Spatial Ecology of Raccoons at Pierce Cedar Creek Institute, in Relation to Raccoon Latrine Sites Know Foci for the Spread of *Baylisascaris procyonis*, Raccoon Roundworm

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ABSTRACT

The common raccoon (*Procyon lotor*) is susceptible to a species of ascarid worm (*Baylisascaris procyonis*) that lives within their intestinal tract. Though raccoons are the definitive host for this roundworm, it can spread from raccoon feces to intermediate hosts, including humans (Gavin et al. 2005; Roussere et al. 2003). Because raccoons can easily adapt to urban environments, the risk of human infection by this nematode is increased. Once infected, ocular, visceral, and neural complications may occur and can lead to brain damage. If untreated, infection can lead to death (Page et al. 2008; Sexsmith et al. 2009). Because the infection rate of roundworms in raccoons is often higher in certain parts of the United States, including the Midwest, and because the results of infection in humans are so severe, it is important to study raccoon populations to better understand how large a threat we are facing.

Our goal was to determine raccoon population density and habitat use (particularly latrine sites) at Pierce Cedar Creek Institute in Hastings, Michigan. We live-trapped and radio collared raccoons to estimate their home ranges, documented how many latrine sites they frequented, and the location of those latrine sites relative to den sites and home range boundaries. It is important to understand dynamics of the raccoon population to interpret information found about raccoon roundworm at Pierce Cedar Creek Institute (i.e., research submitted by Jessica Meppelink and Sara Leonard to the institute).

We identified 6-9 latrine sites within the estimated home ranges of our five radio-collared raccoons and the number of latrine sites was not correlated with estimated home range size. We estimated 1-5 raccoons used individual latrine sites monitored over a two-week period with game cameras. We documented 18 other species visiting latrine sites, with Eastern fox squirrels, Eastern gray squirrels, and Virginia opossums being the most commonly photographed mammals and wild turkeys were the most commonly photographed birds. Latrine use by multiple raccoons and common visitation by potential intermediate hosts confirmed that latrine sites are important sites for roundworm transfer between hosts.

INTRODUCTION

Raccoons (*Procyon lotor*) are a species common throughout the United States, which have adapted to the point of thriving within urban environments (Gehrt 2003; Gompper and Wright 2005; Sexsmith et al. 2009). The highest population densities of raccoons have actually been recorded in urban areas (Prange et al. 2003). The social system of raccoons can be rather dynamic with gazes (or groups of raccoons) defending territory from other gazes (Prange et al. 2011). Social behavior of raccoons includes the mutual use of latrine sites within overlapping home ranges of gazes, which are often located on elevated horizontal features, such as fallen logs, fences, and barn rafters, or at the base of trees (Page et al. 1998).

Adult raccoon roundworms, *Baylisascaris procyonis,* are a parasitic nematode found in the intestinal tract of the common raccoon. The eggs of *B. procyonis* are shed through raccoon feces at a rate of up to 115,000-179,000 eggs per worm per day (Gavin et al. 2005). Because raccoon roundworm can be passed to other mammals and birds

through their fecal matter, their latrine sites are of particular concern for disease transmission (Page et al. 1999). These latrine sites are communal and are often the location in which other species, such as those traveling through the area or foraging for seeds present in the fecal matter, become infected (Page et al. 2009; Kazacos 2001; Roussere et al. 2003). The use of social latrines combined with the high prevalence of raccoon roundworm, which is up to 82% in the Northeast, Midwest, and Western United States, have caused an increase in public health concerns with this zoonotic infection (Kazacos and Boyce 1989; Kazacos 2001; Murray and Kazacos 2004).

