Companion animals as potential contributors to parasite contamination in lakeshore ecosystems of San Pablo, Laguna, Philippines

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ABSTRACT

The Seven Lakes of San Pablo, Laguna are vital freshwater systems that are ecologically and socio-economically important but increasingly vulnerable to contamination and public health risks. While intestinal parasites have been detected in these lakes, their sources remain unclear. Companion animals residing near lakeshores may serve as potential reservoirs of zoonotic parasites, although their role as direct sources of lake contamination has not been confirmed. Therefore, a cross-sectional study was conducted in communities surrounding Lakes Sampaloc, Calibato, and Bunot to assess parasite occurrence and zoonotic potential in companion animals. Previous studies documented the presence of waterborne protozoa in the lakes, including *Cryptosporidium* spp. (30.5%), *Giardia* spp. (14.3%), *Blastocystis* spp. (20.0%), and *Acanthamoeba* spp. (19.1%), with all four protozoan genera detected in Lake Calibato. These findings provided the rationale for investigating companion animals living near the lakes as potential sources of parasite contamination. A total of 71 fecal samples were collected from dogs (n = 52) and cats (n = 19) residing within a 200 m radius of the lakeshores. Helminths were detected in 57.7% of dogs and 63.2% of cats, predominantly hookworms/strongylids, followed by *Trichuris* spp. and *Toxocara* spp. Protozoan infections were identified in 53.8% of dogs and 52.6% of cats, including *Cryptosporidium* spp. and *Giardia* spp.

In univariate analyses, free-ranging behavior and lack of deworming were associated with any infection. In the multivariable model, place of defecation was significantly associated with infection status, with outside defecation showing lower odds of any infection than inside defecation (OR = 0.1442, 95% CI: 0.0216–0.7448, $p = 0.0282$), a counterintuitive finding that should be interpreted cautiously. Deworming showed a borderline association with infection status.

These findings highlight the need for responsible pet ownership, regular deworming, community education, and integrated environmental management to reduce zoonotic parasite transmission risks in lakeshore communities.

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INTRODUCTION

The Seven Lakes of San Pablo City, Laguna, Philippines, serve as vital freshwater resources that provide essential ecosystem services, including freshwater supply, food provisioning through fisheries and aquaculture, and tourism, for local communities and visitors (Brillo, 2023). These lakes are situated within residential and urban areas where continuous interactions among humans, animals, and the environment occur (Paller et al., 2021). However, increasing anthropogenic activities have intensified pressures on these ecosystems, making them increasingly vulnerable to pollution and ecological imbalance.

In recent years, the population of companion animals, particularly dogs and cats, has increased substantially in the Philippines (Alonte et al., 2024; Abadilla & Paller, 2022; Conde et al., 2022; Lo et al.,

KEYWORDS

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2021). While these animals provide social and emotional benefits, their close association with humans may increase the risk of zoonotic and enteric disease transmission. Companion animals can harbor a wide range of zoonotic intestinal parasites, including *Toxocara* spp., hookworms, *Giardia* spp., and *Cryptosporidium* spp. (Overgaauw et al., 2020; Chavez et al., 2021; Arruda et al., 2021; Ubirajara Filho et al., 2022; Zibaei et al., 2007). These parasites may be transmitted through the ingestion of infective stages in contaminated food, water, or soil, or through direct contact with contaminated environments or infected hosts (Aleem et al., 2024; Khatoon, 2024). Animal feces containing parasite eggs or cysts can contaminate soil and nearby water bodies, thereby facilitating the spread of infections to humans and other animals (Ngui et al., 2012).

Recent local studies in the Philippines have documented a high prevalence of intestinal parasites in companion animals, highlighting the magnitude of this public health concern. For example, a survey of dogs and cats in selected rural communities reported intestinal helminth prevalence ranging from ~60%–75%, with hookworms identified as the most common parasites (Alonte et al., 2024). Gastrointestinal parasites, including *Ancylostoma*, *Trichuris*, and *Toxocara* spp., were also detected in owned and shelter dogs in Cebu, demonstrating high levels of parasitic infection (Urgel, Ybañez, & Ybañez, 2019). Additionally, a sentinel study in Sitio Ibayo, Rizal, reported parasitic infection prevalences exceeding 60%–68% among cats and dogs (Labana et al., 2024).

These findings highlight not only the presence of zoonotic parasites in Philippine companion animals, but also their potential role in environmental contamination and human exposure, reinforcing the relevance of a One Health approach that integrates human, animal, and ecosystem health to address pathogen transmission at the human–animal–environment interface.

The Seven Lakes have previously been reported to exhibit varying degrees of fecal contamination, with Bunot Lake showing the highest fecal coliform levels, followed by Lakes Calibato and Sampaloc (LLDA, 2005). Studies have also detected pathogenic protozoans such as *Acanthamoeba*, *Cryptosporidium*, and *Giardia* in lake waters (Ballares et al., 2020; Masangkay et al., 2020), highlighting the potential zoonotic and enteric health risks associated with these freshwater systems. Furthermore, the Global Nature Fund (2014) classified the Seven Lakes as "threatened," underscoring the need for improved management and conservation efforts. However, the prevalence, intensity, and management-related risk factors of intestinal parasitism among lakeshore companion animals have not been fully quantified. This limit understanding of whether dogs and cats living along the lakeshores may serve as potential contributors to zoonotic and environmental parasite transmission.

