EPIDEMIOLOGICAL STUDY OF PARASITES IN DOG FECES IN PARKS FROM COZUMEL, QUINTANA ROO, MEXICO †

[ESTUDIO EPIDEMIOLÓGICO DE PARÁSITOS EN HECES DE PERROS EN PARQUES DE COZUMEL, QUINTANA ROO, MÉXICO]

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SUMMARY

Background: Contamination of public spaces with canine feces containing parasites increases the possibility of transmission of these parasites to people and other canines. **Objective:** To estimate the frequency and variables associated with parasite eggs/oocysts in canine feces collected in public parks from Cozumel Island, Mexico. **Material and methods:** One hundred and fifteen stool samples were collected in 23 public parks, which were selected by convenience and analyzed by direct smear microscopy. The variables evaluated were i) with/without tourism, ii) low/high economic level), iii) high/low number of inhabitants and iv) area collection site paved/unpaved. A statistical association analysis test (X^2) was performed to determine significance of results and the odds ratio (OR) between the studied variables was evaluated. **Results:** A parasite prevalence of 27% was found, recording the following order of species *Ancylostoma* spp > *Trichuris* spp > *Toxocara* spp > *Isospora* spp = *Taenia* spp. Statistical significance was not found in the X^2 tests and ORs. The positive sample frequencies of the variables evaluated did not show any correlation, irrespective of the parasite reported. **Implications:** Stray dogs, pet dogs, people and pet owners visiting public parks of Cozumel Island, Mexico, could be infected by gastrointestinal parasites. **Conclusion:** In public parks from Cozumel Island, gastrointestinal parasite eggs/oocysts are present in canine feces. However, the variables evaluated did correlate with the presence of these parasites.
Key words: Canines**;** Gastrointestinal nematodes; Zoonoses; Environment; Waste management.

RESUMEN

Antecedentes: La contaminación de los espacios públicos con heces caninas que contienen parásitos incrementa la posibilidad de transmisión de estos parásitos hacia las personas y otros caninos. **Objetivo:** El objetivo fue estimar la frecuencia de huevos/ooquistes de parásitos en heces caninas colectadas en parques de la Isla Cozumel, México. **Materiales y métodos:** Se colectaron 115 muestras de heces de 23 parques públicos seleccionados por conveniencia, las cuales fueron analizadas por frotis directo. Los factores de riesgo evaluados fueron: i) con y sin turismo, ii) nivel económico bajo y alto, iii) densidad poblacional alta y baja, iv) colectada en área pavimentada y no pavimentada. Se realizó una prueba de análisis de asociación estadística (X^2) para determinar significancia y se evaluó la razón de momios (OR) entre los factores estudiados. **Resultados:** Se encontró una prevalencia de huevos de parásitos de 27%; con el siguiente orden *Ancylostoma* spp > *Trichuris* spp > *Toxocara* spp > *Isospora* spp = *Taenia* spp. No se encontró significancia estadística en las pruebas de X^2 y los OR. Las frecuencias de muestras positivas de las variables evaluadas no muestran ninguna relación independientemente del parásito reportado. **Implicaciones:** Los perros no domiciliados, las mascotas y personas que visitan los parques públicos en la Isla Cozumel, México pueden infectarse por parásitos gastrointestinales. **Conclusión:** En parques públicos de Isla Cozumel, se encontraron huevos/ooquistes de parásitos gastrointestinales en heces caninas, sin embargo, las variables evaluadas no influyeron en la frecuencia de estos parásitos.
Palabras claves: Caninos**;** Nemátodos gastrointestinales; Zoonosis; Ambiente; Manejo de residuos.

INTRODUCTION

In terms of animal welfare, it is of great importance that pet owners promote pet socialization and exercise in places like public and dog parks. However, it is essential to consider the public health risk of their pets' waste (feces) due to the transmission of pet parasites to the human and dog populations visiting these recreational places, including both stray and pet dogs, pet owners, non-pet owners and especially children in their designated play areas (Savadelis *et al.*, 2019). Although some owners pick up their pets' waste when they bring them to the park, most do not and the transmission of parasites to other pets, owners, or park visitors is maintained in favourable climatic conditions (Raičević *et al.*, 2021).

