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Baylisascaris procyonis: The Little-Known Human Health Threat That Is Literally in Your Backyard

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Abstract: Baylisascariasis is a debilitating and potentially lethal zoonotic, parasitic disease caused by an intestinal ascarid that has a northern hemisphere distribution. *Baylisascaris* spp. are carried by a variety of mammalian hosts, which their larva can infect a large diversity of paratenic hosts that includes birds and mammals, and even humans. Herein, I demonstrate the potential exposure risk of this zoonotic parasite to suburbia America who resides commensally with *Baylisascaris*-infected raccoons (*Procyon lotor*). I surveyed soil of 100 properties within neighborhoods of southern Corpus Christi, Texas, USA, for the presence of viable *Baylisascaris procyonis* eggs, and found 27% of the residential properties were contaminated. Positive soil samples, on average, contained 31,287 ± 6,943 *B. procyonis* eggs, of which, on average, 92% (92.1 ± 2.3; $\bar{x}$ ± SE) of the *B. procyonis* eggs had motile larvae. Locations of contaminated soils appeared random; no specific habitat feature appeared to have a greater likelihood of contamination. I offer residence of *Baylisascaris*-contaminated properties suggestions to reduce their risks of exposure to this potentially debilitating parasite.

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1. Introduction

Baylisascariasis is a zoonotic, parasitic disease caused by an intestinal ascarid of raccoons (*Procyon lotor*), skunks (*Mephitis* spp., *Conepatus* spp., and *Spilogale* spp.), badgers (*Taxedea taxus*), martens (*Martes americana*), fishers (*Martes pennati*), marmots (*Marmota* spp.), and bears (*Ursus* spp.) [1]. The roundworm of the genus *Baylisascaris* has a cosmopolitan distribution and is found in North America, Europe, and Asia [2]. *Baylisascaris* species within the United States are *B. procyonis* in raccoons, *B. columnaris* in skunks, *B. melis* in badgers, *B. devosi* in martens and fishers, *B. laevis* in marmots and ground squirrels, and *B. transfuga* in bears [3]. The larvae of this parasitic roundworm can cause fatal or severe neurologic disease by invading the spinal cord and brain (i.e., neural larva migrans, NLM), blindness by invading the eye (i.e., ocular larva migrans, OLM), and mimic a multitude of illnesses by invading the viscera (i.e., visceral larva migrans, VLM) [4]. The different species of *Baylisascaris* vary in their severity within paratenic hosts due to differences in how the larvae migrate through tissue [5]; however, *B. procyonis* and *B. melis* appear to be the most pathogenic due to their aggressive brain invasions [6].

Typically, *Toxocara canis* was considered the most important ascarid etiologic agent of VLM and OLM in humans [7], mainly because of the close relationship between humans and domestic dogs. However, *Baylisascaris* spp., especially *B. procyonis* and *B. columnaris*, have potential to be threats to human health due to the commensal habits of raccoons and striped skunks (*M. mephitis*), respectively [8,9], and the increasing number of human cases has increased awareness of this once little-regarded parasite. To date, 25 *Baylisascaris* NLM encephalitis cases in humans have been documented [10], but additional cases occur each year as differential diagnoses of meningoencephalitis now include *Baylisascaris* spp. as a cause. Most human cases involve children who are at risk due to poorer hygiene and oral sampling of their environment [11–13]; however, adults also are susceptible to severe NLM

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[10]. Additionally, about 30 cases of *Baylisascaris* OLM have occurred worldwide, and mostly in adults where skunks and raccoons were common [10].

Potential human exposure occurs when an infected animal (e.g., raccoon) defecates, of which, on average, infected raccoon feces has been documented to contain 16,563 ± 4,321 *Baylisascaris* eggs per gram of feces per day [14]. Upon decay, hundreds of thousands of *Baylisascaris* eggs percolate into the soil. Depending upon the fecal decay process (i.e., desiccation, precipitation, wind), eggs can be found up to nearly 1 m from the defecation spot [15]. In addition, 92% of *B. procyonis* eggs have been demonstrated to remain viable and potentially infective for at least 2 years within the environment, and that 60% of the eggs, due to their adhesive outer coating, remain on the soil surface [16]. Such a scenario greatly increases the risk to humans who reside in areas with high densities of raccoons.

Therefore, the objectives of this study were to 1) determine the prevalence of soil contamination by *B. procyonis* eggs within a suburban area with a known population of raccoons, 2) determine if associated habitat features enhanced the likelihood of *B. procyonis* egg contamination, and 3) offer suggestions to reduce human risk of *B. procyonis* exposure.

