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Prevalence and risk factors associated with zoonotic gastrointestinal helminths transmitted by cats in Jabodetabek, Indonesia

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Abstract

Background: Intestinal helminth infections in cats are often neglected major zoonoses spread from pets to humans worldwide.

Aim: This study evaluated the prevalence and identified risk factors associated with zoonotic gastrointestinal helminth infections in different cat populations in the most populous megapolitan areas of Indonesia: Jakarta, Bogor, Depok, Tangerang, and Bekasi (Jabodetabek).

Methods: Fecal samples from the shelter (stray) and household (owned) cats were analyzed using sugar flotation techniques. Intestinal helminth eggs were detected microscopically based on structural and morphometric characteristics. Risk factors for the occurrence of helminth infection were identified through statistical analysis of cat ownership, breed, migrant status, management practices, caging, feed type, and deworming medications used. Human cases of worm larvae infestation identified during the interviews were reported.

Results: Analysis of 354 fecal samples revealed that 37.9% (134/354) of examined cats were infected with *Toxocara* sp., 22.6% (80/354) with *Ancylostoma* sp., 25.4% (90/354) with *Uncinaria* sp., 3.1% (11/354) with *Strongyloides* sp., 2% (7/354) with *Diphyllobothrium* sp., and 0.6% (2/354) with *Dipylidium* sp. Infection with roundworms and hookworms was associated with a variety of factors, including introduction of new animals, management practices, cage cleanliness, feed type, use of deworming medication, routine deworming, and contact with other animals. A human case of cutaneous larva migrans was due to hookworm (*Ancylostoma* sp./*Uncinaria* sp.) infection.

Conclusion: The prevalence of important zoonotic gastrointestinal nematodes (hookworms and roundworms) is high in cats in Jabodetabek, Indonesia. To reduce the risk of transmission to other animals or humans, adequate measures to control, manage, and prevent zoonotic helminth infections are required. This study presents important baseline information that provides a basis for future epidemiologic studies and the development of strategies to manage zoonotic gastrointestinal helminths in cats in the region.

Keywords: Cat, Gastrointestinal helminths, Prevalence, Risk factors, Zoonotic.

Introduction

The established benefits of companion animal ownership on human mental, emotional, and physical health (Paul *et al*., 2010) are thought to play a significant role in observed increases in pet cat populations worldwide (Ursache *et al*., 2021). However, pet ownership is also associated with potential health hazards (Overgaauw and van Knapen, 2013). One such hazard is infection with gastrointestinal helminths, which represent a leading cause of morbidity in domestic cats. Some of these helminths are zoonotic and thus threaten public health

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due to the potential for spread to humans (Yang and Liang 2015; Ursache *et al*., 2021).

Zoonotic helminths include nematodes (*Toxocara sp., Ancylostoma sp., Uncinaria sp.,* and *Strongyloides sp.),* trematodes (*Diphyllobothrium sp.*), and cestodes (*Dipylidium sp*. and Echinococcus sp.) (Overgaauw and van Knapen, 2013; Phosuk *et al*., 2013). Roundworm species such as Toxocara canis, *T. cati,* and *T. malaysiensis* and hookworm species such as *Ancylostoma braziliense*, *A. caninum, A. ceylanicum,* and *Uncinaria stenocephala* are capable of infecting both domestic dogs and cats.

Toxocara species can infect humans, who serve as paratenic hosts, via exposure to contaminated soil/ water, although the parasites are usually acquired via the fecal-oral route through ingestion of live L2 larvae, embryonated eggs found in the environment, larvae present on unwashed hands or raw vegetables, or through ingestion of larvae found in uncooked organs or muscle tissue from other paratenic hosts (Wolfe and Wright 2003; Wu and Bowman 2020). Toxocara infections can produce a variety of clinical symptoms, including ocular larva migrans, visceral larva migrans, and eosinophilic meningoencephalitis (Despommier 2003; Macpherson 2013) and associated complications, including allergic and neurologic disorders/neurotoxocariasis (Ma *et al*., 2018). Human ancylostomiasis occurs when zoonotic hookworm larvae penetrate unprotected skin that has contacted contaminated soil or sand (de Mello *et al*., 2022). These species are regarded as neglected tropical zoonoses because they can induce cutaneous larva migrans (CLMs), a creeping skin eruption affecting humans (Massetti *et al*., 2020).

Four species of Strongyloides have been identified in cats, including *S. felis, S. planiceps, S. tumefaciens*, and *S. stercoralis*, among which *S. stercoralis* is the predominant species affecting humans, dogs, and cats (Wulcan *et al*., 2019). Infection with *Strongyloides sp.* occurs predominantly via oral ingestion or percutaneous penetration facilitated by infectious third-stage larvae, although the precise mechanism by which the organism enters the intestines remains unclear (Wulcan *et al*., 2019). Although the life cycle and diet of host animals play a role in disease transmission, the prevalence of patent infections is often highest in puppies and kittens, lower in juveniles, and lowest in adult dogs and cats (Ridwan *et al*., 2023). Dogs, cats, and humans can acquire helminth infections by consuming contaminated raw flesh, helminth eggs present in the environment, or an infected paratenic host (including chickens and rodents) (Overgaauw and van Knapen, 2013).

Cases of infection with zoonotic helminths in cats are often asymptomatic, and they are usually only identified by fecal screening or spontaneous passage of worms through feces or vomitus (toxocariasis in kittens), as healthy companion cats typically exhibit a low worm burden (Castro and Sapp 2021). Animals with a higher parasite burden, for example, kittens with transmammary toxocariasis infection, may exhibit signs of malnutrition, pot belly appearance, respiratory distress, diarrhea, vomiting, and cachexia (Dantas-Torres *et al*., 2020). Similarly, worm infections in humans are also generally asymptomatic. Clinically apparent infections may go undetected due to the high cost of diagnostic testing and the potential need for pruritic or unaffordable molecular, imaging, or serologic tests (Macpherson 2013). Routine diagnosis of a worm infection involves demonstrating the presence of characteristic eggs in feces (Overgaauw and van Knapen, 2013). Dryden *et al*., (2005) proposed a sedimentation and flotation method as an alternative to centrifugation due to the consistently higher egg recovery compared with centrifugation-based methods.