Uncontrolled populations of dogs and cats, poor deworming practices, inadequate veterinary care, and low awareness of zoonotic diseases exacerbate the risk of environmental contamination (Padua, 2023). These issues are further intensified by uncollected animal feces near lakeshores and agricultural runoff carrying fecal material into the water. Despite environmental health interventions aimed at the sustainable management of the lakes (Paller et al., 2021), the contribution of companion animals to pathogen contamination remains understudied.

Given these concerns, there is a need to assess the potential role of dogs and cats in the transmission of intestinal parasites that may contribute to the contamination of the Seven Lakes of San Pablo. This study aims to: (1) determine the prevalence and intensity of intestinal parasites in companion animals; (2) identify risk factors associated with infection and environmental exposure/transmission pathways; and (3) recommend appropriate animal care, hygiene, and sanitation practices to mitigate zoonotic and ecological risks in these freshwater ecosystems.

Addressing this gap is particularly timely amid accelerating urbanization and climate change pressures, which may further exacerbate pathogen persistence and transmission within coupled human–animal–environment systems.

MATERIALS AND METHODS

Study site and Sampling Design

The study was conducted in the Seven Lakes of San Pablo City, Laguna, focusing specifically on Lakes Sampaloc, Calibato, and Bunot (Figure 1). These sites were selected based on previous findings by Mamawal et al. (2023), which documented higher levels of fecal contamination in these three lakes compared with the others. Sampaloc Lake (14°04.591′, 121°19.523′), with an area of 99.21 hectares and a maximum depth of 27 m, is bordered by five barangays: Barangay IV-A, IV-C, V-A, Concepcion, and San Lucas I. Calibato Lake (14°06.460′, 121°22.520′), covering 27.18 hectares with a maximum depth of 135 m, is located within Barangay Sto. Angel. Bunot Lake (14°04.720′, 121°20.484′), with an area of 38.16 hectares and a maximum depth of 23 m, is situated in Barangay Concepcion.

Households situated within a 200-meter radius of the lakeshores of Sampaloc, Calibato, and Bunot Lakes were identified using barangay household records and on-site geographic mapping to establish the sampling frame. Only households with owned dogs and/or cats were considered eligible for inclusion in the study. Coordination with the Municipal and Barangay Offices was conducted prior to data collection to secure the necessary permits and facilitate community entry. Household owners were personally approached, the objectives and procedures of the study were explained, and written informed consent was obtained prior to participation.

A stratified random sampling design was employed. Households situated within a 200 m radius of the lakeshores of Lakes Sampaloc, Calibato, and Bunot were identified using barangay household records and on-site geographic mapping to establish the sampling frame. Only households with owned dogs and/or cats were eligible for inclusion in the study. Coordination with the Municipal and Barangay Offices was conducted prior to data collection to secure the necessary permits and facilitate community entry. Household owners were personally approached, the objectives and procedures of the study were explained, and written informed consent was obtained prior to participation.

A total of 66 households were approached, of which 57 consented and were included in the final sample. The distribution of participating households was as follows: 26 from Sampaloc Lake, 16 from Calibato Lake, and 15 from Bunot Lake. Dog and cat fecal samples were subsequently collected from consenting households following the approved sampling protocol.

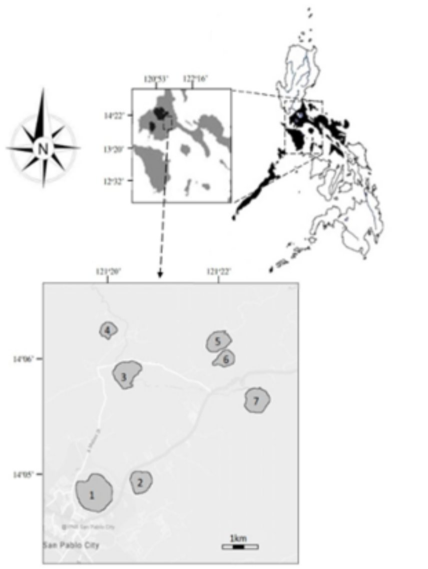

Figure 1: Map of San Pablo, Laguna showing the seven lakes of San Pablo, Laguna. (1) Sampaloc, (2) Bunot, and (7) Calibato lakes are the study sites (Paller, Corpuz, & Bandall, 2017).

Sample Size Calculation

Sample size of dogs and cats were computed and determined using a formula derived from the binomial distribution, which is commonly used to calculate sample size for estimating proportions (Fleiss et al., 2013):

$$n = \frac{(Z^2 x\, p\, x\, (1-p))}{E^2}$$

where n = sample size, Z = Z-score (1.96 for 95% confidence), p = expected prevalence in population based on previous or pilot studies, E = margin of error (0.10). Due to the limited availability of published local prevalence data on intestinal parasites in companion animals residing in lakeshore communities in the Philippines at the time of study design, prevalence estimates from the study of Joffe et al. (2011) were used as reference values for sample size computation. In their study, the reported overall endoparasite prevalence was 15.0% in dogs and 4.0% in cats. Although these estimates were derived from a non-local population, they were utilized to provide a conservative baseline for determining the minimum required sample size in the absence of comparable local epidemiological data. Using the single population proportion formula, the computed sample sizes were as follows:
ad

$$n = \frac{((1.96)^2 x\, 0.15\, x\, (1-0.15))}{0.10^2} = 48\, dogs$$

$$n = \frac{((1.96)^2 x\, 0.04\, x\, (1-0.04))}{0.10^2} = 14\, cats$$

Hence, a sample size of 48 dogs and 14 cats was computed for this study. To account for potential sample loss, a total of 71 samples were collected. Furthermore, morphometrics of household animals were recorded, including estimated age, breed, sex, and estimated weight, as well as animal handling practices such as containment status (penned/leashed or free-ranging) and frequency of deworming.

