Research paper

Ectoparasites of free-roaming domestic cats in the central United States

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ABSTRACT

Free-roaming domestic cat (Felis catus) populations serve as a valuable resource for studying ectoparasite prevalence. While they share a similar environment as owned cats, free-roaming cats do not receive routine veterinary care or ectoparasiticide application, giving insight into parasite risks for owned animals. We examined up to 673 infested cats presented to a trap-neuter-return (TNR) clinic in the central United States. Ectoparasite prevalences on cats were as follows: fleas (71.6%), ticks (18.7%), Felicola subrostratus (1.0%), Cheyletiella blakei (0.9%), and Otodectes cynotis (19.3%). Fleas, ticks, and O. cynotis were found in all months sampled. A total of 1117 fleas were recovered from 322 infested cats. The predominate flea recovered from cats was Ctenocephalides felis (97.2%) followed by Pulex spp. (2.8%), Cediopsylla simplex (0.6%), and Nosopsyllus fasciatus (0.6%). A total of 373 ticks were recovered from 126 infested cats. The predominate tick species was Amblyomma americanum (65.9%) followed by Ixodes scapularis (32.5%), Dermacentor variabilis (10.3%), and Rhipicephalus sanguineus (0.8%). Immature tick stages accounted for 54.7% of all ticks found, highlighting an under-appreciated source of tick burden on domestic cats. The results of this study emphasize the importance of year-round use of ectoparasiticides with both insecticidal and acaricidal activity on domestic cats.

1. Introduction

Free-roaming domestic cat (Felis catus) populations serve as a valuable resource for studying ectoparasite prevalence. Sometimes called community cats, the term free-roaming can be employed to describe feral, stray, and other non-owned cats which are not considered pets and live exclusively outdoors (Centonze and Levy, 2002). Many of these cats have a close association with homes and human activities, sharing a similar environment as domestic pets. However, since these free-roaming domestic cats have limited or no history of veterinary care or ectoparasiticide use, they provide a unique sampling population to estimate risk of ectoparasite exposure for owned cats under veterinary care.

Ectoparasite studies of free-roaming cats provide value over similarly conducted shelter surveys for multiple reasons. Shelters have varying ectoparasiticide protocols, which may differ within a shelter as well, depending on the individual animal’s personality and response to being handled. Shelter animals are obtained from a variety of sources (i.e., owner surrender, confiscation, stray, or feral) and have an unknown history of acaricide use and veterinary care. Variations in shelter holding time prior to sampling also raises the question of whether parasites were acquired prior to shelter acquisition or from contaminated shelter environments. Similarly, shelter surveys may underestimate the prevalence of tick infestations. Ticks feed for a period of 2–14 days (Diamant and Strickland, 1965) and may have fed to repletion and fallen off a host by the time an animal is examined in a shelter survey. Thus, sampling free-roaming domestic cats can provide unique insight into ectoparasite prevalence.

Historically, ectoparasite studies conducted on cats have primarily focused on fleas. This is likely due to the number of recognized flea-transmitted pathogens (i.e., Bartonella spp., Rickettsia felis, Mycoplasma haemofelis, Dipylidium caninum, etc.) and relative ease of flea detection and collection in comparison to other ectoparasites. There are few primary literature reports of natural tick infestations on cats in the United States (Akucewich et al., 2002; Bishopp and Trembley, 1945; Burroughs et al., 2016; Curran...
and Fish, 1989; Magnarelli et al., 1990; Shock et al., 2014) and even fewer comprehensive ectoparasite surveys (Akucewich et al., 2002). The purpose of the current study was to characterize the prevalence of a variety of ectoparasites in a free-roaming domestic cat population presented to a trap-neuter-return clinic in the central United States.

2. Materials and methods

2.1. Feline population

Cats were sampled opportunistically from animals presented to a trap-neuter-return (TNR) clinic in north central Oklahoma, USA. All cats were required to be a minimum of 3 months of age in order to participate in the clinic. Any indication that a cat was owned, as determined by the presence of a collar or microchip, disqualified the cat from participation in the clinic and ectoparasite collection. All research procedures and sample collections were approved by the Oklahoma State University Institution Animal Care and Use Committee (IAUC). Trappers signed a waiver permitting these samples to be collected and data used for research and publication. Cats were anesthetized prior to examination (Williams et al., 2002) in accordance with the clinic’s protocols.

