

ABSTRACT

LOUIS, MEGHAN ELIZABETH. *Baylisascaris procyonis*, a Zoonotic Threat Requiring an Integrated One Health Approach. (Under the direction of Dr. Suzanne Kennedy-Stoskopf).

Baylisascaris procyonis is a zoonotic roundworm that can be commonly found in raccoons (*Procyon lotor*). It does not typically cause disease in raccoons; however, it can cause severe clinical disease and death in humans and many species of birds and mammals. The pathogenicity of *B. procyonis* is dependent on several factors pertaining to the host, the agent, and the environment. Using a One Health approach, we studied the prevalence of *B. procyonis* through surveying raccoon latrines at the North Carolina Zoo, a large, natural habitat zoological institution with an abundant wild raccoon population. No fecal samples positive for *B. procyonis* were found in this study. The results of the prevalence survey show the value of field sampling to properly assess zoonotic disease risk and enable informed decision-making regarding public health and wildlife management. These zoonotic disease risk assessments and informed decisions are usually made by wildlife, human health, and/or veterinary professionals. Ascertaining disease risk perceptions and knowledge of professionals regarding wildlife and their associated diseases improves awareness. We surveyed wildlife, human health, and veterinary professionals in North Carolina to determine their knowledge and risk perceptions regarding raccoons and their associated zoonotic diseases, emphasizing *B. procyonis*. Overall, veterinarians scored the highest on knowledge-based questions and demonstrated the highest level of disease risk perception, however, gaps in knowledge were identified across each profession. As a result, our questionnaire survey identified the need for an integrative One Health approach for targeted communication and health risk management regarding raccoons and their associated zoonotic diseases.

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Baylisascaris procyonis, a Zoonotic Threat Requiring an Integrated One Health Approach

by
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DEDICATION

For my sons – “If one advances confidently in the direction of his dreams, and endeavors to live the life which he has imagined, he will meet with a success unexpected in common hours,”- Henry David Thoreau. For my husband, Gavin – your love, dedication, and support has enabled the pursuit of my dreams.

BIOGRAPHY

Meghan Elizabeth Mayer Louis received her Bachelor of Science degree in biology with a minor in both zoology and sociology from The Ohio State University in 2003. She received her Doctorate of Veterinary Medicine from Ross University in 2008 after completion of her clinical year at The Ohio State University. She practiced clinical medicine for 5 years at a very productive mixed animal practice in Ashland, Ohio prior to joining the United States Army in 2013. She completed the First Year Graduate Veterinary Externship Program at Joint Base Lewis-McChord in 2014 and then became the Officer in Charge of Spangdahlem Treatment Facility in Spangdahlem, Germany. MAJ Louis embarked on this journey of obtaining her Master's of Science in Fisheries, Wildlife, and Conservation Biology from North Carolina State University while concurrently completing a Zoological Medicine Residency, Graduate Certificate in Military Land Sustainability, and Veterinary Preventive Medicine Board Certification to fulfill her life-long dream of becoming a specialized wildlife veterinarian knowledgeable about public health and clinical medicine, practicing at the human wildlife interface.

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TABLE OF CONTENTS

LIST OF TABLES	vii
LIST OF FIGURES	viii
Chapter 1: Introduction and Literature Review.....	1
Introduction.....	1
Literature Review.....	2
Human Health Concerns	6
One Health Review	7
One Health Application in North Carolina	9
References.....	10
Chapter 2: Raccoon Roundworm Prevalence (Baylisascaris procyonis at the North Carolina Zoo, USA.....	15
Abstract.....	15
Introduction.....	16
Materials and Methods.....	17
Results.....	18
Discussion	19
Conclusions.....	22
References.....	23
Chapter 3: Survey Assessment of Risk Perceptions and Knowledge of Raccoons (Procyon lotor) and Associated Zoonotic Diseases Amongst Professionals in North Carolina.....	31
Abstract.....	31
Introduction.....	32
Materials and Methods.....	33
Data Analysis	34

Results.....	34
Discussion.....	35
References.....	41
Conclusions and Future Directions.....	49
Appendices.....	50
Appendix A: Chapter 2: Latrine Data.....	51
Appendix B: Chapter 3: Survey.....	55

LIST OF TABLES

Table 3.1	Demographic characteristics of participants in a survey assessing knowledge and risk perception regarding raccoons and their associated zoonotic diseases	45
Table 3.2	Knowledge questions and percentage of correct answers regarding raccoons and associated zoonotic disease from wildlife, human health, and veterinary professionals. Correct answer is in parentheses. DK- Don't know	46

LIST OF FIGURES

Figure 1.1	Lifecycle of <i>Baylisascaris procyonis</i> (Gavin et al., 2005).....	3
Figure 1.2	Human-Animal-Environmental Dynamics (Kazacos, 2010)	6
Figure 2.1	A map of the North Carolina Zoo displaying raccoon latrines found in October and November of 2018 (n = 33) and 2019 (n = 8). The zoo proper is divided into 6 regions with region 2, 3, 5, and 6 being more developed	28
Figure 2.2	A raccoon latrine on the man-made cement wall in region 5 at the perimeter of a mixed-species exhibit of zebra (<i>Equus quagga</i>), ostrich (<i>Struthio camelus</i>), and giraffe (<i>Giraffa camelopardalis</i>) at the North Carolina Zoo in the fall of 2018. The white oval is identifying a raccoon latrine on the perimeter wall of the exhibit, which demonstrates the potential exposure of both zoo personnel and exhibit animals.....	29
Figure 2.3	A raccoon latrine found in the crux of a man-made termite mound located on a large mixed-species African habitat in region 6 at the North Carolina Zoo in the fall of 2018 and 2019. (A) An overview of the man-made termite mound. (B) Displays a zoomed-in view with a white oval identifying the raccoon latrine. This man-made mound has similar features as a preferred natural substrate of a tree crux.....	30
Figure 3.1	Risk perception questions and answers regarding raccoons and associated zoonotic disease from wildlife, human health, and veterinary professionals. *Questions adapted from (Hanisch-Kirkbride et al. 2013)	47
Figure 3.2	A word cloud including all responses to the survey question asking respondents to record the one word that comes to mind with the mention of “raccoon”.....	48

CHAPTER 1. Introduction and Literature Review

Introduction

Baylisascaris procyonis is a zoonotic parasite that is commonly found in raccoons (*Procyon lotor*). The intestinal roundworm does not usually cause clinical disease in raccoons but can be fatal to humans and many other aberrant host species. Clinical disease has been seen in over 150 species of mammals and birds in North America and elsewhere (Kazacos, 2016).

Raccoons are charismatic mesocarnivores that have adapted well into urban living. They exhibit interesting behavior including that they defecate in communal locations called latrines. Raccoons select for these latrine sites to be on elevated horizontal surfaces with common locations being decks, attics, rooftops, and barn rafters. *B. procyonis* is shed in the feces of raccoons where it can stay in the environment for years. This persistence is mainly due to the ova being very resistant to environmental conditions. Ingestion of the ova is the primary mode of transmission to hosts. The parasite migrates abnormally if ingested by species other than the raccoon and can cause significant disease.

Baylisascaris procyonis is an important One Health topic and public health concern. Infection with *B. procyonis* has health implications for a wide variety of free-ranging and captive wildlife, zoo animals, domestic animals, as well as human beings, on both an individual and population level (Page, 2013). Increased urbanization of the environment together with an intelligent, adaptive mesocarnivore has increased the human-wildlife overlap and potential for disease spread. The raccoon's propensity to choose latrine sites that are often on structures near and around homes likely increases the potential of interaction and transmission of *B. procyonis*. The fecal-oral transmission route is particularly dangerous to young children who explore their world through touch and taste. The resistance of the ova to environmental conditions increases