Rates of cat and dog ownership are increasing in Indonesia (Ridwan *et al*., 2023), particularly in urban regions surrounding Jakarta, Bogor, Depok, Tangerang, and Bekasi (Jabodetabek) (direct communication with cat shelter owners in Bogor and Jakarta, 2022). Nevertheless, many pet owners exhibit a significant lack of awareness regarding the risk of diseased animals contaminating their surroundings or serving as carriers for disease transmission to humans. It is, therefore, important to identify the predominant circulating gastrointestinal parasites in order to assess the relevant risk factors for the spread of parasitic diseases to other animals or humans and initiate appropriate mitigation actions. Furthermore, studies in this subject area in Indonesia are extremely limited.

The present study evaluated the prevalence of zoonotic gastrointestinal helminths in cats and identified risk factors for infection with these helminths and their zoonotic potential among the cat population in Jabodetabek and surrounding areas.

Materials and Methods

Sampling sites and sample collection

A cross-sectional study was carried out between November 2022 and April 2023 in the important urban zone located in the Jakarta metropolitan area, known locally as Jabodetabek (an acronym of Jakarta–Bogor–Depok–Tangerang–Bekasi. This is the most populous megapolitan area in Indonesia and includes the national capital (Jakarta Special Capital Region as the core city), five satellite cities, and three complete regencies (Rustiadi *et al*., 2015). The survey area included cities in Central, South, East, and West Jakarta (DKI Jakarta Province), Bogor and Depok cities (West Java Province), and Tangerang Regency (Banten Province). The study investigated stray cats obtained from cat shelters and door-to-door sampling (owned cats; household companions). Cat shelters in the study area care for stray cats from various locations, especially in the province in which the shelter is located. All cities in the study area are tropical and adjacent to one another. Rainfall in the study area is generally evenly distributed throughout the year. Average annual rainfall at all locations is generally 2,000–4,000 mm, with air temperature in the 24°C–35°C range (Putri and Wibowo, 2023). A total of 354 fecal samples were collected from the following locations: East Jakarta city (10/7 owned/stray cats), South Jakarta city (23/89 owned/stray cats), Central Jakarta city (33 owned cats), Bogor city (55/42 owned/stray cats), Depok city (23 stray cats), Tangerang city/district (20 owned cats), and Bekasi city (52 stray cats). Stool samples were collected from each animal from the litter during initial defecation. Each sample was individually numbered and sealed in a polyethylene container, which was stored at 4°C, with analysis completed within 72 hours. Each cat's sex, age, breed, housing conditions, deworming history, and food were documented on a data entry sheet on the day of sampling. Human cases of worm larvae infestation noted during the interview were reported to the appropriate authorities. The sampling sites selected in this study are presented in Figure 1.

Sample size estimation

A random sampling approach was utilized based on a 35% expected prevalence of ancylostomiasis and toxocariasis determined from a previous report that included the study area (Ridwan *et al*., 2023). The sample size was calculated as follows: $n = z^2 p(1 - p)/d^2$, where n = required sample size, p = estimated prevalence, d = 95% confidence level, and d = margin of error at 5% (Daniel and Cross 2018).

Examination of stool samples

Gastrointestinal nematode eggs were isolated from each sample using a sugar flotation technique as previously described, with some modifications (Sawitri *et al*., 2019). Fecal samples (5 g each) were suspended in distilled water and filtered using a 150 µm sieve. The filtrate was poured into a 50 ml tube and centrifuged at 800 g for 5 minutes, after which as much of the supernatant as possible of each sample was discarded. Sugar solution (specific gravity ~1.2) was added to the sediment of each sample to a scale volume of 45 ml, and 5 ml of distilled water was then added to a scale volume of 50 ml (to form 2 layers). The sample was then centrifuged at 1,200 g for 10 minutes. Worm eggs floating on the surface of the sugar solution (at the border between the saturated sugar and water layers) were collected up to a total of 15 ml using a Pasteur pipette, placed in a new 50 ml centrifuge tube, and washed with distilled water 3 times. Purified eggs were dissolved in 1 ml of phosphate-buffered saline. Finally, samples were stored at 4°C until further analysis.

Identification of isolated eggs

A total of 10 µl of egg-containing solution was placed on a microscope slide and mixed with 10 µl of saturated sugar solution. A cover glass was placed over the specimen, and the slide was examined under a binocular microscope at magnifications of 40 × and 100 × to identify gastrointestinal helminth eggs based on structural and morphometric features (Thienpont *et al*., 2003).

Data management and statistical analysis

Data collected during sample collection and the results of fecal examinations were entered into a Microsoft Excel spreadsheet for analysis. Statistical analyses were carried out using SPSS software, version 25.0 (Ghozali 2021). The prevalence and frequency distribution of overall infection with each parasite were determined using the bivariate analysis method. Chi-square tests