Cats were aged by dentition (Human Society of the United States (HSUS), 1996) and grouped into 3 categories: less than 6 months of age (<6mo), between 6 months and 2 years of age (6mo–2yr), and greater than 2 years of age (>2yr) at time of presentation (Holmstrom et al., 2013; Vogt et al., 2010). Additional information collected included the physical location from which they were trapped and coat length (Dallas et al., 2006).

Sampling corresponded with the dates of the trap–neuter-return clinic, occurring once each month from January–May and September–November 2014.

2.2. Fleas and ticks

Cats were examined for fleas and ticks by parting the coat and visually examining for ectoparasites, as well as combing through the coat using a flea comb (Dryden et al., 1994; Marchiondo et al., 2013). For the current study, time spent examining a cat and removing ectoparasites was limited to 2 min per animal. All ticks found were removed using forceps and recommended removal technique (Centers for Disease Control and Prevention (CDC), 2015; Marchiondo et al., 2013). Evidence of flea infestation was recorded when either the presence of fleas or flea frass was noted. Fleas were caught opportunistically for identification. Flea burden was not determined. Fleas and ticks were stored in 100% ethanol until identification. Fleas were identified using taxonomic keys (Centers for Disease Control and Prevention (CDC), 1969; Fox, 1940; Hopkins and Rothschild, 1953; Hubbard, 1947; Lewis et al., 1988; Traub et al., 1983). Tick species and life stage were identified using taxonomic keys (Clifford et al., 1961; Diamant and Strickland, 1965; Keirans and Durden, 1998; Keirans and Litwak, 1989).

2.3. Lice and fur mites

A 3 cm × 3 cm section of fur was clipped over the jugular furrow from the ventral portion of the animal’s neck to facilitate venipuncture. This hair was collected and placed in an individual, sealed plastic bag in 70% isopropanol until examination. Fur samples were analyzed for 3 min each under dissecting microscope for presence of lice (Felicola subrostratus) or fur mites (Cheyletiella blakei and Lynxacarus radovsky). Lice were identified using appropriate references (Bowman, 2014; Zajac and Conboy, 2012).

2.4. Ear mites

On each cat sampled, the vertical portion of the external ear canal was swabbed using cotton-tipped applicators regardless of presence, color, or texture of exudate. Each swab was placed in an individual vial until examination. Each swab was examined individually using a stereomicroscope within 5 h of collection. Swab surfaces were examined for all life stages of Otodectes cynotis.

2.5. Data analyses

The prevalence of ectoparasite infestation was calculated according to Bush et al. (Bush et al., 1997). 95% confidence intervals were calculated according to Sterne’s exact method (Reiczigel, 2003) using Quantitative Parasitology 3.0 (Rózs et al., 2000). Comparisons of the prevalence of fleas, ticks, and ear mite among months sampled and age group of cats were done using Chi-square (Sokal and Rohlf, 1997). Chi-square tests were performed using SigmaPlot 12.5 (Systat Software Inc., San Jose, California, United States). The prevalence of lice and fur mites were not compared statistically due to the low occurrence of parasites. Statistical significance was assumed at α = 0.05.

3. Results

3.1. Feline population

A total of 941 cats were presented during eight clinics held January–May and September–November 2014. Cats were trapped throughout the state of Oklahoma and from southern Kansas. Of these, 673 cats (71.5% of all cats presented to the TNR clinic) were examined for flea and tick infestation (Table 1). Ages were recorded for 658 of the cats studied for fleas and ticks: 142 cats (21.6%) were <6mo, 385 (58.5%) were 6mo–2yr, and 131 (19.9%) were >2yr.

Hair samples from 589 cats (62.6% of all cats presented to the TNR clinic) were analyzed for lice and fur mites from March–May and September–November. Ages were recorded for 520 of the cats from which hair samples were collected; 80 (15.4%) were <6mo, 325 (62.5%) were 6mo–2yr, and 115 (22.1%) were >2yr.

A total of 472 cats (50.2% of all cats presented to the TNR clinic) were studied for ear mite infestation during the clinics held April–May and September–November. Of the cats examined for ear mite infestation, ages were recorded for 470 animals, and 103 (21.9%) were <6mo, 275 (58.5%) were 6mo–2yr, and 92 (19.6%) were >2yr.

3.2. Fleas and ticks

Of 673 cats examined, 479 (71.6%) cats had evidence of flea infestation (Table 1). Fleas were found in all months sampled. The prevalence of fleas on cats varied ($X^2 = 104.487$, df = 7, $P < 0.001$) by month. The prevalence of fleas or flea dirt was highest in January, September, and October and lowest in April (Supplemental Table 1). The prevalence of fleas varied ($X^2 = 7.948$, df = 2, $P = 0.019$) according to the age of cats with infestations detected on 73.3% of cats <6mo, 66.0% of cats 6mo–2yr, and 78.5% of cats >2yr. A greater proportion ($X^2 = 7.948$, df = 1, $P = 0.019$) of cats >2yr had flea infestations in comparison to cats 6mo–2yr.

