Human–Wildlife Interactions 10(2): 283–291, Fall 2016

Lack of human awareness and the need for increased public education regarding the zoonotic parasite, *Baylisascaris procyonis*

Jacob L. Ogdee, Department of Animal, Rangeland, and Wildlife Sciences, Caesar Kleberg Wildlife Research Institute, MSC 228, Texas A&M University–Kingsville, Kingsville, TX 78363, USA

Scott E. Henke, Department of Animal, Rangeland, and Wildlife Sciences, Caesar Kleberg Wildlife Research Institute, MSC 228, Texas A&M University–Kingsville, Kingsville, TX 78363, USA
scott.henke@tamuk.edu

David B. Wester, Department of Animal, Rangeland, and Wildlife Sciences, Caesar Kleberg Wildlife Research Institute, MSC 228, Texas A&M University–Kingsville, Kingsville, TX 78363, USA

Abstract: *Baylisascaris procyonis* is a large parasitic nematode found in the small intestines of raccoons (*Procyon lotor*), the definitive host, and causes larva migrans in humans and other animals. Humans can become infected by ingesting *B. procyonis* eggs, which can remain viable in the environment for years and adhere to vegetation, soil, water, raccoon feces, or hands. Parasitic infections manifest in humans with neural and ocular larva migrans, characterized by clinical symptoms of head and body tilt, circling, recumbency, ataxia, blindness, nervous behavior, paralysis, and coma, leading to death. Prevalence of *B. procyonis* in humans is unknown. However, human cases may be more common in endemic areas than initially suspected because humans with low-level infections may not develop clinical signs and can go undiagnosed. Therefore, the prevalence of human *B. procyonis* infections can be high, especially in endemic areas where suburban sprawl increases the likelihood of frequent human contact with raccoons and their latrines. We surveyed adults from Texas to ascertain their knowledge of raccoon behavior and of *B. procyonis* as a potential zoonotic disease. No differences were observed in responses due to gender, ethnicity, age, or education level. In general, Texans had superficial knowledge of raccoon behavior and virtually no knowledge of *B. procyonis* and its inherent dangers as a zoonotic disease. Due to the apparent limited public awareness about the potential clinical hazards presented by *B. procyonis*, greater public education efforts are warranted.

Key words: *Baylisascaris procyonis*, human awareness, parasite, *Procyon lotor*, raccoon, survey, zoonosis

The raccoon (*Procyon lotor*) is one of North America's most common mammals. The raccoon's high level of intelligence and ability to thrive in areas dominated by humans have contributed to its success as a species and to its increase in number throughout its range (Kaufmann 1982, Cuarón et al. 2008). Anthropogenic structures found in the human environment, such as buildings, sewers, and wooded parks serve as artificial habitat, bringing raccoons closer to humans (Gehrt 2003, Prange et al. 2003). Human refuse, pet food, and bird feed also contribute to the raccoon's success in human-dominated environments, increasing the probability of raccoons defecating near human habitations (Gehrt 2003, Graser et al. 2012). Raccoon defecation sites, known as latrines, occur in a variety of places, including the crotches of trees, bases of trees, woodpiles, attics of homes, barns, and many horizontal structures found in the human environment (Page et al. 1999, Kazacos 2001, Gavin et al. 2005). The raccoon's ability to thrive alongside humans is likely to increase human–raccoon encounters, as high densities of urban raccoon populations often present nuisance problems (Prange et al. 2003). Williams and McKegg (1987) found that >40% of animal–damage control jurisdictions named the raccoon as the main nuisance animal in urban and suburban areas. Increased human–raccoon encounters and human–latrine encounters increase the probability of humans coming into contact with a zoonotic parasite, *Baylisascaris procyonis*, which is carried by raccoons, the definitive host of the parasite.