Permits and Ethical Clearance

The study was reviewed and approved by the UPLB Institutional Animal Care and Use Committee (PRF: UPLB-2024-071A) and the UPLB Research Ethics Board (UPLB REB 2025-0201). All procedures were conducted under Administrative Order No. 40 series of 1999 (Rules and Regulations on the Conduct of Scientific Procedures Using Animals) in accordance with the Republic Act No. 8485 or the Animal Welfare Act of 1998. Quality measures were observed in the samples during collection and processing to ensure the accuracy and reliability of the parasitological assessment.

Sample Collection, Processing and Examination

Fecal samples from dogs and cats (approximately 20 g each) were collected from selected households within the study site. Sample collection was performed by the researchers using appropriate personal protective equipment (PPE), including gloves and face masks, to ensure biosafety and prevent cross-contamination. Freshly voided fecal samples were collected directly from the ground immediately after defecation and placed into sterile, screw-capped stool container cups. Only single fecal samples were collected per animal. In households with multiple dogs and/or cats, samples were collected from individual animals based on the presence of a high-moisture sheen on the fecal surface, indicating recent defecation and minimizing the likelihood of environmental contamination or sample degradation.

Immediately after collection, fecal samples were preserved in 95% ethanol for molecular preservation and field stabilization during transport. The use of ethanol served to preserve nucleic acids and minimize sample degradation prior to laboratory processing. However, it is acknowledged that ethanol preservation may affect parasite morphology and could influence quantitative recovery during microscopic examination; therefore, microscopy-based observations and intensity estimates were interpreted with caution. Samples were transported to the laboratory under cold-chain conditions using insulated coolers with ice packs. Upon arrival, samples were stored at <4°C and processed within the recommended holding period to maintain sample integrity for downstream analyses.

Fecal samples were processed using a modified sedimentation technique. Approximately 2 g of each sample were filtered through a three-layered surgical gauze into a test tube. Distilled water was added to bring the total volume to 10 mL, followed by the addition of 3 mL of ethyl acetate. The tube was covered and shaken vigorously for 1 min to ensure adequate mixing. The suspension was then centrifuged at 1,500 rpm (RCF not recorded) for 10 min. After centrifugation, the supernatant was carefully decanted, and the remaining sediment was retained for parasitological examination.

For helminth detection, one drop of the sediment was placed on a glass slide and examined microscopically for characteristic eggs of *Toxocara* spp., *Trichuris* spp., and hookworm/strongylid species. Because egg counts were derived from sediment aliquots rather than a standard quantitative fecal egg count method, infection intensity was reported as estimated eggs per gram of feces (estimated EPG) rather than as an exact measure of worm burden. Estimated EPG was calculated based on the raw egg count observed in the examined sediment volume, the total processed sediment volume, and the amount of feces used.

$$\textbf{Eggs per Gram (EPG)}$$
$$= \left(\frac{raw\ egg\ count}{volume\ of\ solution\ examined\ (mL)}\right) x \left(\frac{total\ volume\ of\ solution\ (mL)}{amount\ of\ stool\ mixed\ in\ the\ solution\ (g)}\right)$$

For protozoan parasites, infection intensity was estimated as the number of cysts or oocysts per gram of feces examined. A 100 µL aliquot of the processed sediment was placed on a glass slide, and all observable *Giardia* spp. cysts and *Cryptosporidium* spp. oocysts within the droplet were counted under light microscopy. The counts per droplet were then used to compute the estimated number of cysts or oocysts per gram of feces, considering the total sediment volume and the initial weight of stool processed.

These estimates should be interpreted with caution, as recovery efficiency may vary depending on parasite stage, sediment distribution, preservation condition, and the volume of aliquot examined. Therefore, the values represent estimated infection intensity rather than precise quantitative fecal egg counts.

To enhance protozoan detection and confirmation, an immunofluorescence assay specific for *Cryptosporidium* spp. and *Giardia* spp. was performed using the same fecal concentrates. A 40 µL aliquot of concentrated sediment was pipetted onto a microscope well slide and heat-fixed on a hot plate. The smear was stained according to the manufacturer's instructions (Crypto/Giardia Cel IF Test, Cellabs, Australia). Slides were examined at 200× and 400× magnification using an inverted epifluorescence microscope (Olympus IX73, Olympus America Inc., Melville, NY, USA) equipped with green or combined green-blue filters. *Cryptosporidium* spp. oocysts (spherical, 4–6 µm) and *Giardia* spp. cysts (oval, 8–14 µm) were identified by their characteristic bright apple-green fluorescence under the green filter.

