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ОРИГИНАЛЬНЫЕ СТАТЬИ

ZOONOTIC INTESTINAL PARASITES IN FREE-RANGING DOGS (*CANIS LUPUS FAMILIARIS*): A RISK TO PUBLIC HEALTH IN A MEXICAN PROTECTED AREA

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Domestic dogs (*Canis lupus familiaris*) have been in contact with humans for thousands of years, playing an important role in societies. Nonetheless, the lack of responsible ownership has contributed to the transition from companion dogs to free-ranging or feral dogs that can be reservoirs of zoonotic parasites. Our goal was to identify zoonotic intestinal parasites in free-ranging dogs in a Mexican Protected Area. A total of 132 scat samples from free-ranging dogs were collected and examined using the Faust flotation technique. We identified a total of nine parasite species, four platyhelminthes, and five nematodes. Eight of nine identified parasite are zoonotic. The most frequent zoonotic parasites are *Ancylostoma caninum* and *Ascaris* spp. (19.7% each) followed by *Toxascaris leonina* (17.4%) and *Uncinaria stenocephala* (7.6%). The least frequent are *Dipylidium caninum* (2.2%), *Capillaria* spp., *Hymenolepis diminuta*, and *Hymenolepis nana* (0.75% each). This study provides the first description of intestinal zoonotic parasites richness in free-ranging dogs within a Mexican Protected Area. The presence of zoonotic parasites in canine scats represents a high risk to public health, mainly for the transmission of some species through cutaneous and visceral migrans larvae, especially in infants and kids. We recommend specific measures to prevent, control and mitigate the presence of free-ranging dogs in Protected Areas.

Key words: invasive alien species, Mexico, Nevado de Toluca, public park, zoonosis

Introduction

Domestic dogs (*Canis lupus familiaris* Linnaeus, 1758) have been in close contact with humans for at least 14 000 years (Nobis, 1979), having an important and functional role in humans societies (Nguyen et al., 2021). From herding, hunting, and protection, to companion, service, and a wide variety of trained working dogs, human-dog interaction is as profound as human civilisation itself (MacPherson, 2005; Dantas-Torres & Otranto, 2014). Nonetheless, the increasing dog population and the lack of responsible ownership have contributed to the transition from companion dogs to free-ranging or feral dogs (Young et al., 2011). Free-ranging and feral dogs can negatively impact wildlife through predation, competition, harassment, hybridisation, and disease transmission (Doherty et al., 2017), and human health, as a reservoir of zoonotic parasites (Shepherd et al., 2018; Belsare & Vanak, 2020) such as helminths (Rahman et al., 2020).

According to the World Health Organization, parasitic infectious diseases represent a public health problem worldwide, resulting in considerable morbidity and mortality (WHO, 2020). Helminthiasis in dogs by cestodes and nematodes cause serious public and animal health issues (Eguía-Aguilar et al., 2005; Michalczyk et al., 2019; Othman & Abuseir, 2021). Some well-known zoonotic helminths in dogs are roundworms (*Ascaris* spp., *Toxocara canis* Werner, 1782), hookworms (*Ancylostoma caninum* Ercolani, 1859, *Uncinaria stenocephala* Railliet, 1884), and tapeworms (*Taenia* spp., *Dipylidium caninum* (Linnaeus, 1758), *Echinococcus* spp.) (Cordero del Campillo et al., 1999). Specifically, *Toxocara* spp. and *Ancylostoma* spp.

cause cutaneous and visceral larva migrans, one of the most common zoonotic infections in humans, mainly in young and immunocompromised individuals (Romero Núñez et al., 2011).

Domestic dogs are classified globally (GISD, 2010) and locally (DOF, 2016a) as invasive alien species. One of the goals of the Mexican strategy on invasive species is to prevent and control free-ranging and feral dogs in vulnerable sites such as Protected Areas and other relevant biodiversity areas (CONABIO, 2010). However, the damage that free-ranging and feral dogs cause to ecosystems and human health is either underestimated or overlooked, especially in Latin America (Guedes et al., 2021).

Recent studies report a population of free-ranging dogs inside the Nevado de Toluca Flora and Fauna Protected Area (DOF, 2016b), particularly in the Cacalomacan Ecological Park (CEP), where its impact on wildlife has been demonstrated (Carrasco-Román et al., 2021). Free-ranging dogs in the area mainly result from irresponsible ownership in the surrounding rural and farming lands. Free-ranging dogs often use trails and roads to access forested sites, rural areas, and places where food is available (Sepúlveda et al., 2015). The CEP is a public park with outdoor activities, considered as an important area for biodiversity conservation (Sánchez-Jasso & Cebrián-Abellán, 2015).