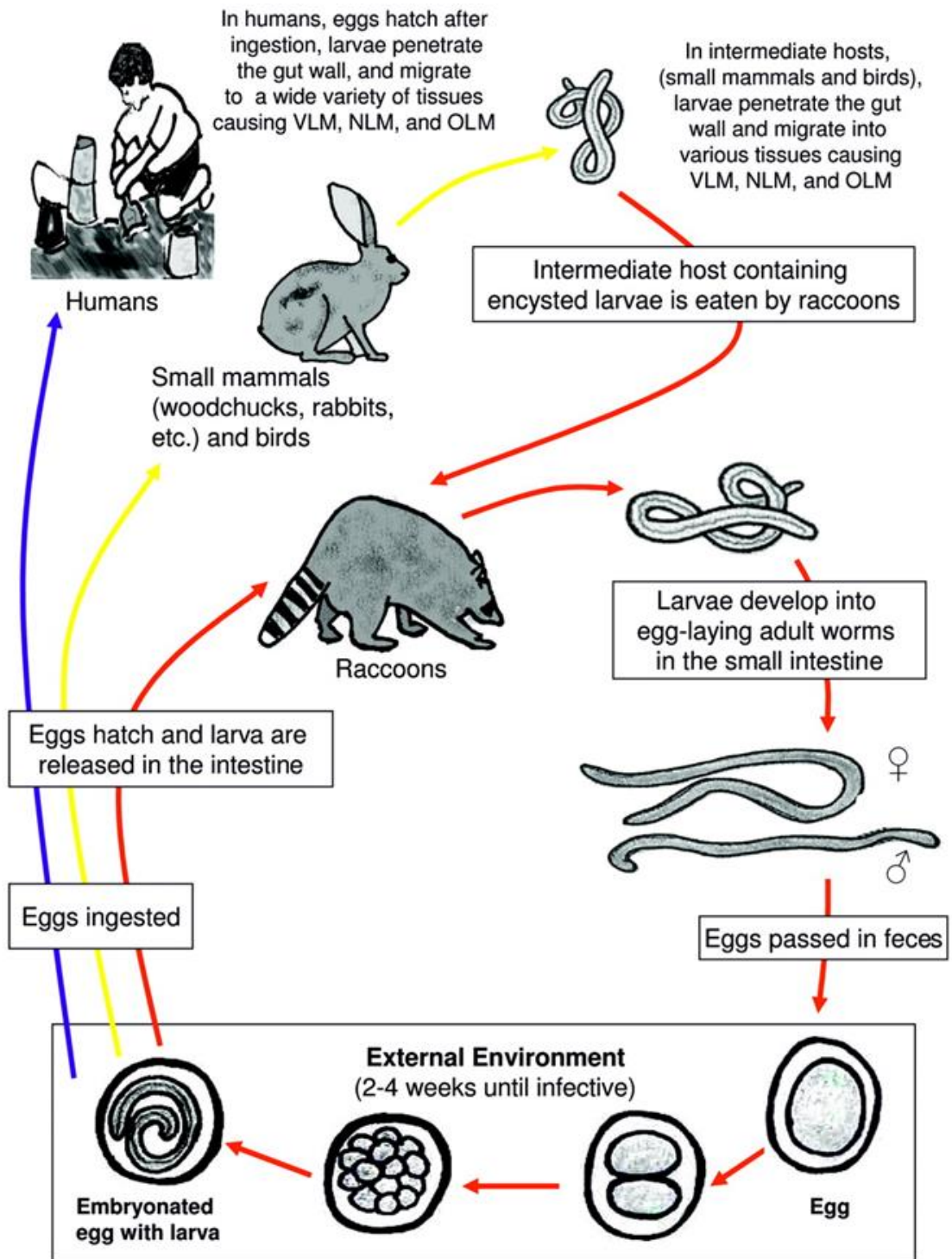
the risk of exposure because of the prolonged period that infectious ova remain in the environment. The life-cycle of *B. procyonis* in the raccoon allows for prolific intermittent shedding that proves problematic in detection and potential management of the parasite.

Key issues that need to be addressed revolve around ascertaining the prevalence of *B. procyonis* globally because outbreaks are often “pocketed” or highly localized. Educational gaps regarding *B. procyonis* need to be identified and filled, especially as it pertains to populations at risk. A One Health approach combining education, research, environmental decontamination, and host mitigation strategies is therefore, considered necessary to address the zoonotic threat of *B. procyonis*.

Literature Review

Baylisascaris procyonis are large roundworms in the nematode Order Ascaridida (Kazacos, 2001). The definitive host of *B. procyonis* is the raccoon, originally native to the Americas. The lifecycle of *B. procyonis* uses paratenic hosts as well that are usually rodents. The parasitic larvae migrate aberrantly and modify the host’s behavior, which is likely evolutionarily purposeful to increase probability of the host being captured and ingested by a carnivore. Juvenile raccoons are more often infected by ingesting ova, whereas adults are more likely infected by the third-stage larva through a paratenic host (Kazacos, 2001; Tiner, 1953). The roundworm establishes itself in the raccoon small intestine, matures, and prolifically produces ova. It has been estimated that this species’ female worm can produce 115,000–179,000 eggs/day (Snyder & Fitzgerald, 1987). Raccoons can tolerate a high worm burden, which amplifies this amount to potentially millions of eggs shed daily (Snyder & Fitzgerald, 1987).

Figure 1.1: Lifecycle of *Baylisascaris procyonis* (Gavin et al., 2005)



Raccoons are a furbearing species with an attractive coat. For this reason, they are commonly trapped and hunted. Legal and illegal displacement of raccoons from one region to

another have occurred throughout the United States for the purpose of restocking hunting areas (Lotze & Anderson, 1979). Translocation has also occurred to Europe and Asia. The adaptability of the raccoon has allowed for their range extension, enabling them to infiltrate and inhabit urban environments.

The prevalence of *B. procyonis* varies geographically. *Baylisascaris procyonis* is indigenous to raccoons in North America, Europe and parts of Asia (Kazacos, 2001). The highest prevalences of *B. procyonis* are found in the Midwest, Northeast, and Mid-Atlantic states, and along coastal areas of Texas, California, Washington, and Oregon. (Kazacos, 2001; Blizzard, Yabsley et al., 2010). In 2016, Kazacos stated that the prevalence of *B. procyonis* in isolated “pockets” is well demonstrated along with variations in prevalence over time.

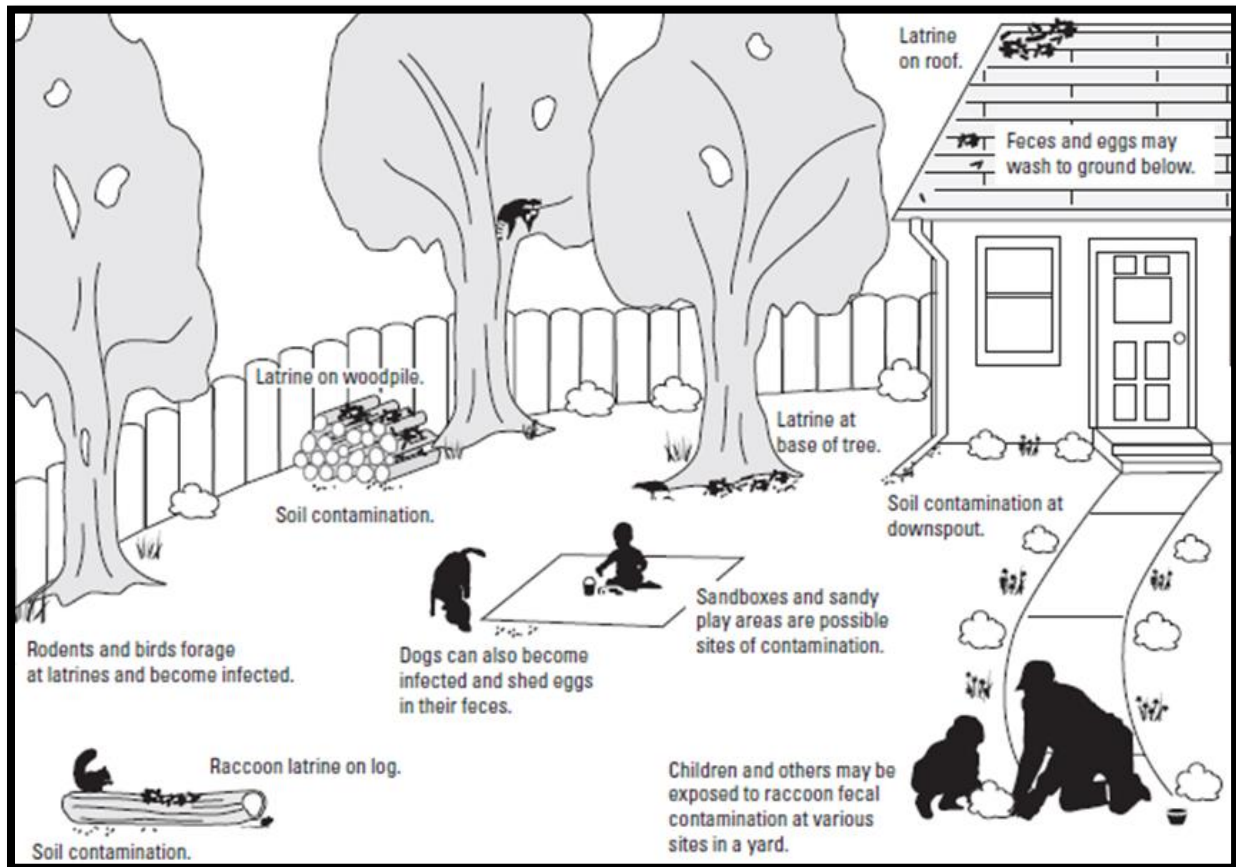
A review of the prevalence studies for *B. procyonis* in raccoons in the United States published prior to 2005 identified 10 studies conducted in West/Southwest region of the USA reporting a 49% aggregate prevalence in 229 raccoons studied (Wise et al., 2005). The review reported 33 studies conducted in the Midwest region with an aggregate of 58% infected of 3,967 total raccoons examined and seven studies were conducted in the Northeast and Mid-Atlantic regions of the USA, reporting an aggregate 64% of 476 infected (Wise et al., 2005). In the Southeast region, only 4% of 1868 raccoons examined in 28 studies were found positive for *B. procyonis* (Wise et al., 2005). More recent reports in the Southeastern region of the USA suggest that this parasite may either be spreading to new regions or has been present in unrecognized locales (Blizzard et al., 2010, Hernandez et al., 2013). Other studies in North and South America where raccoons are native species confirm the widespread distribution of the parasite. In the Greater Metropolitan Area of the Central Valley in Costa Rica, 10 of 20 wild raccoons that were reported as a nuisance were positive for *B. procyonis* (Baldi et al, 2016). Between 2013 and

2016, 1,539 raccoons were submitted to the Canadian Wildlife Health Cooperative and showed a 35% prevalence of *B. procyonis* (French et al. 2020). Recent work focused on the prevalence of serum antibodies to *B. procyonis* in humans suggests that subclinical infections occur in addition to the classically reported cases of larva migrans (Sapp, 2016, Weinstein, 2017).