Companion animal management variables were operationally defined prior to analysis. Containment status was classified as either confined (animals kept within the household premises or enclosed areas) or free-ranging (animals allowed to roam outside the household without restriction). Food source was categorized based on the primary type of food regularly provided to the animal, including commercial pet food, household leftovers, mixed feeding practices, and backyard-grown plant materials or leafy greens. The term 'organic food' in this study referred specifically to backyard-grown plant materials or leafy greens provided to the animals and did not pertain to commercially certified organic pet food products. Water source was classified according to the animal's usual drinking water source, including tap water, well water, lake water, or mixed sources. Deworming status was categorized as regularly dewormed when animals reportedly received deworming treatment within the recommended veterinary interval, and not regularly dewormed when treatment was absent, unknown, or inconsistent. Place of defecation was classified based on the animal's usual defecation site, including within household premises, open outdoor environments, lakeshore areas, or mixed locations.

The questionnaire was administered face-to-face by the researchers using a structured survey instrument. Responses were recorded directly on standardized forms to ensure consistency. To enhance data quality, the questionnaire was pre-tested prior to implementation, and researchers were trained to follow uniform interviewing procedures.

Ethical approval for the study was obtained from the University of the Philippines Los Baños Research Ethics Board (UPLB REB 2025-0201). Written informed consent was secured from all participating household heads prior to data collection. Participants were informed of the study objectives, procedures, voluntary nature of participation, and their right to withdraw at any time. All collected data were anonymized prior to analysis and treated with strict confidentiality.

Data Processing and Analysis

Data obtained were encoded using Microsoft Excel 2010 and backchecked to ensure accuracy of encoding. Any discrepancies noted were resolved by referring to the original data sources. The statistical methods used in the study included prevalence estimation, aggregation distribution analysis, Fisher's exact test, Chi-square test, and binomial logistic regression using RStudio (R version 4.4.0). All statistical analyses were conducted at a 95% confidence level, and p-values ≤ 0.05 were considered statistically significant.

RESULTS AND DISCUSSION

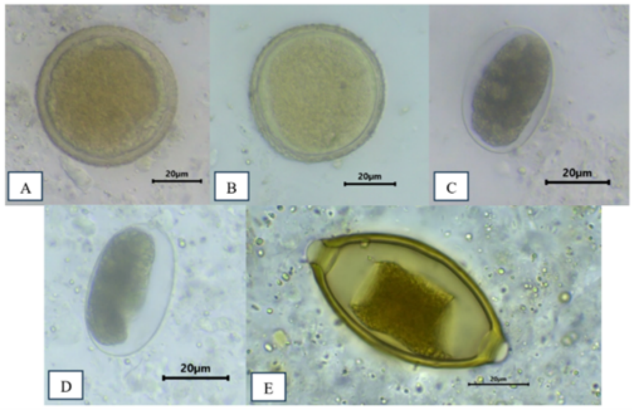

Figure 2: Helminth eggs (A-F) isolated using modified sedimentation technique from fecal samples of dogs and cats from households near the vicinity of the seven lakes of San Pablo, Laguna, (A-B) *Toxocara* spp.; (C-D) hookworms/strongylid; (E) *Trichuris* spp.

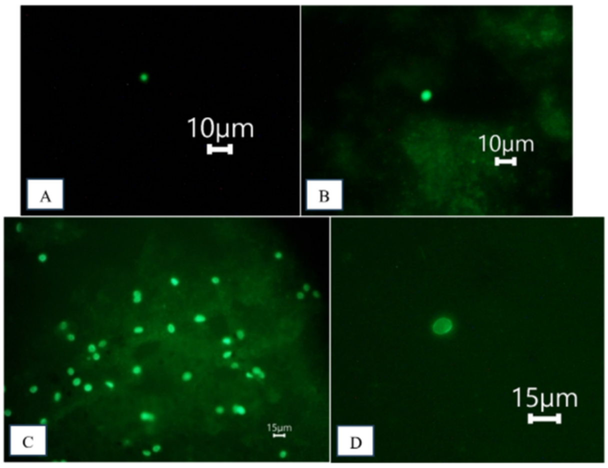

Figure 3: Protozoan oocysts/cysts (A-D) recovered using immunofluorescence assay from fecal samples of dogs and cats from households near the vicinity of the seven lakes of San Pablo, Laguna, (A-B) *Cryptosporidium* spp. oocyst; (C-D) *Giardia* spp. cyst

Prevalence of Intestinal Parasites in Companion Animals

A total of 52 dog and 19 cat fecal samples were examined from households surrounding Lakes Sampaloc, Calibato, and Bunot in San Pablo, Laguna. Results showed high prevalence, with 80.77% of dogs and 84.21% of cats harboring at least one intestinal parasite. Statistical analysis indicated no significant difference in overall prevalence between dogs and cats (p = 1.000), suggesting comparable exposure to infection sources. Among dogs, helminth and protozoan infections were recorded at 57.69% and 53.85%, respectively, while cats showed slightly higher rates at 63.16% and 52.63%. These findings indicate that both species serve as important reservoirs of intestinal parasites within lakeshore communities. This reflects ongoing environmental contamination and close human–animal interactions that may facilitate zoonotic transmission.