Public health of zoonotic parasites in feral and free-ranging dogs has been previously assessed in public parks (Soriano et al., 2010; Stojčević et al., 2010; Romero Núñez et al., 2011; Bojar & Kłapeć, 2012; Sprenger et al., 2014; Tudor, 2015) and in less amount, in Protected Areas (Curi et al., 2017). None of this has been done in Mexico. Free-ranging behaviour facilitates parasite transmission between dogs, humans and wildlife (Rahman et al., 2020). However, there is a gap in the existing knowledge about dogs' parasites and public health, especially in Protected Areas (Curi et al., 2017), where the lack of scientific and governmental attention of free-ranging and feral dogs results in non-existent or insufficient control measures to prevent both, the increasing of free-ranging dogs population inside Protected Areas (Paschoal et al., 2012), and zoonotic parasites dispersion (Belsare & Vanak, 2020).

Here we identify the presence of zoonotic intestinal parasites on free-ranging dog scats. We have estimated the richness of zoonotic intestinal parasites, and compared scats from access roads and hiking trails in a Mexican Protected Area as a step to understand the implications of free-ranging dogs on human health.

Material and Methods

Dog scats were collected from the Cacalomacan Ecological Park (CEP), situated within Nevado de Toluca Flora and Fauna Protected Area (hereafter – Nevado de Toluca) (19.210277° N, 99.745° W; 19.208611° N, 99.730833° W; 19.191944° N; 99.739444° W, 19.196388° N; 99.7525° W) (Sánchez-Jasso et al., 2013). The Nevado de Toluca is considered a priority terrestrial region by the Mexican government (DOF, 2016b). However, like other Protected Areas in Mexico, it is a vulnerable ecosystem due to anthropogenic activities. The Nevado de Toluca encompasses 16 communities with more than 5000 inhabitants, and 25 more communities in the surrounding 1-km buffer zone (INEGI, 2010; DOF, 2016b).

The CEP is one of five community owned public parks in the Nevado de Toluca (Sánchez-Jasso & Cebrián-Abellán, 2015). It is located at 2800–3247 m a.s.l., encompassing 2.44 km^2 (Fig. 1). A temperate, semi-cold climate with rains in summer is predominant (García, 1981). It is an isolated woodland, forested with *Cupressus lindleyi* Klotzsch ex Endl., and *Pinus patula* Schiede ex Schltdl. & Cham., with native vegetation in valleys and along creeks such as *Muhlenbergia macroura* (Kunth) Hitchc., *Abies religiosa* (Kunth) Schltdl. & Cham., and *Alnus jorullensis* Kunth (Sánchez-Jasso et al., 2013).

We collected free-ranging dog scats twice per month from June 2013 to February 2014, with the help of a trained bloodhound, able to specifically locate dog scats in various habitats (Carrasco-Román et al., 2021). Only scats with no signs of deterioration were collected (Sélem-Salas et al., 2011). We sampled all CEP roads and trails by random start locations and compass bearings from trails throughout the CEP so that no area was intentionally sampled first (Carrasco-Román et al., 2021). We mapped scat locations using ArcGIS Desktop Version 10.2 (ESRI, 2013).

We examined dog scats using the Faust flotation technique (Schell, 1962). We performed morphometric observations, photomicrographs and measurements using a Motic microscope ® with 4X, 10X and 40X magnifications and coupled to a Motic BA200 ® digital camera and Motic Image Plus 2.0 ® imaging software. Photographs were deposited and available at the Faculty of Science Invertebrate Collection in the Autonomous University of Mexico State, Mexico.