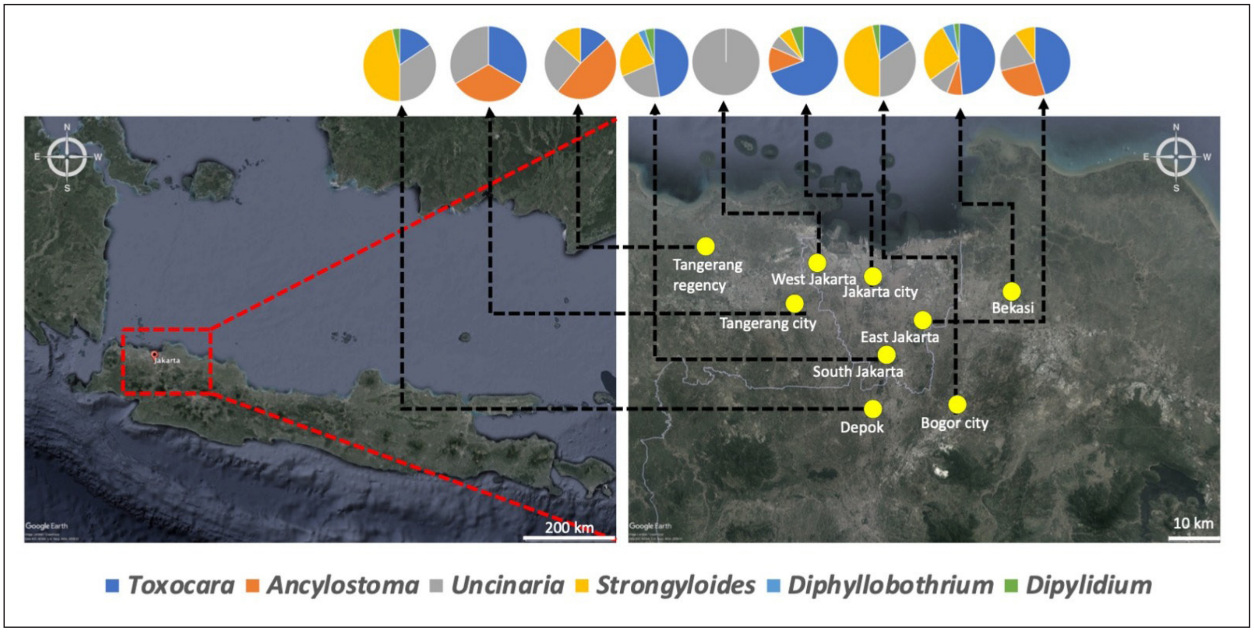

Fig. 1. Map depicting sample collection sites in this study.

were used to analyze associations between risk factors. In cases of fewer than 5 total cells, Fisher's exact test was used. A standardized questionnaire was used to obtain information regarding the management profile of each cat. The following independent variables were considered: age (≤12 months, >12 months), gender, and management (e.g., cat food, outdoor versus indoor housing, contact with other animals, deworming program, and cage cleaning). Dependent variables included eggs of *Toxocara sp., Ancylostoma sp., Uncinaria sp., Strongyloides sp., Diphyllobothrium sp*., and *Dipylidium sp*. In statistical tests, $p < 0.05$ was considered indicative of a statistically significant difference. Human cases of worm larvae infestation identified during interviews were reported to the appropriate authorities.

Ethical approval

The experimental design was approved by the Ethics Committee on Animal Use and the Sosial Humaniora of the National Research and Innovation Agency (approval numbers 094/KE.02/SK/11/2022 and 524/KE.01/SK/11/2022, respectively).

Results

A total of 354 fecal samples were collected during the survey in the Jabodetabek area. The samples were collected from 213 stray cats and 141 owned cats. The overall prevalence of zoonotic gastrointestinal helminth infection in the study was 53.3%, as 188 of 354 samples tested positive for parasite ova. A total of 6 zoonotic gastrointestinal helminths were identified from the examined fecal samples, including *Toxocara sp., Ancylostoma sp., Uncinaria sp., Strongyloides sp., Dipylidium sp.*, and *Diphyllobothrium sp*. (Fig. 2).

The prevalence of infections in the study varied regionally. The most common helminth infections in cats examined in the study were roundworm (*Toxocara sp.*) and hookworm (*Uncinaria sp.* and *Ancylostoma sp*.), with overall prevalences of 37.9% (134/354), 25.4% (90/354), and 22.6% (80/354), respectively. As infections caused by *Strongyloides sp., Dipylidium sp.*, and *Diphyllobothrium sp*. are generally uncommon, the prevalence of infection with these organisms was