In dealing with parasite infections, many pet owners do not have the economic resources to pay for veterinary services and for parasite anthelmintic treatments. So, few owners provide veterinary services for their pets. In addition, despite different laboratory studies have reported that pets, even with veterinary services, can still spread gastrointestinal nematode infective stage (Little *et al.*, 2009) . This situation confirms the need for further studies to evaluate parasite egg contamination in these recreational areas and measure the number of egg parasites in fecal samples and possible associated variables (Hascall *et al.*, 2016; Stock *et al.*, 2014). The latter is especially true in children's play areas, where the infants and their parents can become infected with nematode parasites (Despommier, 2003), as it is known that about 1% of children can develop cutaneous, visceral and ocular *larva migrans* (Congdon and Lloyd, 2011) , which is caused by *Ancylostoma* spp and *Toxocara* spp, respectively (Bowman, 1999) .

Mexico has the highest stray dog population in Latin America and this situation constitutes a public health risk through dogs' actions such as attacks on passers-by and transmission of zoonotic agents by direct or indirect contact with infected dogs and the growing stray dog population (Cortez-Aguirre *et al.*, 2018). This problem in small municipalities is growing due to the spread of these pathogens because of the distances these dogs travel in search of food and mating opportunities. These distances are proportional to their size and weight, which is a factor that influences the density of dogs in defined areas and can even include pet dogs that go in search of females in oestrus (Cadena, 2013).

One of the most common infectious agents is gastrointestinal parasites. Most of the time, pet dog owners provide their pets with food, water and shelter; however, they do not have an adequate health control scheme due to the lack or unaffordability of veterinary services (Ferreira *et al.*,

2017). Also, sometimes, the owners of pets release them on public roads to exercise or defecate, generating similar parasite dissemination to stray dogs. Beck (1973) mentions that feces may be visible on the ground for a week but remain in place for a month.

The main parasitic species of dogs reported in fecal studies are *Toxocara* spp and *Ancylostoma* spp. However, *Trichuris* spp have also been reported and these species can affect humans and cause digestive and skin problems (Aguillón-Gutiérrez *et al.*, 2021). In addition, these parasite species have been reported in public places such as parks and gardens and represent a public health problem that can be evaluated and measures applied to avoid their health impact (Lara-Reyes *et al.*, 2021).

Dog fouling in public places is common and their feces are contaminated with parasites (Rodríguez-Vivas *et al.*, 2011). However, there are more vulnerable areas where a more significant presence of dog feces can be found. On Cozumel Island, there are variables that could promote the presence of dog feces contamination such as areas with and without tourism (Fernández-Rodríguez *et al.*, 2018), low and high economic level (Cadena, 2013; Robledo-Rodríguez, 2018), low and high population density (Sierra and Navarro, 2021), as well as the surface of the different collection sites (Zúñiga Carrasco and Caro Lozano, 2020). In the state of Quintana Roo and specifically in public parks on Cozumel Island, the frequency of gastrointestinal parasite eggs/oocysts, such as *Toxocara* spp, *Ancylostoma* spp, *Trichuris* and *Isospora* spp in dog feces is unknown. Therefore, this study aimed to determine the frequency and variables associated with parasite eggs/oocysts in canine feces collected in parks from Cozumel Island, Mexico.

MATERIAL AND METHODS

Study region and sampling areas

Cozumel Island is a municipality belonging to the state of Quintana Roo, located between the coordinates: Latitude: 20.5101, Longitude: -86.9489, 20° 30′ 36″ North, 86° 56′ 56″ West. The climate is hot and humid, with summer rainfall and an average annual temperature of 25.5 °C with annual rainfall reaching 1,504 mm. The amount of rainfall in summer increases due to cyclones (INAFED, 2020). Due to the COVID-19 contingency, some public places remained closed and samples were taken by convenience in parks with children's play areas open to the public and enabling spaces for the dog visitors' exercise.

San Miguel de Cozumel is divided into 49 basic urban geostatistical areas (BUGA). The BUGAs are related to the theme of well-being of the reference

society: population, education, economy, health and housing. Of the 49 BUGAs in San Miguel de Cozumel, 22 are of medium level, 12 of high level, 8 of low level and 7 of very high level. Medium and high-level BUGAs represent 70% of the urban areas registered in Cozumel. The very high level of well-being is in the northern portion of the city, towards the west coast, coinciding with luxury resorts. The high level of well-being is located towards the center of the town. The medium level of well-being is located in the southern and eastern portions of the city and the low level of well-being is located towards the peripheral areas in the neighborhoods furthest from the center (Padilla-y-Sotelo *et al.*, 2023) (Table 1). A total of 23 parks were selected to collect dog fecal samples.