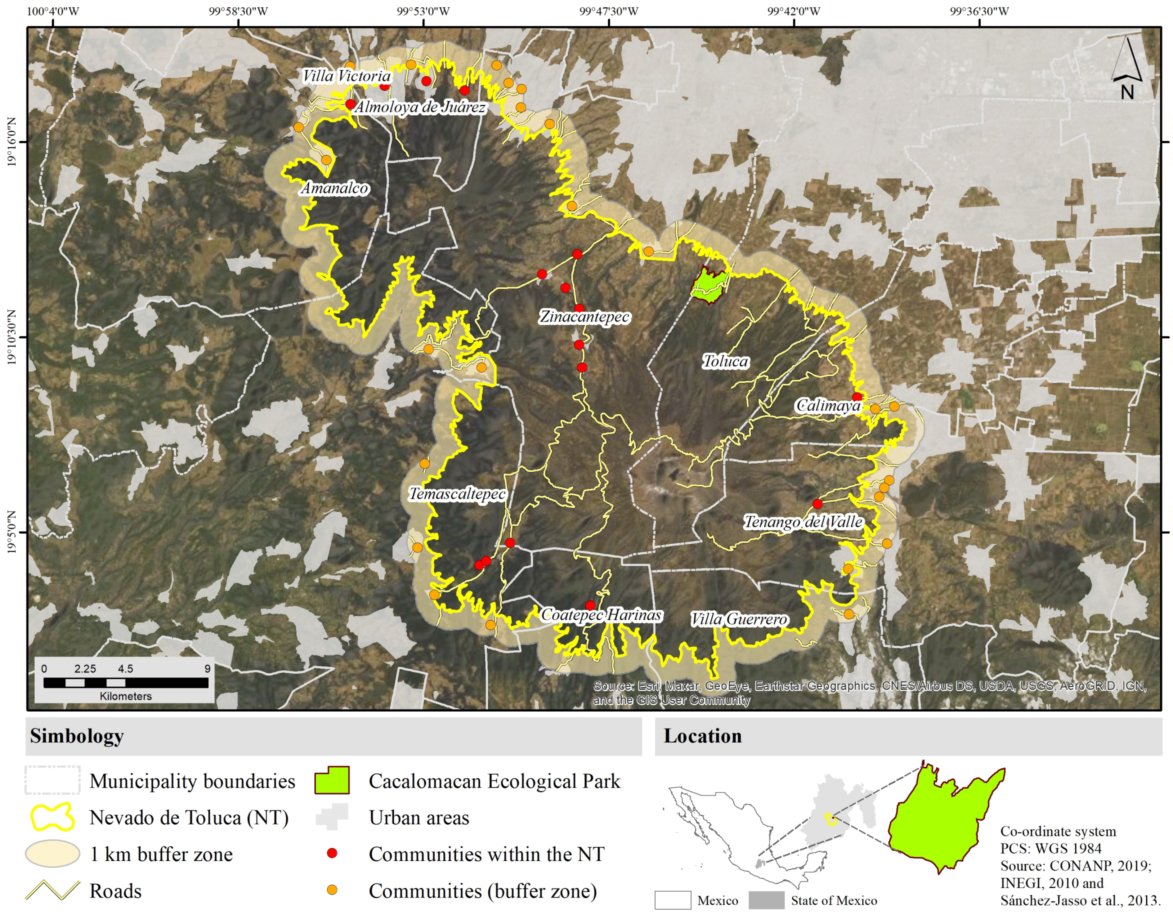


Fig. 1. The location of Cacalomacán Ecological Park within the Nevado de Toluca, Mexico. Datum WGS 84, Zone 14.

We used reference guides and input from experts and specialists for parasite identification. To identify platyhelminthes, we consulted Mönning (1950), Hendrix (1998), Foreyt (2001), Zajac & Conboy (2012), Mehlhorn (2016), and Taylor et al. (2016). Nematodes were identified according to Mönning (1950), Hendrix (1998), Foreyt (2001), Bowman (2011), Zajac & Conboy (2012), Mehlhorn (2016), and Taylor et al. (2016). We determined species richness by adding the number of recorded species in the free-ranging dog scat samples. We fitted a Clench equation model to obtain the species accumulation curve to determine if our sample size was adequate (Clench, 1979) using PAST 3.0 software (Hammer et al., 2001). Clench equation models are widely used whose accuracy has been demonstrated in most real-world situations and for most taxa (Jiménez-Valverde & Hortal, 2003; Martínez-Aquino et al., 2004). We estimated parasite frequency expressed as the absolute number of infected samples (Bush et al., 1997).

Results

Seventy-one of 132 dog scats were positive for intestinal parasites. We identified a total of nine parasite species (Table 1). The species accumulation curve fitted well to the Clench model (S_{obs} = 9, r^2 = 95.35; a/b = 9.8, CI 95%). The expected richness value was 10 with a slope value equal to 0.0012, and a recovered richness proportion of 91.83%. According to this model, the inventory was accurate. We compared parasite morphology to establish similarities and differences with other authors (Table 2).

Table 1. Taxonomic nomenclature of identified parasites in free-ranging dog scats in the Cacalomacan Ecological Park, Mexico

Kingdom	Phylum	Class	Order	Family	Genera	Species
Animal	Platyhelminthes	Cestoda	1	3	3	4
	Nematoda	Enoplea	1	1	1	1
		Chormadorea	2	2	4	4
Total			4	6	8	9

Table 2. Intestinal parasites found in free-ranging dog scats in the Cacalomacan Ecological Park, Mexico, compared with other authors

