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Epidemiology of Ectoparasites and Gastrointestinal Parasites in Dogs Located in Tanzania: A Cross-Sectional Study

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ABSTRACT

Dogs, common companion animals, serve several cultural, social, and economic functions in society but can pose public health risks if not properly managed. The present study aimed to examine the epidemiology of canine parasites in the Mvomero district and the Morogoro municipality in Tanzania. A cross-sectional study was conducted in 2024 involving 400 randomly selected dogs, aged from 3 months to over 1 year, selected from households in the Mvomero district and the Morogoro municipality of Tanzania. The study population consisted predominantly of indigenous mongrels (n = 372), with a smaller proportion of crossbreeds (n = 28). Ectoparasites were collected through full-body examination, including the skin, ears, and interdigital spaces. Ticks, fleas, mites, and lice were manually removed using forceps and combing, with ticks carefully extracted to preserve their mouthparts. Fleas were collected using an acetone application followed by brushing onto white cloths. All samples were preserved in 70% ethanol and identified morphologically under a light microscope using standard identification keys. Fecal samples were collected from the study dogs and examined using flotation, sedimentation, direct saline/iodine wet mount, and modified Ziehl-Neelsen staining techniques. The overall prevalence of ectoparasites was 83.8%, while gastrointestinal parasites were detected in 76.8% of the dogs. Helminths included *Ancylostoma* spp. (60.5%), *Uncinaria stenocephala* (22.0%), *Toxocara canis* (11.5%), *Toxascaris leonina* (6.3%), *Ascaris* spp. (3.8%), *Taeniidae* (6.0%), and *Dipylidium caninum* (1.8%). Protozoa included *Cryptosporidium* spp. (15.5%), *Isospora* spp. (8.0%), *Cyclospora* spp. (4.3%), and *Entamoeba* spp. (3.0%). Dogs from Mvomero, Tanzania, had significantly higher parasite prevalence than those from Morogoro municipality, Tanzania. Risk factors for parasitic infection included dog age, geographic location, management practices, and lack of deworming. The current study highlighted an alarming burden of parasitic infestations among dogs in Morogoro, Tanzania, posing significant threats to animal health, public health, and animal welfare.

Keywords: Disease, Dog, Ectoparasite, Gastrointestinal parasite, Risk factor, Zoonoses

INTRODUCTION

Dogs were the first animals to be domesticated by humans and continue to play multiple roles in various cultures worldwide (Freedman et al., 2014). In many African countries, including Tanzania, dogs serve important functions such as providing security, assisting in hunting, herding livestock, and occasionally as pets (Swai et al., 2010; Whitfield and Smith, 2014). In Tanzania, the majority of dogs are local mongrels, predominantly reared in rural areas where access to veterinary services is limited (Swai et al., 2010). Pastoral and agro-pastoral communities, including the Maasai, Sukuma, Gogo, Barabaig, and Wambulu, commonly keep large numbers of dogs for security, hunting, and livestock herding purposes (Knobel et al., 2008). In urban areas, dogs are also commonly kept, but they are often mismanaged, allowed to stray, and pose significant public health risks (Swai et al., 2010). Stray dogs are frequently infested with ectoparasites and gastrointestinal parasites due to poor management and the absence of effective disease control programs (Swai et al., 2010). Globally, common ectoparasites of dogs include ticks, fleas, mites, and lice (Kumsa et al., 2011; Costa et al., 2013). Fleas, in particular, are notable vectors for *Yersinia pestis*, the causative agent of plague in humans (Gage et al., 2005). Additionally, gastrointestinal parasites such as *Ancylostomum* spp. and *Giardia* spp. are prevalent worldwide, with their prevalence and severity influenced by factors including age, geographical location, breed, and the nutritional and immune status of the host (Swai et al., 2016). Effective parasite control in dogs requires regular and appropriate use of anthelmintic and antiprotozoal medications, alongside sound husbandry practices (Swai et al., 2016).

Despite the well-established roles of dogs and the recognized health challenges affecting them worldwide, substantial gaps remain in the understanding of the epidemiology of parasitic infestations among dogs in Tanzania, particularly across rural and urban settings. Poor management practices observed in Tanzania can make dogs significant

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reservoirs and vectors for zoonotic diseases (Ernest et al., 2013). While global studies have identified risk factors for parasitic infestations in dogs, including age, sex, body condition, and husbandry practices, there is limited specific data on these aspects in Tanzania (Massei et al., 2017). The Morogoro Region, characterized by a high concentration of pastoralist and agro-pastoralist communities, supports a substantial population of stray dogs that pose a significant risk for disease transmission. Therefore, the present study aimed to determine the prevalence of parasitic infestations and associated risk factors among dogs in Mvomero District and Morogoro Municipality in Tanzania, to address existing knowledge gaps and inform effective control strategies for improved animal and public health.

MATERIALS AND METHODS

Ethics approval

A study permit was provided by the Ethics committee of Sokoine University of Agriculture (SUA/DRPSG/R/126/3/93) in Morogoro, Tanzania, and permission letters at the district level were obtained from the Executive Directors (MVDC/D.30/15/VOL.IV/54).

Study location

The study was conducted in the Mvomero District and the Morogoro Municipality to compare dog husbandry practices in rural and urban areas (Figure 1). Mvomero district, located at 06°26'S and 37°32'E, was chosen for its large population of pastoralists and agro-pastoralists who own many dogs; it has 30 wards, 115 villages, and a population of 312,109 (PHCT, 2013). Morogoro municipality, located on the lower slopes of the Uluguru Mountains between latitudes 5.7° and 10°S and longitudes 35.6° and 39.5°E, comprises 29 wards and 272 streets, with a population of 315,866 based on the 2012 census (PHCT, 2013). The area was selected to facilitate a comparative analysis of dog husbandry practices in both urban and rural settings.

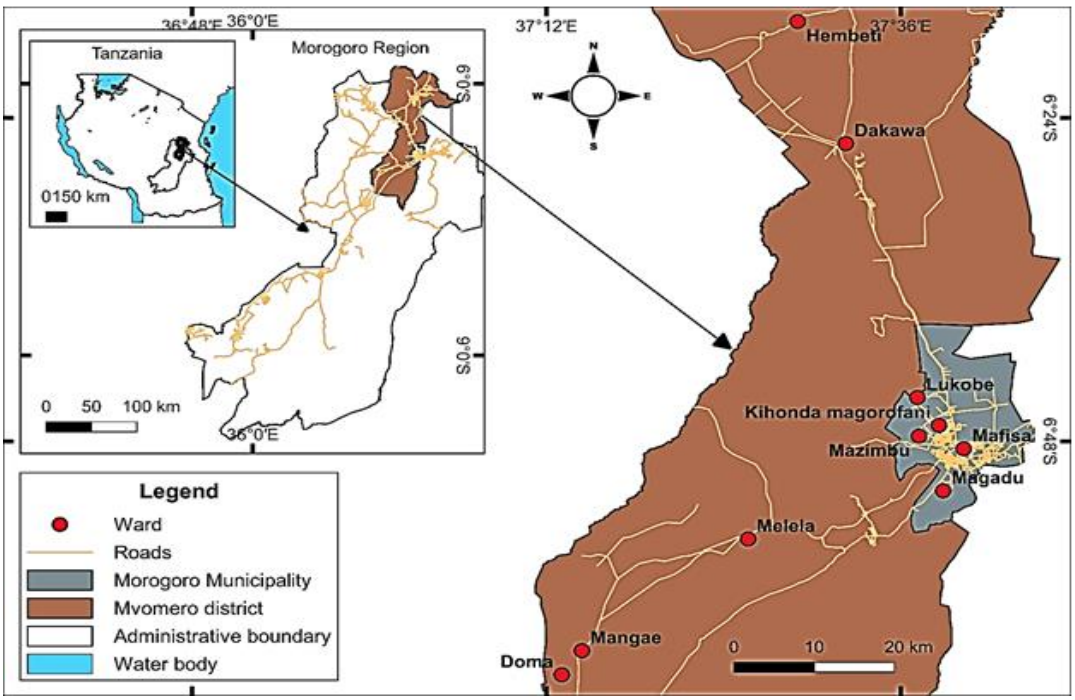

Figure 1. The Morogoro region's location, including Mvomero district and Morogoro municipality. A map was developed in QGIS version 3.29.1. Source: Data catalog for Building Disaster Resilience to Natural Hazards in Sub-Saharan Africa Regions websites (http://riskprofilesundrr.org/layers/geonode:tzwards)

Study design

A cross-sectional study was undertaken to assess the prevalence of ectoparasites, gastrointestinal parasites, and related risk factors in dogs in each district. The study included all households that kept dogs in Mvomero district and Morogoro municipality.