Helminth and Protozoan Prevalence

Microscopic examination of fecal samples from dogs and cats collected from households surrounding the Seven Lakes of San Pablo, Laguna revealed the presence of three nematode taxa: *Toxocara* spp., *Trichuris* spp., and hookworms/strongylids. Cats exhibited a higher prevalence of helminth infections (63.16%) and mean intensity (208 ± 147 eggs per gram), indicating a substantial worm burden. Dogs showed a lower prevalence of helminth infections (57.69%), highlighting differences in exposure and/or susceptibility among companion animals in lakeshore communities.

The hookworm/strongylid eggs detected in this study may include zoonotic species such as *Ancylostoma ceylanicum*, which is increasingly recognized in Asia. However, hookworms were not identified to species level in the present study; therefore, zoonotic interpretation should be framed as potential rather than confirmed.

Using an immunofluorescence assay, fecal samples were examined for protozoan parasites, specifically *Cryptosporidium* spp. and *Giardia* spp. Dogs exhibited a higher prevalence (53.85%) and mean intensity (370 ± 365 (oo)cysts per gram) of protozoan infections compared with cats, which may suggest greater environmental exposure to fecal contamination or waterborne transmission routes. These findings underscore distinct transmission dynamics for protozoans versus helminths in companion animals living in lakeshore communities.
For protozoan parasites, infection intensity was estimated as the number of cysts or oocysts per gram of feces examined. The intensity of helminth infection was determined by calculating eggs per gram (EPG) of feces using the formula provided in the materials and methods section.

Wide confidence intervals in several parasite categories (e.g., feline helminths: 38.36–83.71%; feline *Trichuris* spp.: 1.30–33.14%) suggest limited precision due to small sample size and possible variability in infection distribution. Overlapping confidence intervals between dogs and cats for hookworms/strongylids and *Cryptosporidium* spp. indicate that interspecies differences in prevalence should be interpreted cautiously. Moderately high lower bounds in some estimates (e.g., canine *Cryptosporidium* spp.: 30.47%) support consistent circulation of zoonotic protozoa within the population.

Table 1: Prevalence and mean intensity of intestinal parasites recovered from dogs and cats of households near the vicinity of the seven lakes of San Pablo, Laguna.

Parasite	Number infected	Prevalence (%)	Confidence Interval (95 %)	Mean intensity ± SD
HELMINTH				*
Dog (n = 52)	**30**	**57.69**	**43.20 – 71.27**	**193 ± 145**
Toxocara spp.	4	7.69	2.14 – 18.54	175 ± 96
Trichuris spp.	10	19.23	9.63 – 32.53	195 ± 174
Hookworm/strongylid	25	48.08	34.01 – 62.37	126 ± 87
Cat (n = 19)	**12**	**63.16**	**38.36 – 83.71**	**208 ± 147**
Toxocara spp.	5	26.32	9.15 – 51.20	210 ± 74
Trichuris spp.	2	10.53	1.30 – 33.14	150 ± 141
Hookworm/Strongylid	10	52.63	28.86 – 75.55	115 ± 94
PROTOZOA				**
Dog (n = 52)	**28**	**53.85**	**39.47 – 67.77**	**370 ± 365**
Cryptosporidium spp.	23	44.23	30.47 – 58.67	293 ± 153
Giardia spp.	7	13.46	5.59 – 25.79	518 ± 631
Cat (n = 19)	**10**	**52.63**	**28.86 – 75.55**	**225 ± 99**
Cryptosporidium spp.	8	42.11	20.25 – 66.50	172 ± 93
Giardia spp.	5	26.32	9.15 – 51.20	175 ± 68

All prevalence and intensity values were not significant at $p \geq 0.05$ (p=1.000). This result pertains only to the dog–cat comparison of overall prevalence and does not include risk factor analyses presented in subsequent sections.
*eggs per gram; **oocysts/cysts per gram

Distribution of Co-Parasitism in Dogs and Cats
Analyses of the collected dog (n = 52) and cat (n = 19) fecal samples revealed varying patterns of co-parasitism (Table 2). Among dogs, single parasitic infections were observed in 40.38%, dual infections in 30.77%, and multiple infections (≥3 parasite species) in 9.62%. In cats, single infections (*one parasite*) occurred in 36.84%, dual infections (*two parasites*) in 26.31%, and multiple infections (*three or more parasites*) in 21.05%.

Comparisons across sex, age group, and lake of origin were evaluated using the Chi-square test of independence. However, when expected cell counts were less than five—particularly in the cat subgroup analyses—Fisher's exact test was applied. Across all comparisons, no statistically significant differences were detected ($p > 0.05$), as indicated by the common superscript letters within columns in Table 2.

Although female dogs exhibited a slightly higher proportion of single infections (41.67%) compared to males (39.29%), and male dogs showed a greater proportion of dual infections (35.71%) than females (25.00%), these differences were not statistically significant (Chi-square test, $p > 0.05$). Similarly, in cats, dual infections appeared more frequent among males (66.67%), whereas single infections were more common among females (43.75%); however, these differences were likewise not statistically significant (Fisher's exact test, $p > 0.05$).

Juvenile animals demonstrated higher proportions of dual infections (dogs: 50.00%; cats: 66.67%) compared to adults, but these differences did not reach statistical significance ($p > 0.05$). Likewise, variation in infection patterns among lakes was not statistically significant for either dogs or cats ($p > 0.05$).