Raccoons may be infected directly via fecal-oral contract or indirectly by ingestion of an infected intermediate host (Kazacos 2001). When larvated eggs are ingested by an intermediate host, they hatch and burrow through the wall of the small intestine to travel throughout host tissues, a process known as larval migrans. Once infected by this roundworm, humans and other intermediate hosts may experience larval migrans that targets neural, ocular, and visceral tissues (Gavin et al. 2005; Roussere et al. 2003), which may result in central nervous system disease in humans and other intermediate hosts (Murray and Kazacos 2004). *B. procyonis* eggs are resistant to changes in pH and desiccation, and they are extremely viable (Shafir et al. 2011). Another factor that has caused an increase in the public health concerns is that raccoons can easily adapt and even thrive in urban environments, bringing infective *B. procyonis* eggs with long-term viability in closer proximity to human activity (Sexsmith et al. 2009).

Our objectives were to document home ranges of raccoons at Pierce Cedar Creek Institute and to determine how many latrine sites were located in a typical raccoon home range. A secondary goal was to determine how many raccoons use particular latrine sites, which is important to better understand the spread of raccoon roundworm among raccoons.

METHODS

We located raccoon latrines by systemically searching PCCI property, with emphasis on rocky crevices, tree stumps, dens, and tree cavities, where latrine sites are typically found (Page et al. 1998). Latrines were flagged, their position determined using GPS, and samples were collected to assay for the presence of raccoon roundworm by another research team.

Raccoons were trapped using Tomahawk live traps baited with canned cat food. Live traps were set in the evening and checked in the early morning. Captured individuals were transported to the laboratory for processing. A portable Isoflurane anesthetic machine was used to initially deliver anesthesia to a plexiglass chamber into which the live trap containing a raccoon was placed. Once the raccoon had lost consciousness, it was removed from the chamber and anesthesia was delivered via a face mask. Professors Keenlance and/or Jacquot were always present for the delivery of anesthesia. While under anesthesia, we recorded body mass and gender. Age was estimated through dental examination (following Grau et al. 1970). Raccoons were fitted with two uniquely numbered ear tags and a radio collar (Advanced Telemetry Systems Model 1550, weight 24g). No capture myopathy (i.e., raccoon death related to capture stress and handling) occurred and recovery of individuals from anesthesia was rapid.

Live trapping, handling, and radio collaring were done in accordance with the American Society of Mammalogists guidelines (Sikes et al. 2011) and was approved by the GVSU Animal Care and Use Committee (Protocol 12-9-A).

We radio collared five raccoons, 4 males (3 adult and 1 juvenile) and 1 adult female. These raccoons were located during the day to delineate den locations and at night while they were foraging. Raccoon locations were determined using portable Telonics TR-4 receivers and three-element Yagi antennas. Day fixes consisted of walk-ins to den sites when raccoons were inactive. Den trees were marked with flagging tape marked with the date and an identification number for the den, and GPS coordinates were taken. Night fixes were taken approximately one hour past sunset. They consisted of triangulations made from taking simultaneous compass bearings from marked GPS locations on the PCCI trail system and along the forest edge, where we stood at least 15 meters apart and recorded the azimuth of the strongest telemetry signal. Night locations were then calculated using Locate III Version 3.34 (Pacer Computer Software, Tatamagouche, Nova Scotia, Canada). Estimated raccoon locations were used to create maps in ArcGIS 10 to depict raccoon home ranges and latrine sites found on PCCI property. We used the 100% minimum convex polygon method to estimate home range size.

Remotely triggered cameras were placed by fresh latrine sites to document raccoon and potential intermediate host visitations. Since a portion of the local population was marked with ear tags, the intent was that examining the images from the cameras would allow us to estimate the number of raccoons visiting a particular latrine. We monitored individual latrine sites for two weeks in three different time intervals, beginning June 21-27, July 12-15, and July 25-26, 2013.

RESULTS

Home ranges

The adult female's home range was estimated to be 13.44 ha and that of the three adult males were estimated to be 9.70, 14.48, and 17.45 ha (Table 1). The juvenile male had a home range estimated to be much smaller than the adult raccoons (4.46 ha). The home ranges of the five raccoons overlapped extensively (Figure 1). Our home range size estimates were not significantly related to the number of locations used to generate the size estimate (Table 2, Pearson correlation, $r = -0.66$, d.f. = 4, $P = 0.22$).

