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Original Article

Prevalence of endoparasites in northern Mississippi shelter cats

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ABSTRACT

Parasitism of domestic cats impacts feline health and public health, when zoonotic parasites are present. Our objective was to evaluate endoparasite prevalence in cats from northern Mississippi animal shelters. Feline cadavers (n = 56) were collected from seven shelters from August 2017 to January 2018. Data included shelter, sex, reproductive status, intake date, originating source, and treatment records. Cadavers were processed to isolate stomach, and small and large intestines. Contents were strained and examined using stereomicroscopes for helminth collection and identification. Centrifugal flotation using Sheather's solution was performed on feces; urine sediments were also examined. Descriptive statistics in SAS was performed using the Frequency procedure. Kappa agreement statistics were obtained to determine agreement between fecal flotation and necropsy results. Separate logis loped to test effects of risk factors on the probability for cats to test positive for ot were recovered in 82% of cats (46/56); specifically, *Ancylostoma* spp. (52%), *T niaeformis* (36%), *Dipylidium caninum* (29%), and *Spirometra* spp. (4%) were ide (66%) had parasite eggs or oocysts on fecal examination, including *T. cati* (39%), ospora spp. (23%), *Spirometra* spp. (9%), *T. taeniaeformis* (9%), and capillarid-type source was associated with presence of *T. cati* eggs in feces and presence of *D.* tract. Feral cats were more likely to have *T. cati* eggs in feces than owner surrend 23), or stray cats (OR 8, 95% CI: 1.1, 57.0). Owner surrender cats were more lik ns in the gastrointestinal tract than stray cats (OR = 19.5; 95% CI: 2.0, 190). *Tox* ement (κ = 0.70, 95% CI: 0.52, 0.89), *Ancylostoma* spp. exhibited moderate agreement (κ = 0.44, 95% CI: 0.22, 0.65), and cestodes exhibited poor agreement (κ = 0.02, 95% CI: −0.12, 0.15) between presence of eggs and gross helminths. Capillarid eggs (*Pearsonema feliscati*) were recovered in urine sediment of 6% (3/48) of cats. Overall, our study demonstrates a high level of parasitism in cats that entered Mississippi animal shelters. Parasites with zoonotic potential, such as *Alaria* spp., *Ancylostoma* spp., *D. caninum, Physaloptera* spp., *T. taeniaeformis*, *T. cati,* and *Spirometra* spp. were identified. Our results support the need for effective antiparasitic treatment of cats entering animal shelters in order to improve feline health and prevent environmental contamination with zoonotic parasites.

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1. Introduction

Society often considers companion animals as important members of the household family. In fact, interactions with these animals have been associated with positive health effects in people, such as reduced anxiety and blood pressure (Friedmann et al., 1983; Wilson, 1991). Ownership of the domestic cat has been on the rise over the last two decades, with American families commonly obtaining cats from either animal shelters or as free-roaming/stray cats (APPA, 2017). While the exact numbers on feline intake and their outcomes are unknown in the shelter industry, The American Society for the Prevention of Cruelty to Animals estimates that in the United States, approximately 3.2 million cats enter animal shelters every year and 1.6 million cats are adopted annually (ASPCA, 2017). Thus, animal shelters handle a large volume of cats, often free-roaming or stray cats with unknown medical histories.

Many studies have demonstrated that free-roaming, stray, and feral cats are commonly affected by both external and internal parasites both

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inside and outside the animal shelter (Shoop et al., 1991; Sabshin et al., 2012; Little et al., 2015; Wyrosdick et al., 2017; Taetzsch et al., 2018). Parasitism is considered the most common form of transmissible disease encountered in feral cats (Burton, 1989; Levy and Crawford, 2004). While parasitism is often higher in stray and feral cats, many owners allow their cats outdoors and differentiation between cat populations can be difficult, especially when they enter an animal shelter with no historical information. High parasite burden can cause significant morbidity, especially in young animals (Bowman, 2009). Cats in shelters are susceptible to environmental and physiologic stress, especially if overcrowding is present, increasing susceptibility to infections and facilitating spread of disease (Sabshin et al., 2012). Animal shelters, therefore, must both address the impacts of parasitism for individual cats and prevent the spread of infectious disease within the population through health protocols.