Species	Mönnig (1950)	Hendrix (1998)	Foreyt (2001)	Taylor et al. (2016)	Bowman (2011)	Zajac & Conboy (2012)	Mehlhorn (2016)	This study
Platyhelminthes (Cestoda)								
Dipylidium caninum (Linnaeus, 1758)	–	–	Egg: 25–30 µm. Eggs packets: 150 × 200 µm (20 eggs approx.)	Egg: 25–50 µm.	–	Egg: 35–60 µm. Egg packets: 120 × 200 µm (25–30 eggs).	Egg: 34–40 µm. Egg packets: 120 × 200 µm (8–30 eggs).	Egg: 22.0–22.7 µm. Egg packets: 147.4 × 184.4 µm (30 eggs approx.)
Hymenolepis diminuta (Rudolphi, 1819)	–	Egg: 30–55 × 62–88 µm. Embryo has six hooks.	Egg: 50 × 65 µm.	Egg: 60 µm.	–	Egg: 52–81 × 60–88 µm. Embryo has six hooks.	Egg: 60–80 × 70 µm.	Egg: 78.9 × 81.1 µm. Embryo with six hooks
Hymenolepis nana (Siebold, 1852)	–	Egg: 30–55 × 44–62 µm. Embryo has six hooks.	Egg: 50 × 40 µm.	Egg: 30–55 × 44–62 µm. Embryo has six hooks.	–	Egg: 34–37 × 40–45 µm. Embryo has six hooks.	Egg: 30–50 × 40–60 µm. Egg has polar filaments.	Egg: 35.1 × 38.0 µm. Egg has polar filaments. Embryo has hooks.
Taenia pisiformis (Bloch, 1780)	Adult: 200 cm length. Gravid segments in scats: 4000–5000 × 8000–10 000 µm.	Adult: 200 cm length.	Adult: 20 m length. Gravid segments: only in scats.	–	–	–	Gravid segments in scats: 4000–5000 × 8000–10 000 µm.	Gravid segments in scats: 5000 × 8000 µm.
Nematoda								
Ancylostoma caninum Ercolani, 1859	Egg: 56–65 × 37–43 µm. Embryo has about eight cells when laid.	Egg: 56–75 × 34–47 µm.	Egg: 60 × 40 µm.	Egg: 56–75 × 34–47 µm. Embryo has two to eight blastomeres.	Egg: 65 µm. Embryo in a morula stage.	Egg: 52–79 × 28–58 µm.	Egg: 60 × 40 µm. Embryo has two to eight blastomeres.	Egg: 40.4 × 61.3 µm. Embryo with seven blastomeres
Ascaris spp.	Egg: 40–50 × 50–75 µm. Thick shell with prominent projections.	Egg: 37–40 × 70–89 µm. Golden brown shell, with lumpy, bumpy appearance (*Ascaris suum* Goeze, 1782).	Egg: 80 × 85 µm.	Egg: 40–55 × 50–75 µm. Thick, yellowish-brown shell, with mamillated appearance (*A. suum*).	–	–	Egg: 45 × 60 µm. Thick, yellowish shell, with wrinkles appearance (*A. suum*).	Egg: 48.7 × 57.2 µm. Thick, yellowish-brown shell with mamillated appearance.
Toxascaris leonina (Von Linstow, 1902)	Egg: 60–75 × 75–85µm. Smooth shell.	Egg: 75 × 85 µm. Smooth shell.	Egg: 70 × 80 µm.	Egg: 75 × 85 µm. Smooth thick shell.	–	Egg: 60–75 × 75–85 µm. Smooth thick shell.	Egg: 75 × 90 µm. Thick-walled shell.	Egg: 61.2 × 81.3 µm. Smooth thick shell.
Uncinaria stenocephala Railliet, 1884	Egg: 40–50 × 65–80 µm.	Egg: 40–50 × 65–80 µm	Egg: 45 × 75 µm	Egg: 40–50 × 65–80 µm.	Egg: 70 µm mean.	Egg: 35–58 × 71–92 µm.	Egg: 40 × 73 µm. Their poles are not similar and their side walls are flattened.	Egg: 46.6 × 78.1 µm. Poles are not similar and side walls are flattened.
Capillaria spp.	Egg: 30–40 × 59–80 µm, including the polar plugs.	Egg: 30–40 × 59–80 µm. Broadly barrel-shaped, and lighter in colour (*Capillaria aerophila* Creplin, 1839)	Egg: 35 × 70 µm (*C. aerophila*).	Egg: 59–80 × 30–40 µm, barrel-shaped and colourless. Thick slightly striated shells with bipolar plugs (*C. aerophila*).	–	Egg: 29–40 × 58–79 µm (*Eucoleus aerophilus*). Egg: 30–35 × 54–60 µm (*Eucoleus boehmi* Supperer, 1953).	Egg: 30–35 × 45–60 µm. Shell with polar plugs.	Egg: 24.5 × 58.9 µm. Brownish with barrel shape and polar plugs.