Den sites

We located 24 den sites used by our five collared raccoons. Tree cavities were the most common den site, but other locations included elevated and fallen logs and the meeting of tree branches high in the tree. The three adult males used fewer den sites than the juvenile male and adult female (i.e., adult males: 2, 3, & 5 sites, juvenile male 8 sites, and adult female 10 sites, Table 2). The juvenile was often found with another raccoon of the similar size, presumed to be a sibling. All raccoons reused den sites (Table 3). The adult male with the frequency of 151.234 used a single den four times. The adult female used one den three times and another den five times. The juvenile male used one den twice and two others three times

Latrine sites

We located 48 latrine sites on PCCI's property in the general area of our collared raccoons, 31 of these sites were outside home ranges estimated for our five raccoons. Of the remaining 17 latrine sites, five were unique to one home range, six were found in two home ranges, three were found in three home ranges and three were found in four home ranges (Figure 1).

The adult female had six latrine sites within her home range. The juvenile male and one adult male had seven latrine sites and the other two adult males had nine latrine sites within their home ranges. The number of latrine sites was not correlated with estimated home range size (Table 3, Pearson correlation, $P = 0.96$, $r = -0.03$).

Raccoons were commonly photographed at latrine sites, of these, 18 were marked and 43 were of unmarked individuals. Unfortunately, it was not possible to read the unique tags numbers, which limited our ability to determine how many individuals used specific latrine sites. In 31 cases, raccoons were photographed in such a way that we could not determine whether or not the animal was ear tagged (Table 4).

Significantly more raccoons were recorded during the third time period, beginning July 25-26, than during the first two time periods, beginning June 21st and July 12th (one-way ANOVA, $F_2 = 12.63$, $P = 0.001$). On average, we documented 2.83 ± 2.71 (sd) raccoon visitations per latrine site during the first time period, 1.43 ± 2.50 visitations per latrine site during the second time period, and 10.8 ± 5.27 visitations per latrine site during the third time period.

The most conservative estimate for the number of raccoons visiting individual latrine sites was 1.2 ± 0.9 ($\bar{x} \pm$ sd). The maximum number of raccoons visiting was generated by considering all raccoons as different individuals and was $4.8 \pm 0.5.4$ ($\bar{x} \pm$ sd; Table 4).

We documented 18 additional species at raccoon latrine sites (Table 5). Species with more than then ten occurrences included Eastern Fox Squirrels (*Sciurus niger*, 44), Eastern Gray Squirrels (*Sciurus carolinensis*, 36), Virginia Opossum (*Didelphis virginiana*, 24), and a single feral cat based on its size and coat pattern (*Felis catus*, *15*). A variety of birds visited latrine sites, but in general, their occurrence was uncommon, with American Robins (*Turdus migratorius*, 6) and wild turkeys (*Meleagris gallopavo*, 9) being the most common visitors.

Table 1. The number of latrine sites found within each individual raccoon's estimated home range, which was estimated used 100% minimum convex polygon.

Raccoon	Age/Gender	No. of latrine sites within HR	Home range estimate
151114	Adult Male	7	17.45
151173	Adult Male	9	14.48
151234	Adult Male	9	9.70
151194	Adult Female	6	13.44
151151	Juvenile Male	7	4.46

Table 2. The number of telemetry locations collected for each radio collared raccoon. Dens represent the number of times the raccoon was pinpointed to a particular den, and movements points represent the number of locations triangulated from night tracking. Near points depict day locations that we were not close enough to pinpoint the raccoon's exact location but could detect that the raccoon's den was within a fifty-meters. The total depicts all of the points found per raccoon throughout the entire study.

Raccoon	Age/Gender	Den	Movement	Near	Total
151114	Adult Male	2	23	0	25
151173	Adult Male	5	23	2	30
151234	Adult Male	3	20	5	28
151194	Adult Female	10	22	0	32
151151	Juvenile Male	8	22	3	33

Table 3. The number of unique den sites used by each raccoon.