Sampling collection periods

Sampling was conducted from June to October 2021, from Monday to Friday from 07:00 - 09:00 h and 18:00 - 20:00 h, with hours of least daytime sun exposure minimising the effect on the sample's viability. Fresh and undried feces were collected. Each sample was placed in new polyethene bags and individually identified. They were kept refrigerated until processed in the Facultad de Ciencias Agropecuarias Parasitology laboratory at Escarcega, Campeche, Mexico. Fecal samples were preserved using a ratio of 1:2 of formaldehyde, according to Rubel and Flaibani (2021).

Variables and categories

The following variables were considered:

i)   Tourism (presence and absence): areas with a high tourist influx due to the possibility of transporting dog pets (pet-friendly establishments), classified into areas close to cruise ship tourism as downtown, hotels and resorts (presence) and areas far from cruise ship and touristic areas (absence) as reported by Fernández-Rodríguez *et al.* (2018), see Table 1.

ii)   Socioeconomic level (Low and high): Based on the 49 BUGAs that the city of Cozumel has and the ability to pay for veterinary services, according to the average income per household (MarketDataMéxico, 2023), two areas of socioeconomic level were established: areas of high (BUGAs: Very high, high and medium level of well-being) and low (BUGA: low level of well-being) economic level (Padilla-y-Sotelo *et al.*, 2023).

iii)   Low and high population density, by the number of inhabitants (MarketDataMéxico, 2023) and whether there is a relationship with the number of pets, classifying into areas of high (> 7,000 inhabitants) and low (≤ 7,000) population (Figure 1).

iv)   The collection site is based on variations in the conditions of the location of canine feces, classifying areas into paved (pavement, playground, court or square) and unpaved (garden and sandbox).

Laboratory analysis

Samples were analyzed by direct smear at the Facultad de Ciencias Agropecuarias laboratory, Universidad Autónoma de Campeche. A similar amount of feces and water were mixed on a microscope slide. Tilting the slide helped to separate the heavier debris from lighter eggs/oocysts. Finally, a coverslip was placed on the mixture and examined in the microscope. Samples were first scanned with the 10x objective to confirm the presence of parasites, then switching to the 40x objective to identify the parasite species. For cases of eggs with smaller sizes, the 100x objective was used (Taylor *et al.*, 2015). The genera of the parasite seen was identified according to Girard's methodology (Girard de Kaminsky, 2014).