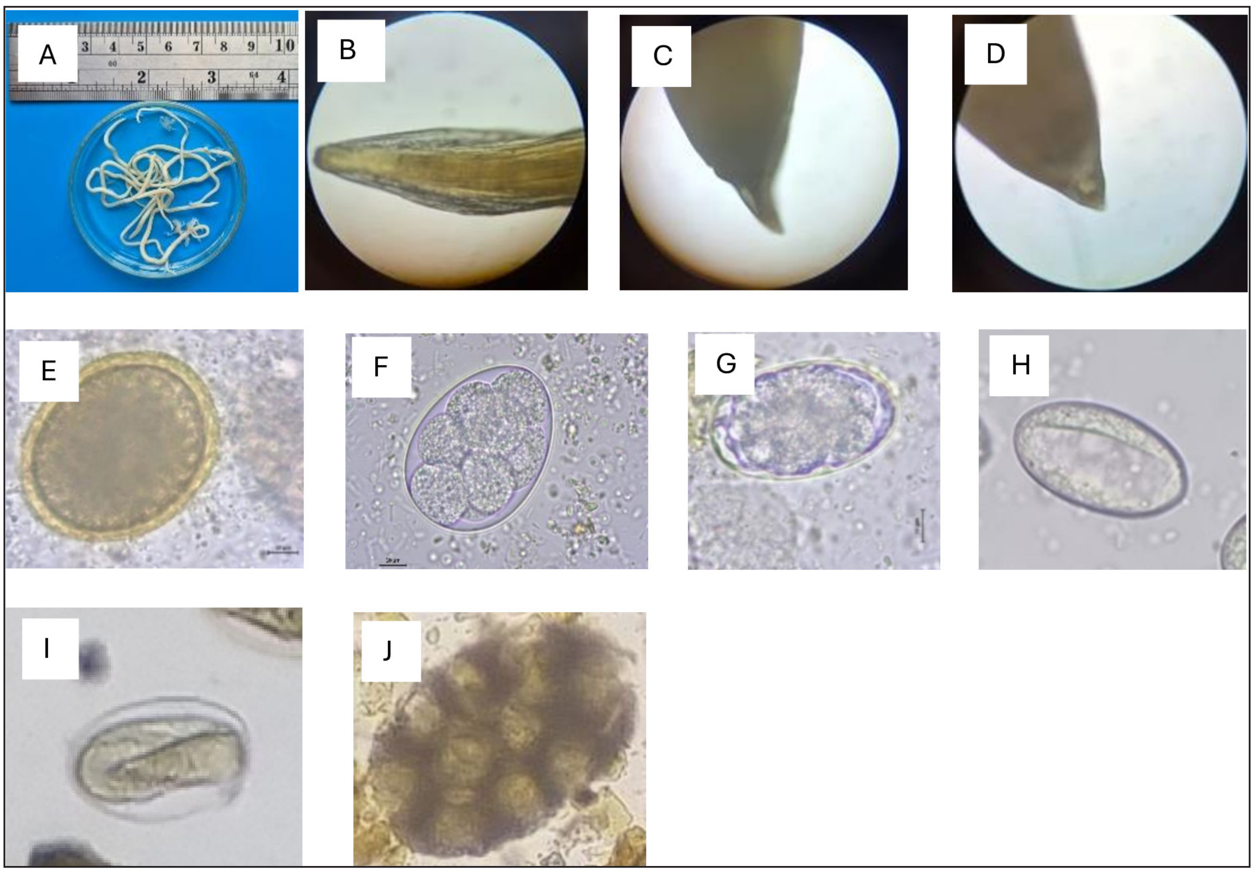

Fig. 2. Helminth worms and eggs found in parasitological examinations of domestic cat feces from the Jabodetabek area, Indonesia. Macroscopic: (A) *Toxocara malaysiensis* worm; microscopic: (B) cephalic alae of *Toxocara malaysiensis*; (C) tail-end of *Toxocara malaysiensis* male (D); tail-end of *Toxocara malaysiensis* female; (E) egg of *Toxocara malaysiensis*; (F) egg of *Ancylostoma* sp.; (G) egg of *Uncinaria* sp.; (H) egg of *Diphyllobothrium* sp.; (I) egg of *Strongyloides* sp.; (J) egg of *Dipylidium caninum*. Photomicrograph of worm (100 × magnification), egg (400 × magnification).

low, at 3.1% (11/354), 1.4% (7/354), and 0.6% (2/354), respectively.

Infection with Toxocara sp. was most prevalent in South Jakarta, at 15.3% (54/354), suggesting that this region bears a greater overall burden of Toxocara infection, followed by Bogor at 9.9% (34/354) and Bekasi at 5.6% (20/354). Bogor city exhibited the highest prevalence of *Ancylostoma sp*. infection, at 8.8% (31/354), followed by South Jakarta at 6.8% (24/354). The prevalence of *Uncinaria sp*. infection was 8.5% (30/354) and 7.6% (27/354) in Bogor and South Jakarta, respectively. The importance of implementing targeted public health measures was underscored by the substantial cumulative prevalence observed across all regions (Table 1).

The cats examined in the present study were often infected with more than one parasite species. The incidence of mixed infections was higher than that of single infections and ranged from 52.3% (185/354) to 53.1% (188/354) (Table 2). Co-infections involving two worm species (*Toxocara sp*. and *Ancylostoma sp*.) or three worm species (*Ancylostoma sp., Toxocara sp*., and *Uncinaria sp.*) exhibited similar prevalence, as shown in Table 3. This finding suggests that helminth infections tend to be mixed rather than single. At all sites in the study area, the prevalence rates of infection with cestode and trematode worms were very low.

Factors associated with Toxocara sp., Ancylostoma sp., and Uncinaria sp. infection

Toxocara sp., Ancylostoma sp., and *Uncinaria sp.* were the dominant nematode species detected in the study area. The predominant predictors of intestinal helminth infection were pet ownership, breed, pet age, introduction of new animals, housing conditions, feed, use of deworming medicine, and contact with other animals (Table 3).

Cats in shelters had a 4.26-fold higher risk of toxocariasis infection than owned cats. The local breed had a 2.72-fold higher risk of toxocariasis than other breeds (purebred and mixed). Cats ≤12 months old had a 0.562-fold higher risk than cats >12 months old. The introduction of new animals increased the risk of transmission of *Toxocara sp*. by 3.39-fold compared with no introduction of new animals. Feeding cats a non-commercial feed increased the risk of contracting an intestinal parasite infection by 0.266-fold compared with cats fed a commercial feed. Cats that did not receive deworming medicine were at a 1.942-fold higher risk of infection with *Toxocara sp.* eggs.

Contact with other animals increased the risk of contracting *Toxocara sp*. eggs by 2.566-fold compared with no contact with other animals. No significant associations ($p > 0.05$) were observed between *Toxocara sp*. infection and factors such as mixed breed, sex, pregnancy status, presence of new animals, management with mixed treatment (caged versus not caged), cage cleanliness, and routine deworming. However, other factors exhibited statistically significant associations ($p < 0.05$), as presented in Table 3.

Cats not subjected to routine deworming were at a 4.9-fold greater risk of being infected with *Ancylostoma sp*. than routinely dewormed cats. Other factors, such as the introduction of new animals, cats held in shelters, coming into contact with other animals/wildlife, female cats, free-range cats, and unclean cages were significantly associated with ancylostomiasis, exhibiting 3.79-, 3.69-, 3.5-, 2.9-, and 2.7-fold greater risk of contracting ancylostomiasis, respectively. Significant associations ($p < 0.05$) were also observed between *Ancylostoma* infection and factors including ownership, pet sex, presence of new animals, management with cage, management without cage, feed type, deworming medicine, routine deworming, and contact with other animals. By contrast, no significant associations were observed with variables such as breed and age ($p > 0.05$).

Table 1. Prevalence of infections with zoonotic gastrointestinal helminths in this study.

	Parasite (%)					
LOCATION (city)	***Toxocara* sp.**	***Ancylostoma* sp.**	***Uncinaria* sp.**	***Strongyloides* sp.**	***Diphyllobothrium* sp.**	***Dipylidium* sp.**
Bekasi	20/354 (5.6)	4/354 (1.1)	11/354 (3.1)	2/354 (0.6)	1/354 (0.3)	0
Bogor	35/354 (9.9)	31/354 (8.8)	30/354 (8.5)	2/354 (0.6)	0	1/354 (0.3)
Depok	5/354 (1.4)	11/354 (3.1)	15/354 (4.2)	0	1/354 (0.3)	0
Central Jakarta	12/354 (3.4)	2/354 (0.6)	1/354 (0.3)	1/354 (0.3)	0	1/354 (0.3)
West Jakarta	0	0	1/354 (0.3)	0	0	0
South Jakarta	54/354 (15.3)	24/354 (6.8)	27/354 (7.6)	4/354 (1.1)	5/354 (1.4)	0
East Jakarta	5/354 (1.4)	3/354 (0.8)	2/354 (0.6)	1/354 (0.3)	0	0
Tangerang	2/354 (0.6)	2/354 (0.6)	2/354 (0.6)	0	0	0
Tangerang district	1/354 (0.3)	4/354 (1.1)	2/354 (0.6)	1/354 (0.3)	0	0
TOTAL	134/354 (37.9)	80/354 (22.6)	90/354 (25.4)	11/354 (3.1)	7/354 (2)	2/354 (0.6)

Table 2. Prevalence of dominant mixed infections with zoonotic gastrointestinal helminths in this study.