Raccoon	Age/Gender	Number of unique den sites used
151114	Adult Male	2
151173	Adult Male	7
151234	Adult Male	5
151194	Adult Female	4
151151	Juvenile Male	7

Table 4. The number of raccoons documented at latrine sites during summer 2013 at PCCI. Marked raccoons were ear-tagged. Unknown raccoons were individuals photographed in such a way that we could not determine if they had an ear tag. The column total visits is the sum of the first three columns and represents an upper limit for the number of raccoons visiting a latrine site. The minimum number of visiting raccoons is the most conservative minimum estimate for the number of raccoons visiting a latrine site.

Camera ID	Latrine Site	Time Frame	Marked Raccoons	Unmarked Raccoons	Raccoon	Total visits	Min. No. Visiting Raccoons
A	1	1 (June 21)				0	0
B	1	1 (June 21)	1	5		6	2
C	2	1 (June 27)				0	0
D	2	1 (June 27)	1	2		3	2
E	3	1 (June 24)		1	1	2	1
F	3	1 (June 24)		5	1	6	1
A	4	2 (July 15)				0	0
B	4	2 (July 15)	1	4	1	6	2
D	5	2 (July 15)				0	0
E	6	2 (July 15)			1	1	1
F	6	2 (July 15)		1	1	2	1
H	7	2 (July 15)				0	0
I	7	2 (July 12)		1		1	1
A	8	3 (July 25)	2	7	3	12	2
B	8	3 (July 25)	5	7	7	19	2
E	9	3 (July 26)	1	4	1	6	2
F	9	3 (July 26)	1	3	1	5	2
G	10	3 (July 26)	5	2	7	14	2
H	11	3 (July 26)	1	1	7	9	2
Total			18	43	31		

Table 5. Eighteen other species were documents at raccoon latrine sites during summer 2013 at PCCI.

Camera ID	Latrine Site	Time Frame	Virginia Opossum	Eastern Cottontail	Woodchuck	Eastern Gray Squirrel	Eastern Fox Squirrel	Red Squirrel	White-footed Mouse	Domestic Cat
A	1	1 (June 21)			1	1				
B	1	1 (June 21)				7	2			
C	2	1 (June 27)				2	1			
D	2	1 (June 27)				10	8			
E	3	1 (June 24)				2	5			
F	3	1 (June 24)								
A	4	2 (July 15)								
B	4	2 (July 15)				2	1			
D	5	2 (July 15)								
E	6	2 (July 15)								
F	6	2 (July 15)								
H	7	2 (July 15)	1			5	3			
I	7	2 (July 12)			1	1				
A	8	3 (July 25)	13	6	1		3	1		11
B	8	3 (July 25)	7	1		1				4
E	9	3 (July 26)	1		1	2	6		1	
F	9	3 (July 26)	1		1	2				
G	10	3 (July 26)			1	1	10			
H	11	3 (July 26)	1		1		5			
Total			24	7	7	36	44	1	1	15

Camera ID	Latrine Site	Time Frame	White-tailed Deer	American Woodcock	Wild Turkey	Barred Owl	Pileated Woodpecker	Blue Jay
A	1	1 (June 21)						
B	1	1 (June 21)	1					
C	2	1 (June 27)						
D	2	1 (June 27)						
E	3	1 (June 24)				1		
F	3	1 (June 24)					1	
A	4	2 (July 15)	1					
B	4	2 (July 15)						
D	5	2 (July 15)						
E	6	2 (July 15)	1					
F	6	2 (July 15)			8			
H	7	2 (July 15)			1			
I	7	2 (July 12)						
A	8	3 (July 25)		2				
B	8	3 (July 25)						
E	9	3 (July 26)					2	
F	9	3 (July 26)						
G	10	3 (July 26)	2					1
H	11	3 (July 26)						
Total			5	2	9	1	3	1