Identifications were determined for 1117 fleas collected from 322 cats. Between 1 and 25 fleas were collected per cat. Ctenocephalides felis was identified on 313 (97.2%) cats, Pulex spp. on 9 (2.8%) cats, Cheyletiella simpllex and Nosopsyllus fasciatus were identified on 2 cats each (0.6%, respectively). Two or more fleas were collected from 205 cats. Of these, 199 cats had single species infestation with C. felis. One cat had Pulex spp. only. Four cats had dual
infestations of *C. felis* and *Pulex* spp.; one cat was infested with both *C. felis* and *N. fasciatus*.

Of 673 cats examined, a total of 373 ticks were found on 126 cats. Ticks were found in all months sampled. The prevalence varied ($X^2 = 40.984$, df = 7, $P = < 0.001$) by month (Supplemental Table 1). The prevalence of ticks on cats ranged from 2.1% in January to 37.1% in May with an overall prevalence of 18.7% (15.9%–21.9%) (Table 1).

Four tick species were found on the cats: *Amblyomma americanum*, *Ixodes scapularis*, *Dermacentor variabilis*, and *Rhipicephalus sanguineus*. *A. americanum* was found on 83 cats, *I. scapularis* on 41 cats, *D. variabilis* on 13 cats, and *R. sanguineus* on 1 cat. Two or more ticks were collected from 63 cats. Of the cats with multiple ticks recovered, 36 cats had a single species infestation with *A. americanum*, 15 had *I. scapularis* only, and 1 had *D. variabilis* only. Six cats had a mixed infestation of *A. americanum* and *D. variabilis*, while 3 were infested with *A. americanum* and *I. scapularis*. One cat each had the following dual infestations: *A. americanum* and *R. sanguineus*; *I. scapularis* and *D. variabilis*. One cat was infested with three species of ticks: *A. americanum*, *I. scapularis*, and *D. variabilis*. All motile life stages of ticks were found including larvae, nymphs, and adults of *A. americanum*; nymphs and adults of *D. variabilis*, adult *I. scapularis*, and adult *R. sanguineus* (Tables 1 and 2). The burden of ticks on cats ranged from 1 to 40 ticks per cat. These cats with more than 10 ticks per cat comprised 32.2% of the ticks recovered. The majority of these ticks were *A. americanum* (92.5%) comprised of adults (12.6%), nymphs (32.4%), and larvae (55.0%). The remainder were adults and nymphs of *D. variabilis* and *I. scapularis*. The cat with 40 ticks was infested with 5 nymphs and 35 larvae of *A. americanum*.

### 3.3. Lice and fur mites

A total of 589 hair samples were analyzed from March–May and September–November 2014. *Felicia subrostratus* was found in 6 of 589 (1.0%; 0.5%–2.2%) of hair samples. The number of positive samples by month were as follows: March (1 of 119), April (0 of 111), May (1 of 62), September (3 of 113), October (1 of 101), and November (0 of 83).

Chyletiella blakei was found in 5 of 589 (0.9%; 0.3%–2.0%) hair samples. The number of positive samples by month were as follows: March (0 of 119), April (0 of 111), May (2 of 62) September (0 of 113), October (1 of 101), and November (2 of 83). In October, one cat was infested with both *F. subrostratus* and *C. blakei*; the cat was also heavily infested with fleas.

### 3.4. Ear mites

A total of 472 cats were examined for ear mite infestation during the clinics held April–May and September–November 2014. *Otodectes cynotis* was found in 91 of 472 (19.3%; 15.9%–23.2%) cats examined. The prevalence of *O. cynotis* ranged from 10.9% in May to 23.5% in April (Table 5). A statistically meaningful difference ($X^2 = 4.899$, df = 4, $P = 0.298$) was not found in the prevalence of *O. cynotis* infestation according to the month cats were sampled nor age.

### 4. Discussion

While management of free-roaming cats is a controversial topic (American Veterinary Medical Association (AVMA), 2016; Ash and Adams, 2003; Wald and Jacobson, 2014), these animals provide an invaluable resource for studying ectoparasite burdens. Community cats share the same outdoor environment with pet cats, but traditionally do not receive routine veterinary care including insecticide or acaricide application. This allows for evaluation of ectoparasite risk for both owned and non-owned animals.