Additionally, there is concern that many parasites of cats, including *Ancylostoma* spp., *Toxocara cati, Dipylidium caninum,* fleas, and ticks, have zoonotic potential. Human infection with zoonotic parasites can have significant impacts on morbidity, with symptoms ranging from fatigue, respiratory and/or abdominal distress, blindness, and pruritus, to diseases including visceral and cutaneous larva migrans (Centers for Disease Control, 2018). Therefore, shelters must also work to protect both their staff and the public from zoonotic disease. All current guidelines for shelters recommend treatment for diseases with zoonotic potential before leaving the shelter, including hookworm and roundworm infections (Sparkes et al., 2013). Additionally, guidelines suggest that shelters should treat animals based on surveillance and prevalence in the population (Newbury et al., 2010).

While guidelines are meant to be broad and applicable to all sheltering agencies, there is currently a lack of comprehensive prevalence data and of resources to perform continued surveillance. Thus, application of these guidelines and further protocol development have been difficult for shelters. Mississippi currently lacks data on the prevalence of internal parasites in shelter cat populations and many shelters lack veterinary personnel able to assist in the development of specific parasite control protocols due to financial constraints. The objective of this study was to characterize and quantify the prevalence of endoparasites in northern Mississippi shelter cat populations in order to improve approaches in shelter medicine management and increase public awareness associated with zoonotic parasites.

2. Materials

2.1. Sample source

We collected a convenience sample of feline cadavers, previously euthanized by shelters for medical issues or population management. Frozen adult feline cadavers ($n = 56$) were collected during August 2017 to January 2018 from seven animal shelters in northern Mississippi. Shelters were assigned to one of three geographical regions in the northern portion of the state, the Delta, Hills, and Pines regions (Fig. 1). Shelters provided information that included cat reproductive status and sex, intake date, originating source, anthelmintic history, and external parasite control history. The originating source of cadavers was categorized as feral, stray, or owner surrender. If source of origin was not recorded by a shelter employee, origin was left blank so that those observations would be excluded from the statistical models. Length of stay (intake date to euthanasia date) was calculated for cadavers. Cadavers were considered adult if permanent canines, premolars and molars were fully erupted. No cats were euthanized for the purpose of this study, requiring no IACUC protocol.

2.2. Gross parasite collection and analysis

Frozen cadavers were transported from animal shelters to the College of Veterinary Medicine at Mississippi State University and stored frozen until necropsy. Euthanasia dates were known for 32 out of 56 of the cats. For these, approximately 2–4 weeks lapsed between the time of euthanasia to processing. For necropsy, frozen cadavers were first brought to room temperature. The heart, lungs, and liver were observed *in situ* and then opened or sectioned to grossly examine for presence of helminths. The stomach, small intestine, and large intestine were separated for subsequent helminth collection and examination. Each section was opened longitudinally, and blunt mucosal scrapings were obtained. Contents were rinsed with tap water and filtered using 200 µm sieves. Contents were preserved in 70% ethanol for potential future molecular analysis and examined using a stereomicroscope. Helminths were identified based on morphological features to species level when possible (Bowman, 2001).