Baylisascaris procyonis is an intestinal nematode of raccoons and is found throughout most of the United States, although the parasite is most common in northeastern, midwestern, and west coast states (Kazacos and Boyce 1989). However, *B. procyonis* recently has been

Figure 1. Most of the general public was unaware that children are at a higher risk of *B. procyonis* infection because kids frequent the outdoors more so than adults, may not thoroughly wash hands prior to eating, and have a propensity to put objects into their mouth. (*Photo courtesy of Scott E. Henke*)

documented in Texas (Long et. al. 2006, Kresta et al. 2010), Georgia and Florida (Blizzard 2010, Blizzard et al. 2010), North Carolina (Hernandez et al. 2013), Colorado (Chavez et al. 2012), and Wyoming (Pipas et al. 2014). *Baylisascaris procyonis* eggs are shed in infected raccoon feces (Kazacos 2001). An infected raccoon can shed 20,000–26,000 *B. procyonis* eggs per gram of feces per day (Kazacos 1982, Reed et al. 2012). Animals and humans become infected by accidentally ingesting infective *B. procyonis* eggs from contaminated areas, objects, and surfaces. The communal defecation habits of raccoons are a key behavior linked to the transmission cycle of the parasite. Raccoon latrines may become heavily contaminated with *B. procyonis* eggs and serve as foci of infection for raccoons and paratenic (i.e., an intermediate host in which no development of the parasite occurs) hosts (Page et al. 2009). *Baylisascaris procyonis* eggs are extremely resistant to a variety of environmental variables and conditions and are unharmed by freeze-thaw action (Kazacos 2001, Shafir et al. 2011) and heat extremes encountered throughout the range of this parasite (Ogdee 2015). *Baylisascaris procyonis* eggs may be killed by desiccation or temperatures exceeding 62° C (Shafir et al. 2011). Ogdee (2015) noted that even the high temperatures characteristic of the southern Texas climate is unlikely to ever prove lethal to *B. procyonis* eggs. The hardy nature of *B. procyonis* eggs enables them to persist in the environment for years, and in some cases, eggs have a survival rate of >92% for at least 2 years (Kazacos 2001, Ogdee 2015).

Because *B. procyonis* is not host-specific, it is able to infect a range of paratenic hosts, including rodents, lagomorphs, birds, and humans (Kazacos 2001). The parasite has the ability to cause devastating neurological and ocular effects in paratenic hosts as a result of *B. procyonis* larvae migration within the body. Approximately 5 to 7% of *B. procyonis* larvae migrate to the central nervous system; this results in neural larva migrans (NLM), which, depending on the intensity of infection and the host, may cause severe neurological clinical manifestations (Tiner 1953, Kazacos 2001) such as head and body tilt, nervousness, stupor, ataxia, recumbency, and coma, leading to death (Kazacos 1997). In addition, larvae can migrate to the retina of paratenic hosts, which results in ocular larva migrans (OLM) causing blindness (Kazacos et al. 2013). To date, ~20 human cases of NLM infection have been documented, with most patients exhibiting severe neurological disease and sometimes death (Gavin et al. 2005, Hung et al. 2012). Most of the 20 human cases of *B. procyonis* involved young children or individuals with developmental delays characterized by a high incidence of pica and geophagia (Gavin et al. 2005).

Actual numbers of human cases of *B. procyonis* infection are largely unknown, as clinical manifestations in human hosts may not occur in low intensity infections (Kazacos 2001). For example, an elderly woman suffering from Alzheimer's-like dementia was found to be positive for *B. procyonis* infection post mortem (Hung et al. 2012). However, the infection in this patient was considered light and not likely to have caused detrimental effects. Therefore, it

is possible that many human cases of *B. procyonis* infection may go unnoticed and undiagnosed (Kazacos 2001).