Flies commonly infest domestic cats (Dryden et al., 1994), and 71.6% cats examined in the current study had evidence of flea infestation. This is consistent with a shelter survey conducted in the same region as the current study, which showed evidence of flea infestation on 73.3% (85 of 116) of cats (Little et al., 2015). Fleas were found in all months studied and the prevalence of flea infestation ranged from 43.1% in April to 89.3% in September.

In a similarly conducted ectoparasite study of free-roaming cats presented to a TNR program in Florida, 92.5% of the animals were...
found to be infested with fleas, but prevalence was not found to vary by month (Akucewich et al., 2002). Climate and time of year likely account for the differences in flea prevalence between these studies. Despite high flea prevalences reported in ectoparasite studies, they are likely overlooked during routine physical examination at veterinary hospitals. In a nationwide study, flea infestation was a reported finding on only 9.2% of cats during examination (Lund et al., 1999). The high prevalence of fleas on free-roaming domestic cats suggest that risk to owned domestic cats is high and substantiates year-round use of labeled flea preventives.

In the current study, four flea species were found infesting domestic cats: *Ct. felis*, *Pulex* spp., *C. simplex* and *N. fasciatus*. All four species of fleas found in the current study have been reported on wildlife in the surrounding regions (Eddy, 1943; Ellis, 1955; Portman, 1944). The wildlife-associated flea species, *C. simplex* and *N. fasciatus*, could have resulted from exposure while pre-dating wildlife or could be reflective of habitat and lifestyle of free-roaming cats.

In contrast to fleas, there are few primary literature reports of ticks naturally infesting cats in the United States (Adolph, 2013; Akucewich et al., 2002; Anderson and Magnarelli, 1980; Bishop and Trembley, 1945; Burroughs et al., 2016; Curran and Fish, 1989; Magnarelli et al., 1990). This may stem from the common misperception that cats are not suitable hosts for ticks, are fastidious groomers, or from difficulty in conducting such studies. Of ticks recovered in veterinary clinics, less than 2% are recovered from cats in comparison to dogs (Burroughs et al., 2016), which may lead veterinary professionals to underestimate this ectoparasite burden. However, cats are brought to a veterinarian with decreased frequency in comparison to dogs (Volk et al., 2011) and usually are less than willing participants in a thorough examination. Challenges encountered during laboratory infestations appear to perpetuate the belief that only certain tick species and life stages will feed on cats (Marchiondo et al., 2013). The common occurrence of ticks on free-roaming domestic cats suggest that risk to owned domestic cats is high and warrants year-round use of labeled acaricides.

To the authors’ knowledge, the current study comprises the most ticks reported from naturally infested domestic cats in the United States to date. The 373 ticks identified account for greater than 70% of all primary reports of ticks naturally infesting U.S. domestic cats. Over eighteen percent (18.7%) of cats examined were infested with ticks, with a prevalence as high as 37.1% during one month of the study. It’s likely that even the current study underestimated tick prevalence and burden due to the time limitation of 2 min to examine each animal, as well as the difficulty in finding and recovering immature ticks within a short duration. Our results were consistent with the work of Magnarelli et al. (1990) in the northeastern United States, which showed 23.7% of owned, domestic cats examined were infested with ticks. Tick-borne disease studies have reported up to 15.5% (25 of 161) of healthy domestic cats presented to veterinary clinics are PCR-positive for *Cytaxozoon felis* in enzootic areas (Rizzi et al., 2013), suggesting that tick infestation is not unique to free-roaming cats.

Infestation of domestic cats by immature tick life stages (larvae, nymphs) is underappreciated. In the current study, all motile life stages of ticks (larvae, nymphs, and adults) were present on cats, with immature, motile stages comprising 54.7% of all ticks found. Our results were consistent with other studies, in which larval and nymphal ticks accounted for up to 61.1% of ticks infesting domestic cats (Bishop and Trembley, 1945; Burroughs et al., 2016; Magnarelli et al., 1990).