Globally the disease has spread with the translocation of raccoons becoming an invasive species in Europe and Asia (Miyashita, 1993; Beltrán-Beck et al., 2012; Salgado, 2018). In Japan approximately 20,000 raccoons were imported from North America as exotic pets beginning in 1977 (Miyashita, 1993; Beltrán-Becket al., 2012). A *B. procyonis* prevalence study in 2003 in Japan reported that of 291 raccoons examined, eggs of *B. procyonis* were found in 39.9% of zoo-kept animals, 8.1% of animals stocked by traders, 7.7% of raccoon pets, and 0 of the 37 wild raccoons examined (Miyashita, 1993). In Denmark, the raccoon is an invasive species in the wild and a recent study found 2 of 18 (11%) wild raccoons were positive for *B. procyonis* (Al-Sabi et al., 2015). The same study documented lack of familiarity with the parasite among veterinarians and staff responsible for health management of the collections in 8 of the 9 zoos in Denmark (Al-Sabi et al., 2015). Other countries that have demonstrated the existence of *B. procyonis* in raccoon populations include Germany, Poland, and the Czech Republic (Kazacos, 2001).

Human Health Concerns

Figure 1.2: Human-Animal-Environmental Dynamics (Kazacos, 2010)



In humans and paratenic hosts, both pets and wildlife, clinical disease occurs due to the abnormal migration of *B. procyonis* out of the gastrointestinal tract. The three main clinical syndromes associated with infection are neural larva migrans (NLM), ocular larva migrans (OLM), and visceral larva migrans (VLM) (Graeff-Teixeira et al., 2016). Neural larva migrans has received the most attention since it can cause eosinophilic meningoencephalitis which usually results in death of the host. Ocular larva migrans can occur independently or in association with NLM. Symptoms of OLM range from transient visual obstruction to blindness (Wise et al., 2005). Visceral larva migrans is the least recognized in the human literature and

occurs when the parasite migrates through organs in the abdominal and thoracic cavities (Wise et al., 2005).

Risk of human infection with *B. procyonis* is present in areas where humans, especially children, come into direct or indirect contact with raccoon populations infected with *B. procyonis* (Wise et al., 2005). Reported human disease cases are rare. Since the clinical disease was first recognized in 1984, there have been at least 50 documented human cases in the United States and Canada (Hernandez et al., 2013; Kazacos, 2016). There is growing evidence that asymptomatic infections occur more frequently (Sapp, 2016; Weinstein, 2017).

One Health Review

Reviewing the literature, it is evident that a One Health approach to *B. procyonis* has value. It is common for authors crossing disciplines (human physicians, veterinarians, parasitologist, & epidemiologist) to work together as evidenced by the co-authorship on important papers. Both human and veterinary literature highlight the importance of prevention, surveillance, diagnosis and treatment of this parasite and disease. Prevention consists of educating One Health professionals as well as the general public, deworming pets, removing and decontaminating latrine sites, and raccoon management and mitigation strategies. Surveillance is accomplished by establishing *B. procyonis* prevalence in human populations, animals, and the environment. Diagnosis of *B. procyonis* in both humans and animals is based on a combination of clinical, laboratory, and pathologic findings (Kazacos, 2016). Treatment of both animals and humans has been unrewarding in the past, but recent success has been found in a few cases with early diagnosis and treatment with albendazole and corticosteroids (Peters et al., 2012; Martinez, 2015; Graeff-Teixeira et al., 2016).

The implementation of a One Health approach is driving innovation regarding surveillance and public health messaging. Four recent studies illustrate this. One such study was a cross-sectional serosurvey of wildlife rehabilitators (Sapp et al. 2016). A follow-up questionnaire was then performed to assess demographics, rehabilitation history, personal-protective equipment usage, and raccoon specific practices (Sapp, Murray, Hoover, Green, & Yabsley, 2018). That study found 24/347 or 7% of wildlife rehabilitators were seropositive for antibodies to *B. procyonis* with the risk factor of being in the western part of the United States where prevalence for *B. procyonis* in raccoons is high. The questionnaire also found that not washing hands after touching feces or a live raccoon was a risk factor (Sapp et al., 2018).

Another pair of notable studies using a One Health approach examined the domestic dog as a potential source for human disease. Dogs are susceptible by exposure to eggs or larvae in non-definitive (paratenic) hosts (Bowman et al., 2005; Miyashita, 1993). Prevalence of *Baylisascaris* in dogs from 2014-2016 was determined by examining feces by fecal floatation. *Baylisascaris spp.* eggs were detected in 504/9,487,672 (0.005%) canine fecal samples. The overall prevalence was low, but the study highlighted the wide geographical range of the parasite in the United States. It also confirmed that dogs can shed *Baylisascaris* ova into the domestic environment, perhaps increasing the risk of human exposure (Yabsley & Sapp, 2017). Other non-traditional procyonid pets like the South American coati (*Nasua nasua*), olingo (*Bassaricyon*), and kinkajou (*Potos flavus*) have shown susceptibility and the ability to carry a patent infection (CDC, 2011).

One Health principles were also used to examine the dynamics and survivability of *B. procyonis* in four different species of field mice while highlighting their geographical range. That work found that the white-footed mouse (*Peromyscus leucopus*) demonstrated tolerance to

severe infection with *B. procyonis* (Sapp et al., 2018). The white-footed mouse has previously been studied in regard to predicting patterns of infection from landscape habitat attributes documenting that habitat fragmentation resulting from anthropogenic land use alters the transmission dynamics of *B. procyonis* (Beasley et al. 2013).

One Health Application in North Carolina

Awareness and education are important aspects in preventing diseases of zoonotic concern. Several studies have elucidated a lack of general knowledge regarding the parasite, *Baylisascaris procyonis* (Al-Sabi et al., 2015; Ogdee et al. 2016; Sapp et al. 2018). *Baylisascaris procyonis* was recently reported in North Carolina along the western border with Tennessee (Hernandez, 2013), but prevalence throughout the state is relatively unknown. We aim to ascertain the prevalence of *B. procyonis* at the North Carolina Zoo, where there are likely daily interactions between humans, a variety of captive animals, native wildlife, and wild raccoons. We will then survey One Health professionals (wildlife, human health, and veterinary) in North Carolina to establish the general knowledge level regarding raccoons with a focus on *B. procyonis* while gaining insight into disease perceived risk by profession.

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CHAPTER 2. Raccoon roundworm prevalence (*Baylisascaris procyonis*) at the North Carolina Zoo, USA

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Abstract

Baylisascaris procyonis is an important zoonotic nematode of raccoons (*Procyon lotor*). Infection with this parasite has important health implications for humans, zoo animals, and free-ranging wildlife. As a large, natural habitat zoo, the North Carolina Zoo (NC Zoo) coexists with native wildlife. Raccoons are abundant at the NC Zoo and the prevalence of *B. procyonis* is unknown. Raccoon latrines were located throughout the zoo and sampled for *B. procyonis* in October and November of 2018 and 2019. Parasite prevalence, latrine location, substrate category and latrine persistence were recorded. Thirty-three latrines were located in 2018 and eight new latrines in 2019 while four latrines from the prior year were no longer available to be sampled. Of the 29 latrines sampled over the two years, 16 (55%) persisted for at least one year. The majority of the latrines were found on natural substrate with rock showing the highest preference. Just over half (n = 21 of 41 total) of the active latrines in the study were in or near animal enclosures. Two latrines were found in public areas including one contaminating children's play equipment. An additional five fresh fecal samples were collected from adult raccoons presented to the zoo's veterinary clinic over two years. All fecal samples tested for both years were negative for *B. procyonis*. The results of this study show the value of field sampling to properly assess risk and enable informed decision-making regarding public health and wildlife management.

Introduction

Baylisascaris procyonis is a zoonotic parasite that can be found in raccoons (*Procyon lotor*). Raccoons defecate in communal locations called latrines that can serve as important foci for *B. procyonis* transmission because the parasite ova are shed in feces and can persist in the environment for many years (Hirsch et al., 2014). The intestinal roundworm does not cause clinical disease in raccoons but can be fatal to humans and many other species. The disease has been well summarized in a recent major review that summarizes the clinical disease observed in over 150 species of mammals and birds (Kazacos, 2016). Neural, visceral, and ocular larva migrans are potential sequelae secondary to infection and aberrant migration of *B. procyonis* in paratenic hosts, including humans (Graeff-Teixeira et al., 2016).

Baylisascaris procyonis was first reported during the 1930s in raccoons in the New York Zoological Park (McClure, 1933; Kazacos, 2016). Zoological institutions have continued to be at the forefront of knowledge and discovery regarding *B. procyonis* (Kazacos et al. 1991; Campbell et al., 1997; Sexsmith et al., 2009; Zimmerman et al. 2019). The North Carolina Zoo (NC Zoo) is situated on 2,600 wooded acres in Randolph County, North Carolina, USA (<https://www.nczoo.org/visit/about-zoo>). Raccoons likely have found the zoo a hospitable location to thrive due to the abundant resources and lack of anthropogenic mortality.

Baylisascaris procyonis was historically thought to be absent from North Carolina and much of the southeastern United States. Helminth surveys from five southeastern states over a 32-year period did not identify *B. procyonis* in raccoons (Harkema & Miller, 1964; Miller, 1992). The parasite was detected for the first time in North Carolina in 2013 along the western border with Tennessee (Hernandez et al., 2013). Reports in the Southeastern region of the United States

suggest that this parasite is either spreading to new regions or has been present in unrecognized locales (Blizzard et al., 2010).

The objective of this study was to ascertain the prevalence of *B. procyonis* at the NC Zoo to assess the risk to collection animals, humans, and wildlife. The results of this study will guide future raccoon and latrine management decisions at the NC Zoo.

Materials and Methods

Latrines were located and sampled primarily within the 500 developed acres of the zoo, where raccoon-human-zoo species interactions were considered most likely. Employee reporting combined with systematic searching of zoo grounds and enclosures were used to identify latrines. Systematic searching was accomplished by walking line transects 300 meter long and 20 meter wide in regions void of enclosures and fence barriers. Within enclosures, specific habitat features were targeted. Raccoon latrines were sampled during the months of October and November of 2018. These latrines were revisited and sampled in October and November of 2019, as well as 8 additional latrines that were found.

