 82 percent (Bafundo et al. 1980; Schaffer et al. 1981; Snyder and Fitzgerald 1987; Cole and Shoop 1987; Kazacos and Boyce 1989; Kidder et al. 1989). These reports of *B. procyonis* infections were of adult worms diagnosed at necropsy, except for Snyder and Fitzgerald (1987; prevalence: 73%) and Kidder et al. (1989; prevalence: 20.3%), which were from fecal samples. The prevalence of egg shedding in our study (38%) is within the range and probably underestimates the true infection rate. Snyder and Fitzgerald (1987) reported that reviewing fecals (for eggs) underestimated true parasite burdens by up to 13 percent. Negative fecal samples are often the result of occult infection (single sex adult), which are not considered detrimental to humans or domestic and feral animals. Although parasite burdens may not always be represented using fecal samples, prevalence of egg shedding is the measure of transmission and zoonotic potential. Characterization of age, gender, site, and seasonal trends are important in determining when the risk of exposure is the greatest.

In this study, egg shedding was significantly higher in juveniles, relative to yearlings and adults. This finding is consistent with other studies (Snyder and Fitzgerald 1987; Kazacos and Boyce 1989; Robel et al. 1989; Kidder et al. 1989). Juvenile raccoons become infected with *B. procyonis* after ingesting infective eggs, and possibly through direct migration of larvae from their dams and by the ingestion of infective intermediate hosts. Adult raccoons become infected predominantly by ingestion of infective intermediate hosts (Kazacos and Boyce 1989). Previous reports indicate that self-clearance of parasites may occur in the winter and that there is some resistance to subsequent infections. The lower prevalence in yearlings, relative to juveniles, and the similarity in prevalence between yearlings and adults, supports the theories of self-clearance and resistance. Egg shedding in males was significantly higher than in females. Cole and Shoop (1987) reported similar findings and speculated that prevalence was lower in females due to transplacental

and transmammary migration of larvae from females to juveniles, decreasing the developing number of mature adults.

Egg shedding was more likely in the farm area than in the park area. Raccoons often use a latrine for defecation (Tester 1953; Caldwell 1963). There was less topographical relief in the farm area than the park area. Cole and Shoop (1987) and Snyder and Fitzgerald (1987) reported higher numbers of *B. procyonis* infections in animals captured in areas with little topographical relief. Differences in habitat and other environmental influences could affect the social behavior of the raccoon. Further research is needed to explore ecological mechanisms responsible for this difference.

Kidder et al. (1989) reported that 80 percent of the *B. procyonis* detected in raccoons from New York were collected in the fall. The overall prevalence (for the fall) in that study was 42.4 percent, while in our study the prevalence was 41 percent. In our study, the higher fall prevalence was due to the number of juveniles captured. The proportion of yearling and adult raccoons shedding *B. procyonis* was lower in the fall than in the spring. The primary diet of raccoons in the spring is animal source (Kaufman 1982). The prepatent period for *B. procyonis* is 30 to 35 days (Kazacos and Boyce 1989). This provides adequate time for raccoons in these studies to develop higher rates of infection in the spring. Yearling and adult raccoons are more likely to feed on plant material during the fall, which might account for the lower prevalence identified in these animals. The lower prevalence of egg shedding in adults during the fall also supports previous reports of self-clearance during the fall, leading to decreased shedding rates. The prevalence of egg shedding was lower in the fall than the spring in adult females, however the difference was not significant. Raccoons often start having litters in April, however parturition is variable (Lehman 1968). Samples from female raccoons in this study were collected primarily in April and May. It has been suggested that transmammary larval migration may occur in raccoons (Shoop and Corkum 1987). The lower prevalence in the fall supports a role for transmammary larval transmission; however, further research is needed to determine if transmammary larval transmission does indeed occur. Other factors, such as immunologic or dietary habits, may also play a role.

Baylisascaris procyonis has a predilection for central nervous tissue in aberrant hosts and has been reported as the cause of ocular, visceral, and cerebro-spinal larval migrans in humans and both avian and mammalian wild and domestic species (Kazacos and Kazacos 1984; Huff et al. 1984; Fox et al. 1985; Kazacos and Boyce 1989). Two fatalities in young children have been reported (Huff et al. 1984; Fox et al. 1985). Human infections occur from the ingestion of eggs (Kazacos and Boyce 1989).

Our findings indicate the importance of preventive measures for individuals working with or around raccoons. The high prevalence of *B. procyonis* in juvenile raccoons poses a special threat to those who work closely with them, such as rehabilitators or those that maintain them as pets. Children playing in sandboxes, on fallen logs, or areas where raccoons have established latrines are also at risk of exposure to potentially infectious larvae. Campers or those utilizing recreational facilities should practice strict hygiene around areas potentially contaminated by raccoons. Raccoons should be quarantined from other species to decrease the risk of contamination. Bleach can be used to treat areas used by raccoons, although only fire destroys *B. procyonis* (Kazacos and Boyce 1989). Fecal material that is collected should be burned.