	Parasite (%)			
Location (city)	***Toxocara* sp./ *Ancylostoma* sp.**	***Toxocara* sp./ *Uncinaria* sp.**	***Ancylostoma* sp./ *Uncinaria* sp.**	***Toxocara* sp./ *Ancylostoma* sp. /*Uncinaria* sp.**
Bekasi	27/354 (7.6)	27/354 (7.6)	26/354 (7.3)	26/354 (7.3)
Bogor	53/354 (15)	51/354 (14.4)	52/354 (14.7)	53/354 (15)
Depok	15/354 (4.2)	16/354 (4.5)	16/354 (4.5)	16/354 (4.5)
Central Jakarta	14/354 (4)	14/354 (4)	13/354 (3.7)	14/354 (4)
West Jakarta	1/354 (0.3)	1/354 (0.3)	1/354 (0.3)	1/354 (0.3)
South Jakarta	66/354 (18.6)	66/354 (18.6)	65/354 (18.4)	66/354 (18.6)
East Jakarta	5/354 (1.4)	5/354 (1.4)	5/354 (1.4)	5/354 (1.4)
Tangerang	2/354 (0.6)	2/354 (0.6)	2/354 (0.6)	2/354 (0.6)
Tangerang district	4/354 (1.1)	4/354 (1.1)	4/354 (1.1)	4/354 (1.1)
Total	188/354 (53.1)	187/354 (52.8)	185/354 (52.3)	188/354 (53.1)

However, routine deworming, the introduction of new animals, ownership type, contact with other animals/wild animals, breed, deworming medicine usage, housing situation, and breed were significantly associated with *Uncinaria sp.* infection (Table 3). Routine deworming exhibited the strongest association with *Uncinaria sp*. infection. Cats not routinely dewormed exhibited an 11.8-fold greater risk of *Uncinaria sp.* infection than cats that were routinely dewormed. Other risk factors associated with *Uncinaria sp*. infection were the introduction of new animals, ownership type, contact with other animals/ wild animals, breed, deworming medicine usage, and housing type, with 7.48-, 5.03-, 2.56-, 2.2-, 2.16, and 2.01-fold greater risk of infection, respectively. Among all variables, significant associations ($p < 0.05$) were observed between *Uncinaria* infection and ownership type, local breed, mixed breed, introduction of new animals, management with cage, management without cage, cage cleanliness, feed type, deworming medicine, routine deworming, and contact with other animals. Other factors were not significantly associated with *Uncinaria* infection ($p > 0.05$).

Factors associated with Strongyloides sp., Diphyllobothrium sp., and Dipylidium sp. infection

Strongyloides sp., Diphyllobothrium sp., and *Dipylidium sp.* exhibited the lowest prevalence rates in the study area. No significant associations were observed between infection with these organisms and cat breed, age, sex, pregnancy, the introduction of new animals, management practices, cage cleanliness, feed type, and routine deworming status (Table 4). In contrast, animals kept without cages and ownership type were associated with *Diphyllobothrium sp.* infection, with 10.9- and 1-fold greater risk of infection, respectively. In contrast, these parameters were not associated with *Strongyloides sp.* and *Dipylidium sp*. infections. It is possible that the small number of infections in the population under study contributed to the lack of significant associations.

CLM in humans

During interviews conducted at the shelter in Depok city regarding cat feces sampling, a 40-year-old female presented with a 6-week history of severe, migratory, and itching dermatitis accompanied by the formation of blisters on her right hand (Fig. 3). This individual was a cat caretaker at a local shelter. The prevalence rates for hookworm infection among the 23 samples collected at that location were approximately 21% (5/23) for *Toxocara sp*., 47.8% (11/23) for *Ancylostoma sp*., and 60.87% (14/23) for *Uncinaria sp*.

Discussion

This survey found that roundworm (*Toxocara sp.*) was the most prevalent zoonotic helminth infection in cats in the Jabodetabek area of Indonesia, followed by hookworm (*Ancylostoma sp*. and *Uncinaria sp*.). Other worms identified in the study included *Strongyloides sp., Diphyllobothrium sp.,* and *Dipylidium sp*., but these were uncommonly characterized by low prevalence. The overall prevalence of roundworm *Toxocara sp.* infection (37.9%), hookworm *Ancylostoma sp.* infection (22.4%), and *Uncinaria sp*. infection (25.6%) in cats in Jabodetabek were higher than the previously reported prevalence of roundworm and hookworm infections in cats in China (17.7% and 6.39%, respectively) (Yang and Liang 2015) as well as in Northern Thailand (2.2% and 13.9%, respectively) (Pumidonming *et al*., 2016). The prevalence of Toxocara sp. in the present study area was comparable to the infection rate in cats in Bogor in a previous study, which was 35%. According to Dantas-Torres (2020) and Phoosangwalthong *et al*., (2022), the prevalence of toxocariasis in cats in the present study was higher than that previously reported in Brazil and

Table 3. Summary of risk factors associated with *Toxocara* sp., *Ancylostoma* sp., and *Uncinaria* sp. infection in the bivariate analysis.