Table 2

<table>
<thead>
<tr>
<th>Species</th>
<th>Adult</th>
<th>Nymph</th>
<th>Larva</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Amblyomma americanum</em></td>
<td>69 (46 females, 23 males)</td>
<td>103</td>
<td>94</td>
<td>266</td>
</tr>
<tr>
<td><em>Ixodes scapularis</em></td>
<td>84 (63 females, 21 males)</td>
<td>0</td>
<td>0</td>
<td>84</td>
</tr>
<tr>
<td><em>Dermacentor variabilis</em></td>
<td>12 (8 females, 4 males)</td>
<td>7</td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td><em>Rhizophalus sanguineus</em></td>
<td>4 (1 female, 3 males)</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>169 (118 females, 51 males)</td>
<td>110</td>
<td>94</td>
<td>373</td>
</tr>
</tbody>
</table>

Though at least nine species of ticks have been reported to infest domestic cats in the United States (Bishop and Trembley, 1945), both immature and mature stages of four tick species were found in the current study: *A. americanum*, *D. variabilis*, *I. scapularis*, and *R. sanguineus*. Additional tick species and life stages may have been detected if the TNR clinic was conducted each month of the year when other tick species are more active.

It was somewhat surprising to find *R. sanguineus* on only 1 cat in the current study. Though consistent with other reports from the United States (Akucewich et al., 2002; Burroughs et al., 2016), these results are dissimilar to other studies (Mendes-de-Almeida et al., 2011) which found that 1.4% of all cats examined were infested with *R. sanguineus*. Worldwide, over ten *Rhizophalus* spp. have been documented to infest domestic cats (Walker et al., 2000). *R. sanguineus* is known to infest premises, and the free-roaming nature of the current study’s cat population may account for the decreased prevalence in comparison to urban or owned populations. Additionally, *Rhipicephalus* spp. have shortened mouthparts, which may allow cats to more successfully remove them by grooming. This is unlikely the sole reason for a low observed prevalence, as another tick with shortened mouthparts, *D. variabilis*, accounted for 5.1% of ticks collected in this study. The *R. sanguineus* group is currently undergoing re-classification (Dantas-Torres et al., 2013). As more is learned about genetic and behavioral differences, it may be determined that one or more *R. sanguineus* species are present in the United States. The *Rhipicephalus* species present in the United States may be less accepting of a felid host.

*Fellicola subrostratus*, was found on roughly 1% of cats sampled in the current study. Though this prevalence is in agreement with a similar study conducted on feral cats in Florida (Akucewich et al., 2002), it may underrepresent natural infestation due to site predilection on the host. *F. subrostratus* is most commonly identified on the head and dorsum of the animal (Wall and Shearer, 2001) but may occur almost anywhere (Bowman, 2014; Mullen and Durden, 2002). The walking dandruff mite, *Cheyletiella bblakai*, was found on 0.85% of cats sampled, an increased prevalence compared to other studies (Akucewich et al., 2002). The area of hair collection in the current study was closer to *C. bblakai’s* natural site predilection of the cat’s head and dorsal surface (Bowman, 2014; Wall and Shearer, 2001). *Lynxacarus radovskyi* is considered rare in North America (Zajac and Conboy, 2012) and was not observed on any cats in the current study. When found, *L. radovskyi* tends to be located on the cat’s dorsal surface, at terminal parts of the hair (Bowman, 2014; Miller et al., 2013).

*Otodectes cynotis* was detected in 19.3% of cats examined in the current study. In United States veterinary hospitals, ear mites were only recognized in 7.4% of feline patients during examination (Lund et al., 1999). Increased prevalence in feral cats may be explained by the differences in habitat between the two populations, or may signal that *O. cynotis* goes undetected in some veterinary patients. Between 11–15% of cats with normal-appearing ears may...
be infested with *O. cyrtos* [Akuciewich et al., 2002; Sotiraki et al., 2001], necessitating the need for proper diagnosis and routine treatment with effective parasiticides.

5. Conclusions

Cats were found naturally infested with fleas, ticks, lice, fur mites, and ear mites. Ectoparasites were found in all months sampled, validating current recommendations for year-round use of approved ectoparasiticides. This study highlights the prevalence of natural tick infestations on cats. In fact, the ticks reported in the current study account for over 70% of all primary reports of natural tick infestations on cats in the United States to date. Ticks were found in all months studied, and immature, motile stages of ticks (larvae, nymphs) are an underestimated source of tick burden on domestic cats.

Conflict of interest statement

In the past five years, MVR and JET have received honoraria and research support from multiple veterinary pharmaceutical companies. These activities were unrelated to the current study.

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Responsibilities

JET and MVR were responsible for study design, IACUC approval, primary parasite collection, taxonomic keying, statistical analyses, and drafting of the manuscript. LS assisted with logistics and critical manuscript revisions. JG assisted in parasite collection, sample analysis, and data curation. All authors have approved the final version of this manuscript for publication.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.vetpar.2016.07.034.

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