Although not many human cases of *B. procyonis* infection have been documented, the devastating effects of NLM and OLM caused by the parasite and its potential to infect humans warrant further research. As human and raccoon populations continue to increase, the probability of human infection with *B. procyonis* is likely to increase correspondingly. It is important to understand the general public's knowledge of raccoons and *B. procyonis* to formulate outreach efforts focused on increasing awareness of a growing health threat. Our research objectives include: (1) to gauge human knowledge of raccoons and (2) to gauge human awareness of *B. procyonis.*

Methods

A paper survey, which consisted of 28 questions, was developed by wildlife biologists and veterinarians knowledgeable about raccoon behavior and about the transmission, spread, and management of *B. procyonis.* The initial portion of the survey consisted of participant demographic information, which included gender (i.e., male or female), ethnicity (i.e., Caucasian, African-American, Hispanic, Asian, Native American, and Middle Eastern), age (i.e., teens, 20s, 30s, 40s, 50s, 60s, and 70s), and highest education level obtained (i.e., high school, some college, B.S. degree, M.S. degree, Ph.D. and professional degree such as M.D., D.V.M, or J.D.). Initial survey questions were designed to gauge a participant's general knowledge of raccoon behavior and associated disease threats. The general raccoon knowledge portion of the survey consisted of true/false, multiple choice, and select all that apply questions. True/false and some multiple choice questions provided an option to indicate whether the participant was not sure of the correct answer; this was done to eliminate the potential for participants guessing the answer of a given question if they were unsure. Following the general knowledge questions, participants were asked if they had any knowledge of *B. procyonis*, and, if so, to proceed to the next set of questions that were designed to gauge general knowledge of this parasite (Table 1). The instrument was pre-tested by university undergraduates to examine question clarity, subject relevance, and general question flow (Dillman 1978). Therefore, the final survey consisted of 2 parts; part one consisted of general knowledge questions, which were completed by each participant, and part two consisted of specific targeted questions concerning *B. procyonis* answered only by participants who expressed at least some knowledge of *B. procyonis.*

Our survey population consisted of a random selection of people from rural and urban backgrounds. We selected locations within southern and central Texas (i.e., Kingsville, Falfurrias, San Antonio, and Killeen, Texas) in which to conduct our survey. Sample size for our study was determined by the equation provided by Charan and Biswas (2013). In short, Z was designated the standard normal variant at 5% type I error, the expected proportion in the population (p) was 7% based on our initial pilot study of university undergraduates, and the absolute error (d) was 5%. Therefore, our study required at least 100 subjects to obtain a cross section of average-knowledge Americans. A random number table (Steel and Torrie 1980) was used to determine who to approach to take our survey. Surveys were conducted at military instillations, Wal-Mart stores, and city parks. Permission to ask their employees and clientele to participate in our survey was obtained from base commanders and Wal-Mart stores prior to initiating contact with participants. Randomly selected people from the general public >18 years old (n = 25 for each location) were approached and asked to take our survey. Surveys were conducted during spring 2014. To examine non-response bias, we encouraged 10% of the initial non-respondents to take our survey. Answers of respondents and initial non-respondents were compared using Chi-square analysis with the Yates correction for continuity (Steel and Torrie 1980).

For statistical analysis, categorical demographic data were combined and condensed when necessary. Chi-square tests (PROC CATMOD, SAS Institute 2013) were used to analyze main and all combinations of interactive effects on participant responses to questions. For example, the effects of age × ethnicity, age × gender, gender × education

Table 1. Survey questions and associated responses concerning general knowledge of raccoons and their behavior and specific questions concerning Baylisascaris procyonis.

	General knowledge[a] true/false statements	T[c] %	F[c] %	NS[c] %
1	Raccoons are very good climbers.	90	3	7
2	Raccoons are omnivores, eating plants, fruits, insects, and animals.	76	11	13
3	Raccoons "wash" their food before eating it.	39	42	19
4	Raccoons are not attracted to pet food left outside.	3	85	12
5	Raccoons are attracted to food waste in garbage cans.	97	1	3
6	Generally, raccoons defecate in communal sites known as latrines.	37	24	39
7	Generally, raccoon populations are lower in areas populated by humans than in the wild.	30	47	23
8	Raccoons are only active at night.	51	40	9
9	Raccoons have large populations in every county in Texas.	39	18	43
10	Raccoons are not aggressive and make good pets.	13	77	10
11	The only disease raccoons can pass on to humans is rabies.	14	59	27
12	Raccoon roundworm is a parasite found in the intestines of infected raccoons.	50	44	6
13	Raccoon roundworms only affect raccoons.	9	49	42