Camera ID	Latrine Site	Time Frame	Gray Catbird	American Robin	Northern Cardinal	Rose-Breasted Grosbeak	Unknown	Unknown bird
A	1	1 (June 21)						
B	1	1 (June 21)					1	
C	2	1 (June 27)						
D	2	1 (June 27)					1	
E	3	1 (June 24)					1	1
F	3	1 (June 24)					1	
A	4	2 (July 15)						
B	4	2 (July 15)					1	
D	5	2 (July 15)						
E	6	2 (July 15)						
F	6	2 (July 15)						
H	7	2 (July 15)		1				
I	7	2 (July 12)						
A	8	3 (July 25)	2	5			1	2
B	8	3 (July 25)					2	
E	9	3 (July 26)				1	1	
F	9	3 (July 26)						
G	10	3 (July 26)			1		5	2
H	11	3 (July 26)					1	
Total			2	6	1	1	15	5

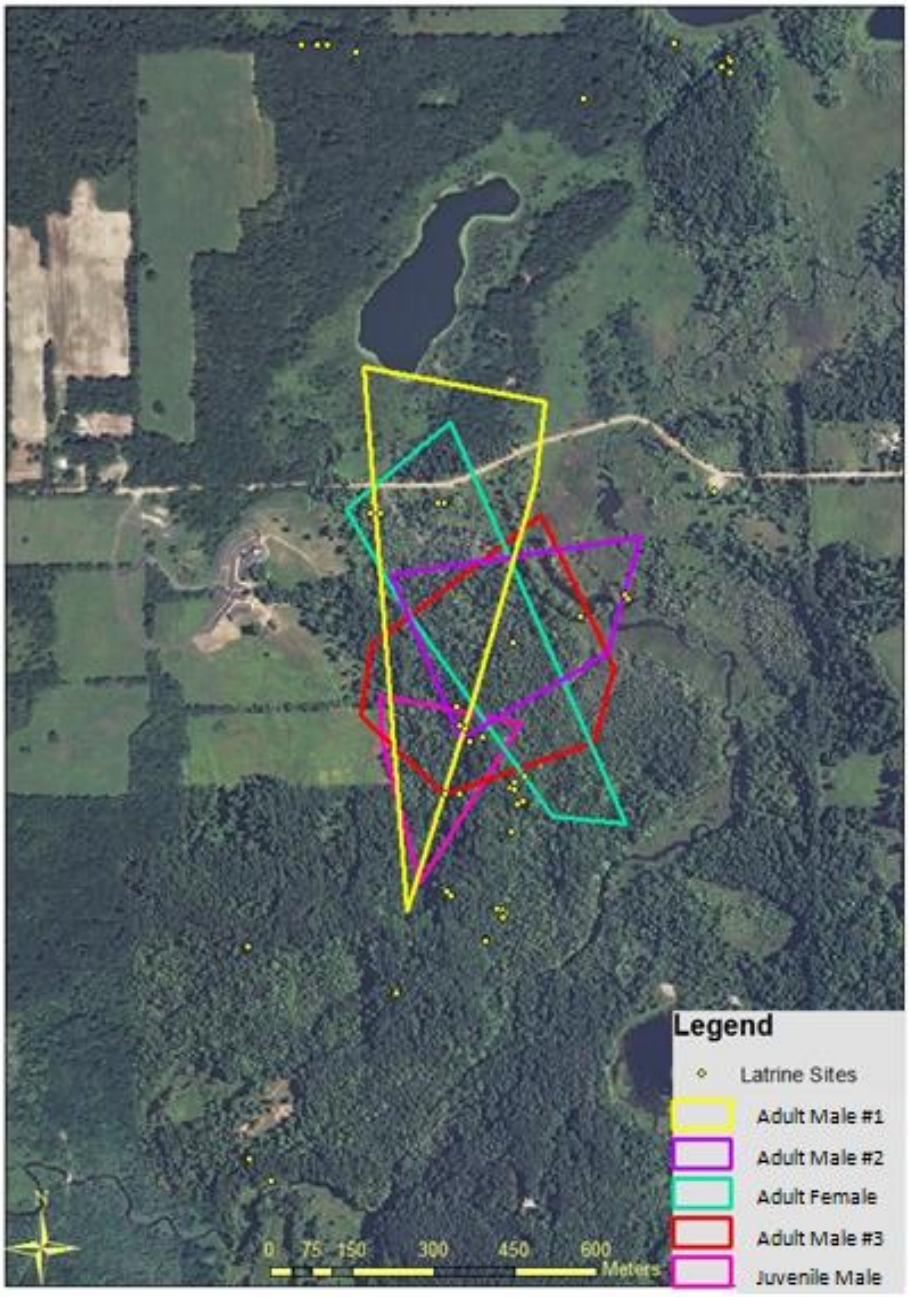

Figure 1. The overlapping home ranges for the all of the radio-collared raccoons and the latrine sites found on PCCI's property. Adult Male #1 represents the raccoon with the frequency of 151144. Adult Male #2 represents the raccoon with the frequency of 151234, and Adult Male #3 represents the raccoon with the frequency of 151173.