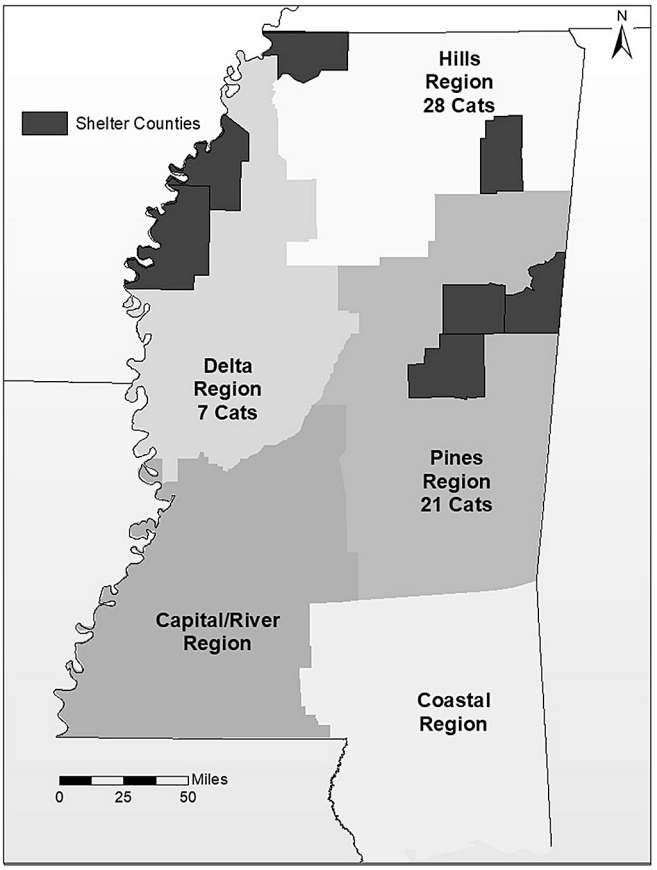

Fig. 1. Regional distribution of cats by shelter county.

2.3. Urinalysis collection and analysis

Urine samples ($n = 48$) were collected from the urinary bladder and refrigerated until examination. Samples were processed using a urine sedimentation technique. Urine was placed into a 15 mL conical tube and centrifuged at 660 x*g* for 6 min. Following centrifugation, supernatant was poured off, and sediment was examined microscopically. The entire coverslip was examined using a 10× objective, and potential parasite stages confirmed using the 40× objective of a compound light microscope. Urinary parasites were identified based on morphological features of eggs to species level (Bowman, 2001; Zajac and Conboy, 2012).

2.4. Fecal collection and analysis

Fecal samples ($n = 56$) were collected from the rectum of individual cats and refrigerated until examination. Samples were processed using a single centrifugation technique using Sheather's sugar solution (specific

gravity 1.27). A minimum of one gram of feces was collected and homogenized with 15 mL of Sheather's solution. Contents were then strained, poured into a 15 mL conical tube, and centrifuged at 660 xg for 10 min. Parasite stages were identified based on morphological features to species level when possible (Bowman, 2001; Zajac and Conboy, 2012).

2.5. Statistical analysis

Descriptive statistics were obtained using frequency procedure (PROC FREQ) in SAS for Windows 9.4 (SAS Institute, Inc., Cary, NC) to determine the percent of samples that were positive for *Ancylostoma* spp., *Cystoisospora* spp., capillarid-type eggs, *D. caninum*, *Spirometra* spp., *T. taeniaeformis*, and *T. cati*. To obtain Cohen's Kappa agreement between fecal microscopy results and gross helminth detection within an individual cat regarding the presence of *Ancylostoma* spp., cestodes, and *T. cati*, PROC FREQ with the "agree" function was utilized. Kappa agreement levels were based on the Landis and Koch publication, where κ values < 0 indicated no agreement, 0–0.20 was slight, 0.21–0.40 was fair, 0.41–0.60 was moderate, 0.61–0.80 was substantial, and 0.81–1 was almost perfect agreement (Landis and Koch, 1977). Separate mixed model logistic regression was utilized to test if origin, region, sex, parasite control status, or the month of euthanasia were associated with the probability for an animal to test positive for *Ancylostoma* spp., *Cystoisospora* spp., capillarid-type eggs, *D. caninum*, *T. taeniaeformis*, *T. cati*, and *Spirometra* spp. Manual forward variable selection was performed within the GLIMMIX procedure with a logit link and binary distribution specified. For independent variables that were significantly associated with a given outcome, LSMEANS with the "diffs" option was used to obtain odds ratios and 95% confidence intervals. Statistical significance was set at $\alpha = 0.05$.

3. Results

3.1. Cat characteristics

Sex and reproductive status of cat cadavers ($n = 56$) was confirmed at necropsy (Table 1). Twenty-nine (52%) cadavers had both intake and euthanasia dates recorded, with cats averaging a 14-day length of stay in a shelter. Of the 56 cats, seven (13%) cats received an anthelmintic, 24 (43%) had no anthelmintic history provided, and 25 (45%) received no anthelmintic upon admittance into the shelter. Thirty-two (57%) received no flea/tick control, and 24 (43%) had no flea/tick control history provided. According to the completed records, flea/tick control at the shelter was not reported for any cats in the study.

Originating source was provided by most shelters, and categories included owner surrender, feral, or stray (Table 1). Regions varied in the number and percentage of cats received. Seven (13%) cats were received from two different shelters located in the Delta Region, 21 (38%) from three different shelters in the Pines Region, and 28 (50%) from two different shelters in the Hills Region (Fig. 1).