Sampling

Five wards from each district were purposely selected from the 15 wards in Mvomero district and the 29 wards in Morogoro municipality. The selected wards in Mvomero district were Dakawa, Mangae, Melela, Doma, and Hembeti,

whereas those in Morogoro municipality were Magadu, Lukobe, Kihonda Magorofani, Mafisa, and Mazimbu. The study covered 12 villages and 100 households in Mvomero District, as well as 27 streets and 100 households in Morogoro municipality. Only dogs aged three months and above were included in the examination. In households with one to five dogs, all eligible dogs were examined, whereas in households with more than five dogs, three to five dogs were randomly selected for inclusion.

Clinical examination

Before examination and sampling, information on age, sex, breed, management system, history of ectoparasite control, and overall body condition was collected and recorded. Dogs aged three months to one year were classified as young, and those over one year as adults, with age determined by owners' records, dentition, and body size (Lawrence et al., 2015). Dogs were categorized as having poor body condition if they were emaciated, had rough coats and showed general weakness, or as having a healthy condition if they were well-muscled, had smooth coats, and appeared alert, and healthy (Lawrence et al., 2015). Rectal temperature, heart rate, and respiratory rate were also measured by qualified veterinarians and animal health experts to assess the general health status of the dogs during examination.

Skin examination

Restrained dogs were carefully inspected for skin lesions and ectoparasites. Following examination, each dog was positioned in lateral recumbency on a clean white cloth, which facilitated the detection and collection of ectoparasites falling from the animal during brushing the fur. A thorough physical examination was conducted from head to tail, and ectoparasites found on the skin, inside the ears, and between the toes were manually collected. Ticks were removed using thumb forceps to ensure the mouthparts were retained for identification (Taylor et al., 2016; Heylen et al., 2021). To collect fleas, absolute acetone (Sigma-Aldrich Corporation, USA) was applied to the skin, and the fur was brushed to dislodge the fleas onto a white cloth (Nguyen et al., 2020). Ectoparasites were preserved in bottles containing 70% ethanol (Sigma-Aldrich Corporation, USA) labeled according to body region, and transported to Sokoine University of Agriculture for analysis. Skin scrapings from dogs suspected of mange were collected and preserved in glass tubes for laboratory examination.

Fecal sampling

Fecal samples (approximately 5-10 g per dog) were collected from the rectum of restrained dogs using a lubricated gloved finger. The samples were transported to the laboratory in a cool box with ice packs for analysis.

Laboratory identification

Ticks, fleas, and mites were identified microscopically after preparing preserved specimens in 70% ethanol using a light microscope (Carl Zeiss, Germany). Ticks were placed directly on clean slides, fleas were mounted under coverslips, and mites were cleared with lactophenol before mounting. The microscope was set to low magnification (4× to 10×) for ticks and fleas, and higher magnifications (40×) were used for mites to observe detailed structures. Key morphological features such as the capitulum and scutum in ticks, the laterally compressed body and combs in fleas, body shape, and setae in mites were examined. Observations were compared with standard identification keys to confirm genera or species (Foreyt, 2013; Krishna Murthy et al., 2017), and findings were recorded.

Qualitative analysis of gastrointestinal parasite

Each fecal sample was initially examined in a Petri dish for the presence of adult worms, larvae, and tapeworm segments. Subsequently, four qualitative techniques were used to detect gastrointestinal parasites; simple test tube flotation, sedimentation, direct saline and iodine wet mount, and modified Ziehl-Neelsen staining (Garcia et al., 2016; Henriksen et al., 2018).

Data analysis

Data were entered, stored, and analyzed using Epi-Info version 7.2.6.0 (CDC, USA). Descriptive statistics were summarized in tables. The prevalence (p) of each parasite in the dog population was calculated as $p = d/n$, where ‘d’ represents the number of dogs diagnosed with a specific parasite at the time of examination and ‘n’ is the total number of dogs examined. Associations between parasitism and categorical variables, including host characteristics and husbandry practices, were assessed using chi-square tests performed in Epi Info version 7.2.6.0 (CDC, USA). The level of statistical significance was set at 5% ($p < 0.05$).

RESULTS

Dog demographic and clinical characteristics

The results indicated that the majority of dogs were male mongrels aged between three months and one year. A significant proportion (64.3%) of the dogs were in healthy condition and had a history of external parasite control, while 30.3% exhibited skin lesions, predominantly dermatitis (Table 1).

Types of ectoparasites

The results showed that 83.8% of the examined dogs were infested with ectoparasites. Specifically, 62.5% had ticks, 64.5% had fleas, 3% had mites, and 2.5% had lice. Ticks were predominantly located on the head and neck, while fleas were most commonly found on the abdomen. A total of 250 ticks, 278 fleas, 11 lice, and 20 skin scrapings for mites were collected during the study (Supplementary Table 1).

Prevalence of ectoparasites

The overall prevalence of ectoparasites was 83.8%. Dogs from the Mvomero district showed significantly higher ectoparasite infestation rates compared to those from Morogoro municipality ($p < 0.05$), with an average of two types of ectoparasites per host observed in both areas (Table 2). Five ectoparasite species were identified, namely *Rhipicephalus sanguineus* (brown dog tick), *Ctenocephalides canis* (dog flea), *Ctenocephalides felis* (cat flea), *Sarcoptes scabiei* (mange mite), *Trichodectes canis* (biting louse), and *Pulex irritans*. Mvomero District dogs had a significantly higher tick infestation rate (74.5%) compared to Morogoro municipality dogs (50.5%; $p < 0.05$). The identified ectoparasites are shown in Figure 2.

Magnitude of ectoparasite based on risk factors

The analysis of risk factors for ectoparasite infestation in dogs revealed higher rates in Mvomero district (88.0%) than in Morogoro municipality (79.5%; $p < 0.05$). In addition, dogs with poor body condition (76.5%), those kept under free-ranging management systems (90%), and dogs with skin lesions showed significantly higher rates of ectoparasite infestation than healthier dogs (Table 3; $p < 0.05$).

Table 1. Clinical characteristics of sampled dogs from Mvomero District and Morogoro municipality, Tanzania

Parameter	Category	Number and percentage of dogs examined in the two districts		Total of dogs examined (%)
		Mvomero district (n = 200)	Morogoro municipality (n = 200)	
Sex	Male	106 (53.0)	108 (54.0)	214 (53.5)
	Female	94 (47.0)	92 (46.0)	186 (46.5)
Age (years)	Young (< 1)	139 (69.5)	120 (60.0)	259 (64.8)
	Adult (> 1)	61 (30.5)	80 (36.0)	141 (35.2)
Breed	Mongrels	198 (99.0)	174 (87.0)	372 (93.0)
	Crosses	2 (1.0)	26 (13.0)	28 (7.0)
Body condition	Good	118 (59.0)	139 (69.5)	257 (64.3)
	Poor	82 (41.0)	61 (32.0)	143 (35.7)
Management system	Free range	122 (61.0)	46 (23.0)	168 (42.0)
	Confined	58 (29.0)	154 (77.0)	212 (58.0)
History of ectoparasite control	Yes	86 (43.0)	140 (70.0)	226 (56.5)
	No	114 (57.0)	60 (30.0)	174 (43.5)
Temperature	Normal (38.5℃)	193 (96.5)	193 (95.5)	386 (96.5)
	Below normal	0 (0.0)	4 (2.0)	4 (1.0)
	Above normal	7 (3.5)	3 (1.5)	10 (2.5)
Presence of lesions on the skin	Yes	67 (33.5)	54 (27.0)	121 (30.3)
	No	133 (66.5)	146 (73.0)	279 (69.7)
Types of lesions on the skin	Alopecia	24 (12.0)	11 (5.5)	35 (8.8)
	Dermatitis	37 (18.5)	41(20.5)	78 (19.5)
	Pruritis	10 (5.0)	6 (3.0)	16 (4.0)

n: Number of dogs. Numbers in parentheses are expressed as a percentage.