Statistical analysis

A descriptive study was performed and any sample in which at least one gastrointestinal parasite egg/oocyst was detected was considered positive (Rodríguez-Vivas *et al.*, 2001). Statistical association analysis tests (Chi-square-X^2) were used to determine significance, relating the presence of gastrointestinal parasite eggs/oocyst (positive and negative) and the different studied variables and categories (tourism: presence and absence; economic level: high and low; population density: high and low; and collection site: paved and unpaved) ("MASS package"). Odds ratios (OR) were calculated for the variables above. Yates' correction was performed where n<40 and frequencies between 1 to 5. Furthermore, Yates' correction was run only for the economic level variable. The R Core Team (2021) statistical program was used for X^2 analyses and OR calculations, specifically the "epitools package". P-values <0.05 were considered as significant differences.
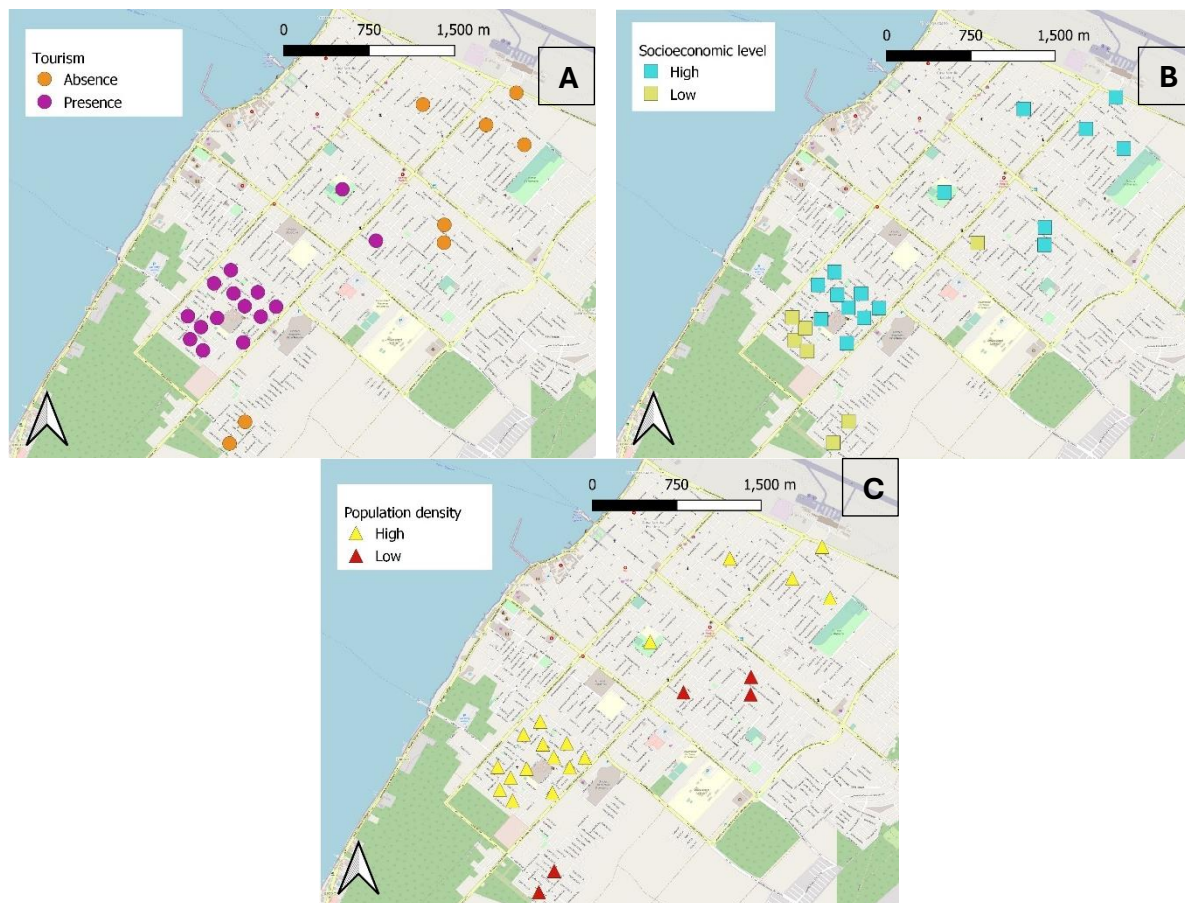
Figure 1. Park categories are based A) tourism (presence and absence), B) socioeconomic level (high and low level) and C) population density (high and low) variables.

Table 1. Park classification is based on tourism, socioeconomic level, population density and site collection variables.

Variables	Codification	Parks	Definition
Tourism	Presence	DIF, Zazil, Las gradas, Álamo, Concha Acústica, Flores Magón II, Lugo, Las Toñas, San José del Mar, El semáforo, Dr. Carlos Canseco, La amistad, Solidaridad, Los almendros, El trueno	Park near tourist areas and cruise tourism
	Absence	Municipio Libre, 10 de abril, Urba, Profa. Maria Viana Rivero, Chentuk, La golondrina, Fausto Leonel Villanueva Marrufo, Niños héroes.	Neighborhoods far from tourist areas and cruise tourism.
Socioeconomic level	High socioeconomic level	Dif, Las gradas, Álamo, Concha Acústica, Flores Magon II, Lugo, San José del Mar, Dr. Carlos Canseco, La amistad, Solidaridad, Municipio Libre, 10 de abril, Urba, Profa. Maria Viana Rivero, Chentuk, Las golondrinas.	BUGAs: Very high, high and medium levels of well-being
	Low Socioeconomic level	Zazil, Fausto Leonel Villanueva Marrufo, Niños héroes, Los almendros, El trueno, Las Toñas, El semáforo.	BUGA: low level of well-being
Population density	High population density	Dif, Las gradas, Álamo, Concha Acústica, Flores Magon II, Lugo, San José del Mar, Dr. Carlos Canseco, La amistad, Solidaridad, Municipio Libre, 10 de abril, Urba, Profa. María Viana Rivero, Los almendros, El trueno, Las Toñas, El semáforo.	> 7,000 inhabitants