Raccoon latrines were identified based on fecal characteristics and contents, and coordinates were recorded using a Global Position System application (Motion X GPSTM, Fullpower Technologies, Inc, Santa Cruz, CA, USA). Fecal piles less than 2 meters apart were considered from the same latrine. Latrines were categorized based on the underlying substrate. Natural environment categories included rock, ground, and wood (stumps and logs). The man-made environment was separated into cement (walls, flooring, and enclosure structures) and wooden structures (barn, roof, and decks).

The freshest one to three scats were collected from each latrine, placed individually in a sample container, and processed the same day. Individual scats were collected rather than

pooling samples to decrease bias regarding latrine size characteristics (Smyser et al., 2010). The freshest feces were collected to minimize the risk to personnel of larvated ova, the infectious stage of the parasite, which develop anywhere from two to four weeks post-defecation. Fresh feces were also collected from five adult raccoons found on zoo grounds that presented as ill at various times during 2018 and 2019.

Approximately 2 grams of feces from each fecal sample were mixed with Sheather's sugar (specific gravity of 1.27) solution (Jorgensen Laboratories, Loveland, CO 80538, USA), centrifuged and microscopically examined for the presence of *Baylisascaris* ova as per Dryden et al., (2005). Samples that were chosen with no particular pattern were submitted for confirmatory examination by a veterinary parasitologist at North Carolina State University College of Veterinary Medicine (NCSU-CVM). The presence of *B. procyonis* or lack thereof, was based on size and morphologic appearance of ova observed in the flotation mounts.

Results

Sixty-two individual fecal samples from 33 raccoon latrines were examined in 2018. All samples were negative for *B. procyonis*. Twenty-nine of the latrine sites were revisited in 2019 and 16 latrines (55%) were still active. Eight new latrines were identified. Forty-four individual fecal samples were collected from the 24 identified latrines in 2019 and all samples were negative for *B. procyonis*. Fecal samples representing 25 of the 41 total latrines (61%) that were examined at NCSU-CVM were also confirmed negative for the parasite ova. The five fresh fecal samples from raccoons that presented to the zoo veterinary hospital during the study period were negative for *B. procyonis*.

Of the 41 total latrines sampled between 2018 and 2019, 21 (51%) were in or around animal enclosures, while 20 (49%) were outside of animal areas (Figure 2.1). Two latrines (5%)

were present in public areas, whereas the rest of the latrines 39 (95%) were in locations only accessible to zoo personnel (including animal habitats).

Seventeen of the 41 (41%) latrines were located on man-made structures, whereas the remaining 24 (59%) were located on natural substrate. Of those 24, a further division into rock, ground, and wood accounted for 12, 7, and 5 latrines, respectively. Of 17 latrines on man-made structures, 6 were on cement and 11 on wooden structures.

Discussion

Baylisascaris procyonis was not detected in fecal samples from latrines at the NC Zoo. Raccoon latrine prevalence surveys are considered the best method for *B. procyonis* surveillance because they provide a direct assessment of the risk of transmission of *B. procyonis* to humans and animals (Page et al., 2005; Sexsmith et al., 2009; Smyser et al., 2010). There is a possibility of not detecting a very low prevalence, and this would be expected to be no more than 3% based on our sample size (Wobeser, 2007). The parasite has not been found previously on routine fecal examinations or necropsy of collection animals at the zoo, despite awareness that it is a potential problem. Based on our results, we believe that *B. procyonis* is not currently present at the NC Zoo.

Sampling of latrines occurred in the fall, when the highest prevalence of *B. procyonis* has been documented in raccoon feces (Kidder et al., 1989; Page et al., 2016). Fall coincides with juvenile raccoon dispersal and young raccoons are more likely to shed ova than adults during this period (Prange et al., 2003; Jardine et al., 2014; French et al., 2019). It has been estimated that a female worm can produce 115,000-179,000 eggs/day, with the potential to increase to millions eggs/day with increased worm burdens (Snyder & Fitzgerald, 1987). *Baylisascaris procyonis* eggs are hardy and have been shown to persist in the environment for years (Kazacos, 2016). Our

sampling occurred over two years to provide information on latrine persistence, which is important regarding aspects of environmental contamination. Approximately half of the latrines persisted through the study, although four of the 33 latrine sites could not be revisited during the second sampling period due to enclosure and habitat restrictions or improvements in fencing. While the results of our study indicated low/no *B. procyonis* prevalence, knowledge of latrine site persistence is important for future surveys and potential modeling.

Raccoon selection of latrine sites shows preference for elevated horizontal surfaces with common locations being on large rocks, logs, at the base and on large limbs of trees and in raised crotches (Yeager & Rennels, 1943; Stains, 1956; Cooney, 1989; Kazacos & Boyce, 1989; Page, Swihart & Kazacos, 1998). In the man-made environment, these horizontal surfaces equate to decks, attics, rooftops, and barn rafters (Kazacos & Boyce, 1989). The NC Zoo has a mixture of both natural habitat and man-made structures (Figure 2.2, 2.3) within individual enclosures and throughout the park. Most latrines were found on natural substrates and over half occurred on rock surfaces, which is a common feature of the NC Zoo due to limestone outcroppings.

Approximately half of the latrines were found in or around animal enclosures and habitats, often directly accessible to the collection animal. Considering that many fatal cases of *B. procyonis* larval infections have occurred in animals at zoological institutions, the risk to collection animals is important to assess (Armstrong et al., 1989; Kazacos et al., 1991; Ball et al., 1998; Sato et al., 2005; Thompson et al., 2008). Most of the habitats at the NC Zoo are open with boundaries of cement walls and/or fence-lines. Raccoons are exceptional climbers and while habitats are meant to keep collection animals in, often the boundaries are not impervious to raccoons. Enclosures are designed to meet the needs of the collection animal, which in-turn can provide shelter and a reliable food source for wild raccoons.

One of the latrines in the public area was discovered on children's play equipment. Given that children under the age of two are the most impacted clinically by *B. procyonis*, identification of the latrine and further demonstration of the absence of the parasite was particularly important (Graeff-Teixeira et al., 2016; Kazacos, 2016). The other latrine was located on the park entrance bridge utilized by hundreds of zoo visitors and staff each day. The groundskeepers remarked that they continuously removed the feces at that location, but it always reoccurred. The lack of latrines found in public areas is likely secondary to the continual upkeep of the grounds and manual removal of latrines by zoo personnel, who are considered at higher risk for *B. procyonis* infection (Graeff-Teixeira et al., 2016).

Latrines appeared to be distributed throughout the developed portions of the park (Figure 2.1). One latrine was found in region 1, a less developed area of the park. There is a high likelihood that other latrines exist in these regions, however, increased leaf litter, abundant raised tree crotches and rock outcroppings, and forest cover may have decreased our detection ability. Raccoons may select for more developed regions due to resource distribution, however, this was not tested in the scope of this study (Prange et al., 2004).

Zoological institutions can serve as surveillance locales providing information regarding the potential risk of *B. procyonis* to surrounding communities. Seroprevalence surveys of non-human primates from zoos and people working in wildlife rehabilitation facilities, suggest exposure to *B. procyonis* without overt clinical disease occurring (Weinstein et al., 2017). Zoological institutions are the perfect One Health intersection of humans, animals, and their environment and can provide invaluable information regarding diseases of public health importance, such as *B. procyonis*.

Conclusions

Baylisascaris procyonis was not found in the latrines at the NC Zoo. Our negative results are important locally, providing insight for future surveillance, monitoring, risk assessments, planning, and wildlife management. In a broader sense, our results contribute knowledge regarding present distribution of this parasite, as it remains a poorly understood, highly pathogenic zoonotic disease (Graeff-Teixeira et al., 2016; Kazacos, 2016).

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Figure 2.1: A map of the North Carolina Zoo displaying raccoon latrines found in October and November of 2018 (n = 33) and 2019 (n = 8). The zoo proper is divided into 6 regions with regions 2, 3, 5, and 6 being more developed.