	General knowledge[a] check all that apply			Responses[b]
14	Raccoon latrine sties (scat or poop) can be found:			
	□ Base of and in trees	□ Garages	□ Hay or straw stacks	22% selected all 88% selected ≥1
	□ Attics	□ Gardens	□ Chimneys	
	□ Barns	□ Sandboxes		
	□ Shed	□ Firewood piles		

	General knowledge[a] multiple choice questions	Responses[b] %
15	The state of Texas lists raccoons as what type of animal?	
	Game species	3
	Furbearer	11
	Nuisance species	35
	Predator	10
	Varmint	41
16	When does Texas law allow for raccoons to be kept as pets?	
	When owners have proper permits to keep raccoons as pets	6
	Texas law prohibits keeping raccoons as pets	24
	Texas has no laws against keeping raccoons as pets and requires no permission	21
	I'm not sure	49
17	Would you consider keeping a raccoon as a pet?	
	Yes, regardless if it is legal or not	7
	Yes, only if it is legal	3
	No	84

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18	Do you have knowledge of raccoon roundworm (*Baylisascaris procyonis*)?	
	No	87
	Some knowledge	9
	Yes	4

	Targeted[a] true/false statements	T[b,c] %	F[c] %	NS[c] %
19	Raccoons infected with raccoon roundworm parasites can shed more than 1 million parasite eggs per day through their feces.	92	0	8
20	Generally, raccoons will die from raccoon roundworm.	31	31	38
21	Children are more apt to get raccoon roundworm than adults.	31	23	46
22	Protective disposable clothing and gloves should be worn to handle raccoon feces.	69	8	23

	Targeted[a] choose all that apply	Responses[b]
23	Symptoms of raccoon roundworm infection include:	
	□ Headache □ Drowsiness	
	□ Stomach cramps □ Confusion	
	□ Blurred vision □ Unable to hold head upright	31% selected all 69% selected ≥1
	□ Cough □ Dizziness	
	□ Fever □ Loss of muscle coordination	
	□ Unable to walk normally □ Nausea	
24	Results of raccoon roundworm infection include:	
	□ Paralysis	
	□ Blindness	
	□ Coma	38% selected all 62% selected ≥1
	□ Loss of cognitive (brain) development	
	□ Death	

	Targeted[a] multiple choice questions	Responses[b] %
25	The raccoon roundworm parasite can infect what?	
	Raccoons only	0
	Dogs, cats, and raccoons	15
	Birds and raccoons	0
	Humans, raccoons, and wild mammals	0
	All of the above	77
	I'm not sure	8
26	Raccoon roundworm eggs will survive in the environment when?	
	Only until sunlight shines on eggs	23
	Until raccoon feces dry	31
	Until next freeze	8
	For years	38

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27	Eggs of raccoon roundworm can be:	
	Inhaled like dust particles	8
	Accidently ingested from contaminated hands	8
	Accidently ingested from contaminated vegetables	8
	All of the above	76
28	To kill raccoon roundworm eggs, the eggs need to be:	
	Soaked in bleach	15
	Washed in detergent	0
	Burned	0
	Any of the above will kill the eggs	85

[a] General knowledge questions were asked before question 18. If the answer to question 18 was "no," respondents needed not proceed to questions 19–28; if "yes" or "some knowledge," respondents then proceeded to questions specific to *Baylisascaris procyonis* (Targeted questions).
[b] General knowledge respondents (n = 100), Targeted respondents (n = 13).
[c] T = True, F = False, NS = Not Sure.

and gender × ethnicity were tested to identify if any proportion of responses to a particular question were attributed to these particular combinations. The age × education interaction was not analyzed, as the level of education may simply be a function of an individual's age. For example, a teenager is unlikely to have greater than some college completed. The ethnicity × education analysis also was not considered due to insufficient data. Due to the large number (approximately 50) of statistical tests performed, we chose an alpha level of 0.005 instead of 0.05.