Table 2. Number of ectoparasite species per host and prevalence of parasites in Mvomero District and Morogoro Municipality, Tanzania

Parameter	Category	Number and percentage of infested dogs		χ^2 test	P value
		Mvomero district (n = 200)	Morogoro municipality (n = 200)		
Ectoparasite infestation status	No parasite	24 (12.0)[a]	41 (20.5)[b]	10.906	0.012
	Single parasite species	73 (36.5)	76 (38.0)		
	Two parasites' species	95 (47.5)	82 (41.0)		
	Three parasites' species	8 (4.0)	1 (0.5)		
General ectoparasite infestation rates	Ticks	149 (74.5)[a]	101 (50.5)[b]	24.576	0.001
	Fleas	123 (61.5)	135 (67.5)	1.572	0.210
	Mites	7 (3.5)	5 (2.5)	0.344	0.558
	Lice	8 (4.0)	2 (1.0)	3.692	0.055
	Ectoparasites prevalence	176 (88.0)[a]	159 (79.5)[b]	5.309	0.021
Ectoparasite infestation according to species	*Rhipicephalus sanguineus*	149 (74.5)[a]	101 (50.5)[b]	24.576	0.001
	Ctenocephalides felis	95 (47.5)	115 (57.5)	4.010	0.045
	Ctenocephalides canis	30 (15.0)	27 (13.5)	0.184	0.668
	Pulex irritans	3 (1.5)	0 (0.0)	3.023	0.082
	Sarcoptes scabiei	7 (3.5)	5 (2.5)	0.344	0.558

n: Number of dogs. Numbers in parentheses are expressed as a percentage. [a,b] Mean different superscript letters indicate a significant difference in a row at $p < 0.05$.

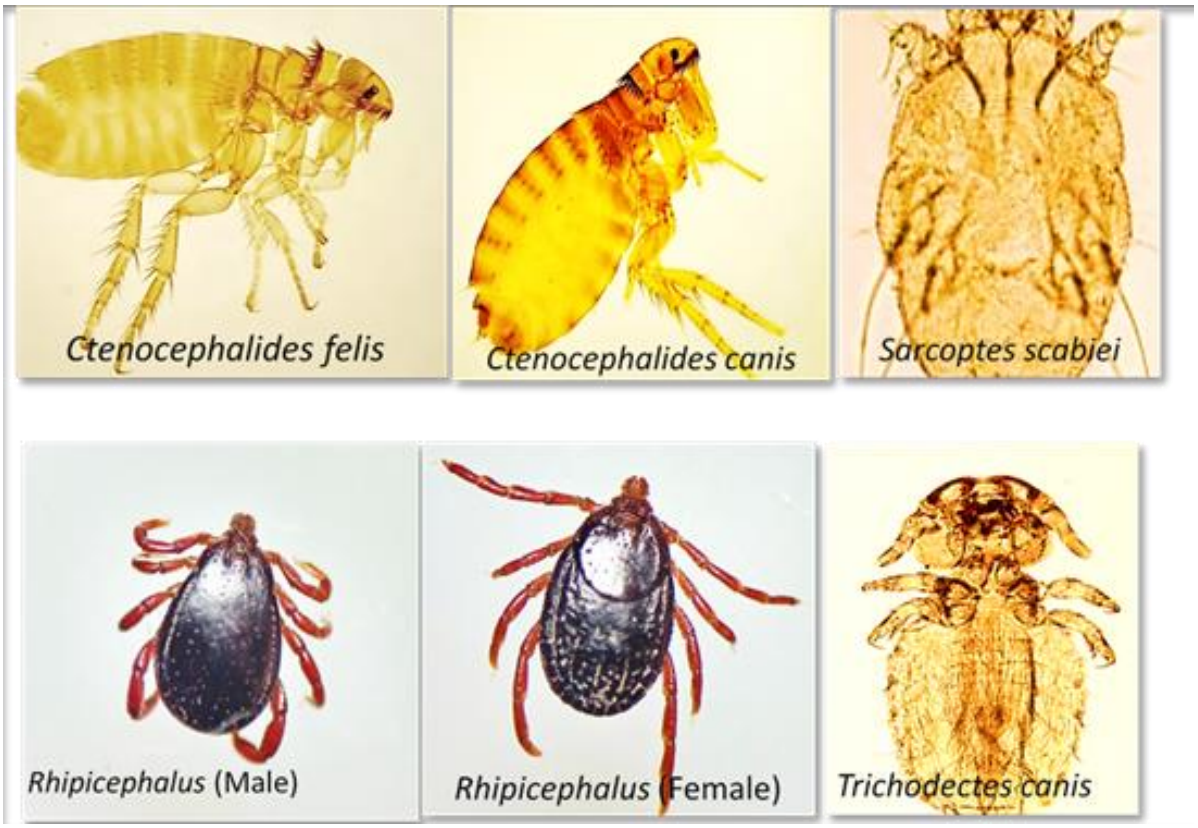

Figure 2. The ectoparasites collected from domestic dogs in Mvomero district and Morogoro Municipality, Tanzania

Ectoparasite infestations based on age, sex, and body conditions

Ectoparasite infestation in dogs varied between Mvomero district and Morogoro municipality, with Mvomero mostly demonstrating higher prevalence rates (Supplementary Table 2). Ticks (*R. sanguineus*) were most common in Mvomero, affecting up to 76.3% of young dogs and 84.0% of those in poor body condition, while fleas (*C. felis*) were more prevalent in Morogoro, especially among young dogs (59.0%) and those in poor condition (74.6%). Mites (*S. scabiae)* and lice (*T. canis*) had lower overall prevalence but were slightly more common in dogs with poor body condition, particularly in Mvomero. Risk factors influencing infestation included young age, poor body condition, and to a lesser extent, sex, with females experiencing slightly higher flea infestations (Supplementary Table 2).

Magnitude and types of gastrointestinal parasites

The study revealed that 76.8% of the 400 dogs examined were infested with gastrointestinal parasites, comprising seven genera of helminths and four genera of protozoa (Table 4; Figure 3).

Table 3. Prevalence of ectoparasite infestations based on animal and management risk factors in Mvomero District and Morogoro Municipality, Tanzania

Risk factor	Category	Number (%) of dogs with ectoparasites	Number (%) of dogs without ectoparasites	χ^2 test	P-value
Sex	Male	174 (81.3)	40 (18.7)	2.016	0.156
	Female	161 (86.7)	25 (13.4)		
Age	Young (< 1)	217 (82.8)	45 (17.2)	0.478	0.489
	Adult (> 1)	118 (85.5)	20 (14.5)		
Breed	Mongrels	312 (83.4)	62 (16.6)	0.454	0.501
	Crosses	23 (88.5)	3 (11.5)		
Location of origin	Mvomero district	176 (88.0)[a]	24 (12.0)[b]	5.309	0.021
	Morogoro municipality	159 (79.5)[a]	41(20.5)[b]		
Body condition	Good	195 (76.5)[a]	60 (23.5)[b]	27.390	0.0001
	Poor	140 (96.6)[a]	5 (3.5)[b]		
Management system	Free range	208 (90.0)[a]	23 (10.0)[b]	12.388	0.0001
	Confined	127 (75.1)[a]	42 (24.9)[b]		
History of ectoparasite control	Yes	87 (79.1)	23 (20.9)	2.420	0.120
	No	248 (85.5)	42 (14.5)		
Access to veterinary services	Yes	222 (83.8)	43 (16.2)	0.000	0.986
	No	113 (83.7)	22 (16.3)		
Skin lesions	Yes	140 (100.0)[a]	0 (0.0)[b]	41.791	0.0001
	No	195 (75.0)[a]	65 (25.0)[b]		

[a,b] Mean different superscript letters indicate a significant difference in a row at $p < 0.05$. The total number of dogs was 400. Numbers in parentheses are expressed as a percentage.