Overall, while multiple infections were relatively infrequent across most host categories, the detection of co-parasitism highlights the potential for simultaneous transmission of multiple parasite species within lakeshore communities.

Table 2: Prevalence of multiple co-infections with intestinal parasites of dogs and cats of households near the vicinity of the seven lakes of San Pablo, Laguna.

Variables	Total		Single Infection		Dual Infection		Multiple Infection	
	n	(%)	n	Prevalence (%)	n	Prevalence (%)	n	Prevalence (%)
Dog	**52**	**100.00**	**21**	**40.38**	**16**	**30.77**	**5**	**9.62**
Sex								
Male	28	53.85[a]	11	39.29[a]	10	35.71[a]	2	7.14[a]
Female	24	46.15[a]	10	41.67[a]	6	25.00[a]	3	12.50[a]
Age								
Juvenile (6-12 months)	6	11.54[a]	2	33.33[a]	3	50.00[a]	1	16.67[a]
Adult (> 12 months)	46	88.46[a]	19	41.30[a]	13	28.26[a]	4	8.69[a]
Lake								
Sampaloc	22	42.31[a]	6	27.27[a]	9	40.91[a]	2	9.09[a]
Calibato	17	32.69[a]	9	52.94[a]	5	29.41[a]	2	11.76[a]
Bunot	13	25.00[a]	6	46.15[a]	2	15.38[a]	1	7.69[a]
Cat	**19**	**100.00**	**7**	**36.84**	**5**	**26.31**	**4**	**21.05**
Sex								
Male	3	15.79[a]	0	0.00[a]	2	66.67[a]	0	0.00[a]
Female	16	84.21[a]	7	43.75[a]	3	18.75[a]	4	25.00[a]
Age								
Juvenile (6-12 months)	3	15.79[a]	0	0.00[a]	2	66.67[a]	0	0.00[a]
Adult (> 12 months)	16	84.21[a]	7	43.75[a]	3	18.75[a]	4	25.00[a]
Lake								
Sampaloc	7	36.84[a]	4	57.14[a]	0	0.00[a]	1	14.28[a]
Calibato	6	31.58[a]	2	33.33[a]	2	33.33[a]	2	33.33[a]
Bunot	6	31.58[a]	1	16.67[a]	3	50.00[a]	1	16.67[a]

Prevalence for each variable in the same column followed by a common letter are not significantly different at the 5% level
No significant differences were detected across sex, age, or lake groups.

In terms of study site, dogs within the vicinity of Sampaloc Lake (40.91%) had the highest prevalence for dual infection among Calibato Lake (29.41%) and Bunot Lake (15.38%). Single (52.94%) and multiple (11.76%) parasitic infections in dogs were most prominent in Calibato Lake. Meanwhile, cats within the vicinity of Sampaloc Lake (57.14%) had the highest prevalence for single infection, followed by Calibato (33.33%) and Bunot (16.67%). The multiple infection in cats was highest in Calibato Lake (33.33%), while dual infection was highest in Bunot Lake (50.00%). There were no dual infections in cats recorded within the vicinity of Sampaloc Lake. However, all differences were not significant at $p \geq 0.05$.

Aggregation of Parasite Infections in Dogs and Cats
The variance-to-mean ratio (VMR) for parasite counts in companion animals (dogs and cats), as shown in Figure 4, was calculated at 3.168, indicating that the variance substantially exceeds the mean. This finding reflects an aggregated

(overdispersed) distribution of parasites among hosts, wherein infection intensity is unevenly distributed across the population, with a small proportion of animals harboring high parasite burdens while most carry few or none.

Such aggregation is a well-recognized pattern in parasitic infections and is commonly influenced by heterogeneity in host exposure, immune response, and environmental conditions (Shaw et al., 1998). In the present study, this distribution pattern may suggest that certain animals experience greater infection pressure, potentially associated with behavioral and management-related factors such as outdoor roaming, inconsistent deworming practices, or frequent contact with contaminated soil or water.

The presence of highly infected animals may plausibly contribute to localized hotspots of environmental contamination. These findings provide a basis for future studies investigating environmental contamination levels and the spatial clustering of infections within lakeshore communities.

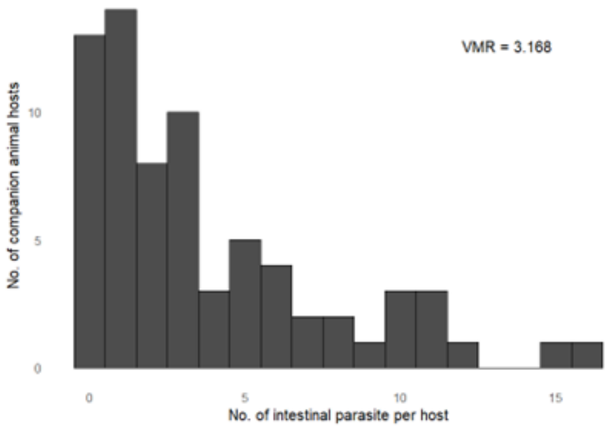

Figure 4: Aggregation of Parasite Infections from Companion Animals

Association of Animal Practices and Host Factors with Parasite Infection

Across all examined companion animals, several significant associations were identified between infection prevalence and selected animal management practices. Free-ranging animals exhibited a significantly higher prevalence of *Toxocara* infection (24.2%), indicating that unrestricted outdoor activity may increase exposure to contaminated soil and fecal matter. Likewise, non-dewormed animals demonstrated a markedly higher prevalence of hookworm infection (70.6%), underscoring the importance of regular anthelmintic treatment in reducing parasite burden.