Variables	Codification	Parks	Definition
Collection site	Low population density	Zazil, Fausto Leonel Villanueva Marrufo, Chentuk, Las golondrinas, Niños héroes.	≤ 7,000 inhabitants
	Paved	Dif, Álamo, Dr. Carlos Canseco, La amistad, Municipio Libre, 10 de abril, Urba, Los almendros, El trueno, El semáforo, Zazil, Fausto Leonel Villanueva Marrufo, La golondrina.	Pavement, playground, court or square
	Unpaved	Las Gradas, Concha Acústica, Flores Magon II, Chentuk, Profa. María Viana Rivero, Niños Héroes, Lugo, Las Toñas, San José del Mar, Solidaridad.	garden and sandbox

RESULTS

A total of 115 dog fecal samples were collected and analyzed from public parks on Cozumel Island. The presence of gastrointestinal parasite eggs/oocyst was detected in 27% (31/115), of which 83.8% (26/31) samples showed single species infection and 16.2% (5/31) showed co-infection. The main interactions were *Ancylostoma* spp + *Trichuris* spp (3/5), *Ancylostoma* spp + *Taenia* spp (1/5) and *Isospora* spp + *Trichuris* spp (1/5).

Positive samples and their association with study variables

Table 2 displays the positive and negative results from fecal samples obtained from public parks in Cozumel Island. In addition, Table 1 shows some variables related to tourism (presence and absence), economic level (high and low), population density (high and low) and collection site (unpaved and paved) of gastrointestinal parasites from dog fecal samples.

Dog feces in parks without tourist traffic showed a percentage of infection with *Ancylostoma* spp. of (29.0%), followed by *Toxocara* spp. (6.5%) and *Trichuris* spp (6.5%). In parks in low socioeconomic areas, feces were found to have an infection percentage with *Ancylostoma* spp of (29.0%), followed by *Toxocara* spp. (9.7%) and *Trichuris* spp. (12.9%). The parks in areas with a high population density presented feces infected with *Ancylostoma* spp. at (29%), followed by *Toxocara* spp. and *Trichuris* spp. (9.7% each). The unpaved areas of the parks showed dog feces infected with the following gastrointestinal parasites genera *Ancylostoma* spp (25.8%), followed by *Trichuris* spp. (16.1%), while the paved areas of the parks showed 16.1% samples infected with *Toxocara* spp. (Table 3).

When analyzing the frequency with the odds ratio, it can be seen that the presence of parasitosis only affected the socioeconomic variable (P<0.05) (Table 4).

DISCUSSION

The study aimed to estimate the frequency and variables associated with the presence of parasite eggs/oocyst in canine feces collected in parks from Cozumel Island, Mexico, as well as its association with variables such as a high influx of tourists, the economic level or income of the people, the population density and the collection site of the samples in the different parks of the city.

This study found that fecal matter contaminated with gastrointestinal parasite eggs/oocyst is present in 27% of the analyzed samples collected in parks from Cozumel Island, Mexico. Fecal contamination of both stray and pet dogs in parks and city streets has been reported in different parts of the world (Stock *et al.*, 2014) and particularly in Latin America where it is common for dogs to roam the streets (Flores *et al.*, 2022). Regarding the individual frequencies by species of parasite eggs, it was found that the parasite with the highest prevalence was *Ancylostoma* spp., which was found in 12.2% of the samples analyzed, followed by *Toxocara* spp and *Trichuris* spp with a prevalence of 4.3%. *Taenia* spp. and *Strongyloides* spp. were found to be at a lower percentage, at 0.86%. On the other hand, the most important combinations were *Ancylostoma* spp. and Trichuris spp. with 0.86%, followed by *Ancylostoma* spp. and *Taenia* spp. and *Trichuris* spp. and *Isospora* spp. with 3.2% respectively. These results differ from those recorded in Escarcega Campeche by Encalada-Mena *et al.* (2011), where the most prevalent parasite was *Ancylostoma spp.*, followed by *Isospora* and *Toxocara canis,* which were the genera with the highest risk of contamination in the environment. However, Escarcega is reported to have a high marginalization index (DGPB, 2022) and a population with a low socioeconomic level, which lacks sanitary measures towards their pets, which roam the streets (Encalada-Mena *et al.*, 2011). The latter conditions favor the presence of parasite eggs/oocyst and their persistence as a pollutant on public roads and city parks.