Table 4. Gastrointestinal parasites prevalence in dogs of Mvomero District and Morogoro municipality, Tanzania

Parameter	Category	Number and percentage of dogs infested		χ^2 test	P-value
		Mvomero district	Morogoro municipality		
Gastrointestinal infestation status	No parasite genera	27 (13.5)[a]	66 (33.0)[b]	33.348	0.0001
	Single parasite genus	58 (29.0)[a]	68 (34.0)[b]		
	Two parasites' genera	80 (40.0)[a]	40 (20.0)[b]		
	Three parasites' genera	30 (15.0)[a]	24 (12.0)[b]		
	Four parasites' genera	3 (1.5)[a]	2 (1.0)[b]		
	Five parasites' genera	2 (1.0)	0 (0.0)		
Types of gastrointestinal parasites	Helminthes	159 (79.5)[a]	120 (60.0)[b]	18.022	0.0001
	Protozoa	55 (27.5)[a]	35 (17.5)[b]		
Gastrointestinal spp. prevalence	*Ancylostoma caninum*	142 (71.0)[a]	100 (50.0)[b]	18.454	0.0001
	Uncinaria stenocephala	46 (23.0)	42 (21.0)	0.233	0.629
	Toxocara canis	29 (14.5)	17 (8.5)	3.537	0.060
	Toxascaris leonina	15 (7.5)	10 (5.0)	1.067	0.302
	Ascaris spp.	6 (3.0)	9 (4.5)	0.623	0.430
	Dipylidium caninum	6 (3.0)	1 (0.5)	3.635	0.057
	Taeniidae spp.	14 (7.0)	10 (5.0)	0.709	0.400
	Diphylobothrium latum	3 (1.5)	0 (0.0)	3.023	0.082
	Troglotrema salmincola	1 (0.5)	0 (0.0)	1.003	0.317
	Cryptosporidium spp.	36 (18.0)	26 (13.0)	1.909	0.167
	Cyclospora spp.	11 (5.5)	6 (3.0)	1.536	0.215
	Isospora spp.	25 (12.5)[a]	7 (3.5)[b]	11.005	0.001
	Entamoeba spp.	9(4.5)	3 (1.5)	3.093	0.079

[a,b] Mean different superscript letters indicate a significant difference in a row at $p < 0.05$. The total number of dogs was 400, 200 dogs in each district. Numbers in parentheses are expressed as a percentage.

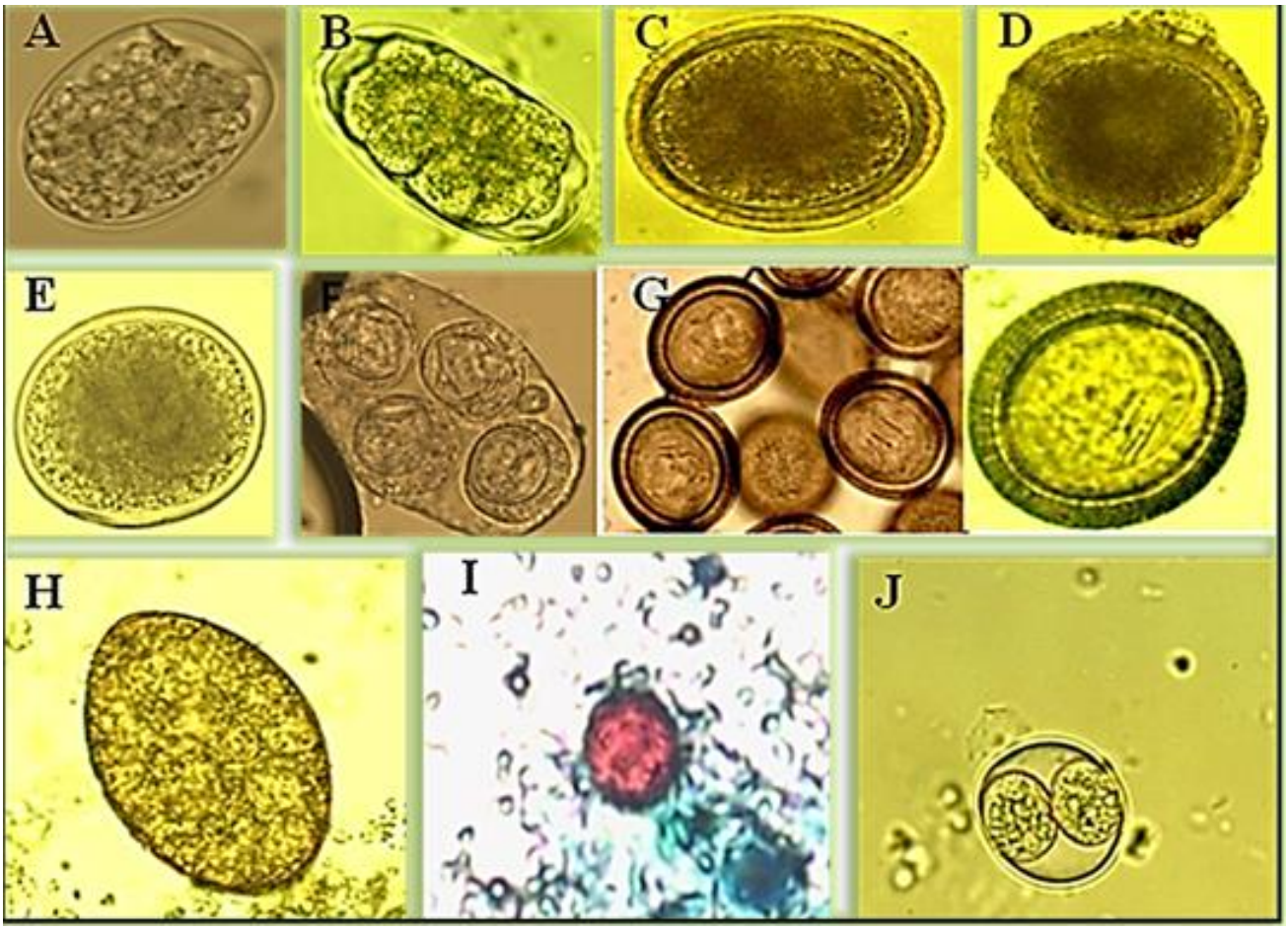

Figure 3. Eggs/oocysts of intestinal parasites derived from dog fecal samples in Mvomero District and Morogoro Municipality, Tanzania, in 2024. **A**: *Ancylostoma caninum* egg, **B**: *Uncinaria stenocephala* egg, **C**: *Toxocara canis* egg, **D**: *Ascaris* egg, **E**: *Toxascaris leonina* egg, **F**: *Dipylidium caninum* packet of eggs, **G**: *Taeniidae* spp. eggs, **H**: *Diphyllobothrium latum* egg, **I**: *Cryptosporidium* cyst, **J**: *Isospora* cyst.