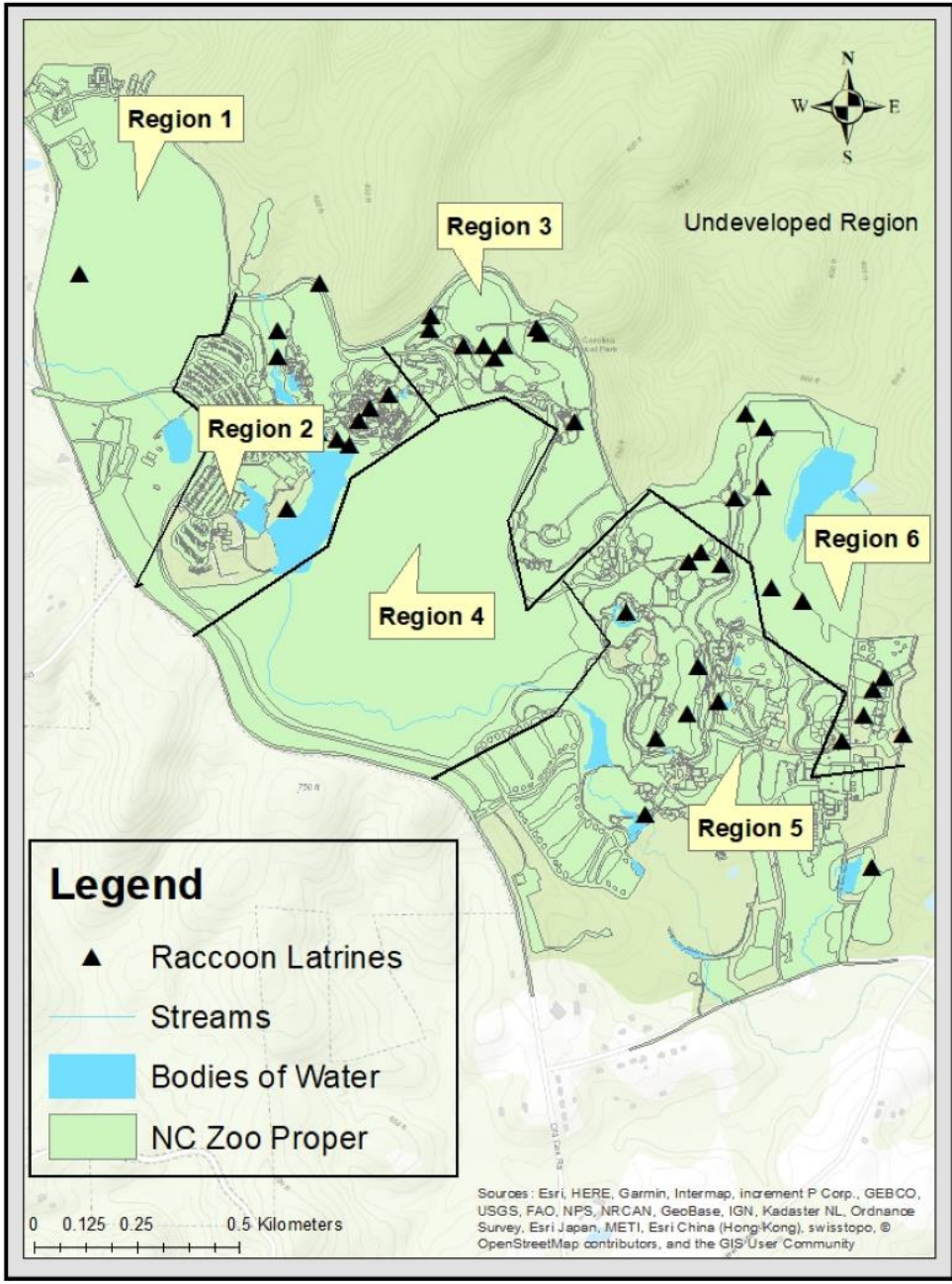
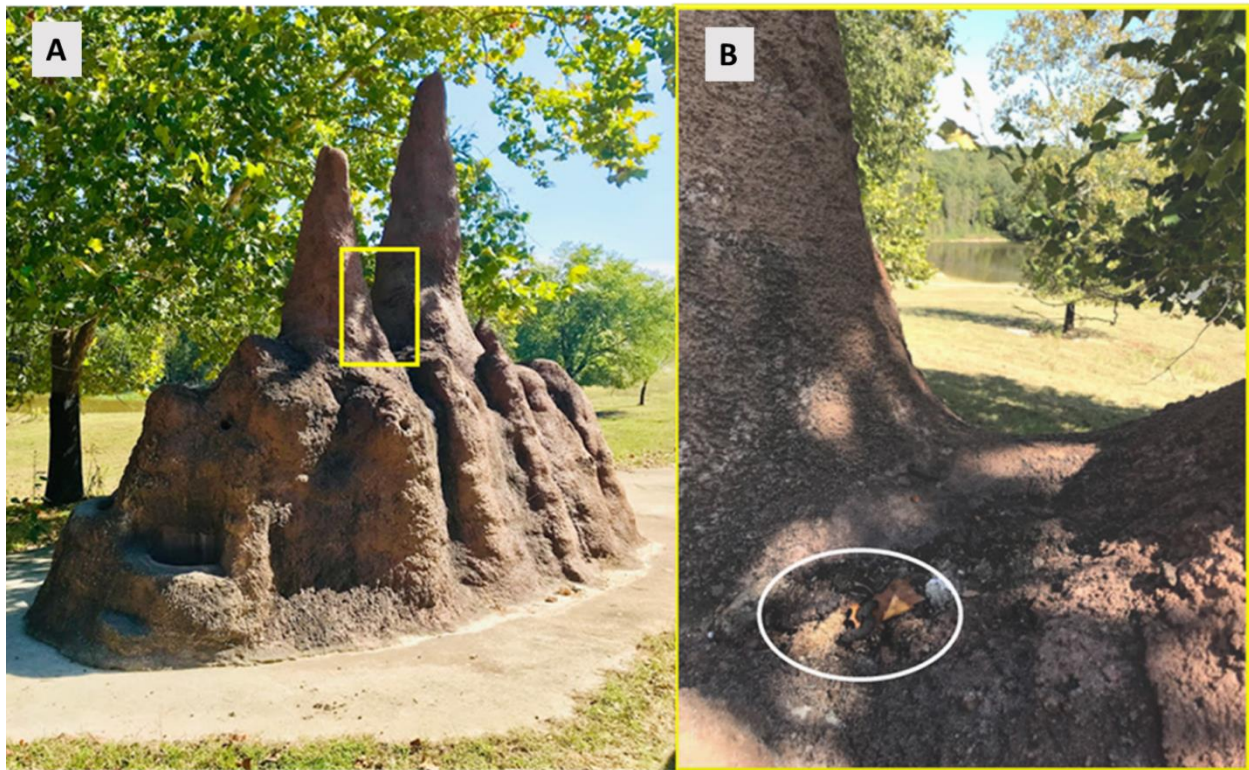


Figure 2.2: A raccoon latrine on the man-made cement wall in region 5 at the perimeter of a mixed-species exhibit of zebra (*Equus quagga*), ostrich (*Struthio camelus*), and giraffe (*Giraffa camelopardalis*) at the North Carolina Zoo in the fall of 2018. The white oval is identifying a raccoon latrine on the perimeter wall of the exhibit, which demonstrates the potential exposure of both zoo personnel and exhibit animals.



Figure 2.3: A raccoon latrine found in the crux of a man-made termite mound located on a large mixed-species African habitat in region 6 at the North Carolina Zoo in the fall of 2018 and 2019. (A) An overview of the man-made termite mound. (B) Displays a zoomed-in view with a white oval identifying the raccoon latrine. This man-made mound has similar features as a preferred natural substrate of a tree crux.



**CHAPTER 3. Survey Assessment of Risk Perceptions and Knowledge of Raccoons
(*Procyon lotor*) and Associated Zoonotic Diseases Amongst Professionals in North Carolina**

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Abstract

Wildlife, human health, and veterinary professionals are called upon to make risk assessments and judgements regarding human and animal care. Ascertaining risk perception and knowledge of professionals regarding wildlife and their associated disease improves awareness. Raccoons (*Procyon lotor*) are known reservoirs for a host of zoonotic diseases, including *Baylisascaris procyonis*. The roundworm typically does not cause clinical disease in raccoons, however, it can cause severe clinical disease and even death in humans and a wide variety of other mammals and birds. Through this study, we sought to determine knowledge and risk perception of wildlife, human health, and veterinary professionals in North Carolina pertaining to raccoons and their associated zoonotic diseases, emphasizing *B. procyonis*. Profession of the individual was the only variable that had an impact on knowledge, and both profession and knowledge of someone affected by *B. procyonis* were the only influencers of disease risk perception. No differences related to age, gender, or the number of years in the identified profession were found. Overall, veterinarians scored the highest on knowledge-based questions, as well as demonstrating the highest level of disease risk perception between the professions, however gaps in knowledge and ranges of risk perception were identified within each profession. Our survey revealed the need for an integrative One Health approach for targeted communication and disease risk management of raccoons and their associated zoonotic diseases.

Introduction

Raccoons (*Procyon lotor*) are charismatic mesocarnivores that are present throughout the state of North Carolina. They have adapted well to urban living, thereby increasing the likelihood of human-raccoon interactions. Raccoons serve as a reservoir for several zoonotic agents. Rabies virus is the most notable with a human fatality rate of 99% without pre-exposure and or timely post-exposure prophylaxis (Pieracci 2019). The nematode parasite, *Baylisascaris procyonis*, may also cause severe clinical disease and potentially death in people. Although the actual risk of a human acquiring rabies or *B. procyonis* from a raccoon in the United States is relatively low (Murray 2002; Hennenfent et al. 2018), the consequences are severe and have garnered targeted public health attention.

Wildlife, human health, and veterinary professionals are called upon to make risk assessments and judgements regarding human and animal care. Ascertaining individual risk perception regarding raccoon-associated zoonotic disease increases awareness and facilitates communication between professions. Risk perception is an individual's subjective judgement regarding a particular risk relative to the associated severity and potential outcomes (Paek and Hove 2017). Risk perception is dynamic and made up of both cognitive and emotional dimensions (Slovic and Peters 2006). The cognitive dimension refers to a person's knowledge of the risk, whereas the emotional dimension refers to a person's feelings about the risk (Slovic and Peters 2006; Paek and Hove 2017).

The aim of this study was to determine the disease risk perceptions and general knowledge of wildlife, human health, and veterinary professionals regarding raccoons, with an emphasis on *B. procyonis*. We hypothesized that knowledge gaps would exist within and

between professions and that general knowledge regarding raccoons and associated diseases would be inversely associated with the perception of disease risk level.

Materials and Methods

An online questionnaire was created using Qualtrics (Qualtrics, Provo, Utah, USA) and was distributed among three professional organizations within North Carolina: (1) The North Carolina Veterinary Medical Association, (2) North Carolina Association of Local Health Directors, and (3) The North Carolina Wildlife Society. The convenience sample of respondents were enrolled through their respective professional association email listserv and open from October 29, 2019 to November 29, 2019 with one reminder email provided to each organization.

