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Research article

Factors affecting canine fecal and parasitic contamination of public green spaces of Buenos Aires city, Argentina, and visitors' perception of such contamination

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Abstract

Canine fecal contamination in public green areas is difficult to control. Our objectives were to assess: (i) the relationship between fecal contamination in public green spaces of Buenos Aires (Argentina) and the type of green space (boulevard/square/park), considering their area, presence/absence of control measures, and human population density in the surroundings (high or low); (ii) the perception of people of such contamination and (iii) the frequency of parasites in dog feces. In each green space ($n = 26$), feces were counted in thirty 25-m^2 plots randomly located. The opinion survey consisted of asking people (358) what their perception of fecal contamination was, whether it bothered them and whether they thought it was hazardous to the dogs' or people' health. Canine fecal samples randomly collected ($n = 112$) were concentrated and examined microscopically. Mixed-effect generalized linear models were fitted to evaluate the effect of selected variables on fecal contamination. People's perception of human and canine health risks were assessed by logistic regression. Canine fecal contamination was lower in squares with control measures and in parks with control measures located in densely populated areas, and higher in boulevards located in densely populated areas. The visitor's perception was that feces were associated with dirtiness (77%) and odor (30.8%). Parasites were detected in 51.8% of fecal samples. Our results confirm that environmental control measures decrease canine fecal contamination of public green spaces, and that more than 65% of the people interviewed do not relate fecal contamination to risks to human/dog health.

Key words: green spaces, fecal contamination, control measures

Introduction

Public green areas provide important ecosystem services for residents of large cities (Flores et al. 1998; Garay and Fernández 2013). People use these areas both for their leisure and for walking their canine pets. Consequently, the issue of fecal contamination and the possible dog-to-dog or dog-to-human transmission of gastrointestinal parasites becomes relevant. The 'fecalization' of urban environments is a global health problem that is difficult to control (Poglayen and Marchesi 2006) and an indicator of the risk of transmission of numerous parasitoses to animals and humans, including toxocariosis, hookworm infection, trichuriosis, giardiosis, cryptosporidiosis and entoamebiosis.

Both fecal density and parasitic fecal load determine the amount and distribution of the infective stages of parasites in the soil, which are the main source of infection (Uga 1993; Mizgajska-Wiktor and Uga 2006; Poglayen and Marchesi 2006; Morgan, Azam, and Pegler 2013; Otero et al. 2018).

In the city of Buenos Aires different measures were implemented in order to reduce the canine fecal contamination in green spaces: (i) construction of exclusive fenced sectors for dogs (a fenced space in which the dogs run, play and defecate), (ii) hiring of companies for the maintenance and cleaning of green spaces and (iii) legal framework that penalize the dogs' owners who do not clean the waste of their pets (Ordinance No. 41831, art. 29, Government of Buenos Aires City 1987).

Despite the implementation of these measures, canine fecal contamination in Buenos Aires city squares increased from 220 feces per square in 1995/2000 to 1290 in 2012 (Rubel and Wisnivesky 2010; Vaccaro et al. 2012). This failure to reduce contamination could be due to multiple factors, such as an increase in the canine population density (Anderson et al. 1996) and a deficient application of monitoring and control measures (Rubel and Wisnivesky 2010).

With respect to parasites, they are present in canine feces collected in public spaces all over the world (Minnaar and Krecek 2001; Chen et al. 2012; Wang et al. 2012; Kroten et al. 2016; Ferreira et al. 2017; Gillespie and Bradbury 2017) and also is the situation in Argentina (Andresiuk et al. 2003; Sánchez et al. 2003; Sánchez Thevenet et al. 2003; Milano and Oscherov 2005; Martin and Demonte 2008; Soriano et al. 2010; La Sala et al. 2015) and Buenos Aires city (Sommerfelt et al. 1994; Rubel and Wisnivesky 2010; Duré et al. 2013). The presence of parasites of veterinary and public health importance implies a risk for dog and human health. However, the relationship of the level of canine and parasitic fecal contamination with the type of green space and the implementation of control measures has been poorly studied.