Table 5. Intestinal parasites and associated risk factors for infestations in dogs in the districts of Mvomero and Morogoro, Tanzania

Risk factor	Category	Number and percentage of dogs with GIT parasites	Number and percentage of dogs without GIT parasites	χ^2 test	P-value
Sex	Male	165 (77.1)	49 (22.9)	1.641	0.200
	Female	133 (71.5)	53 (28.5)		
Age	Young (< 1)	206 (78.6)[a]	56 (21.4)[b]	6.805	0.009
	Adult (> 1)	92 (67.7)[a]	46 (33.3)[b]		
Breed	Mongrels	282 (75.4)	92 (24.6)	2.459	0.117
	Crosses	16 (61.5)	10 (38.5)		
Location of origin	Mvomero district	173 (86.5)[a]	27 (13.5)[b]	21.055	0.001
	Morogoro municipality	134 (67.0)[a]	66 (33.0)[b]		
Body condition	Good	178 (69.8)[a]	77 (30.2)[b]	8.166	0.004
	Poor	120 (82.8)[a]	25 (17.2)[b]		
Management system	Free range	184 (79.7)[a]	47 (20.3)[b]	7.644	0.006
	Confined	114 (67.5)[a]	55 (32.5)[b]		
History of deworming	Yes	44 (44.9)[a]	54 (55.1)[b]	59.872	0.001
	No	254 (84.1)[a]	48 (15.9)[b]		
Access to veterinary services	Yes	202 (76.2)	63 (23.8)	1.232	0.267
	No	39 (28.9)	96 (71.1)		
Dog feeding	Yes	288 (74.0)	101 (26.0)	1.603	0.205
	No	10 (90.0)	1 (9.0)		
Feeding system	In a container	123 (63.7)[a]	70 (36.3)[b]	22.769	0.0001
	Throw on ground	175 (84.5)[a]	32 (15.5)[b]		

GIT: Gastrointestinal parasites. [a,b] Mean different superscript letters indicate a significant difference in a row at $p < 0.05$. The total number of dogs was 400. Numbers in parentheses are expressed as a percentage.

Gastrointestinal parasites and risk factors

Age, body condition, geographic location, husbandry and housing practices, lack of routine deworming, and feeding practices were significant risk factors associated with gastrointestinal parasite infestations in dogs (Table 5; $p < 0.05$).

Helminths, protozoan species, and risk factors

Gastrointestinal (GIT) parasite infections in dogs showed significant variation depending on age, sex, and body condition in both Mvomero district and Morogoro municipality, with *Ancylostoma caninum* being the most commonly detected parasite across the two areas (Supplementary Tables 3a and b). In Mvomero, *Ancylostoma caninum* affected 58.2% of young dogs, 60.7% of adults, and more males (66.1%) than females (51.1%), with higher prevalence in dogs with poor body condition (61.7%). Similarly, in Morogoro, it affected 53.3% of young dogs, 44.9% of adults, and more males (57.4%) than females (41.3%), with 54.0% prevalence in dogs with poor body condition. *Toxocara canis* was more common in young dogs (18.7%) and females (17.6%) in Mvomero, while in Morogoro, it was slightly more prevalent in females (10.9%) and dogs with poor body condition (12.7%). *Uncinaria stenocephala* and *Toxascaris leonina* showed moderate prevalence, particularly in adults and dogs in poor condition, in both areas. Among protozoa, *Cryptosporidium* spp. was common, affecting young dogs and those with healthy body condition, with a prevalence of 21.5% in Mvomero and 20.5% in Morogoro. Less prevalent parasites, including *Cyclospora* spp. and *Isospora* spp., showed variations based on age, sex, and body condition, highlighting young dogs as a high-risk group. Overall, the findings emphasize *A. caninum* as the dominant parasite and underline the effects of age, sex, and body condition on infestation rates.

Mixed infection based on age, sex, and body conditions

The findings indicated that *Ancylostoma caninum* and *Uncinaria stenocephala* were the most common mixed parasites in dogs, with a higher prevalence observed in adult dogs compared to young ones (Supplementary Table 4).

Relationship between the prevalence of parasites and risk factors

The study identified a significant association between the prevalence of certain parasites and specific risk factors, showing that *Toxocara canis*, *Cryptosporidium*, and *Isospora* spp. affected young dogs significantly more than adult dogs (Supplementary Table 5; $p < 0.05$). Poor body condition and origin from Mvomero District were significant predictors of parasitic infestation in dogs when compared to those originating from Morogoro municipality (Table 5; $p < 0.05$).

Magnitude of zoonotic gastrointestinal parasites

The study identified 11 genera of zoonotic gastrointestinal parasites in dog fecal samples, with *Ancylostoma, Uncinaria* and *Toxocara* being the most common helminths and *Cryptosporidium* the most common protozoan parasite. Overall, a high prevalence of zoonotic gastrointestinal parasites was recorded in dogs of Mvomero District (Table 6).

Table 6. Prevalence of zoonotic gastrointestinal parasites identified in fecal samples of dogs from Mvomero and Morogoro districts, Tanzania

Type of parasites	Species of zoonotic parasites	Mvomero district (n=200)	Morogoro municipality (n=200)
		Prevalence	Prevalence
Helminthes	*Ancylostoma caninum*	142 (71.0)	100 (50.0)
	Uncinaria stenocephala	46 (23.0)	42 (21.0)
	Toxocara canis	29 (14.5)	17 (8.5)
	Ascaris lumbricodes	6 (3.0)	9 (4.5)
	Dipylidium caninum	6 (3.0)	1 (0.5)
	Taeniidae spp.	14 (7.0)	10 (5.0)
	Diphyllobothrium latum	3 (1.5)	0 (0.0)
	Troglotrema salmincola	1 (0.5)	0 (0.0)
Protozoa	*Cryptosporidium* spp.	36 (18.0)	26 (13.0)
	Cyclospora spp.	11 (5.5)	6 (3.0)
	Entamoeba spp.	9 (4.5)	3 (1.5)
	Overall prevalence of zoonotic parasites	169 (84.5)	126 (63.0)

n: Number of dogs. Numbers in parentheses are expressed as a percentage.

DISCUSSION

The present study examined the occurrence of parasitic infestations and zoonotic gastrointestinal parasites among the examined dogs in Mvomero District and Morogoro municipality. The findings revealed a substantial prevalence of ectoparasites in dogs (83.8%), including ticks, fleas, mites, and lice, with higher infestation rates observed in dogs from Mvomero District (88.0%) compared to those from Morogoro municipality (79.5%). These findings underscore challenges in dog management practices and the limited implementation of routine parasite control measures. A previous investigation conducted in Morogoro municipality by Mwangengwa and Rhanga (2023) reported an ectoparasite prevalence of 71.7% among dogs. Similarly, a study by Kumsa and Mekonnen (2011) in Hawassa, southern Ethiopia, reported an even higher prevalence of ectoparasite infestations in dogs, reaching 99.5%. Comparable findings were also reported in Nigeria, where Ugbomoiko et al. (2008) documented an ectoparasite prevalence of 60.4% among dogs, while in Maranhão State, Brazil, Costa et al. (2013) recorded prevalence rates of 73.9% in rural dogs and 51.3% in urban dogs, indicating that canine ectoparasitism is a widespread global concern. Variations in prevalence across studies may be attributed to differences in climatic conditions, environmental parasite dynamics, dog husbandry practices, and variations in sampling periods.

Rhipicephalus sanguineus, commonly referred to as the brown dog tick or kennel tick. It is the most prevalent ixodid tick species infesting dogs globally (Klimpel et al., 2010). In the present study, dogs from Mvomero District exhibited a higher prevalence of tick infestation (74.5%), predominantly *R. sanguineus*, compared to those from Morogoro municipality (50.5%), indicating suboptimal husbandry practices.

