The Geographic Expansion of *Baylisascaris procyonis* and the Need for Increased Surveillance and Education

KAONA AYRES,
MS in Biology Candidate

Abstract

Baylisascaris procyonis is an emerging zoonotic parasite in the sense that is a known pathogen appearing in new geographic regions. In the United States, this parasite was traditionally found in the Midwest and west coast, but has been spreading rapidly throughout the south and Southeast over the last decade **(1).** *Baylisascaris procyonis* is also known as raccoon roundworm because racoons (*Procyon lotor*) are the definitive host. It infects a wide range of other vertebrates including small birds, mammals, and occasionally humans. In these organisms, infection can cause a host of complications, including fatal neural larval migrans (NLM) (**2**). As this parasite continues to spread throughout the United States, and as modern environmental and urban changes bring humans and wildlife closer together, it is important to increase surveillance and education for *Basylisascaris procyonis* in areas most affected. Wildlife centers are useful resources for testing for the presence of *Baylisascaris procyonis*, as well as initiating deworming efforts. As a side project, I paired with three wildlife centers in the state of Virginia in an attempt to better understand the prevalence of this parasite throughout the state. Additionally, I propose methods for reducing the spread of *Baylisascaris procyonis* and educating the public through means such as zoos and the health system.

Background

Raccoon roundworm (*Baylisascaris procyonis*) is a nematode parasite highly prevalent in racoons throughout the United States and various parts of the world where they were introduced. Briefly, the life cycle includes:

- Raccoons, *Procyon lotor*: the definitive hosts where larvae mature and produce eggs,
- external environment, where eggs must first embryonate before they become infective,
- paratenic hosts, who ingest the eggs which develop into migratory larvae.

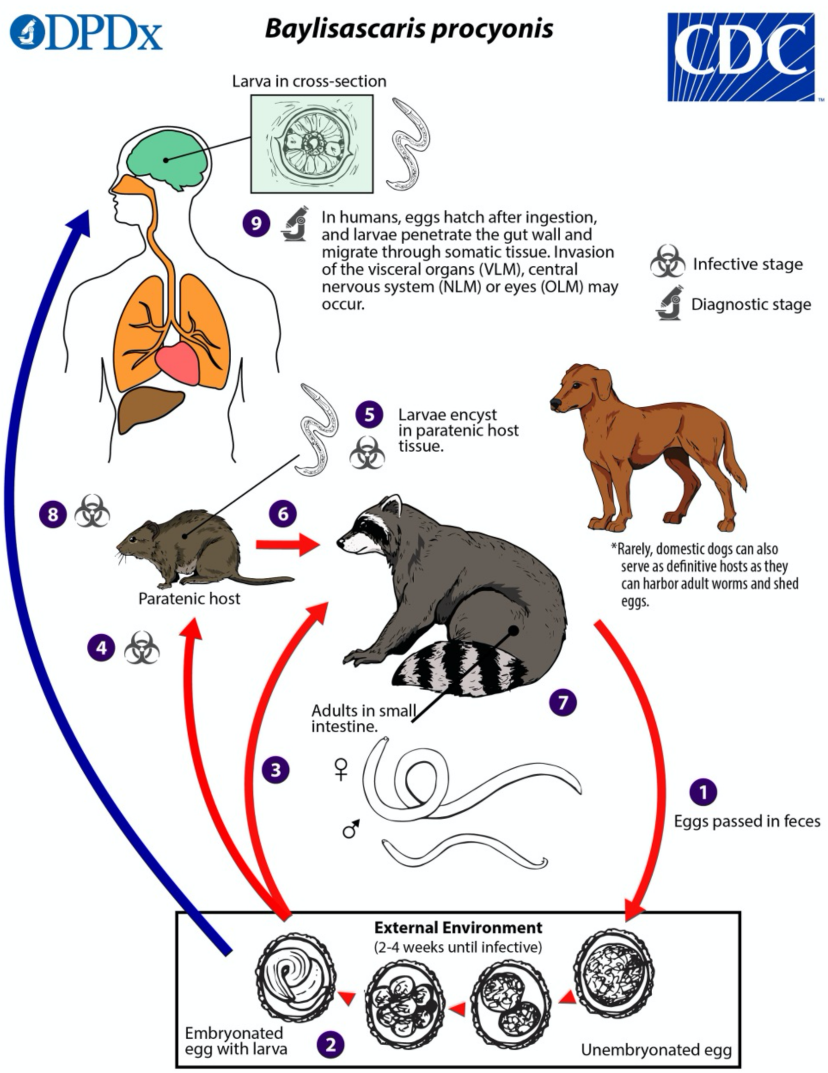

Figure 1. Life cycle of Baylisascaris procyonis (**3**)