Another aspect which needs to be addressed is how the practices and beliefs of dog owners and users of public green spaces affect the sustainability of control measures (Sampson 1984). In England, Webley and Siviter (2000) and Westgarth et al. (2010) showed that, despite educational campaign, only 60% of owners complied with regulations. These findings appeared to be influenced by different aspects, for example picking up dogs' feces was more common in parks than in sidewalks (Webley and Siviter 2000), and owners who carried their dog on a leash were more likely to pick up their dogs' feces than those who did not (Wells 2006; Westgarth et al. 2010). The situations described may also change depending on the site studied (e.g. different cities or different neighborhoods). These local effects make it necessary to assess each urban environment, because the understanding of human behavior would be essential to properly implement control measures.

In this context, the main objective of the present study was to investigate the features that may influence the canine fecal contamination in public green spaces of the city of Buenos Aires performing a descriptive, observational and transversal study.

Our specific objectives were to assess the relationship between the fecal contamination in public green spaces of Buenos Aires city and the type of green spaces, considering their area, the implementation of control measures, and the surrounding population density. Additionally, in the most contaminated green space, we went to study people perception of such contamination and the frequency of parasites in dog feces.

Materials and methods

Study area and classification of green spaces

The climate of the study area is temperate humid with a mean annual RH of 76% and a mean annual temperature of 15.8 (Anonymous 1992). Annual cumulative rainfall is 1200 mm on average, and rainfall events are recorded throughout the year (between 7 and 10 rainy days per month to average data for the period 1981–2010, National Meteorological Service 2014).

To evaluate fecal contamination under different conditions, we selected 26 public green spaces of the city of Buenos Aires, Argentina, and classified them according to their area (*boulevard* if the area was $\leq$5000 m^2, *square* if the area was between 5000 m^2 and 20 000 m^2, and *park* if the area was $>$20 000 m^2), human population density in the surroundings (*low* if no buildings taller than two storeys were observed in the surroundings, *high* if otherwise), and the presence/absence of control measures (Table 1). Also, regarding the latter issue, we considered green spaces as *controlled* when they met all of the following requirements: availability of fenced sectors for dogs (a fenced space to allow dogs to exercise and play without leashes and to contain their waste), a private company in charge of cleaning, and a perimeter fence for night closing; otherwise, the green space was classified as *not controlled*.

Sampling design

Feces or fecal fragments were counted in 2 boulevards, 19 squares and 5 parks, during spring 2014, from August through November. Location of the studied green spaces is shown in Fig. 1. Feces were counted on the ground (with or without vegetation) in 5×5 m^2 randomly located sample plots since it had been previously shown that these sectors concentrate 82% of animal feces (Rubel and Wisnivesky 2010). The number of plots examined in each green space was proportional to its total area, with a minimum of 30. Each green space was sampled in a single day.

Additionally, we counted feces and fecal fragments in sidewalks surrounding each green space, recording the microenvironment in which excrement was observed (e.g. tiles or tree pits) and whether the sidewalk was adjacent to an avenue (more than two car lanes) or a street.

Table 1: Canine fecal contamination in public green spaces (squares, parks and boulevards) in the city of Buenos Aires, 2014

Green space	Population density[a]	Control measures[b]	*n*[c]	Median (Q1–Q3)[d]
Sq-1[e]	Low	No	31	1 (0–4)
Sq-2	High	No	35	3 (2–7)
Sq-3	High	Yes	35	2 (1–4)
Sq-4	High	Yes	31	0 (0–1)
Sq-5	High	Yes	30	3 (0.8–5.2)
Sq-6	Low	No	35	0 (0–1)
Sq-7	High	No	32	1 (0–2)
Sq-8	Low	No	32	2 (1–4)
Sq-9	Low	Yes	39	0 (0–1)
Sq-10	Low	No	31	9 (4–13)
Sq-11	High	Yes	32	1 (0.2–3)
Sq-12	High	No	32	8 (5–14)
Sq-13	High	Yes	32	2 (0–5)
Sq-14	High	No	40	2 (1–5.8)
Sq-15	Low	No	33	1 (0–2)
Sq-16	High	No	32	1.5 (0–2.8)
Sq-17	Low	No	31	14 (7–21)
Sq-18	High	No	34	2 (1–4.2)
Sq-19	High	Yes	32	1 (0–2.8)
Pk-1[e]	Low	No	60	0.5 (0–2)
Pk-2	Low	Yes	64	0 (0–1)
Pk-3	High	Yes	119	0 (0–1)
Pk-4	High	No	120	1 (0–3)
Pk-5	Low	Yes	129	0 (0–1.5)
Blvd-1[e]	High	No	79	3 (1–6)
Blvd-2	Low	No	151	0 (0–1)
Total			1351	1 (0–3)

[a]Population density. Low: the neighborhood included only houses of up to two floors; High: predominance of buildings or equal proportions of houses and buildings.