Variable		*Toxocara* sp.		*p*-value	OR	*Ancylostoma* sp.		*p*- value	OR	*Uncinaria* sp.		*p*-value	OR
		Yes	No			Yes	No			yes	No		
Ownership	Shelter	107 (30.2%)	106 (29.9%)	0.000	4.262	65 (18.4%)	148 (41.8%)	0.000	3.689	76 (21.5%)	137 (38.7%)	0.000	5.032
	Personal	27 (7.6%)	114 (32.2%)			15 (4.2%)	126 (35.6%)			14 (4%)	127 (35.9%)		
Local breed	Yes	120 (33.9%)	167 (47.2%)	0.001	2.720	70 (19.8%)	217 (61.3%)	0.095	–	80 (22.6%)	207 (58.5%)	0.028	2.203
	No	14 (3.95%)	53 (14,9%)			10 (2.8%)	57 (16.1%)			10 (2.8%)	57 (16.1%)		
Puebred	Yes	7 (2%)	34 (9.6%)	0.004	0.302	7 (2%)	34 (9.6%)	0.368	–	9 (2.5%)	32 (9%)	0.587	–
	No	127 (35.8%)	186 (52.5%)			73 (20.6%)	240 (67.8%)			81 (22.8%)	232 (65.5%)		
Mixed Breed	Yes	7 (2%)	19 (5.4%)	0.233	–	3 (0.8%)	23 (6.5%)	0.161	–	1 (0.3%)	25 (7.1%)	0.009	0.107
	No	127 (35.8%)	201 (56.7%)			77 (20.6%)	251 (70.9%)			89 (25.1%)	239 (67.5%)		
Age	≤12 months old	36 (10.2%)	87 (24.6%)	0.015	0.562	22 (6.2%)	101 (28.5%)	0.122	–	29 (8.2%)	94 (26.6%)	0.560	–
	>12 months old	98 (27.7%)	133 (37.6%)			58 (16.4%)	173 (48.9%)			61 (17.2%)	170 (48%)		
Sex	Female	105 (29.7%)	165 (46.6%)	0.471	–	71 (20.1%)	199 (56.2%)	0.003	2.973	73 (20.6%)	197 (55.6%)	0.211	–
	Male	29 (8.2%)	55 (15.5%)			9 (2.5%)	75 (21.2%)			17 (4.8%)	67 (18.9%)		
Pregnant	Yes	1 (0.3%)	1 (0.3%)	0.722	–	1 (0.3%)	1 (0.3%)	0.353	–	1 (0.3%)	1 (0.3%)	0.423	–
	No	133 (37.6%)	219 (61.9%)			79 (22.3%)	273 (77.1)			89 (25.1%)	263 (74.3%)		
New animals	Yes	115 (32.5%)	141 (39.8%)	0.000	3.391	71 (20.1%)	185 (52.3%)	0.000	3.795	84 (23.7%)	172 (48.6%)	0.000	7.488
	No	19 (5.4%)	79 (22.3%)			9 (2.5%)	89 (25.1%)			6 (1.7%)	92 (26%)		
Management with cage	Yes	31 (8.8%)	84 (23.7%)	0.003	0.487	14 (4%)	101 (28.5%)	0.001	0.363	20 (5.6%)	95 (26.8%)	0.016	0.508
	No	103 (29%)	136 (38.4%)			66 (18.6%)	173 (48.8%)			70 (19.8%)	169 (47.7%)		
Management without cage	Yes	65 (18.4%)	64 (18.1%)	0.000	2.296	37 (10.5%)	92 (26%)	0.038	1.702	44 (12.4%)	85 (24%)	0.004	2.014
	No	69 (19.5%)	156 (44%)			43 (12.1%)	182 (51.4%)			46 (12.9%)	179 (50.5%)		
Management with mixed treatment (caged and not caged)	Yes	38 (10.7%)	72 (20.3%)	0.389	–	29 (8.2%)	81 (22.9%)	0.255	–	26 (7.3%)	84 (23.7%)	0.604	–
	No	96 (27.1%)	148 (41.8%)			51 (14.4%)	193 (54.5%)			64 (18%)	180 (50.8%)		
Cage cleanliness	No	9 (2.5%)	21 (5.9%)	0.354	–	3 (0.8%)	27 (7.6%)	0.085	–	2 (0.6%)	28 (7.9%)	0.014	0.192
	Yes	125 (35.3%)	199 (56.2%)			77 (21.8%)	247 (69.8%)			88 (24.9%)	236 (66.7%)		

(Continued)

Variable		***Toxocara* sp.**		***p*-value**	**OR**	***Ancylostoma* sp.**		***p*- value**	**OR**	***Uncinaria* sp.**		***p*-value**	**OR**
		Yes	**No**			**Yes**	**No**			**yes**	**No**		
Feed	Others	5 (1.4%)	28 (7.9%)	0.005	0.266	2 (0.6%)	31 (8.8%)	0.017	0.201	2 (0.6%)	31 (8.8%)	0.007	0.171
	Commercial	129 (36.4%)	192 (54.2%)			78 (22%)	243 (68.6%)			88 (24.9%)	233 (65.8%)		
Deworming medicine	No	63(17.8%)	69(19.5%)	0.003	1.942	38 (10.7%)	94 (26.6%)	0.032	1.733	46 (13%)	86 (24.3%)	0.002	2.164
	Yes	71(20.1%)	151(42.7%)			42 (11.9%)	180 (50.8%)			44 (12.4%)	178 (50.3%)		
Routine deworming	No	124 (35%)	198 (55.9%)	0.419	–	78 (22%)	244 (68.9%)	0.020	4.795	89 (25.1%)	233 (65.8%)	0.002	11.841
	Yes	10 (2.8%)	22 (6.2%)			2 (0.6%)	30 (8.5%)			1 (0.3%)	31 (8.8%)		
Contact with other animals	Yes	108 (30.5%)	136 (38.4%)	0.000	2.566	69 (19.5%)	175 (49.4%)	0.000	3.549	74 (20.9%)	170 (48%)	0.002	2.557
	No	26 (7.3%)	84 (23.7%)			11 (3.1%)	99 (28%)			16 (4.5%)	94 (26.6%)		

Fig. 3. Case of CLMs in a human after a 6-week infection.

Bangkok (6.7% and 0.6%, respectively). However, the prevalence in the present study was lower than the *T. cati* prevalence in cats in Vietnam (47.8%) (Anh *et al*., 2016) and Romania (40.2%) (Ursache *et al*., 2021) In contrast, the prevalence of hookworm in this study was higher than that reported by Ursache *et al*., (2021), and Yang and Liang (2015) for central China (6.39%), Romania (3.7%), and Algeria (1.15%), respectively. Hookworm prevalence rates vary regionally due to factors such as climate, living conditions, diagnostic resources, and the quality of veterinarian care (Garcia-Campos *et al*., 2019). Although the present study found an association between *Toxocara sp*. and *Ancylostoma sp*. infection rates and several risk factor parameters, only two parameters were associated with diphyllobothriasis in cats, namely cage management and owned cats. Cats kept outdoors (without cages) or in shelters are at a 10-fold and 1-fold greater risk of infection with *Diphyllobothrium sp*., respectively, compared with cats kept indoors and owned cats.