In Nigeria, *R. sanguineus* prevalence in dogs has been shown to range widely from 0.3% to 80% (Oguntomole et al., 2018). Similarly, studies from Brazil have documented diverse infestation levels depending on ecological context and host exposure. In Fortaleza and Belo Horizonte, urban dog populations showed infestation rates ranging from approximately 29.0% to 38.5%, influenced by serological grouping and exposure status rather than universal infestation (Paz et al., 2010). However, higher prevalence has also been reported in specific settings, including up to 100% infestation in urban stray dogs in Fortaleza (Klimpel et al., 2010). In Indonesia, particularly in Bogor, Jakarta, and Bandung, exceptionally high infestation levels have been observed, with reports reaching 67.9% in kennel and police dogs in Bogor and up to 100% in controlled kennel populations such as Atang Sendjaja Air Force dogs (Kesumawati et al., 2015). Beyond their veterinary importance, *Rhipicephalus* spp. have also been reported to occasionally parasitize humans (Oguntomole et al., 2018) and are recognized as potential vectors of zoonotic rickettsial diseases (Khrouf et al., 2014; Haule et al., 2023). The study found that 64.5% of examined dogs were infested with fleas, which can be attributed to inadequate husbandry practices such as irregular cleaning, disinfection, and external parasite control. Flea infestations cause symptoms such as pruritus, self-inflicted trauma, allergic dermatitis, and general discomfort, often observed in dogs with skin lesions and poor body condition (Mwangengwa and Rhanga, 2023). Flea infestations in dogs in Morogoro pose a significant public health concern due to their high population and potential for pathogen transmission. *Ctenocephalides* spp. are known vectors for *Yersinia pestis*, the causative agent of human plague (Mwangengwa and Rhanga, 2023), and serve as intermediate hosts for the zoonotic tapeworm *Dipylidium caninum* (Beugnet et al., 2014). High prevalence rates of *Ctenocephalides* spp. infestations in dogs have been reported in several African countries, including northeastern Tanzania, where Haule et al. (2023) documented a prevalence of 90.0%, and Ethiopia, where Kumsa and Mekonnen (2011) reported a prevalence of 82.8%. These infestations are influenced by management practices, seasonal variations, and the geographic distribution of parasites. Besides flea infestations, the study also identified *Sarcoptes scabiei* (3.0%) and *Trichodectes canis* (2.5%) among the ectoparasites affecting dogs. *Sarcoptes scabiei* is of particular public and veterinary health importance, as it can cause sarcoptic mange in both dogs and humans (Bandi et al., 2013). The results underscore the significance of improving dog management practices and routine parasite control measures to safeguard both canine and human health in Mvomero and Morogoro districts.

The overall high prevalence (76.8%) of gastrointestinal parasites (helminths and protozoa) in dogs of Mvomero and Morogoro districts indicates chronic health challenges in these animals. Previous studies conducted on dogs in Tanzania have reported varying prevalence rates of gastrointestinal parasites, including 50.5% and 74.0% in Ethiopia (Abere et al., 2013) and 59.3% in Arusha (Swai et al., 2010). Similar studies conducted in Nigeria (Amadi et al. 2021), Ghana (Johnson et al. 2015), and Egypt (Awadallah and Salem, 2015) have also demonstrated varying levels of gastrointestinal parasite infections among dogs. Factors such as environmental conditions, host characteristics, and husbandry practices play crucial roles in determining parasite prevalence. These findings highlight the need for comprehensive parasite control measures to protect both animal and public health in Mvomero and Morogoro districts.

The present study revealed that hookworm eggs (*Ancylostoma* spp.) are the most frequently detected parasites in both study areas, indicating their widespread occurrence. Similar findings have been reported in previous studies involving dogs from Tanzania and other African countries. In Arusha municipality, northern Tanzania, Swai et al. (2010)

reported *Ancylostoma* spp. in 59.3% of non-descript local dogs. In Morogoro, Abere et al. (2013) documented prevalence rates of 50.5% and 74.0% among domestic dogs from rural and peri-urban settings. In Lusaka, Zambia, Bwalya et al. (2011) reported hookworm infestations in 63.2% of mixed-breed owned and stray dogs, while in Egypt, Awadallah and Salem (2015) recorded *Ancylostoma* spp. infections in 44.7% of household dogs. Variations in prevalence across studies are likely associated with differences in environmental conditions, seasonal factors, dog systems, anthelmintic use, and sanitation practices. Collectively, the findings of the present study emphasize management of hookworms as the predominant intestinal helminths affecting dogs in Morogoro and comparable regions.

Other helminths identified in the present study include *stenocephala*, *Toxocara canis*, *Toxascaris leonina*, *Ascaris* spp., and *Dipylidium caninum Uncinaria*, consistent with previous reports from Tanzania and other regions. For instance, in Mvomero District, Tanzania, Swai et al. (2016) documented *Toxocara canis* in 18.7% and *Dipylidium caninum* in 9.3% of domestic dogs. In Zambia, Siwila (2016) reported *Toxocara canis* in 14.8% and *Dipylidium caninum* in 6.5% of examined dogs. Similarly, in Ghana, Amissah et al. (2016) identified multiple zoonotic gastrointestinal helminths, including *Toxocara* spp. in 22.4% and *Dipylidium caninum* in 11.6% of dogs. The study by Sowemimo and Asaolu (2009) in Ibadan, Nigeria, also reported the prevalence of various helminths in stray dogs as following, *Toxocara canis* (9.0%), *Ancylostoma* spp. (17.9%), *Toxascaris leonina* (0.6%), *Uncinaria stenocephala* (0.4%), and *Dipylidium caninum* (0.2%). The findings of the present study confirm that canine gastrointestinal helminths remain widely distributed across diverse ecological and management systems.

The current study provides the first documented evidence of the presence of two fish-associated helminths, *Diphyllobothrium latum* (1.5%) and *Troglotrema salmincola* (0.5%), in dogs in Tanzania. Their occurrence is most likely linked to the widespread practice of feeding dogs raw or undercooked fish and fish by-products, facilitating the transmission of fish-borne zoonotic helminths. Most of the sampled dogs were fed a homemade diet of maize bran and sardines, which may explain *Troglotrema salmincola* infection. These parasites (*Diphyllobothrium latum* and *Troglotrema salmincola*) were primarily found in dogs from Mvomero District, where dogs often scavenge for food in ponds and rivers, potentially consuming infested fish. Further studies are recommended to explore this phenomenon. The presence of *Taeniidae* eggs (6.0%) in dog fecal samples is of epidemiological importance and may be attributed to free-roaming dogs scavenging condemned raw meat or animal carcasses, even in cases where they are primarily fed homemade diets. Studies in Tanzania have reported high infestation rates (73.2%) of *Taeniidae* spp. in stray dogs (Swai et al., 2016), suggesting that dogs may act as reservoirs for human infections. The present study documented four protozoan parasites in dog feces, including *Cryptosporidium* spp., *Isospora* spp., *Cyclospora* spp., and *Entamoeba* spp. Similar findings have been reported in previous investigations involving domestic dogs from specific geographical locations. For instance, Perera et al. (2013) identified intestinal protozoan infections, including *Cryptosporidium* spp. and *Isospora* spp., among owned and free-roaming domestic dogs in Colombo and the surrounding urban areas of Sri Lanka. Likewise, Sarmiento-Rubiano et al. (2024) reported enteric protozoan parasites, including *Cryptosporidium* spp. and *Entamoeba* spp., in household and shelter dogs of mixed breeds in Colombia. Dogs in Mvomero District exhibited a higher prevalence (27.5%) compared to those in Morogoro municipality (17.5%), likely due to free-ranging management practices that increase exposure to a contaminated environment.

Previous studies on the epidemiology of canine parasites have identified geographic location, seasonality, demographics, and husbandry practices as key risk factors (Nijsse et al., 2015; Kidima et al., 2019). The present study observed a higher susceptibility of young dogs, likely due to immature immune systems, transplacental and trans-mammary transmission, and continuous exposure to contaminated environments (Abere et al., 2013; Swai et al., 2016). Furthermore, zoonotic intestinal parasites were highly prevalent in dogs from Mvomero District (84.5%) and Morogoro municipality (63%), posing a significant health risk. The identified zoonotic helminths in the present study included *Ancylostoma caninum*, *Uncinaria stenocephala*, *Toxocara canis*, *Dipylidium caninum*, and *Ascaris* spp., along with protozoa such as *Cryptosporidium* spp., *Cyclospora* spp., and *Entamoeba* spp. These findings are consistent with previous reports from Tanzania and other regions. Given the high levels of infection and close human-dog interactions, there is a substantial risk of zoonotic transmission. Therefore, raising public awareness is essential to prevent the spread of parasitic diseases from dogs to humans.

CONCLUSION

The study concludes that ectoparasites and gastrointestinal parasites are highly prevalent, especially in Mvomero District, with considerable zoonotic parasite occurrence in dogs across Mvomero and Morogoro, indicating a need for targeted control interventions. Importantly, fish-borne helminths (*Diphyllobothrium latum* and *Troglotrema salmincola*) were detected in Tanzanian dogs for the first time. Infection risk is influenced by age, location, husbandry practices, housing conditions, irregular deworming, and feeding behavior. Strengthening owner education on responsible dog

management, including vaccination, biosecurity, and routine deworming, is essential. Future studies should use longitudinal, seasonal, molecular, and One Health approaches to clarify transmission dynamics and zoonotic risk.