Eight of nine identified parasites in the CEP are zoonotic. Only *Taenia pisiformis* (Bloch, 1780) is not known to infect humans (Schoeb et al., 2007). The most common zoonotic parasites were *Ancylostoma caninum* and *Ascaris* spp. (19.7%) followed by *Toxascaris leonina* (Von Linstow, 1902) (17.4%) and *Uncinaria stenocephala* (7.6%). *Dipylidium caninum* was positive in 2.3% of dog scats. *Capillaria* spp., *Hymenolepis diminuta* (Rudolphi, 1819), *H. nana* (Siebold, 1852) and *Taenia pisiformis* were positive in 0.75% of dog scats (Table 3).

Among the 132 examined dog scats, 71 (53.8%) were positive for at least one intestinal parasite. We observed monoparasitism in 53 (40.2%) dog scats samples, biparasitism in 15 (11.3%) samples and poliparasitism in three (2.3%) samples. *Ancylostoma caninum*, *Ascaris* spp., *Toxascaris leonina* and *Uncinaria stenocephala* were parasites that cohabited the most (Table 4).

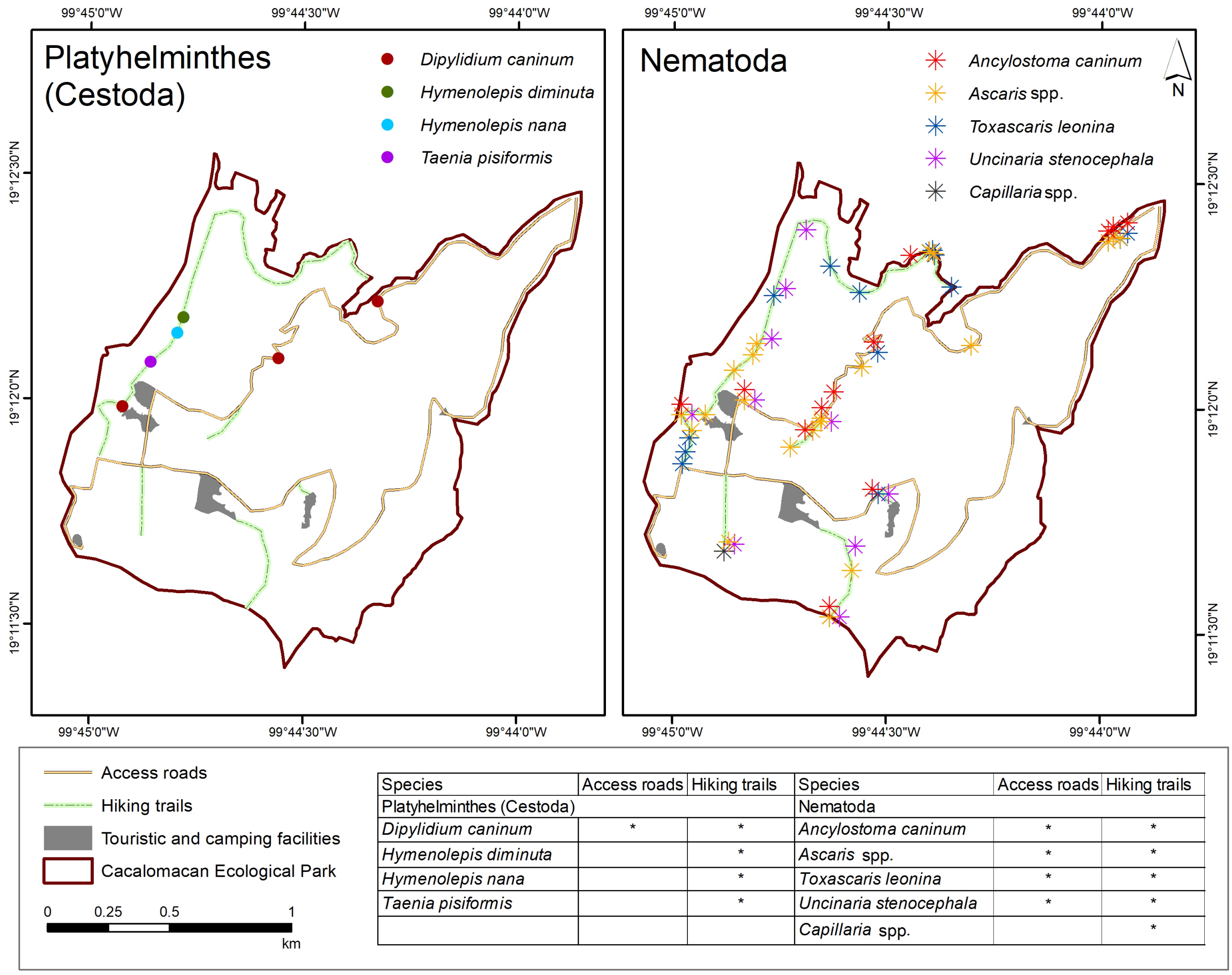
Nematodes were the most frequent species collected on access roads and hiking trails. *Capillaria* spp. was the only nematode that was not found on access roads. Regarding Cestoda species, only *Dipylidium caninum* was found on both, access roads and hiking trails. We highlight the presence of *Ascaris* spp. and *D. caninum* on dog scats on roads and hiking trails near the camping facilities (Fig. 2).