[b]Implementation of control measures in the green space. Yes: fenced kennels, perimeter fencing for night closing, and a company devoted to cleaning and maintenance.

[c]Number of squared plots, 5 m by side.

[d]Number represents the median of canine feces per plot per green space and the interquartile range (Q1–Q3).

[e]Type of green space according to their surface: Boulevard (Blvd: 5000 m^2 or less); Square (Sq: 5001–20 000 m^2) and Park (Pk: 20 001–99 999 m^2).

Opinion survey and coproparasitological sampling

To evaluate people's perception of fecal contamination in green spaces, we conducted an opinion survey during spring 2014 (November and December). Among all visited green spaces, we chose to interview randomly selected passers-by in Park 4 because this site met the following conditions: lack of fecal contamination control measures, high level of fecal contamination and high human density in the neighborhood. This allowed us to have access to a large number of people who were certainly exposed to fecal contamination. The Park 4 is located in the Commune 14, one of the city Communes whose households have the higher per capita family income of the city (Government of the City of Buenos Aires 2015).

Surveys were conducted every tenth day for a total of six days, at alternating times of the day on each occasion (morning, afternoon and evening, see questionnaire in Table 2).

In addition, on each of the six survey days, all green spaces and paths in the park were walked through and thoroughly searched for dog feces. All fresh feces found were sampled and a sufficient amount of the middle portion was collected and placed in a collector vial with sodium acetate–acetic acid–formaldehyde solution (SAF) in the ratio 1:2. Each vial was sealed with Parafilm® and vigorously shaken to crush the solid and fix the biological material and to be transported to the laboratory for parasitological analysis.

Samples were collected in the field by professional technicians who worked in teams of two and used the appropriate biosecurity protection (gloves, surgical masks, acrylic goggles and clothing protection). Each batch of vials was transported in watertight containers under biosecurity conditions to the laboratories of the Department of Biological Chemistry which were authorized and classified with biosecurity level 2 by the Health and Safety Department.

Parasitological diagnostic methods

Samples were processed the day they were obtained. Two aliquots of 15 ml of well-homogenized fecal suspension were centrifuged (5 min, 1000 rpm). One of the pellets was enriched by centrifugation performing at least two washings with saline solution in order to recognize and diagnose protozoan trophozoites and to recover heavy or operculated eggs. The second pellet was floated in saturated NaCl solution (specific gravity 1.20 g/ml) in which almost all helminthes eggs and protozoan cysts and oocysts would float (Garbossa et al. 2013). At least two preparations from each tube were examined by light microscopy (400× magnification) by two trained professionals so that the diagnosis of each sample required the whole observation of eight independent slides. Morphometric data were obtained with the aid of a calibrated micrometer eye-piece to identify helminthes species and/or for the differential diagnosis between *Cystoisospora canis* and *Cystoisospora ohioensis* complex. Coccidia were confirmed by the modified Kinyoun staining method (Duré et al. 2013). Two hundred microscopic fields (1000× magnification) were observed before registering a negative result for *Cryptosporidium* spp. or *Cyclospora* spp.

Statistical methods

The Wilcoxon Rank-Sum Test was used to compare the number of feces per plot in the different types of green spaces studied and the number of feces in the different types of sidewalks analyzed (i.e. sidewalks next to avenues vs. sidewalks next to streets) (Siegel and Castellan 1995).

The impact of control measures on the number of feces per plot was analyzed by generalized linear mixed-effect models (GLMMs), using the negative binomial as the model distribution and the green space as a random factor. Parks, squares and boulevards were analyzed separately to test for the interaction between control measures and population density for each type of green space. The special case of boulevards ($n = 2$) was analyzed in a similar way but taking into account the variability between their longitudinal sections as a random factor.