Raccoons first acquire the parasite either through ingesting embryonated eggs directly from the environment or by preying on infected paratenic hosts such as small forest dwelling mammals. The worms then mature in the raccoon small intestine and produce thousands of eggs that pass into the environment via feces. Once expelled, the eggs take up to 30 days to fully embryonate to an infective stage (**3**). Paratenic hosts, such as small rodents that root through raccoon feces for seeds, may ingest these infectious eggs. The larvae then burrow through the intestinal wall and depending where they insist, can cause visceral, ocular or neural larval migrans. The cycle continues when raccoons consume these infected hosts, especially if they develop debilitating clinical signs that encourage predation. Unfortunately for humans, dogs can be an alternative definitive host for this parasite (**4**). *B. procyonis* eggs are equipped to develop into mature worms in dog small intestines. Once established, they are able to produce large numbers of eggs which will be shed in very close human proximity. Humans can become an accidental host by ingesting eggs from food or objects contaminated by infected racoon or dog feces.

Due to this parasite's rapid spread throughout the United States and its increasing proximity to humans, it is important to increase surveillance and public awareness in order to decrease human exposure. This is especially true for rural and suburban settings in areas of high prevalence, but also into cities as the raccoon becomes increasingly peridomestic. Thankfully, studies have shown that urban raccoons, due to their shift in diet from paratenic hosts to garbage, bird feeders and pet food, are less likely to harbor the parasite so close to dense human populations **(5**).

B. procyonis is well established in Virginia, yet it's prevalence here is not definitively known since it is not a reportable disease. I chose to investigate regional prevalence of *B. procyonis* in Virginia by testing raccoon fecal samples from patients admitted to three wildlife centers around the state. Additionally, this is useful for assessing the effectiveness of wildlife centers as partners in surveillance. Wildlife centers take in hundreds of raccoons from all over the state year round. Therefore they have the untapped potential to act as sampling stations to get a better idea of where *B. procyonis* is most common, and where it is spreading.

To investigate how widespread *B. procyonis* is in Virginia, I paired with three centers: The Wildlife Center of Virginia in Waynesboro, Rockfish Wildlife Sanctuary near Lovingston, and Blueridge Wildlife Center in Boyce. Rehab and vet staff collected fecal samples from each raccoon patient upon admission and logged the date, county from which the patient was found, and its age (juv/adult), before freezing the samples. Collection ran from late fall of 2020 to early spring 2021. A total of 18 samples were collected representing 11 different counties.

Table 1: Demographics of racoon fecal samples collected around Virginia

N =18
Age Juv 4, Adult 14

County	Frequency
Albemarle	3
Allegheny	1
Alexandria	1
Augusta	1
Clarke	1
Fauquier	1
Fredrick	1
Loudon	3
Prince William	2
Rockingham	1
Waynesboro	1

Methods

In order to analyze these samples, I performed standard fecal floats. Because I have no official training in this procedure, nor access to any basic fecal kits, I took to the internet to study various protocols and methods in order to compose my own. During the procedure, special care was taken to avoid contamination of the lab since eggs could have survived the months of freezer storage at the wildlife centers.

To perform the fecal floats, I prepared a magnesium sulfate (Epson salt) solution with a specific gravity of 1.26. This is dense enough to float even the heaviest helminth eggs, which can have a specific gravity of up to 1.24 (**6**). Approximately 2 grams of each fecal sample was placed in into individual 120 ml urine specimen collection containers and mixed with 60 ml of floatation solution. After thorough mixing, the debris was strained away with a standard tea strainer. Next, a portion of the liquid from each sample was poured into a 15ml centrifuge tube until a slight, convex meniscus topped the tube. Immediately after, microscope coverslip slides were placed on the top of the meniscus of each tube for 15 minutes. This allows adequate time for the eggs to float upwards through the dense solution and be caught by the coverslips. Once the time was up, the coverslips were removed from the tubes and placed on slides to be analyzed for the presence of helminth eggs under a microscope. *B. procyonis* eggs were identified by size and morphology.