Strongyloides sp. can have both parasitic and free-living stages (Soulsby 1982). The direct life cycle of *Strongyloides* spp. can lead to a high rate of infection in contaminated areas. Previous studies performed in Texas and Florida detected *Strongyloides* sp. in raccoons at necropsy. The prevalence in the studies was 3 percent and 49 percent respectively (Schaffer et al. 1981). The prevalence in our study was in the lower midrange (15%) of these findings and probably underestimates the true infection rate.

In domestic animals, *Strongyloides* spp. are most often a problem in young animals. Domestic animals typically develop immunity after multiple infections. Nursing is a potential source of infection (Moncol and Battle 1966). In this study, the prevalence of shedding was considerably lower in juvenile raccoons than in yearlings and adults, however juvenile raccoons were only captured during the fall trapping period. Surveying juveniles during the spring would be essential to determine if the burden is truly higher in very young animals due to transmammary infection or initial infections. The relatively low prevalence of *Strongyloides* sp. in adults, yearlings, and fall juveniles could be associated with natural immunity subsequent to initial infections.

In our study, *Strongyloides* sp. shedding was more likely in the farm area than the park area. Higher egg shedding was also found for *B. procyonis* in the farm area. Raccoons typically use latrines or shared defecation sites, increasing risk of exposure to infective larvae collecting at the latrine site (Tester 1953; Caldwell 1963). This suggests that the defecation behavior of

the raccoons in the park may be different than in an agricultural habitat. Further research is needed to explore the underlying ecological mechanisms responsible for this difference.

Strongyloides sp. infections in domestic species are often seasonal. High rates of infection are associated with warm periods and rainy weather (Basir 1950; Trioantophyllou and Moncal 1977). In our study, the prevalence of *Strongyloides* sp. was higher during the spring season, which correlates to previous reports in domestic species (Soulsby 1982). Environmental conditions are considered important to the survival of the larvae, and it has been suggested that the larvae are probably not long-lived in the environment because they are highly mobile and rapidly expend their energy. The higher moisture associated with spring in Illinois might increase larval survivability.

The pathogenicity of these parasites in raccoons has not been reported. In domestic animals, disease is often the result of inflammation of the small intestine, leading to diarrhea and dehydration (Soulsby 1982). Human exposure has been reported to cause a range of syndromes including inapparent infection, dermatitis, diarrhea, and fatal generalized disease (Little 1965; Rivera et al. 1970; Dwork et al. 1975; Meyers et al. 1976). Although the prevalence of shedding in raccoon populations in the present study was low, implementation of preventive measures to reduce the risk of exposure in areas of high raccoon density is recommended. Further research is needed to identify the species of *Strongyloides* in these raccoons and determine if they are parasitic or saprophytic, so that the risk to humans and domestic animals can be characterized.

Capillaria spp. are nematodes commonly found in domestic and wild mammals (Hanson 1933; Butterworth and Beverly-Burton 1980; Schaffer et al. 1981; Soulsby 1982; Snyder and Fitzgerald 1985a; Cole and Shoop 1987). *Capillaria* spp. have been associated with insidious and chronic disease. *Capillaria aerophila* in foxes causes poor growth, unthrifty furs, and death (Hanson 1933). Previous studies which examined adult parasites in necropsied feral raccoons have identified four *Capillaria* species: *C. aerophila*, *C. plica*, *C. procyonis* and *C. putori* (Schaffer et al. 1981; Snyder and Fitzgerald 1985a; Cole and Shoop 1987; Robel et al. 1989; Richardson et al. 1992). The prevalence of parasites in other studies ranged from 7 to 82 percent (Schaffer et al. 1981; Snyder and Fitzgerald 1985a; Cole and Shoop 1987; Richardson et al. 1992). The prevalence in our study (48%) was based on egg shedding and is within the range; however, it probably underestimates the true infection rate.

The life cycle for *Capillaria* spp. can be direct or involve a paratenic host, such as the earthworm, *Lumbricus terrestris* (Soulsby 1982). During the spring, animal protein is the preferred diet of raccoons (Llewellyn and Uhler 1952; Dorney 1954). Raccoons eat both vertebrate and invertebrate animals, while invertebrates are preferred (Kaufman 1982). Many fecals reviewed in this study contained *Monocystis* sp., an earthworm parasite. Spring rains often flood earthworm burrows, bringing them to the surface and giving raccoons greater access to earthworms during this time. The prepatent period for *C. aerophila* is forty days (Christensen 1938). This provides adequate time for raccoons in these studies to develop higher rates of infection in the spring.