Animals that relied on surface water sources showed a higher prevalence (35.7%); however, the association was not consistently statistically significant across all parasite categories, suggesting a possible but unconfirmed relationship. Similarly, animals fed with organic food—defined in this study as backyard-grown plant materials such as leafy greens—displayed notable infection patterns. Although this may suggest potential exposure through soil-contaminated produce, the association was borderline and did not reach statistical significance (e.g., overall $p = 0.057$).

Free-ranging behavior and lack of deworming were identified as significant risk factors in this study. Associations involving surface water consumption and organic food sources also suggest potential environmental and dietary pathways of parasite transmission. These findings provide a basis for further investigation of these pathways within lakeshore community settings.

(overdispersed) distribution of parasites among hosts, wherein infection intensity is unevenly distributed across the population, with a small proportion of animals harboring high parasite burdens while most carry few or none.

Such aggregation is a well-recognized pattern in parasitic infections and is commonly influenced by heterogeneity in host exposure, immune response, and environmental conditions (Shaw et al., 1998). In the present study, this distribution pattern may suggest that certain animals experience greater infection pressure, potentially associated with behavioral and management-related factors such as outdoor roaming, inconsistent deworming practices, or frequent contact with contaminated soil or water.

The presence of highly infected animals may plausibly contribute to localized hotspots of environmental contamination. These findings provide a basis for future studies investigating environmental contamination levels and the spatial clustering of infections within lakeshore communities.

Figure 4: Aggregation of Parasite Infections from Companion Animals

Association of Animal Practices and Host Factors with Parasite Infection

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Table 3: Univariate analysis of animal-level factors associated with intestinal parasite detection in dogs and cats from lakeshore households.

Variables	Categories	N	Intestinal Parasites		*Toxocara* spp.		*Trichuris* spp.		Hookworm		*Cryptosporidium* spp.		*Giardia* spp.	
			Positive (%)	P value	Positive (%)	P value	Positive (%)	P value	Positive (%)	P value	Positive (%)	P value	Positive (%)	P value
Age	Juvenile (6-12 months)	9	88.9	1	22.2	0.319[a]	33.3	0.172[a]	66.7	0.307[a]	33.3	0.722[a]	11.1	1[a]
	Adult (> 12 months)	62	80.6		11.3		14.5		46.8		45.2		17.7	
Sex	Male	31	80.6	0.841[b]	3.2	0.068[a]	25.8	0.078[b]	51.6	0.731[b]	38.7	0.459[b]	16.1	0.878[b]
	Female	40	82.5		20		10		47.5		47.5		17.5	
Containment Status	Penned/Leashed	38	78.9	0.521[b]	2.6	0.01[a]*	21.1	0.317[b]	50	0.899[b]	36.8	0.214[b]	15.8	0.788[b]
	Free-range	33	84.8		24.2		12.1		48.5		51.2		18.2	
Food Source	Commercial pet food	18	77.8	0.057[a]	5.6	0.664[a]	16.7	0.749[a]	44.4	0.289[a]	50	0.188[b]	27.8	0.414[a]
	Organic	1	100		0		0		100		0		0	
	Leftover	32	90.6		21.9		15.6		59.4		46.9		21.9	
	Both Feeds and Organic	3	100		0		0		0		100		0	
	Both Feeds and Leftover	13	76.9		7.7		23.1		46.2		30.8		0	
	Both Organic and Leftover	2	50		0		50		50		0		0	
	Feeds, Organic and Leftover	2	0		0		0		0		0		0	
Deworming	Yes	37	75.7	0.172[b]	5.4	0.077[a]	16.2	0.872[b]	29.7	0.001[b]*	45.9	0.686[b]	16.2	0.872[b]
	No	34	88.2		20.6		17.6		70.6		41.2		17.6	
Water source	Ground	54	80.7	1[a]	7	0.012[a]*	15.8	0.693[a]	47.4	0.512[b]	45.6	0.503[b]	17.5	1[a]
	Surface	17	85.7		35.7		21.4		57.1		35.7		14.3	

*p-value < 0.05; a . Fisher exact test; b. Chi-square test

Risk Factors Associated with Intestinal Parasite Infection

A multivariable logistic regression analysis was conducted to determine factors associated with intestinal parasite infection in companion animals (Table 4). Among the variables evaluated (species, age, sex, containment status, food source, deworming status, place of defecation, and water source), only place of defecation was significantly associated with infection status ($p = 0.0282$). Animals that defecated outside the house had significantly lower odds of infection compared with those that defecated within the household premises (OR = 0.1442, 95% CI: 0.0216–0.7448). Although statistically significant, this association was counterintuitive and should be interpreted with caution. Rather than indicating that outdoor defecation is protective, the finding may reflect differences in household management practices, confinement, sanitation, repeated exposure to contaminated indoor environments, or possible misclassification of defecation behavior. Thus, place of defecation appears to be associated with infection status, but its role as a risk or protective factor requires further verification.