2. Materials and Methods

2.1. Study Area

The Oso Creek area of southern Corpus Christi (27° 39′ 06″ N, 97° 24′ 25″ W, 7 m elevation), Nueces County, Texas, USA, was selected as the study site to demonstrate the potential risk of *B. procyonis* exposure. The area is newly developed (<25 years old), typical US suburbia with an average of ~350 households/km^2 [17] that maintain landscaped yards (i.e., live oak (*Quercus virginiana*) and honey mesquite (*Prosopis glandulosa*) are common trees), a known raccoon density of 2.1 ± 0.5 raccoons/ha [15], and an average of 3.7 people/household [18].

2.2. Experimental Design

An informational flyer about *B. procyonis* was placed on the front doors of approximately 600 houses of the Oso Creek area. The flyer contained information about the parasite, how it is transmitted, potential risks to humans, and how to reduce one's risk of exposure [19]. The flyer also described the current experiment and asked residents if they were willing to participate in the study, and if selected, they would have the soil of their property tested for *B. procyonis* eggs. I received 463 (77%) of the property owners willing to participate in this study, of which 334 owners (72%) stated that they had observed raccoons on their property and/or had raccoons defecate on their property. From these 334 respondents, I randomly selected 100 properties (30%) from which to collect soil samples.

Soil samples were collected from May–July 2021. I first spoke with each property owner to learn where raccoons had been observed on their property. I collected a soil column with a 2.7 cm diameter AMS soil probe (Forestry Suppliers, Jackson, Mississippi) from each location identified by the property owner where a raccoon or its feces was observed. I also would collect a random soil sample from the property by locating the southwestern most corner of the house and walk 20 m due south, and use this location as a starting point. I then would use a random number generator to select one of the eight cardinal directions with 1 = south, 2 = southeast, 3 = east, and proceed in a clockwise fashion until 8 = southwest. Once the direction was selected, I again selected a random number from 1-10, walked the randomly selected number of meters, and I collected a soil column at that point as previously described. Each soil sample was placed in an individualized plastic bag, which was labeled for property, date, and soil location within the property.

At the laboratory, soil samples and bags were washed using a centrifugal sedimentation-floatation method [20]. Briefly, soil was treated with a 20% bleach solution to remove the outer protein coat of any eggs, making them non-adherent [20]. Eggs, if present, from each soil sample were concentrated by centrifugation and counted with a Beckman Coulter cell counter (Z series, Beckman

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Coulter, Indianapolis, Indiana). *Baylisascaris procyonis* were identified in lactophenol wet mounts using nematode features according to Sprent [21] and Bowman [22]. A sample of eggs were placed on a hemocytometer and 100 *B. procyonis* eggs were counted to determine motility of larvae in eggs, using motility as a proxy for viability [23]. Soil samples that contained at least one viable, verifiable *B. procyonis* egg were considered a positive sample.

2.3. Statistical Analysis

I used chi square goodness of fit analysis to determine if the frequencies of prevalence of *B. procyonis*-contaminated soil samples differed between randomly selected and owner-identified locations and if the frequency of positive *B. procyonis* locations differed between the identified locations by the property owners. All tests were considered significant at $P < 0.05$. All means are reported ± 1 standard error.

3. Results

I collected 100 random soil samples and an additional 141 soil samples from locations identified by the property owner as locations where raccoons or their scats were observed. Thirty-four (14.1%) of the soil samples were positive for containing *B. procyonis* eggs, which were found on 27 (27% of properties sampled) residential properties. Of the positive *B. procyonis* soil samples, 12 (35.3%) were from randomly collected soil samples and 22 (64.7%) were from locations that the property owner identified as previous raccoon-observed sites. Positive soil samples, on average, contained 31,287 ± 6,943 *B. procyonis* eggs, of which, on average, 92% (92.1 ± 2.3; $\bar{x}$ ± SE) of the *B. procyonis* eggs had motile larvae.

One property had 3 locations within it that were positive for *B. procyonis* eggs; 1 randomly selected location and 2 locations identified by the property owner. Six properties had 2 locations identified by the property owner that were *B. procyonis* positive, and 10 properties had 1 *B. procyonis* positive location, which was identified by the property owner. Eleven other properties were positive for *B. procyonis* eggs at their randomly selected soil location.

Besides random locations within their yard, property owners identified woodpiles, tree bases, near porches, and the perimeter base of buildings (e.g., sheds, garages) as locations where raccoons were observed on their properties. However, the frequency of positive and negative *B. procyonis*-contaminated soil samples between randomly selected and owner-identified locations within the 100 sampled properties did not differ ($\chi^2 = 0.62$, df = 1, $P = 0.43$). In addition, the frequency of positive *B. procyonis* locations did not differ ($\chi^2 = 6.29$, df = 4, $P = 0.18$) between the identified locations by the property owners.