Results

One hundred people participated in the survey, of which 53 and 47 were male and female, respectively; 58, 30, 4, 4, 3, and 1 were of Hispanic, Caucasian, Middle Eastern, Asian, African-American, and American Indian descent, respectively; 3, 31, 30, 15, 12, 5, and 4 were in their teens, 20s, 30s, 40s, 50s, 60s, and 70s, respectively; and 23, 45, 23, 8, and 1 had a high school diploma, some college, B.A./B.S. degree, M.S./M.A. degree, and a Ph.D./professional degree, respectively, as their highest level of education. Differences were not observed (χ^2 < 0.44, df = 1, P > 0.5) between the answers of respondents and non-respondents; therefore, a non-response bias was not present. Neither main nor interactive effects were observed (χ^2 < 9.2, df < 6, P > 0.03) for any question. General knowledge questions consisted of mixed results, as some questions were answered correctly more frequently than others (Table 1). Of the general knowledge questions, respondents correctly answered questions regarding raccoon behavior more frequently than questions regarding *B. procyonis*. For example, when asked if raccoons were attracted to food waste in garbage cans, 97% of respondents answered correctly. However, when the same participants were asked if raccoon roundworm only affected raccoons, the majority of respondents (51%) answered incorrectly or was unsure.

Of the 100 survey participants, 87% claimed to have no knowledge of *B. procyonis* while only 13% claimed to have at least some knowledge of the parasite. However, of these 13 respondents, no one correctly answered all the targeted questions. The general responses were largely inconsistent as some questions the majority of respondents answered correctly, while other questions were most frequently missed, and differing proportions of correct, incorrect, and unsure responses were noted for the remaining questions. For example, 85% of the 13 respondents answered incorrectly that soaking eggs in bleach or washing them with detergent would kill *B. procyonis* eggs. However, when asked if infected raccoons are capable of shedding millions of eggs per day, 92% answer the correct response of "yes." When asked if children are more vulnerable to raccoon

roundworm infection, the responses were split fairly evenly.

Discussion

Our survey was successful in gauging human awareness and knowledge of raccoons and *B. procyonis*. Survey participants had a cursory knowledge of general raccoon behavior. However, regardless of gender, age, ethnicity, or education, the general public had no knowledge of *B. procyonis* or its associated public health implications. Of the very few respondents who claimed to have knowledge of *B. procyonis*, their responses indicate that respondent knowledge base lacks detailed information regarding the parasite, its effect on human health, and the potential life-altering ramifications of infection.

Baylisascaris procyonis is considered endemic to the midwestern, northeast, and west coast states, where prevalence may range from 68 to 82% (Kazacos and Boyce 1989). Historically, limited or no data existed for *B. procyonis* distribution in some areas of the United States, such as the southeastern states and Rocky Mountain states. Kerr et al. (1997) documented the parasite in southern coastal Texas, where it is now considered common. Subsequent detection efforts in Texas also proved positive for the presence of *B. procyonis* (Long et al. 2006, Kresta et al. 2010).

Therefore, the general public is in need of, and would benefit from, educational outreach regarding the public health implications of *B. procyonis*. Human–raccoon encounters are likely to increase as urban and suburban sprawl increases, and consequently, the general public in at-risk areas needs to be informed of the health threat posed by *B. procyonis*.