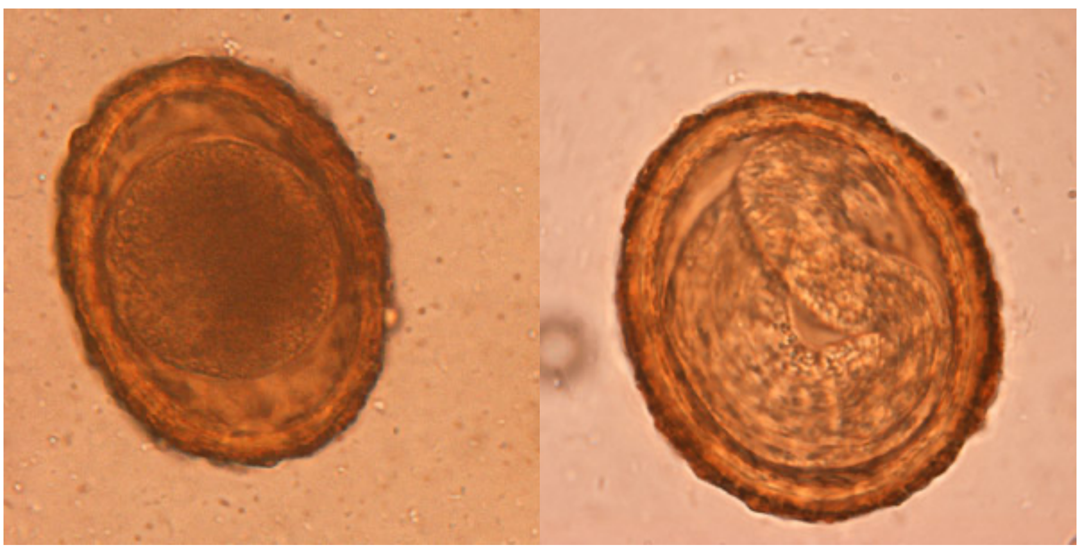

Figure 2. Microscope images of unembryonated and embryonated *Baylisascaris procyonis* eggs, respectively (**3**).

Results

Only two of the eighteen samples (11%) were found to be positive for *B. procyonis* eggs. In both cases the eggs were unembryonated (appearing as the image on the left above) and therefore un-infectious. The two positives were from adults of Loudon and Frederick counties. Several studies have found juvenile raccoons to be more commonly infected than adults, which was not the case in this analysis (**7**,**8**). It may be important to note that the two positive cases were both euthanized due to obvious clinical signs of distemper, for which there is no treatment.

Discussion

Loudon county is at the very northern tip of Virginia, bordering West Virginia, Maryland and DC. It is likely that the parasite is in the surrounding counties of all three states, and possibly in the capital city. More intense sampling of the urban and suburban regions of northern Virginia is necessary. Fredrick county is also located at the northern most portion of the state but to the west, bordering West Virginia which is known to be positive for the parasite. Because surveillance is currently so limited, it is impossible to tell where the parasite came from; but with increased efforts, we *can* monitor where it is going.

These three wildlife centers were able to passively sample raccoons from approximately 1/9 of the counties in Virginia in just 5 months. With more time, it is plausible that samples from these centers could have covered an even wider range of Virginia. There are at least 8 other wildlife centers/rehabilitation facilities around the state spanning from the coastal plains to the Appalachian plateau. If a surveillance system were put in place to collect samples from every raccoon patient that came in, it would not be difficult to gather information on the prevalence of *B. procyonis* in each county of Virginia and to monitor its spread. Wildlife centers are an underutilized resource for surveying many wildlife parasites.

Some, but not all wildlife centers test their raccoon patients for parasites upon intake, and some even go so far as to deworm them. The Blue Ridge Wildlife Center in particular, from where received the majority of my samples, has fecal float and deworming protocols put in place for their long term/releasable raccoon patients. According to their Director of Veterinary Services, Dr. Jennifer Riley, this is due to an incident several years ago where the outdoor pre-release caging became contaminated with *B. procyonis* eggs. Because of that, racoons moved there to prepare for release could become infected and carry the parasite to their release site. The center had to deconstruct the entire pre-release caging and thoroughly disinfect it with fire to (via flamethrower) it to kill all eggs. Now, in order to prevent this scenario from occurring again, the center standardly deworms all releasable adult racoon patients on intake.