According to Kurnosova *et al*., (2019), pets can serve as long-term sources of infection due to the subclinical nature of many parasitic diseases, especially helminthiases. The course and duration of the disease depend on a number of factors, including the type and intensity of infestation, the animal's age and immune status, and the presence of any concurrent underlying diseases (Kurnosova, 2009). Yang and Liang (2015) reported that regional differences in the frequency and availability of veterinary care during different seasons of the year and the type of cat population (household, stray, feral, or shelter cats) can affect the prevalence of intestinal parasites.

Table 4. Summary of risk factors associated with *Strongyloides* sp., *Diphyllobothrium* sp., and *Dipylidium* sp. infection in the bivariate analysis.

Variable		*Strongyloides* sp.		*p*-value	OR	*Diphyllobothrium* sp.		*p*-value	OR	*Dipylidium* sp.		*p*-value	OR
		Yes	No			Yes	No			yes	No		
Ownership	Shelter	7 (2%)	206 (58.2%)	1.000	–	7 (2%)	206 (58.2%)	0.045	0.967	1 (0.3%)	212 (59.9%)	1.000	–
	Personal	4 (1.1%)	137 (38.7%)			0 (0%)	141 (39.8%)			1 (0.3%)	140 (39.5%)		
Local breed	Yes	10 (2.8%)	277 (78.2%)	0.398	–	7 (2%)	280 (79.1%)	0.355	–	2 (0.6%)	285 (80.5%)	1.000	–
	No	1 (0.28%)	66 (18.6%)			0 (0%)	67 (18.9%)			0 (0%)	67 (18.9%)		
Purebred	Yes	0 (0%)	41 (11.6%)	0.223	–	0 (0%)	41 (11.6%)	1.000	–	0 (0%)	41 (11.6%)	1.000	–
	No	11 (3.1%)	302 (85.3%)			7 (1.97%)	306 (86.4%)			2 (0.56%)	311 (87.8%)		
Mixed breed	Yes	1 (0.3%)	25 (7.1%)	0.822	–	0 (0%)	26 (7.3%)	0.369	–	0 (0%)	26 (7.3%)	1.000	–
	No	10 (2.8%)	318 (89.8%)			7 (1.97%)	321 (90.6%)			2 (0.56%)	326 (92.1%)		
Age	≤12 months old	3 (0.8%)	120 (33.9%)	0.754	–	2 (0.6%)	121 (34.2%)	1.00	–	0 (0%)	123 (34.7%)	0.545	–
	>12 months old	8 (2.3%)	223 (63%)			5 (1.4%)	226 (63.8%)			2 (0.6%)	229 (64.7%)		
Sex	Female	10 (2.8%)	260 (73.4%)	0.470	–	6 (1.7%)	264 (74.6%)	1.000	–	1 (0.3%)	269 (76%)	0.419	–
	Male	1 (0.3%)	83 (23.4%)			1 (0.3%)	83 (23.4%)			1 (0.3%)	83 (23.4%)		
Pregnant	Yes	0 (0%)	2 (0.6%)	1.000	–	0 (0%)	2 (0.6%)	1.000	–	0 (0%)	2 (0.6%)	1.000	–
	No	11 (3.1%)	341 (96.3%)			7 (2%)	345 (97.5%)			2 (0.6%)	350 (98.9%)		
New animals	Yes	9 (2.5%)	247 (69.8%)	0.734	–	7 (2%)	249 (70.3%)	0.197	–	1 (0.3%)	255 (72%)	0.478	–
	No	2 (0.6%)	96 (27.1%)			0 (0%)	98 (27.7%)			1 (0.3%)	97 (27.4%)		
Management with cage	Yes	4 (1.1%)	111 (31.4%)	0.753	–	1 (0.3%)	114 (32.2%)	0.435	–	1 (0.3%)	114 (32.2%)	0.545	–
	No	7 (1.97%)	232 (65.5%)			6 (1.7%)	233 (65.8%)			1 (0.3%)	238 (67.2%)		
Management without cage	Yes	6 (1.7%)	123 (34.7%)	0.205	–	6 (1.7%)	123 (34.7%)	0.011	10.93	0 (0%)	129 (36.4%)	0.535	–
	No	5 (1,4%)	220 (62.1%)			1 (0.3%)	224 (63.2%)			2 (0.56%)	223 (62.9%)		
Management with mixed treatment (caged and not caged)	Yes	1 (0.3%)	109 (30.8%)	0.183	–	0 (0%)	110 (31.1%)	0.104	–	1 (0.3%)	109 (30.8%)	0.526	–
	No	10 (2.8%)	234 (66.1%)			7 (1.97%)	237 (66.9%)			1 (0.3%)	243 (68.6%)		
Cage cleanliness	No	1 (0.3%)	29 (8.2%)	1.000	–	0 (0%)	30 (8.5%)	1.000	–	0 (0%)	30 (8.5%)	1.000	–
	Yes	10 (2.8%)	314 (88.7%)			7 (2%)	317 (89.5%)			2 (0.6%)	322 (91%)		

(Continued)