In our study, *Capillaria* sp. shedding was more likely in males than in females. This was especially true for yearling males. Male raccoons tend to have larger home ranges than females and females with young tend to severely limit their home range (Kaufman 1982). The increased area covered by male raccoons could result in greater exposure to infective *Capillaria* sp. in the environment. Further research is needed to determine if an association between home range and environmental exposures exists.

The life cycle of *Capillaria* spp. predisposes animals sharing habitats to infective eggs and larvae. *C. aerophila* eggs can remain viable in an environment for over a year under favorable conditions (Soulsby 1982). Several of the *Capillaria* spp. identified in raccoons are pathogens in domestic species (Butterworth and Beverly-Burton 1980; Soulsby 1982). Dogs and cats may be exposed to the parasite when spending time around raccoon habitats, especially latrines. Control through restricting the contact of domestic animals and performing regular fecal exams on pets followed by proper anti-helminthics should be instituted. Humans may also be infected with *Capillaria* sp., causing asthma-like symptoms, but such cases are extremely rare (Acha and Szyfres 1987).

Coccidia have been described in over 900 species of animals (Levine 1973; Noble and Noble 1976). Coccidia are considered to have a high degree of host specificity (Joyner 1982). *Eimeria procyonis* and *Eimeria nuttali* are the two species of coccidia most commonly detected in raccoons (Adams et al. 1981; Dubey 1982; Robel et al. 1989). Previous studies have found prevalence levels of *Eimeria* spp. ranging from 22.2 to 82 percent (Robel et al. 1989; Dubey 1982). The prevalence of egg shedding in our study (57%) was similar to the findings in Adams et al. (58%; 1981).

Coccidial infections in domestic animals are usually self-limiting and in the absence of reinfection will

only undergo one cycle (Soulsby 1982). *Eimeria* sp. infections often stimulate at least partial immunity in the host. Rose (1987) reported an 87% reduction of first generation schizonts in immune chickens when compared to nonimmune chickens. In this study, oocyst shedding rates were high in all three age groups, suggesting that this parasite (in these raccoons) does not stimulate complete immunity or that there is a chronic environmental exposure to the oocysts.

Robel et al. (1989) detected no difference in oocyst shedding between exploited and unexploited raccoons in Kansas. In our study, a higher shedding prevalence was detected in the park area, where the density of raccoons was greater (Nixon et al. 1994). A higher shedding prevalence would be expected where animals are in close proximity, however, the prevalence of *B. procyonis* and *Strongyloides* sp. was found to be higher in the farm area. *Eimeria* sp. oocysts are not stable in the environment, whereas *B. procyonis* and *Strongyloides* sp. can persist for extended periods. Differences in the environmental persistence of a parasite, and the social and defecation behaviors of raccoons in the two areas, may account for the variation in these populations. Further research is needed to explore the underlying ecological mechanisms responsible for these differences.

The high degree of host specificity by *Eimeria* sp. implies that the risk of raccoon-borne infection to humans and domestic animals is limited. Cross-transmission between families of vertebrates has only been described for *Eimeria chinchillae* (de Vos 1968). Severe infections primarily occur in immunocompromised animals (Soulsby 1982). Coccidial infections can cause severe diarrhea and result in severe dehydration (Soulsby 1982). In these cases, *Eimeria* sp. could increase mortality rates from immunosuppressive pathogens, such as canine distemper virus.

Conclusions

Surveys of the raccoon gastrointestinal tract have reported finding protozoa, trematodes, cestodes, and nematodes (Schaffer et al. 1981; Snyder and Fitzgerald 1985a; Cole and Shoop 1987; Robel et al. 1989; Richardson et al. 1992). Our findings were limited primarily to four species of parasites. *Physaloptera rara* has been reported in Illinois raccoons previously (Barnstable and Dyer 1974; Snyder and Fitzgerald 1985a). The prevalence in those studies was 69 percent and 94 percent respectively. In both studies, samples were collected at necropsy. Snyder and Fitzgerald (1985a) reported that the majority of the *P. rara* recovered were immature forms. If *P. rara* infections are self-regulated and remain primarily in the immature form, it might account for our inability to detect *P. rara* eggs in our samples. Cestode eggs might not be detected in fecal samples collected per rectally because proglottids remained intact. In addition, parasites transmitted via the respiratory tract, such as some trematodes, may not be detected by our sampling techniques. Sampling based upon fecal samples probably underestimates true infection rate for these parasites, but provides a measure of transmission and zoonotic potential.

Results of this study indicate significant levels of intestinal parasites among healthy, free-ranging raccoons that are potentially transmissible to humans and domestic species. The risk patterns detected provide information on factors affecting transmission of these parasites and quantify possible public health risks. Awareness of prevalence levels in wild raccoon populations is necessary for informed decision-making in management of raccoon-human and raccoon-domestic animal interactions.

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