Table 3. Parasite frequency in free-ranging dog scats collected in the Cacalomacan Ecological Park, Mexico

Species	Frequency	Percentage	Zoonotic parasite
Platyhelminthes (Cestoda)			
Dipylidium caninum	3/132	2.3	✓
Hymenolepis diminuta	1/132	0.75	✓
Hymenolepis nana	1/132	0.75	✓
Taenia pisiformis	1/132	0.75	–
Nematoda			
Ancylostoma caninum	26/132	19.7	✓
Ascaris spp.	26/132	19.7	✓
Toxascaris leonine	23/132	17.4	✓
Uncinaria stenocephala	10/132	7.6	✓
Capillaria spp.	1/132	0.75	✓

Table 4. Parasite associations in free-ranging dog scats collected in the Cacalomacan Ecological Park, Mexico

Species	Positive samples	Percentage, %
Monoparasitism		
Ancylostoma caninum	15	21.1
Ascaris spp.	15	21.1
Dipylidium caninum	2	2.8
Toxascaris leonina	13	18.3
Uncinaria stenocephala	6	8.5
Hymenolepis nana	1	1.4
Hymenolepis diminuta	1	1.4
Biparasitism		
Ancylostoma caninum + *Toxascaris leonina*	5	7
Ascaris spp. + *Ancylostoma caninum*	3	4.2
Ascaris spp. + *Dipylidium caninum*	1	1.4
Ascaris spp. + *Taenia pisiformis*	1	1.4
Ascaris spp. + *Toxascaris leonina*	2	2.8
Ascaris spp. + *Uncinaria stenocephala*	1	1.4
Uncinaria stenocephala + *Capillaria* spp.	1	1.4
Uncinaria stenocephala + *Toxascaris leonina*	1	1.4
Polyparasitism		
Ascaris spp. + *Toxascaris leonina* + *Ancylostoma caninum*	2	2.8
Ascaris spp. + *Ancylostoma caninum* + *Uncinaria stenocephala*	1	1.4



Species	Access roads	Hiking trails	Species	Access roads	Hiking trails
Platyhelminthes (Cestoda)			Nematoda		
Dipylidium caninum	*	*	*Ancylostoma caninum*	*	*
Hymenolepis diminuta		*	*Ascaris* spp.	*	*
Hymenolepis nana		*	*Toxascaris leonina*	*	*
Taenia pisiformis		*	*Uncinaria stenocephala*	*	*
			Capillaria spp.		*

Fig. 2. Location of parasitised free-ranging dog scats in the Cacalomacan Ecological Park, Mexico. Datum WGS 84, Zone 14.

Discussion

We provide the first description of zoonotic intestinal parasites in free-ranging dogs inside a Mexican Protected Area. Zoonotic parasites are responsible for 61% of all human infectious diseases (Taylor et al., 2001). Worldwide, hookworms (e.g. *Ancylostoma*, *Ascaris*, *Toxascaris* or *Uncinaria*) infected 438.9 million people, where intestinal nematodes infected 1.45 billion people with at least one species (Pullan et al., 2014). Globally, zoonotic tapeworm infections caused by eggs or larval of *Taenia*, *Dipylidium*, and *Hymenolepis* are a significant cause of morbidity and mortality in humans (Raether & Hänel, 2003). Contaminated soil, water, and food are the most important routes of parasites transmission, where animals and humans might get infected by accidental ingestion or cutaneous contact (Tudor, 2015). Several studies around the world have demonstrated that public parks represent a high risk of infections by zoonotic parasites, where the principal cause is soil contaminated by dog scats (Soriano et al., 2010; Stojčević et al., 2010; Romero Núñez et al., 2011; Bojar & Kłapeć, 2012; Sprenger et al., 2014; Tudor, 2015; Curi et al., 2017).

The presence of zoonotic parasites in public parks worldwide is similar to our results. *Ancylostoma caninum* was one of most reported species in different studies (Stojčević et al., 2010; Bojar & Kłapeć, 2012; Sprenger et al., 2014), followed by *Toxascaris leonina* (Soriano et al., 2010; Tudor, 2015), *Dipylidium caninum* (Soriano et al., 2010; Curi et al., 2017), and *Ascaris* spp. (Stojčević et al., 2010; Bojar & Kłapeć, 2012; Curi et al., 2017).