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Authors' contributions

Amina Ramadhani Issae contributed to conceptualization, data curation, formal analysis, investigation, methodology, validation, and preparation of the first draft of the manuscript, as well as reviewing and editing the manuscript. Hezron Emanuel Nonga contributed to conceptualization, funding acquisition, investigation, methodology, project administration, supervision, validation, and review and editing of the manuscript. All authors have read and approved the final edition of the manuscript before publication in the present journal.

Availability of the data and materials

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors confirmed that they have no conflicts of interest in the present study.

Ethical considerations

The present study is original and has not been submitted to or published in any other journal. The authors have verified the originality of the content using plagiarism-detection tools and confirmed that the article is based on their own original scientific research findings. Additionally, artificial intelligence tools were not used in the preparation and writing of this study.

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Supplementary Table 1. Ectoparasites collected from different body parts of dogs in Morogoro municipality and Mvomero district, Tanzania

Region of the body	Number and percentage of ectoparasites in Mvomero district				Number and percentage of ectoparasites in Morogoro municipality			
	Ticks	Fleas	Mites	Lice	Ticks	Fleas	Mites	Lice
Head & Neck	98 (67.6%)	5 (3.7%)	0 (0.0)	0 (0.0)	85 (81.0%)	0 (0.0)	0 (0.0)	0 (0.0)
Abdomen	19 (13.1%)	106 (77.4%)	2 (22.2%)	8 (100.0)	3 (2.9%)	113 (80.1%)	0 (0.0)	2 (66.7%)
Back	12 (8.3%)	26 (19.0%)	7 (77.8%)	0 (0.0)	11 (10.5%)	28 (19.9%)	11 (10.5%)	1 (33.3%)
Legs	7 (4.8%)	0 (0.0)	0 (0.0%)	0 (0.0)	5 (4.8%)	0 (0.0)	0 (0.0)	0 (0.0)
Around the genital area	9 (6.2%)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0%)	0 (0.0)	0 (0.0)	0 (0.0)
Total	145 (100.0%)	137 (100.0%)	9 (100.0%)	8 (100.0)	105 (100.0%)	141 (100.0%)	11 (100.0%)	3 (100.0%)

Numbers in parentheses are expressed as a percentage.

Supplementary Table 2. Ectoparasite infestation in dogs based on risk factors such as age, sex, and body condition in Morogoro municipality and Mvomero district, Tanzania

Study area	Ectoparasites identified	Species identified	Dogs' factors considered					
			Age		Sex		Body condition score	
			Young (n = 122)	Adult (n = 78)	Male (n = 108)	Female (n = 92)	Good (n = 137)	Poor (n = 63)
Morogoro municipality	Ticks	*Rhipicephalus sanguineus*	57 (46.7)	44 (56.4)	56 (51.9)	45 (48.9)	60 (43.8)	41 (65.1)
	Fleas	*Ctenocephalides felis*	72 (59.0)	43 (55.1)	58 (53.7)	57 (62.0)	68 (49.6)	47 (74.6)
		Ctenocephalides canis	13 (10.7)	14 (17.9)	11 (10.2)	16 (17.4)	18 (13.1)	9 (14.3)
	Mite	*Sarcoptex scabiei*	2 (1.6)	3 (3.8)	4 (3.7)	1 (1.1)	2 (1.5)	3 (4.8)
	Lice	*Trichodetes canis*	1 (0.8)	1 (1.3)	2 (1.9	0 (0.0)	2 (1.5)	0 (0.0)
Mvomero district	Ticks	*Rhipicephalus sanguineus*	106 (76.3)	44 (72.1)	80 (75.5)	70 (74.5)	82 (68.9)	68 (84.0)
	Fleas	*Ctenocephalides felis*	65 (46.8)	21 (34.4)	49 (46.2)	37 (39.4)	54 (45.4)	32 (39.5)
		Ctenocephalides canis	20 (14.4)	12 (19.7)	16 (15.1)	16 (17.02)	17(14.3)	15 (18.5)
		Pulex irritans	0 (0.0)	3 (3.8)	2 (1.9)	1 (1.1)	0 (0.0)	3 (4.8)
	Mite	*Sarcoptes scabiae*	5 (3.6)	2 (3.3)	4 (3.8)	3 (3.2)	3 (2.5)	4 (4.9)
	Lice	*Trichodetes canis*	7 (5.04)	1 (1.6)	3 (2.8)	5 (5.3)	1 (0.8)	7 (8.6)

n: Number of dogs. The total number of dogs was 400. Numbers in parentheses are expressed as a percentage.

Supplementary Table 3a. Gastrointestinal parasite infestation in dogs based on age, sex, and body condition in Mvomero district, Tanzania

Group of GIT parasites	Species identified	Number and percentage of dogs with different species of helminths and protozoan gastrointestinal parasites					
		Age		Sex		Body condition score	
		Young (n = 139)	Adult (n = 61)	Male (n = 106)	Female (n = 94)	Good (n = 119)	Poor (n = 81)
Helminthes	*Ancylostoma caninum*	81 (58.2)	37 (60.7)	70 (66.1)	48 (51.1)	68 (57.1)	50 (61.7)
	Uncinaria stenocephala	22 (15.8)	14 (23.0)	20 (18.9)	16 (17.0)	20 (16.8)	16 (19.8)
	Toxocara canis	26 (18.7)	1 (1.6)	11 (10.4)	16 (17.6)	17 (14.3)	10 (12.4)
	Toxascaris leonina	8 (5.8)	7 (11.5)	8 (7.6)	7 (7.5)	7 (5.9)	8 (9.9)
	Ascaris spp.	5 (3.6)	0 (0.0)	4 (3.8)	1 (1.1)	5 (4.2)	0 (0.0)
	Dipylidium caninum	4 (2.9)	2 (3.3)	4 (3.8)	2 (2.2)	2 (1.7)	4 (4.9)
	Taeniidae spp.	12 (8.6)	2 (3.2)	9 (8.5)	6 (6.4)	7 (5.9)	7 (8.6)
	Diphyllobothrium latum	0 (0.0)	2 (3.2)	2 (1.9)	0 (0.0)	0 (0.0)	2 (2.5)
	Troglotrema salmincola	1 (0.7)	0 (0.0)	0 (0.0)	1(1.1)	0 (0.0)	1 (1.2)
Protozoa	*Cryptosporidium* spp.	30 (21.5)	6 (9.84)	19 (17.9)	17(18.1)	22 (18.5)	14 (17.3)
	Cyclospora spp.	11 (7.9)	1 (1.6)	5 (4.7)	7 (7.5)	8 (6.7)	4 (4.9)
	Isospora spp.	22 (15.8)	3 (4.9)	12 (11.3)	13 (13.8)	15 (12.6)	10 (12.4)
	Entamoeba spp.	8 (5.8)	1 (1.6)	4 (3.8)	5 (5.3)	5 (4.2)	4 (4.9)

n: Number of dogs. The total number of dogs was 200. Numbers in parentheses are expressed as a percentage.