Inclusion criteria from respondents included age (18+) and professional association. Individuals who identified as students were excluded from this survey. Demographic data, including age, sex, and years in the profession were collected. The survey was piloted on a small subset of individuals to assess questions for clarity. Research methods were approved for use by the North Carolina State University Institutional Review Board (IRB #20332).

The questionnaire, totaling 25 questions, included both knowledge-based and disease risk perception questions pertaining to raccoons and their associated zoonotic diseases, with an emphasis on *B. procyonis*. One open-ended style word association question was included. Disease risk perception questions were assessed primarily using mostly Likert scales, as well as one yes-no question, and one ranking question. Due to problems within the Qualtrics platform reported after the survey began, the ranking question was discarded. Knowledge-based questions were either yes-no or true-false questions. Respondents were allowed to skip any question. Surveys were included for evaluation if they were near-complete, meaning that less than three knowledge-based, risk-perception, or demographic questions were left unanswered.

Data Analysis

Disease risk perception and knowledge scores were calculated as the sum of the respondent's correct responses divided by the total possible points on the number of questions answered. The answer to the open-ended question was categorized as either related to raccoon natural history and biology, anthropogenic associations, or pest concerns including zoonotic diseases and property damage.

A multiple linear regression with Akaike Information Criterion for backward model selection (R version 3.6.2) was used for both the risk scores and the knowledge scores. A chi-squared test (R version 3.6.2) was used to compare word associations. Significance was set at $\alpha = 0.05$. Generalized data evaluation was done in SPSS (version 26).

Results

A total of 347 complete or near-complete questionnaires were collected. Thirty-four student surveys were excluded. The survey was distributed by electronic means through the three professional listservs, and the estimated total response rate for all respondents combined was 8.5% (347/4,059). The response rate by occupational category for wildlife professionals, human health professionals, and veterinarians was 14%, 3.5%, and 10%, respectively.

The 313 respondents included wildlife professionals (non-veterinary) (n=65), human health professionals (n=43), and veterinary professionals (n=205). The majority of the respondents were female (n=205, 65.7%) and nearly half (n=144, 46.2%) of the respondents had more than 20 years of professional experience. The majority (n=223, 72.4%) of all respondents reported having participated in fishing, hunting, and/or trapping during their lifetime. A summary of the demographic data is presented in Table 3.1.

Profession of the individual was the only variable that had an impact on correct answers to knowledge-based questions. Veterinary professionals scored higher on knowledge-based questions on average than human health professionals (9.01 percentage points, $p < 0.01$). Wildlife professionals did not score significantly higher than human health professionals ($p = 0.12$). A summary of questions and answers to knowledge questions is presented in Table 3.2.

Profession type and having known someone affected by *B. procyonis* were the only influencers of risk perception identified. Using human health professionals as a baseline, veterinary professionals perceived a higher level of disease risk perception on average (5.18 percentage points, $p < 0.01$). Knowledge and demographic questions did not affect disease risk perception. A summary of disease risk perception questions and responses to disease risk perception questions is presented in Figure 3.1.

Human health professionals and veterinary professionals associated raccoons with pest (disease and destruction) more than would be expected with no association. Wildlife professionals associated raccoons with biology-related words more frequently than either veterinarians or human health professionals.

Discussion

Veterinarians scored the highest on overall knowledge-based questions, but also had the highest perception of disease risk regarding raccoons and their associated zoonotic disease in comparison to both wildlife and human health professionals. This was contrary to the hypothesis that an inverse relationship would exist between knowledge and risk perception. Gaps in knowledge and ranges in disease risk perception were apparent across all three professions.

Raccoons are well known reservoirs for the rabies virus, but also have the potential to transmit several zoonotic diseases to humans: *Leptospira interrogans serovars*, *Salmonella*

enterica serotypes, *Mycobacterium bovis*, *Francisella tularensis*, *Bartonella rochalimaea*, *Sarcoptes scabiei*, *Trichinella spiralis*, *Cryptosporidium spp*, *Giardia spp*, and *Toxoplasmosis gondii* (Cole and Shoop 1987; Dubey et al. 1992; Fitzgerald et al. 2004; Bischof and Rogers 2005; Feng et al. 2007; Berentsen et al. 2010; Hwang and Gottdenker 2013; Rainwater et al. 2017). Even though these zoonotic diseases were not directly mentioned in the survey instrument, scenarios regarding potential exposure through direct (handling) and indirect (urine and feces) contact with raccoons were used to elucidate individual's disease risk perception with these potential agents in mind. This survey highlighted *B. procyonis* for several reasons: its classification as a highly pathogenic infectious disease; its potential to cause clinical disease in at least 150 species of mammals and birds (Kazacos 2016); and lastly its potential devastating clinical course including ocular, visceral, and neural larva migrans in humans that can result in death (Graeff-Teixeira et al. 2016).

This survey highlighted an overall lack of familiarity with *B. procyonis*. When asked if respondents were familiar with *B. procyonis*, only 27.9% of human health professionals answered yes, compared to 44.6% of wildlife professionals and 75.1% of veterinary professionals. Parasitology is part of the core curriculum of most American veterinary schools but has been de-emphasized, especially in American medical schools (Acholonu 2003). Due to a greater volume of parasitic infections and higher infection rates for animals versus humans, veterinary students typically receive considerably more exposure to parasitology than medical school students (Kaplan et al. 2009). Because many respondents indicated having been at least 20 years in their profession, the time from formal schooling may also account for some of the knowledge unfamiliarity. The high percentages of “don't know” pertaining to *B. procyonis* in the knowledge-based questions across all three professions may also be a product of geography.

This survey was specific to North Carolina, which had its first detection of *B. procyonis* from raccoons in the western part of the state in 2013 (Hernandez et al. 2013). This newly established presence of the parasite may explain why each profession did not seem overly concerned about getting *B. procyonis* in North Carolina (Figure 3.1). Overall, awareness may be limited in areas that have relatively recently established *B. procyonis* or low prevalence when compared with regions where the parasite is well-established and prevalence rates are high (Sapp et al. 2018).

Two specific knowledge questions that were missed most frequently by respondents or answered “don’t know” pertained to the eggs of *B. procyonis*. The larvated ova is the infectious stage of the parasite, which develop anywhere from two to four weeks post-defecation (Kazacos et al. 2013). Sapp et al. (2018) reported a similar deficit in knowledge in that 52% of wildlife rehabilitator respondents believed that fresh feces represented a risk for *B. procyonis* infection. It is important to emphasize that old feces are the most dangerous, especially for cleaning and decontaminating procedures. The second question that was frequently missed pertained to the hardiness of the eggs. *Baylisascaris procyonis* eggs are highly resistant to desiccation and disinfection (Shafir et al. 2011; Kazacos 2016). Shafir et al. (2011) found that eggs survived complete desiccation for at least 6 months at room temperature and that exposure to undiluted household bleach for 90 minutes did not affect viability of the eggs. Similar to both the wildlife (66.7%) and veterinary (64.4%) scores, wildlife rehabilitators were correct (65%) in that common disinfectants were not sufficient to kill *B. procyonis* eggs (Sapp et al. 2018). A survey of the general public revealed that 85% of the respondents believed that bleach and detergents were sufficient for decontamination (Ogdee et al. 2016).

Interdisciplinary collaboration and open communication are essential, and this need is demonstrated in our survey results. For instance, a majority (81%) of human health professionals

answered “don’t know” regarding raccoon defecation in communal areas called latrines. Latrines can serve as an important foci for *B. procyonis* and are important to recognize to mitigate the risks to both humans and animals (Hirsch et al. 2014). Communal defecation by raccoons is a behavior that is linked to the transmission cycle of *B. procyonis* (Ogdee et al. 2016). Both wildlife and veterinary professionals scored considerably higher on this question and could aide human health professionals in educating clients and the public. The widest range in risk perception between professions pertained to the level of concern regarding a raccoon traveling in daylight. One hundred percent of wildlife professionals were not concerned at all compared to 58% of human health and 60% of veterinarians expressing at least being moderately concerned. An explanation for this differential may be secondary to human health professionals and veterinarians considering diseases that affect raccoon behavior, such as rabies. Wildlife professionals may have more field experience with raccoons and could educate both veterinary and medical professionals with their observations, thereby placing concerns in a better perspective.

Knowledge of someone affected by *B. procyonis* influenced disease risk perception. This finding is similar to Hanisch-Kirkbride et al. (2013) who found that respondents who knew someone affected by rabies, plague, or West Nile virus reported greater disease risk perceptions than those that did not. Reported cases of *B. procyonis* are rare with approximately 50 recognized human cases existing in the United States and Canada (Hernandez et al. 2013; Kazacos 2016). Evidence is mounting from advances in detection capabilities that asymptomatic/undiagnosed human cases may also be occurring (Sapp et al. 2016; Weinstein et al. 2017).

The open-ended word association question provided insight into an individual's perception of risk by examining the potential emotional and cognitive dimensions associated with raccoons. The significant associations between profession type and word category (pest and biological characteristics) presented more of a cognitive state, rather than an emotional one. Experts are assumed to rely on scientific information and objective assessment (Paek and Hove 2017). A word cloud of all responses is included in Figure 2.

There were limitations to our study. Most notably, the low overall response rate, which increased the possibility of a non-response bias. A higher response rate could have provided more assurances of a representative sample of the professions. The method of convenience sampling enlisted one professional organization from each of the three professions, which depending on the professional association's goals and values, might have added bias to our sample.