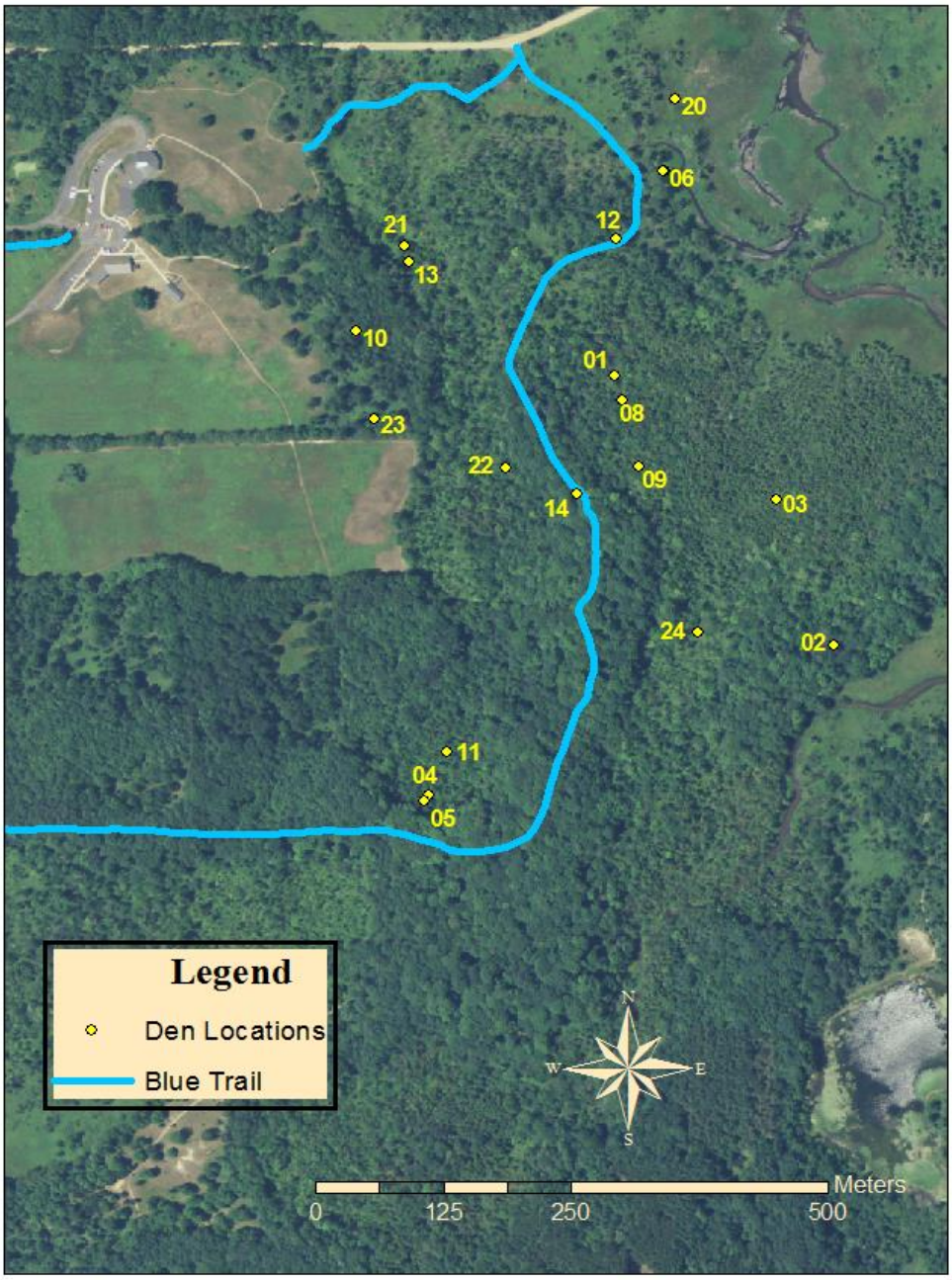

Figure 2. The location of the raccon den sites on PCCI property, Hastings, MI summer 2013.

DISCUSSION

Our home range size estimates were within the broad range reported for this species (Lotze and Anderson 1979). Prange et al. (2004) found rural and suburban raccoons to have home ranges approximately 20-40 hectares in size, but found rural raccoons to have home ranges exceeding 70 hectares. Our home range estimates are relatively low compared to those of Prange et al. (2004). This is likely due to the limited duration and intensity of our sampling and may also reflect the high-quality nature of PCCI property for raccoons.

Our second goal was to determine how many latrine sites were found within typical raccoon home ranges. We found 6-9 latrine sites within our estimated home ranges and this should be viewed as a minimal estimate. It would require systematic searching within known home ranges to determine how close our minimal estimates are to the actual number. To the best of our knowledge this is the first attempted estimation of this variable.

Of the 17 latrine sites we identified within the estimated home range of our five raccoons, only five were unique to a single home range. Twelve of the 17 latrine sites were within the home range of multiple individuals, being shared by 2 – 4 individuals. Historically, raccoon latrine sites have been viewed as foci for disease transmission (e.g., Page et al. 1998) primarily because raccoons are thought to share latrine sites. This is in agreement with the only published estimate of this variable, of 1-7 raccoons sharing a latrine site over the same two-week period we used (Hirsch et al. 2014).