This is not a bad idea for all wildlife centers overall. If initiatives are put in place to establish this protocol across Virginia, it could aid in decreasing *B. procyonis* prevalence in the wild once these patients are released. This would also create a safer setting for both human staff and other wildlife at the center. There have been instances in the past of raccoons infecting other captive animals; for example, in Japan there was an outbreak of fatal NLM in rabbits housed next to infected raccoons at a zoo (**9**). On a human health level, a 2016 testing study of 347 asymptomatic wildlife rehabbers showed 24 of them to test positive for *B. procyonis* antibodies, suggesting exposure or possible subclinical infection from muscle or visceral migration (**10**). Deworming all raccoon patients that are not destined to be euthanized could reduce the risk of both human and animal infections at wildlife centers.

Additionally, there have been initiatives throughout the US to evaluate the efficiency of mass deworming platforms for free ranging wild raccoons through the use of anthelminthic baits, similar to the oral rabies vaccine baits that have been used in Virginia since 2002 (**11**). This requires the inexpensive creation of medicated baits, typically made with standard fishmeal and filled with about 200 mg of pyrantel pamoate, a common dewormer used for dogs. These requires minimal labor to be distributed monthly, but does require prior knowledge/surveying of the wild raccoon population dynamics, as the amount and location of bait placement depends on the specific targeted racoon population. In locations ranging from the Chicago suburbs to rural agricultural lands, this tactic has proven to be effective in deworming wild racoons, reducing parasite egg load found in latrines, and reducing infections of paratenic hosts (**12, 13, 14**). This is good news for some species especially hard hit by the spread of raccoon roundworm, such as the Allegheny wood rat. This species has faced severe population declines in the Blueridge Mountains due to high infection rates by the parasite **(15).**

While deworming efforts, both in wildlife centers and the wild, are one way to reduce the risk of human infection, another important and necessary step is educating the public. Children are most commonly infected and most at risk, primarily due to their curiosity to explore and tendency to put unclean hands and nonfood items into their mouth. Most children infected in the past also had an eating disorder known as pica (ingestion of dirt, clay, other inedible materials), which is now considered another risk factor (**16**). For this reason, it is of utmost importance to educate parents, especially in areas of high raccoon and *B. procyonis* prevalence. This could be done through simple "Did you know…" posters/brochures available in pediatrician offices or even occasional PSA's from schools to parents. Another way to increase education for the public is through zoos. For example, at exhibits that house animals of the Procyonidae family such as the kinkajou or ring tailed cat, or even raccoons themselves, there can be informational material informing the public of the *Baylisascaris procyonis* parasite, likely right in their backyard. This is not meant to be alarmist in any way (*B. procyonis* infections are currently fairly rare) but to be informative and therefore preventative.

Conclusion

Baylisascaris procyonis is a highly pathogenic, emerging infectious parasite spreading throughout the southeastern United States, with increasing proximity to humans and limited data on its prevalence. My overall goal was to better understand the condition of this parasite in Virginia, and to propose ways to tackle its spread and reduce the risk of human infection.

While my study contained a sample size too small to draw any definitive conclusions on the current state of *B. procyonis* in Virginia, it did demonstrate that Wildlife Centers can be useful allies in surveillance. Requiring wildlife centers in the state to test each racoon patient for the parasite and to log cases on a common database would dramatically increase our understanding of *B. procyonis* incidence. This in turn would improve our knowledge on where the parasite is highly concentrated and where it may be spreading, which is helpful for deworming campaigns.

I also propose that wildlife centers deworm their raccoon patients on intake if they plan to attempt rehabilitation and release. This will reduce risk to other patients and human staff, and potentially reduce the transmission of the parasite once the patient is released. Additionally, since *B. procyonis* eggs are difficult to kill (they require the use of fire/flamethrowers), deworming on intake would prevent contamination and time consuming disinfection of shared enclosures. On an even larger scale, statewide deworming campaigns of wild, free-ranging raccoons through medicated baits would also go a long way in decreasing Baylis prevalence in the wild.

Finally, as *B. procyonis* spreads and risk of human infection increases, I propose increased education campaigns for the public. This can be done by schools, doctors, zoos, or even PSA's by the CDC in highly infected areas. The human/animal interface is increasing exponentially, and with that comes infectious diseases of wildlife, sometimes right into our backyards. It is important that we stay informed of the risks these diseases present, where they are located, and how to combat them.

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