Surveying professionals across overlapping disciplines, especially pertaining to zoonotic disease, can add perspective and opportunity for collaboration and understanding. Identifying gaps in knowledge and differences in disease risk perception expose the need for a One Health multi-disciplinary approach to prevention and control of zoonotic diseases, like *B. procyonis*. The premise of One Health is that human health, animal health, and environmental health are interdependent, and that the well-being of all can be enhanced through cooperation and collaboration between human health professionals, veterinarians, and other scientific health professionals (Decker et al. 2010, www.onehealthinitiative.com). Through our survey, we identified knowledge gaps and ranges in risk perception that established educational opportunities to increase awareness and professional collaboration.

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Table 3.1: Demographic characteristics of participants in a survey assessing knowledge and risk perception regarding raccoons and their associated zoonotic diseases.

Characteristic	Total		Wildlife		Human Health		Veterinary	
	N	%	N	%	N	%	N	%
Gender								
Female	205	65.7	25	38.5	26	60.5	154	75.5
Male	103	33.0	37	56.9	17	39.5	49	24.0
Not specified	4	1.3	3	4.6	0	0	1	0.5
Years in Profession								
0-5	40	12.8	15	23.1	3	7.1	22	10.7
6-10	53	17	9	13.8	6	14.3	38	18.5
11-15	36	11.5	10	15.4	6	14.3	20	9.9
16-20	39	12.5	7	10.8	2	4.8	30	14.6
>20	144	46.2	24	36.9	25	59.5	95	46.3
Age								
20-30	30	9.6	16	24.6	2	4.7	12	5.9
31-40	72	23	16	24.6	7	16.3	49	23.9
41-50	78	24.9	11	16.9	10	23.2	57	27.8
51-60	74	23.6	13	20	15	34.9	46	22.4
>60	59	18.9	9	13.9	9	20.9	41	20
Participated, All that apply:								
Fishing	219	70	62	95.3	33	76.6	124	60.5
Hunting	128	40.9	55	84.6	24	55.8	49	23.9
Trapping	55	17.6	43	66.2	3	7	9	4.4
None	90	28.8	3	4.6	10	23.3	77	37.6

Table 3.2: Knowledge questions and percentage of correct answers regarding raccoons and associated zoonotic disease from wildlife, human health, and veterinary professionals. Correct answer is in parentheses. DK- Don't know

		Wildlife Profession n=65	Human Health Profession n=43	Veterinary Profession n=205
<i>Raccoon knowledge-based questions</i>				
<i>All questions pertain to the state of North Carolina</i>				
<i>It is legal to relocate a raccoon to public lands within the state. (False)</i>	Correct DK	(51/57) 89.5% 12.5%	(17/23) 73.9% 46.5%	(85/98) 86.7% 52.2%
<i>It is legal to own a raccoon as a pet. (False)</i>	Correct DK	(56/63) 89.9% 3.1%	(36/40) 90.0% 7.0%	(185/190) 97.4% 7.3%
<i>It is legal for a landowner to shoot a raccoon outside of hunting season if a raccoon is caught in the act of causing property damage. (True)</i>	Correct DK	(51/61) 83.6% 6.2%	(21/32) 63.6% 23.3%	(97/118) 82.2% 42.4%
<i>Drowning is an approved method to kill a raccoon according to the North Carolina Wildlife Resources Commission. (False)</i>	Correct DK	(39/53) 73.6% 18.5%	(30/30) 100% 30.2%	(117/124) 94.4% 40.0%
<i>Baylisascaris procyonis knowledge-based questions</i>				
<i>Raccoons defecate in communal areas called latrines. (True)</i>	Correct DK	(38/44) 86.4% 32.3%	(3/8) 37.5% 81.3%	(118/124) 95.2% 39.5%
<i>Dogs can harbor the parasite and shed eggs into their feces. (True)</i>	Correct DK	(29/34) 85.3% 47.7%	(14/17) 82.4% 60.5%	(114/140) 81.4% 31.7%
<i>Eggs in fresh raccoon feces are the most infectious. (False)</i>	Correct DK	(6/31) 19.4% 52.3%	(5/17) 29.4% 60.5%	(78/127) 61.4% 38.0%
<i>The eggs are sensitive to desiccation and can be deactivated with common household cleaners. (False)</i>	Correct DK	(18/27) 66.7% 58.5%	(4/13) 30.8% 69.8%	(76/118) 64.4% 42.4%
<i>Swimming pools can be a point-source of infection of children. (True)</i>	Correct DK	(16/20) 80.0% 69.2%	(11/16) 68.8% 62.8%	(60/96) 62.5% 62.5%
<i>Are you familiar with Baylisascaris procyonis? (Yes)</i>		(29/65) 44.6%	(12/43) 27.9%	(154/205) 75.1%

Figure 3.1: Risk perception questions and answers regarding raccoons and associated zoonotic disease from wildlife, human health, and veterinary professionals. *Questions adapted from (Hanisch-Kirkbride et al. 2013)

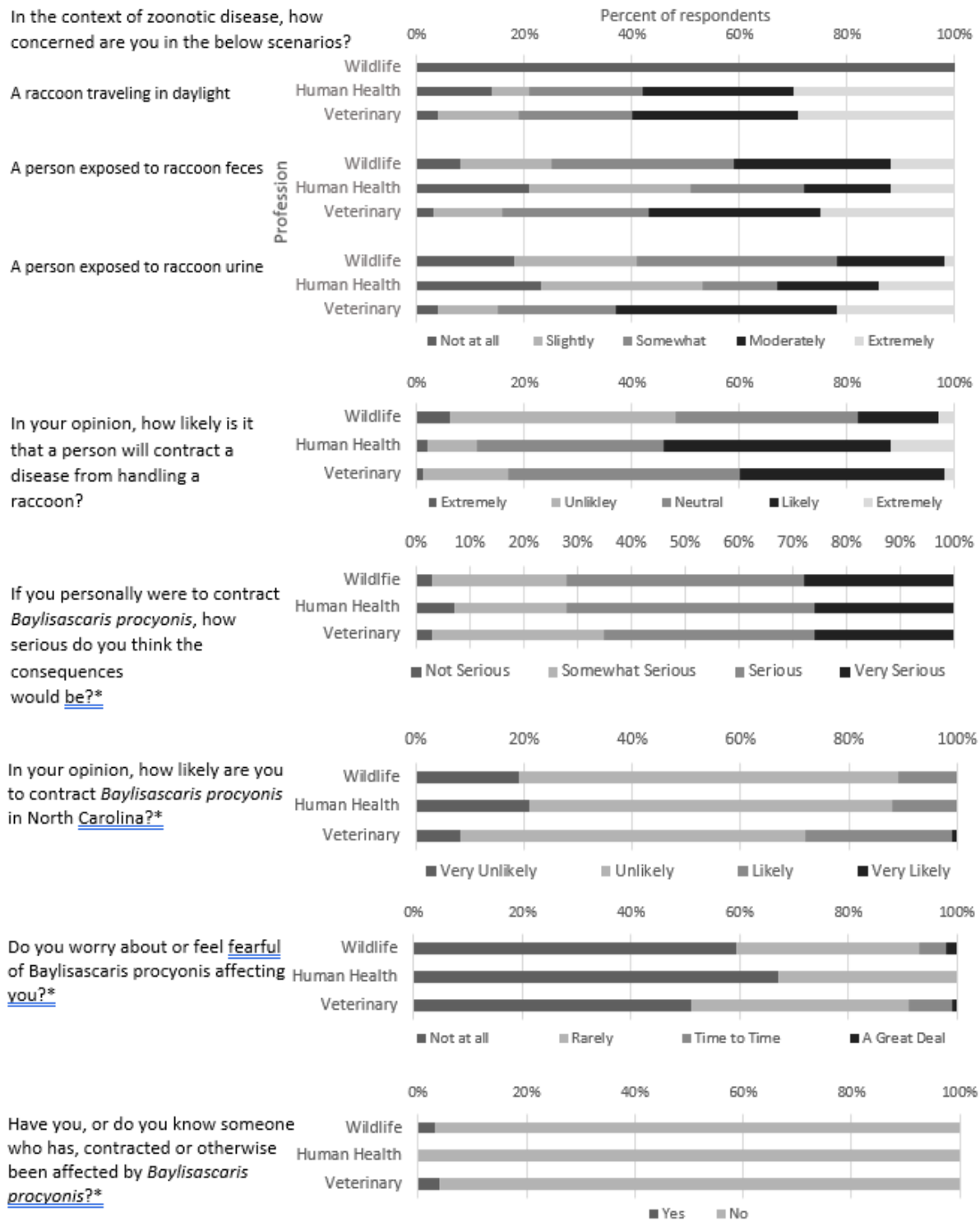


Figure 3.2: Word cloud including all responses to the survey question asking respondents to record the one word that comes to mind with the mention of “raccoon”.



Conclusions and Future Directions:

Baylisascaris procyonis is a zoonotic threat that is best managed by an integrative One Health approach and response. There is need to increase our understanding regarding the interplay between host, pathogen, and environmental factors related to this disease to increase our ability to identify innovative ways to interrupt transmission of this parasite. Through exploring *B. procyonis* in North Carolina, we identified key areas for improvement regarding education and collaboration.

Knowledge gaps regarding *B. procyonis* are present within wildlife, human health, and veterinary professionals. A curriculum-based review of educational programs could identify learning objectives and aspects of zoonotic disease that are lacking, with *Baylisascaris procyonis* serving as a case-study. The survey instrument on knowledge and disease risk perception used in chapter 3 was recently given to veterinary students at the North Carolina State University College of Veterinary Medicine in years 1, 2, 3, and 4 of their curricula. The data obtained will be analyzed and could aid in identifying when knowledge gaps are greatest in the curriculum and/or when intervention strategies could be inserted. The data could also serve as a comparison to those already polled and practicing in the veterinary profession in North Carolina. This survey method could be extrapolated to medical schools or graduate programs within the region, with the potential to explore knowledge of other zoonotic diseases of concern.