Our final goal to estimate the number of raccoons using latrine sites was hampered by our inability to distinguish unique ear tag numbers in our wildlife camera photographs. Therefore, our minimum estimate could be no greater than two (i.e., one marked and one unmarked individuals). Our maximal estimates consisted of the sum of all raccoon visits to a latrine site. Our estimated range for the number of raccoons visiting latrine sites was 1.2 to 4.8 individuals is in line with Hirsch et al. (2014). Seasonally, the prevalence of raccoon roundworm peaks in the fall (Kazacos 2001) and it is easy to understand how it can spread quickly among raccoons with one infected individual being able to expose multiple individuals at latrine sites.

The latrine sites we identified were on logs or at the base of trees, which have previously been documented for raccoons (Page et al. 1998). These structures are commonly used as pathways and foraging sites for a variety of animals, increasing the likelihood of contact for intermediate hosts. Granivorous animals, such as mice and squirrels, are particularly at risk since raccoon latrine sites can be common foraging sites for them (Page et al. 1999). We found Eastern fox and gray squirrels to be the most common visitors to raccoon latrine sites in support of this idea. It was also common to have Virginia opossums and domestic cats visit latrine sites, less common were white-tailed deer, and Wild Turkey. The transmission of raccoon roundworm to game species, and its impact on their survival have not to the best of our knowledge been considered at this time. Given that photographed domestic cats may or may not be feral, reaffirms the potential risk to house pets (Kazacos 2001). However it is currently thought that if pets are current on heartworm medication they should be protected from infection by raccoon roundworm (Kazacos 2001).

Though the results of this study are limited in sample size and duration they do provide novel quantitative data on the number of latrine sites within raccoon home ranges and the number of raccoons visiting latrine sites. Such quantitative variables should help better model the spread of raccoon roundworm among raccoons and to intermediate hosts.