Negative Binomial models were challenged against GLMMs fitted to the Poisson distribution (which is a special case of Negative Binomial distribution with no overdispersion) with the same arrangement of fixed and random factors, using likelihood ratio tests (LRTs) to establish whether the Negative Binomial was the best available distribution for the data (Lawless 1987). In all cases, the negative binomial distribution was significantly better ($P \ll 0.001$). Statistical analyses were performed in R (R Core Team 2016). GLMMs were fitted using the lme4 package (Bates et al. 2015). Incidence rate ratios (IRRs; the exponential of the model parameters) and associated 95%

Figure 1: Location of the sampled green spaces in Buenos Aires city

Table 2: Questionnaire design including questions and answer options

Sex . . ..
Age . . ..
1. Do you live in the neighborhood? *Yes/no*
2. Do you own a dog? *Yes/no*
3. Do you think that there is fecal contamination in this park? *A lot/some/nothing*
4. Does fecal contamination in this park bother you? *A lot/somewhat/no*
5. Do you see dog owners picking up their dog's feces? *always/sometimes/never*
6. What do you think is the drawback of the presence of dog feces in the park? *Odor; waste; human risk; dog risk*
Suggest what control measures should be implemented to solve the problem of canine fecal contamination *Open*

confidence intervals (95% CIs) were calculated to better demonstrate the effect of human density and control measures on fecal contamination (Hilbe 2011). When needed, multiple comparisons were carried out with a Benjamini and Hochberg correction of the *P*-value (Benjamini and Hochberg 1995).

The questionnaire data were analyzed using the Chi-squared test with *P*-values computed by Monte Carlo simulations (with 10 000 replicates) to compare proportions (Fleiss 1981) and the Extended Mantel-Haenszel Chi square test to analyze the linear trend of the proportions (Schlesselman 1982). Polychoric correlations (ρ) were used to correlate proportions (Fox 2016).

For the analyses of people's perception of human and canine health risks, data were fitted by logistic regression, taking into account the age, sex, home location (around to the green space or not) and dog ownership (yes/no) of the interviewed as factors. Moreover, the odds ratio (OR) and their 95% CI were calculated when needed.

Results

Fecal contamination and associated variables

Feces and fecal fragments were counted in 1351 plots randomly located in the 26 public green spaces selected (Table 1). The number of feces per plot varied from 0 to 44. Data are grouped and summarized in Fig. 2.

Considering all the plots, the median number of feces per plot was 0 (Q1–Q3 = 0–2) for parks and boulevards ($n = 492$ and 230) and 2 (0–4) for squares ($n = 791$). When median feces per plot for each green space were compared, parks showed fewer feces per plot than squares ($U_{18,5} = 77.0$, $P = 0.0073$).

GLMM results showed that squares with control measures had lower levels of fecal contamination than those without control measures (Table 3). For parks, the model showed a significant interaction between the variables 'human density of the neighborhood' and 'implementation of control measures', with