Ancylostoma caninum is a common species found in dogs in Mexico (Ortega-Pacheco et al., 2015). This hookworm can cause eosinophilic enteritis and chronic pain in humans (Siyadatpanah et al., 2019; Hawdon & Wise, 2021). *Ancylostoma caninum* eggs may occur in feral dogs year-round and are twice more common in pets (MacPherson, 2005). Since free-ranging dogs share habitat and habits with feral dogs (Young et al., 2011), they could be significant contributors to human hookworm infections (Siyadatpanah et al., 2019). The frequency of *A. caninum* in our study could be related to the temperature and humidity of the soil since eggs and larvae develop favourably in temperatures between 23°C and 30°C, with moderate moisture and shaded soil with good drainage (Bowman, 2011), which are the climatological and environmental conditions in the study site.

Our results also indicated a greater frequency of monoparasitism instead of polyparasitism (Table 4), similar to previous studies (Fontanarrosa et al., 2006; Ugbomoiko et al., 2008), which might be related to the interaction among species that depend on parasite burden rather than on the mere presence of other species (Fontanarrosa et al., 2006). Nonetheless, polyparasitism has recently gained relevance due interspecific interactions that may modify the susceptibility to other parasites, the risk of transmissions, and increased morbidity in humans and wildlife (Enriquez et al., 2019). The presence of zoonotic parasite species in free-ranging dogs and their potential interspecific interaction between humans and biodiversity suggest the need to design and implement integrated plan management based on a One Health framework, which aims to attain optimal health for people, domestic animals, wildlife, and environment (WHO, 2017).

We highlight the presence of *Ascaris* spp. in free-ranging dog scats. This parasite has the most frequent parasitic associations in our study (Table 4). Worldwide, ascariasis is one of the most common human and pig parasitic infections (Midha et al., 2021) and is considered a neglected zoonotic disease (Else et al., 2020). It can contribute to chronic morbidity; via anorexia, malabsorption of nutrients, and negative effects on cognitive development, mainly in children (Else et al., 2020).

The presence of *Ascaris* spp. in the free-ranging dog scats suggests that dogs might be acting as accidental or paratenic hosts. The pig (*Sus scrofa* Linnaeus 1758) is a definitive host of several helminth species, including *Ascaris* spp. Also, *S. scrofa* was previously reported as a part of the diet of free-ranging dogs in the CEP due to an illegal dump of livestock remains in an open pit area adjacent to the CEP (Carrasco-Román et al., 2021). *Ascaris* spp. eggs in dog scats have been reported in Canada and India, demonstrating that *Canis lupus familiaris* can be a reservoir or mechanical transmitter of this parasite (Shalaby et al., 2010).

The egg identification in our study relied on morphology and morphometry, which could be a limitation. However, most of the eggs of intestinal parasites found in this study are well described, which allowed us to efficiently compare them with those described by other authors to confirm most of the species (Table 2). Nonetheless, for *Ascaris* spp., the similarity of egg morphology between *Ascaris lumbricoides* Linnaeus, 1758 and *Ascaris suum* Goeze, 1782 did not allow us to identify at species level (Leles et al., 2012). We face the same scenario with *Capillaria* spp., where the species level could not be confirmed because of the egg similarities between *Capillaria aerophila* Creplin, 1839 (*Eucoleus aerophilus* (Creplin, 1839)) and *Capillaria boehmi* (Supperer, 1953) (*Eucoleus boehmi* (Supperer, 1953)) (Traversa et al., 2011; Gillis-Germitsch et al., 2020). To identify *Capillaria* species at genetic level is also complicated due to the similarity in gene sequences between species (Guardone et al., 2013).

Free-ranging dogs do not only represent a public health risk to humans but also a health risk to wildlife. *Hymenolepis diminuta* and *H. nana* are rodent cestodes that could be spurious in dogs and definitive in humans (Bowman, 2011). In the CEP, several species of rodents are part of the diet of free-ranging dogs (Carrasco-Román et al., 2021), which could explain the presence of these parasites in dog scats collected on hiking trails close to forested areas, where dogs might exchange parasites with wildlife (MacPherson, 2005). In addition, 19 species of mammals in the CEP are reported as part of the diet of free-ranging dogs (Carrasco-Román et al., 2021), which suggests that mammals could be acting as definitive or accidental hosts of zoonotic parasites. For example, *Didelphis virginiana* Kerr, 1792, can be parasitised by *Ancylostoma caninum*, *Ascaris* spp. and *Capillaria* spp. (Aragón-Pech et al., 2018); *Urocyon cinereoargenteus* Schreber, 1775 by *Dipylidium caninum* (Rankin, 1946), *Ancylostoma caninum*, *Toxascaris leonina*, *Uncinaria stenocephala* and *Capillaria* spp. (Erickson, 1944; Rankin, 1946; Hernández-Camacho et al., 2011); and *Linx rufus* Schreber, 1777 by *Ancylostoma caninum* and *Toxascaris leonina* (Hiestand et al., 2014). For these reasons, it is necessary to expand research into the understanding of the zoonotic parasites and wildlife interactions.