Table 2. Presence and absence of eggs/oocyst of gastrointestinal parasites in dog feces collected in parks from Cozumel Island according to tourism, socioeconomic level, population density and collection sites.

Status	Variables*							
	Tourism		Socioeconomic level		Population density		Collection site	
	Presence	Absence	High	Low	High	Low	Unpaved	Paved
Eggs/oocyst presence (+)	14 (12.17)	17 (14.78)	12 (10.43)	19 (16.52)	20 (17.39)	11 (9.56)	16 (13.91)	15 (13.04)
Eggs/oocyst absence (-)	44 (38.26)	40 (34.78)	55 (47.83)	29 (25.22)	58 (50.43)	26 (22.61)	53 (46.09)	31 (26.96)
Total	58	57	67	48	78	37	69	46

*Numbers within the parenthesis are percentages of each variable.

Table 3. Frequencies of zoonotically relevant gastrointestinal parasite and the study factors in canine feces collected in parks on Cozumel Island, Quintana Roo.

Genera	Variables							
	Tourism		Socioeconomic level		Population density		Collection site	
	Presence	Absence	High	Low	High	Low	Unpaved	Paved
Ancylostoma spp	5	9	5	9	9	5	8	6
Toxocara spp	3	2	2	3	3	2	0	5
Trichuris spp	3	2	1	4	3	2	5	0
Isospora spp	1	0	0	1	1	0	0	1
Strongyloides spp	1	0	0	1	0	1	0	1
Ancylostoma spp +Trichuris spp	1	3	3	1	3	0	1	2
Ancylostoma spp + Taenia spp	0	1	1	0	1	0	1	0
Trichuris spp + Isospora spp	0	0	0	0	0	1	1	0

Table 4. The odds ratio between the presence or absence of eggs/oocyst in dog feces and the associated variables.

Variable	Level	n	Odds Ratio	CI (95%)	P-value
Tourism	Presence	58	0.751	0.322-1.728	0.633
	Absence	57			
Socioeconomic level	High	67	0.337	0.139-0.787	0.017*
	Low	48			
Population	High	78	0.813	0.341-2.001	0.644
	Low	37			
Collection site	Paved	69	1.595	0.686-3.713	0.264
	Unpaved	46			

*Chi-Square test $P<0.05$.

On the other hand, the results of this study agreed with those of Medina-Pinto *et al.* (2018) who reported a prevalence of 11% of gastrointestinal parasite eggs in parks in Merida with *Ancylostoma* spp. being the parasite with the highest prevalence at 10%. In this regard, it is considered that in the Yucatan Peninsula, there are environmental conditions for this parasite species to occur, in addition to its great capacity to infect hosts by different routes, which is why it is reported as one of the most important nematodes in dogs (Rodríguez-Vivas *et al.*, 2011). This last data is reinforced by the research carried out by Rodríguez-Vivas *et al.* (2001), who conducted a review of fecal samples from different species of domestic animals, including dogs, submitted to the parasitology laboratory of FMVZ-UADY from 1984 to 1999 and found that *Ancylostoma* sp. it was found in 37.35% of the samples of dog feces submitted so it is considered the parasite with the highest presence in the state (Medina-Pinto *et al.*, 2018; Mex-Álvarez *et al.*, 2018). It has been reported that 14.44% for *Toxocara* spp, 9.25% for the genus *Trichuris* spp and 1.1% for *Isospora* spp in Campeche (Encalada-Mena *et al.*, 2011), percentages higher than those reported in the present study. On the other hand, in

other countries such as Poland and Italy, a similar percentage is reported when evaluating gastrointestinal parasites of feces from public places and in household and shelter dogs, respectively, where values were recorded for *Ancylostoma* spp (16.2% and 9.6%), *Trichuris* spp (6.6% and 9.9%), *Toxocara* spp (23.4% and 6.8%), *Isospora* spp (10.9 % and 3.7%) and *Taenia* spp (4.6% and 0.1%) (Felsmann *et al.*, 2017; Scaramozzino *et al.*, 2018). It is confirmed that contamination of public sites persists over the years and in all sites, which may be due to several factors such as increased resistance to dewormers, owners no longer providing timely veterinary services to their pets, or a favorable environment in which immature forms of parasites develop (Felsmann *et al.*, 2017; Scaramozzino *et al.*, 2018).