Table 1
Sex, reproductive status, and originating source of cat cadavers ($n = 56$).

	Number	Percentage (%)
Sex and reproductive status		
Female	26	46
Spayed female	3	5
Intact female	23	41
Male	30	54
Neutered male	3	5
Intact male	27	48
Source of origin		
Owner surrender	8	14
Feral	10	18
Stray	15	27
Unknown (excluded from analysis)	23	41

Table 2
Prevalence and number of felines positive for parasites, eggs and oocysts present at necropsy.

Parasite	Fecal Parasite Eggs and Oocysts (n = 56)		Gastrointestinal parasite recovery (n = 56)		Urinary parasite eggs (n = 48)	
	Freq	%	Freq	%	Freq	%
Ancylostoma spp.	19	34	29	52	N/A	N/A
Alaria spp.	0	0	3	5	N/A	N/A
Capillarids[a]	3	5	1	2	3	6
Cystoisospora spp.	13	23	N/A	N/A	N/A	N/A
Dipylidium caninum	0	0	16	29	N/A	N/A
Molineus barbatus	UNK[b]	UNK[b]	1	2	N/A	N/A
Physaloptera spp.	0	0	1	2	N/A	N/A
Spirometra spp.	5	9	2	4	N/A	N/A
Taenia taeniaeformis	5	9	20	36	N/A	N/A
Toxocara cati	22	39	24	43	N/A	N/A

[a] Capillarids were identified as *Aonchotheca putorii* based on egg morphology from fecal flotations; capillarid eggs in urine sedimentation were identified as *Pearsonema feliscati*.

[b] Hookworm-like eggs were observed on fecal analysis but could not be differentiated from *Molineus barbatus*. Adult *Ancylostoma* spp. were also recovered from this feline cadaver.

3.2. Descriptive fecal and urine results

Thirty-seven (66%) of the 56 cats had parasite eggs or oocysts recovered on fecal flotation, with 30 (54%) cats actively shedding a zoonotic parasite in the feces. Fourteen cats (25%) had no parasites detected on fecal examination, but had gross helminths present in the gastrointestinal tract. Five cats (9%) had no parasites detected on fecal examination and no gastrointestinal parasites observed at necropsy. Of the 37 cats with a positive fecal exam, 16 (43%) cats harbored a single genus of parasite, and 21 (57%) harbored more than one genus of parasite based on fecal analysis. The percent of cats with parasite stages in the feces and urine was determined (Table 2). *Toxocara cati* was the most common fecal parasite observed. Urine samples from 48 cats were collected; approximately 6% (3/48) of cats were infected with capillarid-type eggs, morphologically consistent with *Pearsonema feliscati*. Due to the prior freezing of cadavers, morphological features of some eggs and oocysts were sufficiently distorted so as to preclude identification to species. However, we identified those eggs and oocysts to species based on descriptions of these species infecting cats in the southeastern United States (Bowman, 2001).

3.3. Descriptive gross helminth results

The presence of gastrointestinal helminths was determined, and prevalence estimates at necropsy are provided in Table 2. Forty-six (82%) of the 56 cats had at least one gross helminth present in the gastrointestinal tract, with *Ancylostoma* spp. (52%; 29/56 cats) being the most common parasite observed, followed by *T. cati* (43%; 24/56 cats), *T. taeniaeformis* (36%; 20/56 cats), *D. caninum* (29%; 16/56 cats), and *Spirometra* spp. (4%; 2/56). Fourteen (25%) cats presented with a single helminth parasite infection in the gastrointestinal tract, 32 (57%) presented with a co-infection. Of the 32 cats, 18 (56%) had two helminth parasite genera present, eight (25%) had three genera present, four (13%) had four genera of parasites, and two (6%) had five genera of parasites present in the gastrointestinal tract. Mean helminth intensity was measured for *Ancylostoma* spp. and T. *cati*. Cat cadavers averaged 6 (range: 0–41) helminths recovered from the gastrointestinal tract during necropsy for *Ancylostoma* spp., and 4 (range: 0–42) for *T. cati*. Of the 56 cats, additional gastrointestinal helminths recovered at

necropsy were as follows: *Alaria* spp. in two cats; co-infection of *Aonchotheca putorii* and *Alaria* spp. in one cat; *Physaloptera* spp. in one cat; and *Molineus barbatus* in one cat.