Management implications

Due to the public's lack of knowledge on the debilitating and potentially fatal implications of *B. procyonis* infection, every effort should be made to inform local health care professionals, veterinarians, public health officials, wildlife professionals, and the general public about the ecology and human health and safety risks of infection with this parasite. Therefore, a bulletin for the general public was developed and is available online at <http://www.ckwri.tamuk.edu/publications/bulletins/> (Ogdee and Henke 2015). Although the management bulletin focuses on Texas, the information concerning raccoon behavior, *B. procyonis* ecology, dangers to humans, and management recommendations can be relevant to anyone. We recommend that extension biologists make local teachers aware of the management bulletin so teachers can incorporate the information into their lesson plans when teaching wildlife ecology. Often elementary and secondary students discuss what they have learned with their parents. In this manner, several age groups can become educated about this potentially serious parasite.

In addition, state health departments should include surveillance efforts to detect *B. procyonis* prevalence. A 3-pronged approach could be utilized to reduce the frequency of accidental human infection with *B. procyonis*: (1) reducing *B. procyonis* environmental contamination, (2) minimizing contact with contaminated areas, and (3) educating the public regarding the implications of human infection with *B. procyonis* (Kazacos 2001).

Reducing environmental contamination can include treating infected raccoon populations with anthelmintics, lethal removal of raccoons, removal of raccoon latrines, or a combination of these approaches to achieve the best results (Page et al. 2011). The public should be discouraged from utilizing self-feeders for outdoor pets, or using pet doors in areas with high raccoon densities and incidences of nuisance encounters with raccoons. Homes should be wildlife-proofed by repairing damaged roofs and eaves, capping chimneys, and burying fencing around the openings of pier and beam homes. Garbage cans with wildlife-proof lids should be utilized, and pet food containers with any food should never be left in accessible places overnight in order to dissuade raccoon visitors; this may also decrease the chances of raccoon latrines being created in close proximity to human dwellings. Also, because the domestic dog (*Canis familiaris*) has been known to foster patent *B. procyonis* infections (Kazacos 2001), deworming the family dog should be a standard practice.

Minimizing contact with *B. procyonis*-contaminated areas can be accomplished by becoming aware of the habits of wildlife frequenting areas dominated by humans. Increasing the public's awareness and knowledge of how to identify signs of raccoon visitation may help to minimize contact with

contaminated areas. For example, identifying raccoon scats, latrines, and tracks and being aware of where common raccoon latrines may occur in the human environment can help prevent accidental exposure in at-risk areas. The general public also would benefit from awareness regarding the need for added caution with infants and toddlers in areas frequented by raccoons. Infants, toddlers, and individuals with developmental delays or disabilities have a high affinity to place soil and objects, such as toys, in their mouths, and, therefore, are at a higher risk for *B. procyonis* infection (Gavin et al. 2005).

Acknowledgments

We thank the Harry L. Willet Foundation for their generous financial support of this research. We also thank the Caesar Kleberg Wildlife Research Institute and Texas A&M University-Kingsville for providing the facilities. This is contribution number 16-116 of the Caesar Kleberg Wildlife Research Institute.

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Jacob L. Ogdee is a graduate student and research assistant with the Caesar Kleberg Wildlife Research Institute at Texas A&M University–Kingsville. He received his B.S. degree in range and wildlife management from Texas A&M University–Kingsville, and is currently pursuing a master's degree. His research interests include a broad array of topics concerning wildlife ecology, management, and conservation.

Scott E. Henke is a regents professor and chair of the Animal, Rangeland, and Wildlife Sciences Department at Texas A&M University–Kingsville and a research scientist with the Caesar Kleberg Wildlife Research Institute. He received his B.S. degree from Purdue University and his M.S. and Ph.D. degrees from Texas Tech University. His research interests include human–wildlife conflict and zoonotic diseases of mammals.

David B. Wester is a professor in the Animal, Rangeland, and Wildlife Sciences Department at Texas A&M University–Kingsville and a research scientist with the Caesar Kleberg Wildlife Research Institute. He received his B.S. degree from Colorado State University and his M.S. and Ph.D. degrees from Texas Tech University. His research interests involve all aspects of plant and quantitative ecology. A large amount of his professional activities include working with colleagues and students to design experiments and analyze data.