Deworming status demonstrated a borderline association with infection. Animals that had not been dewormed showed higher odds of infection (OR = 5.94, 95% CI: 0.9611–53.2297), approaching statistical significance ($p = 0.0554$). Although this did not meet the conventional $\alpha = 0.05$ threshold, the magnitude of the odds ratio suggests a potentially meaningful association that may have been underpowered in the present sample.

No statistically significant associations were observed for species, age, sex, containment status, food source, or water source ($p > 0.05$). Several estimates exhibited wide confidence intervals, indicating variability and limited precision, likely attributable to the modest sample size.

Overall, the analysis identifies defecation practices as a significant factor associated with intestinal parasite infection in this population, while also suggesting a potential role of deworming status that warrants confirmation in larger, adequately powered studies.

Table 4: Logistic regression analysis of the associated risk factors with internal parasites detected in companion animals

Variable	Risk Factor	OR	95% CI	p value
Companion Animals	Dog *(Ref.)*	1		NA
	Cat	2.4171	0.3648 - 23.9403	0.3756
Age	Juvenile (6-12 months) *(Ref.)*	1		NA
	Adult (> 12 months)	1.0504	0.0548 - 8.3621	0.9657
Sex	Male *(Ref.)*	1		NA
	Female	2.0141	0.4458 - 10.5014	0.3661
Containment Status	Penned/Leashed *(Ref.)*	1		NA
	Free-range	0.3162	0.045 - 1.6504	0.1762
Food Source	Commercial pet food *(Ref.)*	1		NA
	Organic	1		NA
	Leftover	1.5914	0.1761 - 16.2956	0.6785
	Both Feeds and Organic	7.8556	0.4253 - 1341.847	0.1792
	Both Feeds and Leftover	0.254	0.0252 - 2.1127	0.2042
Deworming	Yes *(Ref.)*	1		NA
	No	5.9354	0.9611 - 53.2297	0.0554
Place of Defecation	Inside *(Ref.)*	1		
	Outside	0.1442	0.0216 - 0.7448	0.0282*
Water source	Ground *(Ref.)*	1		NA
	Surface	1.4077	0.2643 - 10.028	0.6975

*p-value < 0.05
Outcome variable: presence or absence of intestinal parasite infection.
Ref. = reference category used in logistic regression analysis.
Statistically significant at p < 0.05.

Limitations of the Study

The cross-sectional design allows estimation of parasite prevalence and associated animal-level factors but cannot establish causality or confirm companion animals as the definitive source of lake contamination. Only one fecal sample was collected per animal, which may underestimate parasites with intermittent shedding. Parasite identification was based on microscopy and immunofluorescence assay; hence, species-level confirmation of hookworms/strongylids and molecular characterization of *Giardia* and *Cryptosporidium* were not performed. The modest sample size, especially for cats and juveniles, and sparse categories in some risk-factor variables resulted in wide confidence intervals and limited precision. Future studies should combine animal fecal, soil, and lake water sampling with molecular typing to clarify transmission links among companion animals, households, and freshwater environments.

CONCLUSION

The high prevalence and measurable infection intensity of intestinal parasites among dogs and cats in lakeshore communities surrounding Lakes Sampaloc, Calibato, and Bunot indicate substantial parasite circulation within companion animal populations, including taxa with recognized zoonotic potential. The predominance of parasites such as hookworms/strongylids, *Cryptosporidium* spp., and *Giardia* spp., together with significant animal-level risk factors associated with infection and shedding, suggests that companion animals represent an important component of the local epidemiological cycle. These findings further indicate that unmanaged animal movement, inconsistent deworming practices, and improper fecal disposal may contribute to environmental exposure within lakeshore communities.

These results are contextualized by the documented detection of waterborne protozoan parasites, including *Cryptosporidium* sp., *Giardia* sp., *Blastocystis* sp., and *Acanthamoeba* sp., in the Seven Lakes of San Pablo (DOST-GIA Terminal Report, 2022). The presence of these organisms in lake waters, alongside established fecal–oral and waterborne transmission routes, supports parasite circulation across animal and environmental compartments within these shared ecosystems.

The convergence of high parasite burden in companion animals and documented environmental contamination provides epidemiological evidence consistent with potential zoonotic and environmental transmission dynamics. These findings underscore the contribution of companion animals to environmental contamination within lakeshore settings.

Collectively, the results highlight the importance of adopting a One Health approach in managing parasitic infections in freshwater systems. Coordinated efforts across veterinary, public health, and environmental sectors are essential to mitigate transmission risks, promote responsible pet ownership, improve sanitation practices, and safeguard the ecological integrity of the Seven Lakes of San Pablo and similar ecosystems.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

Vachel Gay V. Paller: Conceptualization, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing; Quintin Karl O. Cueto: Investigation, Methodology, Writing – original draft; Andrey Emmanuel D. Morales: Investigation, Methodology, Writing – review & editing; Allen Jethro I. Alonte: Conceptualization, Writing – review & editing; Marvin Pizon: Investigation, Data analysis, Writing – review & editing; Kennesa Klariz Llanes: Conceptualization, Writing – review & editing; Jeph Roxy M. Macaraig: Conceptualization, Writing – review & editing; Sharmen Berlin: Investigation, Writing – review & editing.

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