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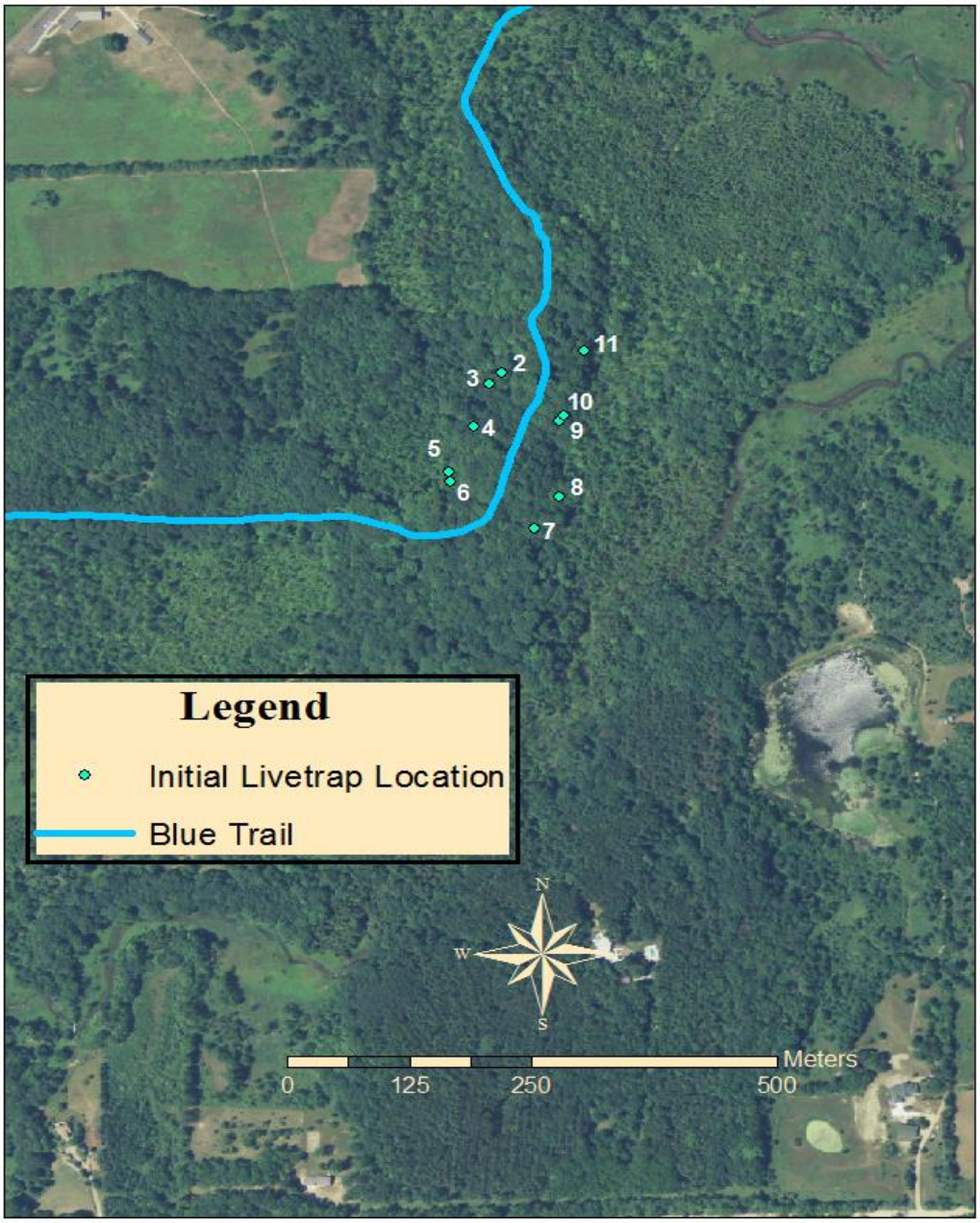

Appendix 1. Live trap locations on PCCI property, Hastings, MI summer 2013.