Variable		*Strongyloides* sp.				*Diphyllobothrium* sp.				*Dipylidium* sp.			
		Yes	No	*p*-value	OR	Yes	No	*p*-value	OR	yes	No	*p*-value	OR
Feed	Others	1 (0.3%)	32 (9%)	1.000	–	0 (0%)	33 (9.3%)	1.000	–	0 (0%)	33 (9.3%)	1.000	–
	Commercial	10 (2.8%)	311 (87.9%)			7 (2%)	314 (88.7%)			2 (0.6%)	319 (90.1%)		
Deworming medicine	No	5 (1.4%)	127 (35.9%)	0.569	–	6 (1.7%)	126 (35.6%)	0.012	10.524	0 (0%)	132 (37.3%)	0.531	–
	Yes	6 (1.7%)	216 (61%)			1 (0.3%)	221 (62.4%)			2 (0.6%)	220 (62.1%)		
Routine deworming	No	10 (2.8%)	312 (88.1%)	1.000	–	7 (2%)	315 (89%)	1.000	–	1 (0.3%)	321 (90.7%)	0.173	–
	Yes	1 (0.3%)	31 (8.8%)			0 (0%)	32 (9%)			1 (0.3%)	31 (8.8%)		
Contact with other animals	Yes	8 (2.3%)	236 (66.7%)	1.000	–	6 (1.7%)	238 (67.2%)	0.443	–	2 (0.6%)	242 (68.4%)	1.000	–
	No	3 (0.8%)	107 (30.2%)			1 (0.3%)	109 (30.8%)			0 (0%)	110 (31.1%)		

The case of CLM in a shelter worker in Depok demonstrated that human zoonotic hookworms can be transmitted through contact with cat excrement contaminated with hookworm larvae. The individual was a cat caretaker, and her daily responsibilities included feeding and cleaning cat litter. She did not wear gloves and sometimes went barefoot while cleaning the cages. The cats in this shelter were stray cats removed from streets and markets, and they were not owned and had never been dewormed. Coello *et al*., (2019) reported that penetration of human skin by infective larvae (stadium III) of *Ancylostoma sp.* or *Uncinaria sp*. can lead to CLM. According to Yavuzer *et al*., (2010), the most common ways people become infected is through contact with contaminated materials during activities such as gardening, cleaning cat litter without gloves, sitting in contaminated sand or dirt, or going barefoot. Typically, these larvae travel through the epidermis and create raised tracks because they are unable to pass through the epidermis basal barrier (Reichert *et al*., 2018). The incubation period can be >5 months but is most often between 5 and 15 days (Sears *et al*., 2022).

Investigation of the prevalence of *Toxocara sp*. infection revealed that animals in shelters, local breeds, and recently introduced cats exhibited higher prevalence than owned cats, emphasizing the impact ownership, breeding, and introduction of new animals have on infection rates (Bonilla-Aldana *et al*., 2024). Additionally, management practices such as enclosed habitat, feed variety, and use of deworming medication are vital. Chi-square analyses of infections with *Ancylostoma sp.* and *Uncinaria sp*. demonstrated comparable patterns, underscoring the complex and diverse array of factors that contribute to gastrointestinal infections in animals (Table 3). The present study also showed associations between toxocariasis and ancylostomiasis infection and the introduction of new animals, management practices, cage cleanliness, feed type, deworming medicine, routine deworming, and contact with other animals, similar to the report by Arruda *et al*. (2022). Prevention of toxocariasis and ancylostomiasis requires targeted management strategies. Dami *et al*. (2023) reported that if domestic carnivores do not receive routine basic veterinary care and coexist in the same environment as wild animals, there is a greater chance that environmental pollution will spread parasitic infections from domestic carnivores to humans.

The absence of significant associations between infection with *Strongyloides sp., Dipylidium sp.*, and *Diphyllobothrium sp.* and the variables under study may be attributed to the small number of infections in the population under study. According to Vafae Eslahi *et al*. (2022), cats are the most common carriers of *Diphyllobothrium sp*. in Asia, whereas dogs are the most common carriers in Africa. Furthermore, no noteworthy correlations were observed between

Dipylidium sp. infection and breed, age, gender, introduction of new animals, management practices, cage cleanliness, feed type, deworming medicine, routine deworming, and contact with other animals, which can be attributed to the low prevalence of *Dipylidium sp*. infection in the sample population. The species of vertebrate and its life cycle can impact the chance of *Dipylidium caninum* infection. However, animals that are less likely to have access to veterinary treatment, such as animals in shelters and those on the streets, are more likely to become infected (ESCCAP 2021).

Overall, the results of the present study provide a more comprehensive understanding of the prevalence of gastrointestinal helminth infections in different regions of Indonesia and shed light on the varied factors that influence these infections. Considering the disparate prevalence rates of various gastrointestinal infections in the studied areas, the results of this study highlight the need for region-specific interventions. In order to effectively prevent and control gastrointestinal infections in animals, targeted interventions that consider ownership, breed, age, management practices, and other relevant factors are crucial, as demonstrated by the present findings.

Conclusion

In conclusion, the research findings presented here indicate that the prevalence of infection with *Toxocara sp., Ancylostoma sp.,* and *Uncinaria sp*. is higher in Jabodetabek, Indonesia. Significant factors contributing to the development of infection with these parasites include ownership, breed, introduction of new animals, management practices, caging, feed type, and deworming medication use. The presence of CLM in humans carrying hookworm larvae in Depok city is due to the high prevalence of hookworm infection in animals in the area. This study emphasized the importance of individualized prevention strategies that can reduce the risk of hookworm and roundworm transmission (e.g., using gloves when handling cat feces, washing hands after handling cats, and wearing footwear when outdoors). However, proper management practices, including providing adequate housing and high-quality feed, and instituting interventions to reduce environmental contamination such as limiting free-roaming cat populations, deworming new arrivals, routine deworming of outdoor cats, preventing owned cats from accessing public places, and preventing contact between owned cats and stray cats are important for controlling and preventing gastrointestinal infections in animals.

The results of this study provide important baseline data that can be used by veterinarians and public health officials to establish a framework for epidemiologic studies and the development of strategies for treating and controlling parasites that can potentially cause zoonotic infections of feline origin.

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Conflict of interest

The authors declare that there are no conflicts of interest.

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Authors' contributions

DHS and AHW conceived of and designed the study. Field sampling, data collection, and laboratory work: DHS, AHW, ESP, FN, DE, YRN, NAD, RAP, and EK. Data entry, analysis, and interpretation: DHS, AHW, DE, RAP, and YRN. The manuscript was drafted by DHS and YRN, and AHW and MM revised the intellectual content. All authors have read, reviewed, and approved the final version of the manuscript.

Data availability

All data used to support the primary findings of this study are included in the article. Complete datasets generated and analyzed during the study are available from the corresponding author upon reasonable request.

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