Although the percentages are higher than those found in the present investigation, the frequency of the parasites is similar, with a higher number of cases of *Ancylostoma* spp and *Trichuris* spp. Since the tests of association (Chi-square) of the factors as tourism ($X^2 = 0.227$), population ($X^2 = 0.214$) and collection site ($X^2 = 0.811$) had no significant difference with the frequencies found in the collected canine feces ($P > 0.05$). The socioeconomic level was the only factor associated with the eggs/oocyst absence in fecal samples in parks in Cozumel, Quintana Roo, Mexico (Table 4, $X^2 = 5.615, P<0.05$).

Absence or presence of tourism

It can be hypothesized that the statistical analyses were limited due to different variables, *i.e.* the reduced number of parks sampled (COVID-19 pandemic) and the inclusion criteria utilized in this study. Additionally, some variables displayed a low number of positive samples that could explain the lack of association between variables and the presence of the gastrointestinal nematode in fecal samples from public parks in Cozumel Island. Unfortunately, the study design was focused on dog stools from parks without considering the animal *per se.* The latter could affect the number of positive samples recorded during the experimental period.

It has been reported that tourists take walks with their pets to the streets and public spaces where contamination with dog feces is high (Andresiuk *et al.*, 2007). On the other hand, there is the phenomenon of importation of parasitic zoonoses since tourists' dogs can become a source of pollution since tourists and their pets regularly walk through the streets and parks of the cities, they visit (Marko *et al.*, 2020). In this study, however, no such association was found because Cozumel Island is small and receives a large number of tourists, so the areas with the highest tourist influx are cleaned more frequently, discouraging stray dogs looking for food

(Morales and Esquivia, 2014). Another possible explanation is related to government programs. For example, in the cities with the greatest influx of tourists, the authorities are concerned about having control programs for stray dogs (Tamponi *et al.*, 2020).

Low or high economic level

In this study, the variable of high socioeconomic status resulted in a protective factor, which indicates a lower amount of feces contaminated with gastrointestinal parasites in the public parks studied, observing 0.337 the probability of finding positive samples of canine feces in parks of high socioeconomic status compared to parks of low socioeconomic status.

At the economic level, it is usually related to pet care, *i.e.*, a higher budget corresponds to greater care. Robledo-Rodríguez (2018) observed that a high economic income increases the possibility of pets accessing veterinary medical services, allowing them to be provided with adequate space and thus avoiding parasitosis to a large extent. The opposite happens with low economic incomes, where there is limited or no veterinary care, in addition to having inappropriate spaces for pets, leading owners to allow animals to go out into public spaces to defecate, where they are exposed to all kinds of infections, including gastrointestinal parasites (Garibotti *et al.*, 2021).

On the other hand, the presence of gastrointestinal parasites could be affected by the area sampled, as it is highly dependent on environmental hygiene and the socioeconomic conditions of the location (Papajová and Šoltys, 2019). Such is the case of excessive human waste generation that attracts stray dogs, which can be present without distinction in areas of high/low economic status. Usually, areas with lower levels of income have higher percentages of feces positive with gastrointestinal parasitosis and a significant number of parasitic species, which has been reported in Latin American countries such as Panama (Fung *et al.*, 2014), Argentina (La Sala *et al.*, 2015; Rivero *et al.*, 2017), indicating that the association between income level and the presence of litter on the streets is a factor that increases the number of dogs roaming the streets and the risk of environmental contamination by feces contaminated with parasitic eggs disseminated by dogs (Flores *et al.*, 2022).