Developing communication channels and collaboration opportunities across the professions to nurture relationships and promote knowledge exchange is key to the One Health approach. *Baylisascaris procyonis* is a proven zoonotic threat that requires an integrated One Health approach.

APPENDICES

Appendix A: Chapter 2: Latrine Data

Date	Location	x	y	Substrate	# Samples	Fecal Float	Exhibit	Public	Persist
2018	ZOG Rock	-79.7544	35.6230556	Rock	2	Neg	Yes		NE
2018	ZOG Wall backside	-79.7536	35.6236111	Cement	3	Neg	Yes		NE
2018	Elephant Rock	-79.7528	35.6238889	Rock	3	Neg	Yes		no
2018	Lemur Wall	-79.7553	35.6258333	Cement	1	Neg	yes		no
2018 2019	Pavilion Rock	-79.7536	35.6269444	Rock	1 & 2	Neg	No		yes
2018	Hoofstock Barn 1	-79.7489	35.6236111	Barn	1	Neg	yes		no
2018	Hoofstock Barn 2	-79.7486	35.6241667	Barn	1	Neg	yes		No
2018 2019	Hoofstock Barn 3	-79.7483	35.6244444	Barn	1 & 2	Neg	Yes		Yes
2018 2019	Hoofstock Barn B	-79.7494	35.6230556	Barn	3 & 2	Neg	No		Yes

2018 2019	Africa Plains Log	-79.7506	35.6261111	Log	3 & 1	Neg	Yes		Yes
2018 2019	Africa Plains Culvert	-79.7514	35.6263889	Cement	1 & 2	Neg	yes		Yes
2018 2019	Africa Termite Mound	-79.7517	35.6286111	Cement	1 & 3	Neg	Yes		Yes
2018 2019	Africa Bridge	-79.7547	35.6213889	Bridge	1 & 1	Neg	No	yes	Yes
2018 2019	Education Center Rock	-79.7644	35.6280556	Rock	3 & 3	Neg	No		Yes
2018 2019	Marsh Walk Rock	-79.7636	35.6297222	Rock	3 & 3	Neg	No		Yes
2018	Paddleboa t ground	-79.7628	35.6294444	Ground	1	Neg	No		No
2018	Tree Base Rocky Coast 1	-79.7622	35.6302778	Ground	3	Neg	No		No
2018 2019	Tree Base Rocky Coast 2	-79.7625	35.6300000	Ground	3 & 1	Neg	No		Yes
2018	Compost Lake Rock	-79.7486	35.6202778	Rock	1 & 1	Neg	No		Yes
2018	Prairie Wall	-79.7597	35.6316667	Wall	1	Neg	Yes		No

2018 2019	Prairie Rock 1	-79.7586	35.6316667	Rock	3 & 2	Neg	Yes		No
2018	Prairie Rock 2	-79.7589	35.6313889	Rock	3	Neg	Yes		Yes
2018	Prairie Stump	-79.7592	35.6316667	Stump	2	Neg	Yes		No
2018 2019	Swamp Log	-79.7647	35.6313889	Log	1 & 1	Neg	No		Yes
2018 2019	Rotten Swamp Log	-79.7647	35.6319444	Log	3 & 1	Neg	No		Yes
2018	African Plains Viewing Rock	-79.7524	35.628352	Rock	1	Neg	No		No
2018	ZOG wall Giraffe Deck Wall	-79.7533	35.624650	Ground	2	Neg	Yes		No
2018 2019	Baboon Pavilion Deck	-79.7533	35.627175	Deck	3 & 2	Neg	No		Yes
2019	Grizzly Roof	-79.7567	35.630009	Roof	1	Neg	No		NE
2018	Elk Barn ladder	-79.7576	35.631932	Barn	1	Neg	Yes		No
2018 2019	Elk Barn Roof	-79.7578	35.632053	Roof	3 & 2	Neg	No		Yes

2018	Black Bear Roof	-79.7606	35.632292	Roof	1	Neg	Yes		NE
2018	Shack Ground	-79.7636	35.633	Ground	1	Neg	No		No
2019	Africa Plains North 1	-79.7521	35.630216	Rock	2	Neg	Yes		NA
2019	Africa Plains North 2	-79.7516	35.629923	Rock	3	Neg	Yes		NA
2019	Africa Log Across HS Barn	-79.7478	35.623208	Tree	1	Neg	Yes		NA
2019	Pavilion Corner	-79.7527	35.626895	Ground	3	Neg	No		NA
2019	Kid Zone	-79.7617	35.630556	Wood	1	Neg	No	yes	NA
2019	Rock b/w PB & PB	-79.7631	35.629577	Rock	2	Neg	No		NA
2019	Black Bear	-79.7606	35.632007	Cement	2	Neg	Yes		NA
2019	Hole in tree	-79.7701	35.633166	Ground	1	Neg	No		NA

Appendix B: Chapter 3: Survey

Raccoon Survey-Professionals

Start of Block: Consent

I am conducting a short survey to determine knowledge and risk perceptions regarding raccoons and their associated zoonotic disease. The survey will take approximately **5 minutes** to complete. All responses will be treated as strictly confidential and all results will be presented in aggregate form. A click yes will access the survey and provide consent to have your data used for research. A click no will terminate the survey with a thank you for your consideration. Please feel free to contact me should you have any questions: melouis@ncsu.edu.

Kind Regards, Meghan Louis, DVM, DACVPM

- I consent (1)
- I do not consent (2)

Skip To: End of Block If I am conducting a short survey to determine knowledge and risk perceptions regarding raccoons and... = I consent

Skip To: End of Survey If I am conducting a short survey to determine knowledge and risk perceptions regarding raccoons and... = I do not consent

End of Block: Consent

Start of Block: Feelings Based Questions

Q1 What is one word that comes to mind with the mention of "raccoon"?

End of Block: Feelings Based Questions

Start of Block: Legal Questions

Q2 T/F: All questions pertain to the state of North Carolina:

	True (1)	False (2)	Don't know (3)
It is legal to relocate a raccoon to public lands within the state.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is legal to own a raccoon as a pet.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is legal for a landowner to shoot a raccoon outside of hunting season if a raccoon is caught in the act of causing property damage.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Drowning is an approved method to kill a raccoon according to the North Carolina Wildlife Resources Commission.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

End of Block: Legal Questions

Start of Block: Risk Perception Questions

Q3 In the context of zoonotic disease, how concerned are you in the below scenarios?

	Not at all concerned (1)	Slightly concerned (2)	Somewhat concerned (3)	Moderately concerned (4)	Extremely concerned (5)
A raccoon traveling in daylight	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A person exposed to raccoon feces	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A person exposed to raccoon urine	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q4

	Extremely unlikely (1)	Unlikely (2)	Neutral (3)	Likely (4)	Extremely likely (5)
In your opinion, how likely is it that a person will contract a disease from handling a raccoon?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

End of Block: Risk Perception Questions

Start of Block: Zoonotic Disease Questions

Q5 With regards to raccoons and zoonotic disease, rank order the below from most concern (1) to least concern (3).

_____ Leptospirosis (1)

_____ Rabies (2)

_____ *Baylisascaris procyonis* (3)

End of Block: Zoonotic Disease Questions

Start of Block: Block 7

Q6 Are you familiar with *Baylisascaris procyonis*?

Yes (1)

No (2)

End of Block: Block 7

Start of Block: Disease Specific Questions

Q7 With regards to *Baylisascaris procyonis*, please mark the following statements as true/false/don't know.

	True (1)	False (2)	Don't know (3)
Raccoons defecate in communal areas called latrines.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Dogs can harbor the parasite and shed eggs into their feces.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Eggs in fresh raccoon feces are the most infectious.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The eggs are sensitive to desiccation and can be deactivated with common household cleaners.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Swimming pools can be a point-source of infection for children.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

End of Block: Disease Specific Questions

Start of Block: Disease Specific Risk Perception

Q8

	Not serious (1)	Somewhat serious (2)	Serious (3)	Very serious (4)
If you personally were to contract <i>Baylisascaris procyonis</i> , how serious do you think the consequences would be?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q9

	Very unlikely (1)	Unlikely (2)	Likely (3)	Very likely (4)
In your opinion, how likely are you to contract <i>Baylisascaris procyonis</i> in North Carolina?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q10 Have you, or do you know someone who has, contracted or otherwise been affected by *Baylisascaris procyonis*?

- Yes (1)
 - No (2)
-

Q11

	Not at all (1)	Rarely (2)	From time to time (3)	A great deal (4)
Do you worry about or feel fearful of <i>Baylisascaris procyonis</i> affecting you?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

End of Block: Disease Specific Risk Perception

Start of Block: Demographic Questions

Q12 What is your primary profession?

- Wildlife Professional (1)
 - Human Health Professional (2)
 - Veterinary Profession (3)
 - Student- State the name of the program that you are enrolled in and your major.
(4) _____
-

Q13 Number of years in profession:

- 0-5 (4)
 - 6-10 (5)
 - 11-15 (6)
 - 16-20 (7)
 - >20 (8)
-

Q14 What is your gender?

- Male (1)
 - Female (2)
 - Prefer not to answer (3)
-

Q15 What is your age?

- 20-30 (1)
 - 31-40 (2)
 - 41-50 (3)
 - 51-60 (4)
 - >60 (5)
-

Q16 Have you ever participated in (select all that apply):

Hunting (1)

Fishing (2)

Trapping (3)

None (4)

End of Block: Demographic Questions