The home range of free-ranging dogs in rural/forested areas has been documented from 4.44 km^2 to 28.5 km^2 (Nesbitt, 1975; Scott & Causey, 1973). With 16 communities interconnected through the 535.91 km^2 in the Nevado de Toluca (INEGI, 2010; DOF, 2016b), the free-ranging dogs represent a significant problem beyond the boundaries of the Cacalomacan Ecological Park.

We encourage to prioritise attention and control measures in the Nevado de Toluca Protected Area since residents, visitors, and wildlife, could be at risk of infections with these zoonotic intestinal parasites (Curi et al., 2017).

We further recommend specific measures to manage the problem inside similar Protected Areas in Mexico. Managers should: 1) promote responsible ownership programmes; 2) post informative signage inside the park; 3) designate permitted areas where companion dogs are required to be on-leash; 4) ban companion dogs from vulnerable ecosystems; 5) daily disposal of solid waste and cleaning dog scats found in touristic facilities and camping areas; 6) report the presence of free-ranging dogs to the environmental authorities; 7) work together with stakeholders and the authorities to remove free-ranging dogs from parks; 8) adopt management protocols that are based on the health and behaviour of dogs; 9) develop a monitoring program to prevent and control free-ranging dogs; 10) promote research on free-ranging dogs ecology. There is no single solution to reduce free-ranging or feral dog populations that can be applied universally, but we consider these actions can help to address the problem.

Conclusions

This manuscript provides the first evidence on how free-ranging dogs that live within Protected Areas in Mexico, such as the Nevado de Toluca, could represent a risk to wildlife and public health due to the transmission of zoonotic parasites. It is necessary to formulate management policies based on a One Health approach, which aims to attain optimal health for people, domestic animals, wildlife, and the environment. Although the Nevado de Toluca management plan specifies some activities and actions against invasive alien species, it does not incorporate specific measures to mitigate the impact of free-ranging and feral dogs (DOF, 2016b). We recommend that Nevado de Toluca stakeholders, including local communities, visitors, academy, and government, develop strategies that include holistic views to formulate agreements and commitment to properly manage the free-ranging dog populations.

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ЗООНОЗНЫЕ КИШЕЧНЫЕ ПАРАЗИТЫ У СВОБОДНО ЖИВУЩИХ СОБАК (*CANIS LUPUS FAMILIARIS*): РИСК ДЛЯ ЗДОРОВЬЯ НАСЕЛЕНИЯ НА ОСОБО ОХРАНЯЕМОЙ ПРИРОДНОЙ ТЕРРИТОРИИ МЕКСИКИ

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Домашние собаки (*Canis lupus familiaris*) контактировали с людьми на протяжении тысячелетий, играя важную роль в жизни общества. Тем не менее, отсутствие ответственного владельца способствовало переходу собак от домашнего образа жизни к бродячему или дикому образу жизни. Эти животные могут быть резервуарами зоонозных паразитов. Наша цель состояла в том, чтобы выявить зоонозных кишечных паразитов у собак на свободном выгуле на особо охраняемой природной территории Мексики. В общей сложности было собрано и исследовано 132 образца экскрементов свободно живущих собак с использованием метода флотации Фауста. Всего было обнаружено девять видов паразитов, в том числе четыре платигельминта и пять нематод. Восемь из девяти идентифицированных паразитов являются зоонозными. Наиболее часто встречающимися зоонозными паразитами являются *Ancylostoma caninum* и *Ascaris* spp. (19.7%), за которыми следуют *Toxascaris leonina* (17.4%) и *Uncinaria stenocephala* (7.6%). Наименее распространены *Dipylidium caninum* (2.2%), *Capillaria* spp., *Hymenolepis diminuta* и *Hymenolepis nana* (0.75%). Это исследование представляет собой первое описание обилия зоонозных паразитов кишечного тракта свободно живущих собак на особо охраняемой природной территории Мексики. Присутствие зоонозных паразитов в экскрементах собак представляет высокий риск для здоровья населения, в основном, с помощью передачи некоторых видов через кожные и висцеральные мигрирующие личинки; особенно велик риск для младенцев и детей. Мы рекомендуем конкретные меры для предотвращения, контроля и уменьшения присутствия свободно живущих собак на особо охраняемых природных территориях.

Ключевые слова: зооноз, инвазионный чужеземный вид, Мексика, Невадо де Толука, общественный парк