3.4. Agreement between fecal and necropsy findings

There was substantial agreement (κ = 0.70, 95% CI: 0.52, 0.89) between *T. cati* presence in feces and gross helminths at necropsy. Moderate agreement (κ = 0.44, 95% CI: 0.22, 0.65) was observed between paired fecal and gastrointestinal helminth presence of *Ancylostoma* species. Paired fecal and gross helminth presence of cestodes exhibited poor to no agreement with a Kappa of 0.02 (95% CI: −0.12, 0.15).

3.5. Factors associated with fecal parasite presence

Origin, region, sex, parasite control status, or the month of euthanasia was not associated with the probability to detect *Ancylostoma* spp., capillariad-type eggs, *Cystoisospora* spp. *Spirometra* spp., or *T. taeniaeformis* in fecal samples.

Origin was associated with the probability for a fecal sample to be positive for *T. cati* ($P = .03$). Cats of feral origin had 28 times the odds for fecal *T. cati* presence compared to cats from owner surrender origin (OR = 28; 95% CI: 1.9, 423). Feral cats had 8 times the odds for *T. cati* in fecal samples compared to stray cats (OR = 8; 95% CI: 1.1, 57.0). There was no difference in probability for detection of *T. cati* in feces between stray and owner surrender cats ($P = .30$).

3.6. Factors associated with gastrointestinal helminths

We failed to detect any factors associated with the presence of *Ancylostoma* spp., *Spirometra* spp., or *T. taeniaeformis* in the gastrointestinal tract specimens. Similar to the fecal results, origin was associated with the probability of *T. cati* helminths observed ($P = .02$). Cats of feral origin had 28 times the odds for *T. cati* presence in the gastrointestinal tract compared to cats from owner surrender origin (OR = 28; 95% CI: 1.9, 423). Feral cats had 11 times the odds for *T. cati* in gastrointestinal tracts compared to stray cats (OR = 11; 95% CI: 1.5, 81.8). There was no difference in probability for detection of *T. cati* in gastrointestinal tracts between stray and owner surrender cats ($P = .45$).

Additionally, origin was associated with the probability for detecting *D. caninum* in gastrointestinal tracts ($P = .04$). Interestingly, cats that were taken in by shelters through owner surrender had 19.5 times the odds for *D. caninum* compared to cats obtained as strays (OR = 19.5; 95% CI: 2.0, 190). There was no difference in probability to detect *D. caninum* between feral cats and owner surrenders ($P = .29$) or between feral cats and strays ($P = .07$).

4. Discussion

To our knowledge, this is the first known report of the helminth prevalence in Mississippi shelter cats. Other reports of internal parasitism from the Southeast United States, utilizing fecal analysis, include data from the Companion Animal Parasite Council, (CAPC) for Mississippi, and studies from Florida, Virginia, and Arkansas (Shoop et al., 1991; Wyrosdick et al., 2017; Taetzsch et al., 2018). Our study reports higher fecal parasite prevalence than those observed by the CAPC for *Ancylostoma* spp. (34% vs. 3%, respectively) and *T. cati* (39% vs. 6%, respectively) in the same region (Companion Animal Parasite Council, 2017a, b). Although the sample size used by CAPC was higher with 701 samples, CAPC commonly receives fecal samples from reference laboratories, reflecting owned cats who receive medical care. It may, therefore, not be comparable to shelter data, which reflects a majority of unowned animals without medical care, as studies of other parasitic infections, such as heartworm infection, have found that shelter animals have markedly increased prevalence of infection when compared to owned animals (Tzipory et al., 2010).

In this study, *Ancylostoma* spp. demonstrated a greater fecal parasite prevalence compared to similar shelter studies (Wyrosdick et al., 2017; Nagamori et al., 2018; Taetzsch et al., 2018; Hoggard et al., 2019), but lower compared to a study conducted in Arkansas (Shoop et al., 1991). Additionally, *T. cati* demonstrated a greater fecal parasite prevalence compared to studies conducted in Georgia and Florida (Wyrosdick et al., 2017; Hoggard et al., 2019), but lower in studies conducted in Arkansas, Oklahoma, and Virginia (Shoop et al., 1991; Nagamori et al., 2018; Taetzsch et al., 2018). Prevalence variation between studies may be affected by population size and several additional factors. For instance, geographic, environmental or climatic variation may have a direct effect on a parasite's ability to infect a host (Morand, 2010). It is possible that the prevalence and distribution of parasites in the cat population has changed over time. Additionally, anthelmintic protocols may vary by shelter, thereby introducing another source of variables that may cause differences observed among published studies.