Supplementary Table 3b. Gastrointestinal parasite infestation in dogs based on age, sex, and body condition in Morogoro municipality, Tanzania

Group of GIT parasites	Species identified	Number and percentage of dogs with different species of helminths and protozoan gastrointestinal parasites					
		Age		Sex		Body condition score	
		Young (n = 122)	Adult (n = 78)	Male (n = 108)	Female (n = 92)	Good (n = 137)	Poor (n = 63)
Helminthes	*Ancylostoma caninum*	65 (53.3%)	35 (44.9%)	62 (57.4%)	38 (41.3%)	66 (48.2%)	34 (54.0%)
	Uncinaria stenocephala	33 (27.0%)	9 (11.5%)	26 (24.1%)	16 (17.4%)	30 (21.9%)	12 (19.0%)
	Toxocara canis	11 (9.0%)	6 (7.7%)	7 (6.5%)	10 (10.9%)	9 (6.6%)	8 (12.7%)
	Toxascaris leonina	10 (8.2%)	7 (11.7%)	4 (3.7%)	6 (6.5%)	8 (5.8%)	2 (3.2%)
	Ascaris spp.	6 (4.9%)	3 (3.8%)	7 (6.5%)	2 (2.2%)	4 (2.9%)	5 (7.9%)
	Diphyllobothrium. caninum	0 (0.0)	1 (1.3%)	1 (0.9%)	0 (0.0)	0 (0.0)	1(1.6%)
	Taeniidae spp.	5 (4.1%)	5 (6.41%)	5 (4.63%)	5 (5.43%)	4 (2.92%)	6 (9.52%)
Protozoa	*Cryptosporidium* spp.	25 (20.5%)	1 (1.3%)	15 (13.9%)	11 (12.0%)	19 (13.9%)	7 (11.1%)
	Cyclospora spp.	2 (1.6%)	4 (5.1%)	3 (2.8%)	3 (3.3%)	4 (2.9%)	2 (3.2%)
	Isospora spp.	5 (4.1%)	2 (2.6%)	3 (2.8%)	4 (4.3%)	7 (5.1%)	0 (0.0)
	Entamoeba spp.	1 (0.8%)	2 (2.6%)	3 (2.8%)	0 (0.0)	2 (1.5%)	1 (1.6%)

n: Number of dogs. The total number of dogs was 200.

Supplementary Table 4. Prevalence of mixed infestation of gastrointestinal parasites according to age, sex, and body condition of dogs of Mvomero district and Morogoro municipality, Tanzania

Study area	Species identified	Number and percentage of dogs with mixed species of gastrointestinal parasites					
		Age		Sex		Body condition score	
		Young (n = 139)	Adult (n = 61)	Male (n = 106)	Female (n = 94)	Good (n = 119)	Poor (n = 81)
Mvomero district	*Ancylostoma caninum* and *Uncinaria stenocephala*	5 (3.6%)	21 (34.4%)	19 (17.9%)	7 (7.5%)	15 (12.6%)	10 (12.4%)
	Ancylostoma caninum and *Cryptosporidium* spp.	14 (10.1%)	3 (4.9%)	10 (9.4%)	7 (7.5%)	8 (6.7%)	9 (11.1%)
	Ancylostoma caninum and *Toxocara canis*	13 (9.4%)	4 (6.6%)	9 (8.5%)	8 (8.5%)	5 (4.2%)	11 (9.2%)
	Ancylostoma caninum, Uncinaria stenocephala, and *Cryptosporidium* spp.	3 (2.2%)	1 (1.6%)	2 (1.9%)	2 (2.1%)	3 (2.5%)	1 (1.2%)
	Ancylostoma caninum, Uncinaria stenocephala, and *Taeniidae* spp.	4 (2.9%)	2 (3.3%)	2 (1.9%)	4 (4.3%)	1 (0.8%)	5 (6.2%)
	Ancylostoma caninum and *Isospora* spp	3 (2.2%)	1 (1.6%)	2 (1.9%)	2 (2.1%)	1 (0.8%)	3 (3.7%)
	Ancylostoma caninum, Toxacaris leonina, and *Cryptosporidium* spp.	4 (2.9%)	1 (1.6%)	1 (0.9%)	4 (4.3%)	4 (3.4%)	1 (1.2%)
	Ancylostoma caninum, Toxocara canis, and *Taeniidae* spp.	2 (1.4%)	1 (1.6%)	2 (1.9%)	1 (1.1%)	0 (0.0)	3 (3.7%)
	Ancylostoma caninum and *Dipylidium caninum*	0 (0.0)	2 (3.3%)	2 (1.9%)	0 (0.0)	0 (0.0)	2 (1.7%)
	Ancylostoma caninum and *Ascaris* spp.	3 (2.2%)	1 (1.6%)	2 (1.9%)	2 (2.1%)	3 (1.5%)	1 (1.2%)
	Toxocara canis, *Ancylostoma caninum*, and *Uncinaria stenocephala*	3 (2.2%)	1 (1.6%)	1 (0.9%)	3 (3.2%)	1 (0.5%)	3 (3.7%)
Morogoro municipality	*Ancylostoma caninum* and *Uncinaria stenocephala*	12 (9.8%)	8 (10.3%)	14 (13.0%)	6 (6. 5%)	13 (9.5%)	7 (11.1%)
	Ancylostoma caninum and *Cryptosporidium* spp.	5 (4.1%)	0 (0.0)	3 (2.8%)	2 (2.2%)	4 (2.9%)	1 (1.6%)
	Ancylostoma caninum and *Toxocara canis*	6 (4.9%)	1 (1.3%)	3 (2.8%)	4 (4.4%)	3 (2.2%)	4 (6.4%)
	Ancylostoma caninum, Uncinaria stenocephala, and *Cryptosporidium* spp.	6 (4.9%)	4 (5.1%)	5 (4.6%)	5 (5.5%)	7 (5.1%)	3 (6.4%)
	Ancylostoma caninum, Uncinaria stenocephala, and *Taeniidae* spp.	5 (4.1%)	2 (2.6%)	1 (0.9%)	4 (4.4%)	2 (1.5%)	3 (6.4%)
	Ancylostoma caninum and *Entamoeba* spp.	0 (0.0)	2 (2.6%)	2 (1.9%)	0 (0.0)	0 (0.0)	2 (3.2%)
	Ancylostoma caninum and *Ascaris* spp.	3 (2.5%)	0 (0.0%)	3 (2.8%)	0 (0.0)	0 (0.0)	3 (6.4%)
	Ancylostoma caninum, Toxocara canis, and *Uncinaria stenocephala*	5 (4.1%)	2 (2.6%)	6 (5.6%)	1 (1.1%)	3 (2.2%)	4 (6.4%)
	Ancylostoma caninum and *Uncinaria stenocephala*	12 (9.8%)	8 (10.6%)	14 (13.0%)	6 (6. 5%)	13 (9.5%)	7 (11.1%)
	Ancylostoma caninum, Toxocara canis, and *Uncinaria stenocephala*	5 (4.1%)	0 (0.0)	3 (2.8%)	2 (2.2%)	4 (2.9%)	1 (1.6%)

n: Number of dogs. The total number of dogs was 400.

Supplementary Table 5. Proportional comparisons of parasites based on selected risk factors among dogs in Mvomero and Morogoro districts of Tanzania

Type of gastrointestinal parasites	Species of parasite	P values of proportional comparisons of parasite infections in dogs				
		Breeds of dogs	Body condition	Age	Sex	Location (Mvomero and Morogoro)
Helminths	*Ancylostoma caninum*	0.125	0.070	0.506	0.022	0.016
	Uncinaria stenocephala	0.584	0.443	0.157	0.761	0.450
	Toxocara canis	0.293	0.293	0.001	0.332	0.111
	Toxscaris leonina	0.601	1.000	0.464	0.114	0.302
	Ascaris spp.	0.021	0.094	0.663	0.291	0.277
	Dipylidium caninum	0.482	0.703	0.995	0.812	0.057
	Taeniidae spp.	0.632	0.148	0.901	0.946	0.400
Protozoa	*Cryptosporidium* spp.	0.543	0.846	0.0001	0.013	0.217
	Isospora spp.	0.420	0.570	0.018	0.847	0.001
	Cyclospora spp.	0.253	0.794	0.637	0.869	0.148
	Entamoeba spp.	0.794	0.102	0.917	0.981	0.079
Ectoparasites	Mites	0.724	0.026	0.053	0.914	0.558
	Lice	0.398	0.114	0.094	0.822	0.055
	Ticks	0.009	0.0001	0.284	0.525	0.0001
	Fleas	0.025	0.0001	0.231	0.544	0.125
Intestinal parasites	Protozoa	0.289	0.777	0.001	0.035	0.023
	Helminths	0.346	0.022	0.041	0.114	0.0001
Ticks	Degree of ticks' infestation	0.018	0.0001	0.463	0.693	0.0001

n: Number of dogs. The total number of dogs was 400.