Low- or high-density population

Several authors have reported that environmental contamination with canine feces and parasite eggs in public spaces, such as sidewalks and parks, is positively related to the population density of residential areas and neighborhoods since these

areas have high dog populations (Flores *et al.*, 2022; Marko *et al.*, 2020; Tamponi *et al.*, 2020). Similarly, there is a positive relationship between the increase in population and the increase in pets (dogs), whether owned or strayed (Rinaldi *et al.*, 2007; Rubel *et al.*, 2019; Rubel and Wisnivesky, 2010). It has been reported that there is more fecal environmental contamination in parks to the extent that densely populated areas surround them and such contamination decreases as areas have less population (Rubel and Wisnivesky, 2010). However, this relationship was not found in the present study, which can be explained by the fact that Cozumel as an island, special care is taken in the management of food waste to avoid accumulation, which is reflected in its sanitation law that obliges visitors and inhabitants to take care as a tourist destination by paying a fee for the right to environmental sanitation for lodging and arrival by sea (Ayuntamiento de Cozumel, 2024). It has been reported that areas with a greater influx of people tend to have fewer stray dogs because this influx frightens the dogs and causes them to look for less crowded places with greater availability of food waste (Morales and Esquivia, 2014). On the other hand, actions are carried out to control stray dogs and cats, such as sterilization campaigns, to comply with animal welfare laws. Finally, in the case of population factors and collection sites, sampling was considered limited due to restricted access to high-traffic areas such as parks, playgrounds and public squares due to the COVID-19 environmental contingency.

Paved or Unpaved site of collection

For the collection site, it has been reported that the green areas of public spaces, in which control measures are not carried out, show higher fecal contamination compared to paved areas (Rubel *et al.*, 2019); this is because it is proposed that dogs prefer to defecate in areas with grass or soil instead of an area with concrete, in addition, grassy areas protect the eggs of parasites from direct sun exposure (Ferreira *et al.*, 2017). No differences were found in the collection site for Cozumel Island, although a greater number of *Ancylostoma* spp. eggs were observed in the sites without concrete, but this was not significant. Similar results were reported by Romero *et al.* (2010) who found no differences between fecal sample collection sites, while Rubel and Wisnivesky (2005) report that the collection site is of minor importance compared to dog population density and that contamination increases in this direction. On the other hand, it is reported that the highest concentration of dog feces is found on grassy surfaces, regardless of whether they belong to parks or sidewalks (Rubel and Wisnivesky, 2005). The knowledge of these data represents an opportunity for veterinarians to create comprehensive health schemes with the vision of "One Health". Since the

role played by veterinarians in public health is recognized and encouraged, the dissemination of this information favors the awareness of communities and authorities, which, with the support of veterinarians, can reduce the impact of this parasitosis among the pet population and the environment risk of transmission to the population (Savadelis *et al.*, 2019).

Considering that there are a set of factors that favor the appearance of these problems, it is suggested to carry out more studies on the frequency of these parasitoses in other tourist areas, including other methodologies (quantitative techniques), delimiting the factors (better-delimited aspects) or including new factors in the evaluation (age, pet dogs, among others), as well as considering the variables mentioned above.

CONCLUSION

The frequency of gastrointestinal parasite eggs/oocyst in canine feces collected in parks on Cozumel Island was 27%; the genera with the highest number of positive cases was *Ancylostoma* spp, followed by *Toxocara* spp. and lastly, *Trichuris* spp, *Taenia* spp and *Isospora* spp. The socioeconomic level was the only factor associated with the positive fecal samples in parks, indicating that public parks of high socioeconomic level are a protective factor, which means lower odds of positive fecal samples are expected compared with parks characterized by low socioeconomic level. Parks with the presence and absence of an influx of tourists and parks with a high and low human population have a similar presence of gastrointestinal parasites from dog fecal samples collected on Cozumel Island and finally, according to the collection site, *i.e.*, areas with and without pavement did not affect the presence of gastrointestinal nematodes from dog feces.

Conflict of interest. All authors declare no competing interests.

Compliance with ethical standards. This research did not require approval by the ethical committee to process the samples.

Data availability. Data are available with J. Vargas-Magaña (jjvargas@uacam.mx) upon reasonable request.

Author contribution statement (CRediT). Á. Alcázar-Hernández – Writing – original draft., **J. Espadas-Escalante** – Investigation, Methodology., **J.J. Vargas-Magaña** – Conceptualization, Writing – review and editing., **F. Méndez-Ortíz** - Writing –

review and editing, Supervision., **A. Pérez-Roque** – Conceptualization - Writing – review and editing, **J. Ventura-Cordero** - Data curation, Formal Analysis, Software, Writing – review and editing.

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