While most studies report fecal parasite prevalence, our study also included necropsy and gross helminth identification with counts from each cat. *Ancylostoma* spp. were most prevalent, being identified in 52% of cats, with *T. cati* (43%), *T. taeniaeformis* (36%), and *D. caninum* (29%) also being prevalent in this population. Notable findings include, *T. taeniaeformis* identified on necropsy 4 times as often as on fecal examination. Additionally, *Diplydium caninum* was only found on necropsy. Both of these findings are consistent with the known limitation of fecal flotation for cestodes (Little et al., 2015). Interestingly, 9% of cats had *Spirometra* spp. eggs found on fecal flotation while only 4% had *Spirometra* spp. identified on necropsy. It is possible that reduced collection of gross *Spirometra* was due to the freezing and thawing process, resulting in the disintegration of samples and possible misidentification of parasites as debris; *Spirometra* spp. eggs are shed via a genital pore and do not depend on the presence of a gravid proglottid in the fecal sample for detection of eggs on flotation (Little and Ambrose, 2000). The freeze/thaw process may also have affected our ability to identify other parasites in the study, including other Platyhelminthes such as *Alaria* spp., which are less resistant to these conditions (Sepulveda and Kinsella, 2013) in comparison to nematodes and also difficult to detect because of their small size (Bowman, 2001). With the exception of *Spirometra* spp., it should be noted that the gross intestinal prevalence was higher than the fecal examination prevalence, demonstrating that, should fecal examination have been used alone, prevalence of parasitism in this population would have been underestimated, as previously mentioned by Lucio-Forster and Bowman (2011).

In our study, comparison of fecal and necropsy results demonstrated that fecal exam exhibited substantial agreement for *T. cati* infections, moderate agreement for *Ancylostoma* spp. presence, and poor to no agreement for cestodes. These findings are consistent with another study of shelter cats which found that fecal exam correctly identified 77% of *T. cati* infections but no *D. caninum* infections (Little et al., 2015). Intact gravid *D. caninum* proglottids containing egg packets are typically passed in the feces, and unless the proglottid is damaged, it is difficult to observe egg packets during a fecal analysis (Centers for Disease Control, 2017). It should be noted that fresh feces are recommended for fecal analysis and our study utilized frozen feces which may have affected yield as several specimen presented with significantly distorted or degraded ova, affecting parasite identification. Even with this limitation, our data suggests that fecal flotation may not be a reliable means of identifying infected animals for targeted treatment. This is especially true regarding the cestodes, *D. caninum* and *T. taeniaeformis*. Furthermore, fecal analysis requires access to microscopes, fecal solution, and ideally to a centrifuge as well as training in the identification of parasites. All of these are resources that may not be available in an animal shelter. Thus, although detection of parasitic infections via fecal analysis remain essential components of companion animal care (Lucio-Forster et al., 2016), they may be impractical in

some animal shelter settings.

Similar to Nagamori et al. (2018) and Hoggard et al. (2019), no effect of sex on fecal parasite prevalence was observed. Analysis of risk factors for cats in our sample demonstrated that only origin was significantly associated with parasitic infection. *Toxocara cati* observed in the feces or gastrointestinal tract was more likely to occur in cats identified as having a feral origin in our study, versus "stray" or "owner surrender" cats. While "feral" cats in animal shelters are generally accepted to be those cats who cannot be handled and show no affinity for humans (Levy and Crawford, 2004), the definition may have been different for each of the shelters contributing samples in our study. The finding of an association between "feral" origin cats and a zoonotic parasite has important implications for shelter management. This finding may suggest that "feral" origin cats enter the shelter infected and, thus, were previously infected in their environment. Feral cats in urban settings often live in colonies, centered around feeding stations provided for by a humane caretaker (Centonze and Levy, 2002). In instances like this, it becomes increasingly important to stress public health education, and simple precautions like hand washing are tangible solutions to prevent zoonotic diseases such as toxocariasis. Human toxocariasis infections are treatable and preventable and are designated as a neglected parasitic infection due to the severe health implications associated with the parasite (Centers for Disease Control, 2017). It is likewise important that these same precautions be taken by shelter staff who may be handling these cats or their feces.