4. Discussion

This study demonstrates that people who live commensally with *B. procyonis*-infected raccoons have potential exposure to *B. procyonis* eggs; and thus, have a significant risk to this potentially devastating parasite. Those exposed are unaware of their exposure until their health has deteriorated via NLM or OLM and have experienced central nervous system impairment, seizures, blindness, or cognitive impairment [10].

Once considered a health threat specific to the midwestern United States (i.e., Indiana, Michigan, Illinois, Ohio), *B. procyonis* in raccoons now have been documented throughout nearly the entire 48 contiguous states [10], throughout most of Europe (i.e., Spain, France, Poland, Germany, Belgium, Netherlands, England, Norway, Sweden, Italy [24,25]), and into Asia (i.e., Russia, Japan, and China; [26–28]). Thus, baylisascariasis should be considered a global problem.

The issue is exacerbated by the fact that one *B. procyonis*-infected raccoon scat can contain >500,000 *B. procyonis* eggs, which upon decay, by desiccation or precipitation, can contaminate a 1-m^2 area [15]. In addition, a single *B. procyonis*-infected raccoon can contaminate 0.03 ± 0.1 ha/yr with *B. procyonis* eggs [15], of which 60% of those eggs remain on the soil surface and remain viable for at

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least 2 years [16]. Thus, if exposed to such a highly contaminated area, a human could potentially acquire more than a sufficient dose of *B. procyonis* eggs to develop central nervous system (CNS) disorders. Tiner [29] noted that only 5-7% of *B. procyon*is larvae that were ingested need to enter the brain to result in clinical disease.

The above scenario only considers the risk created by raccoons. However, striped skunks, which potentially carry *B. columnaris*, also are commensal with humans, and have potential to contaminate the environment. Unfortunately, little has been documented concerning this parasite as a potential health risk to humans [30].

It is worthy to note that nearly 100% of the property owners, who received my flyer concerning this study and the potential health risks of *B. procyonis*, had never heard of the parasite or knew a health risk existed. The general public, and potentially physicians, are unaware of the inherent dangers of this zoonotic parasite [31]. Greater public education efforts, especially in areas with high raccoon densities, are warranted.

To date, treatment for patients with CNS disorders caused by baylisascariasis is the larvicidal drug, albendazole, in combination with steroids to reduce inflammation [1]. Early treatment, if possible, is best to kill migrating larvae and thus, limit further damage. However, in most reported cases, treatment was ineffective and CNS disease progressed [10].

The best method to combat baylisascariasis is to take precautions to reduce exposure to *B. procyonis* eggs. First and foremost, raccoons are not pets. They are wild animals and should remain as such. Numerous adult humans who were diagnosed with OLM or subacute neuroetinitis admitted to having a pet raccoon [10]. Secondly, eliminate enticements that attract raccoons to your property. Enticements are, but not limited to, self-pet feeders, pet doors, brush piles, and fallen fruit from trees. Although self-pet feeders are convenient, they provide an easy source of food to raccoons as well. Also, pet doors allow family pets to freely choose to be indoors or outdoors, but such devices are quickly learned by raccoons as to how to maneuver. As fruit ripen on trees, often the fruit will fall to the ground. However, such a food source could easily be exploited by multiple raccoons. It is prudent to discard fallen and unwanted fruit from your property.

When playing and working outdoors, it is pragmatic to wear shoes and gloves. Vigilantly watch toddlers, who have a propensity to place items in their mouth, and discourage such behavior while they play outdoors. If being barefoot is a necessity for outdoor enjoyment, thoroughly wash hands and feet when returning indoors, and especially before eating. If children have sandboxes in which to play and dig, invest in a tight cover to keep animals from using the sandbox as a litter box.

Trim tree branches away from your house and secure any open or damaged areas of your home. Raccoons can find even small openings as access points to enter attics, basements, etc.

If you have a home-grown garden for vegetables and fruits, always wear gloves when digging in the soil, and thoroughly wash hands after the work is completed. Also, thoroughly wash your produce before consuming it.

If you are aware of a raccoon latrine site, extreme heat (>62^{o}C) is the best method to kill *B. procyonis* eggs [23]. Direct flame from a hand-held propane torch has been demonstrated as effective to kill *B. procyonis* eggs [32]. Flame the scat until ash and flame the soil for >30 seconds, sift the soil with a rake, and then flame again for another 30 seconds to increase the likelihood of killing the eggs [32]. However, check local laws and city ordinances regarding the use of fire devices within neighborhoods prior to use.

It may be impossible to eliminate 100% of the potential risk, but with diligence, the risk of exposure to this zoonotic parasite can be reduced. Effort to inform local health care professionals, public health officials, veterinarians, and the general public about the human health and safety risks associated with *Baylisascaris* spp. should be made.

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Conflicts of Interest: The author declares no conflict of interest.

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