Dipylidium caninum observed on necropsy in the gastrointestinal tract was significantly higher in cats that were surrendered by an owner, versus stray cats, but not compared to feral cats. While cats were classified as owner surrender, stray, or feral by the shelter, the true origin of many of the cats cannot be determined. Previously owned cats may have had a burden of flea infestation, and thus tapeworm infections, equal to or greater than unowned cats. Owner surrender cats may have lacked proper parasite control prior to their admittance into the shelter environment, similar to feral cats, while stray cats may have had access to antiparasitics in the past. As shelters often define stray cats as free-roaming, and lacking an observable household, but more manageable than feral cats, it is possible that stray cats actually belonged to households where they received preventative care but resided outdoors and were inadvertently identified as strays. Thus, shelters should not use origin of the cats to determine what kind of preventive care the cat has received in the past. *Dipylidium caninum* infections are typically observed in cats and dogs but may also be observed in humans if a flea harboring infective cysticercoids is ingested. While we did not perform a complete ectoparasite survey of these cats due to their storage conditions, prior reports indicate that free-roaming cat populations may provide meaningful insight into ectoparasite prevalence (Akucewich et al., 2002; Thomas et al., 2016). Ectoparasites are a common causative agent of dermatological disorders in cats (Akucewich et al., 2002). *Otodectes cynotis* was incidentally found in the fecal samples of five (9%) of the 56 cadavers. This is likely due the ingestion of the *Otodectes* mite during grooming. More than half of the cats did not receive flea/tick preventive and the remainder had unknown preventive status. Additionally, the cats in this study that had a reported length of stay averaged 14 days in the shelter. These findings suggest that shelters should consider prophylactic flea and tapeworm treatment at the time of intake into the shelter environment for all cats, including those with a history of being owned in order to prevent the spread of both ecto- and endoparasites in the shelter environment. With almost 30% of the cats in the population having cestodes present in the gastrointestinal tract, it might also be beneficial to consider treatment of all cats on intake for cestodes, or if resources are limited, to prioritize treatment of owner surrender type cats.

Interestingly, *Molineus barbatus* was observed in one cat during the study. *Molineus barbatus* is a trichostrongylid parasite, and its eggs are similar to those of hookworms (Chandler, 1942). The parasite is commonly found in raccoons (Chandler, 1942; Reinard and Grover, 1964) and bobcats in southeastern United States (Reinard and Grover, 1964; Watson et al., 1981). While there are no known reports of *M. barbatus* in domestic cats from Mississippi, *M. barbatus* was reported in seven cats in Arkansas (Shoop et al., 1991). The eggs of *M. barbatus* and that of hookworms are similar in size and shape, *M. barbatus* helminths often go unnoticed at necropsy due to their relatively small size (Bowman, 2001). Similarly to Shoop et al. (1991), our study did not observe *M. barbatus* eggs upon fecal analysis, but it is possible that hookworm eggs were misidentified.

5. Conclusion

A high prevalence of gastrointestinal parasitism was detected in Mississippi shelter cats and is likely associated with access to intermediate hosts, and lack of parasite control prior to shelter confinement. This is significant for individual cat health as well as shelter population management. Our findings demonstrate that fecal examination, while a useful tool, underdiagnoses infections and may not be a good use of a shelter's limited resources. Instead, routine internal/external parasite control should be recommended for all cats. This parasite control should primarily focus on *Ancylostoma* spp. and *T. cati* as both were prevalent within the population and have zoonotic potential. Additionally, shelter personnel should be educated on the proper ways to handle feral cats and their feces to reduce transmission risks of *T. cati*. Parasitized feral or stray cats that cannot be treated may pose a potential health risk to people and owned cats if released into the community. Use of oral anthelmintics that can be mixed in food and provided to cats which cannot be handled, may provide shelters with a feasible means to decrease parasitic burden in their feline population. Targeted treatment of owner surrender type cats for cestode infections may also be beneficial to improving feline health within the shelter. Zoonotic disease may be best minimized through targeted public prevention efforts, such as environmental management, public health education, and routine parasite control for indoor and outdoor cats.

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Declaration of Competing Interest

None.

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