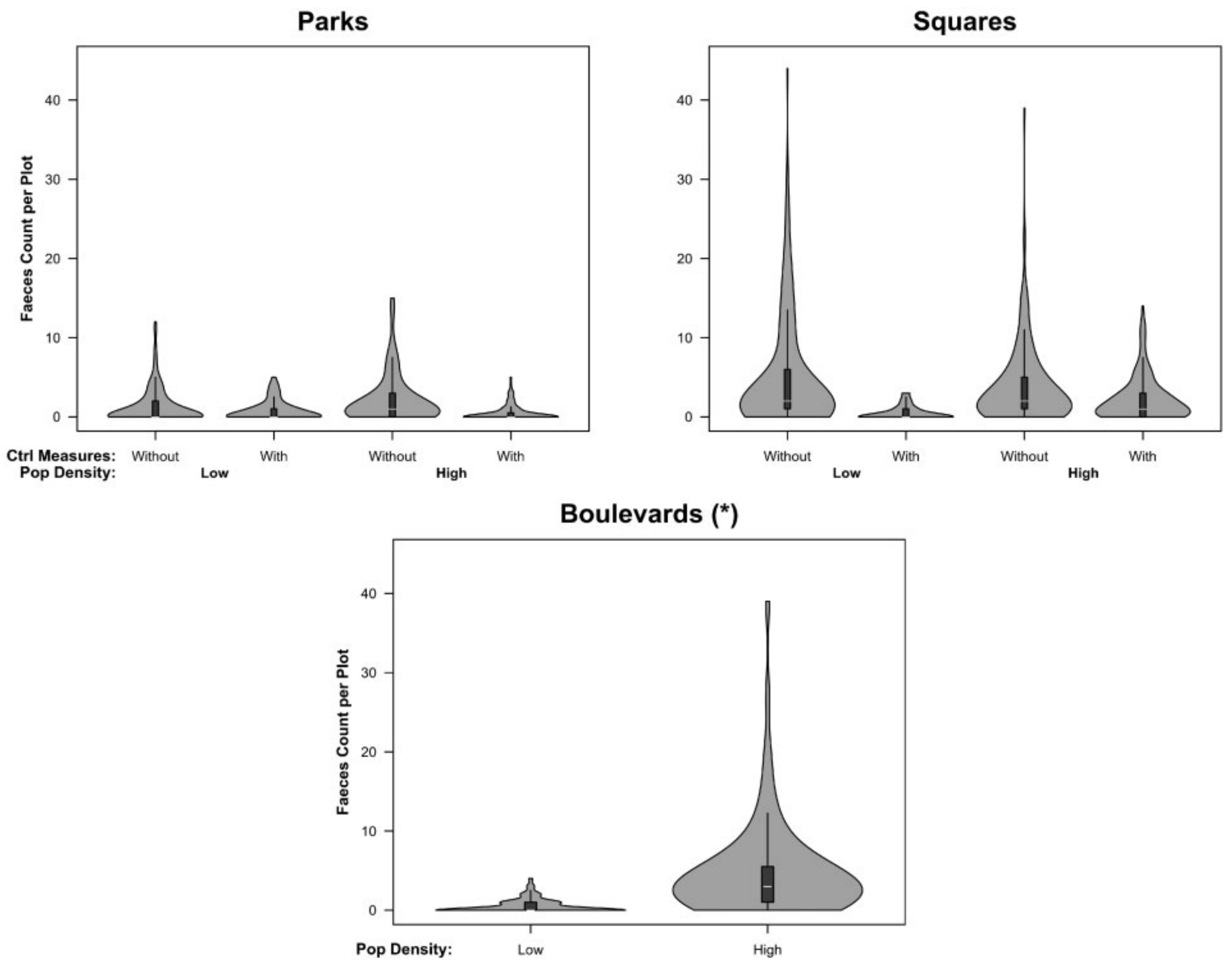

Figure 2: Canine fecal contamination in different public green spaces of Buenos Aires city grouped according control measures and sorrounding human density, 2014. Panels show violin plots for feces counts per plot in Parks, Squares and Boulevards, grouped according to control measures and surrounding human density. *None of the boulevards studied presented control measures for fecal contamination

Table 3: Effects of control measures and human density on the fecal count per plot in public green spaces of the city of Buenos Aires, 2014

Green space	Incidence rate ratio (95% CI)[a]
Squares	
Density	0.992 (0.395–2.505)
Control	0.146 (0.025–0.860)[b]
Density × Control	4.491 (0.608–33.020)
Parks	
Density	1.695 (1.175–2.446)[b]
Control	0.617 (0.377–1.019)
Density × Control	0.329 (0.167–0.644)[b]

[a]Incidence rate ratios were extracted from the GLMMs and related to baseline green spaces with low density and no control measures.
[b]Significant effect.

the latter reducing the fecal contamination only in parks of high human density areas (LRT $\chi^2 = 8.5701$, df = 1, $P = 0.003417$, $P_{corrected} = 0.01366879$ vs. $\chi^2 = 3.1857$, df = 1, $P = 0.07429$, $P_{corrected} = 0.07428565$ in low human density areas) (Table 3). Likewise, fecal counts per plot in parks located in high-density neighborhoods increased only in the absence of control measures (LRT: $\chi^2 = 5.2159$, df = 1, $P = 0.02238$, $P_{corrected} = 0.04476128$ vs. $\chi^2 = 3.4129$, df = 1, $P = 0.06469$, $P_{corrected} = 0.07428565$ when control measures are implemented).

When analyzing boulevards, the results showed that those located in densely populated areas were significantly more contaminated than those located in not densely populated areas [$\chi^2 = 21.953$, $P = 2.793e{-}06$, IRR (95% CI): 8.995 (4.690–17.302)].

The total number of canine feces counted on the perimetral sidewalks ($n = 144$) of the green spaces studied was 6080 (feces or fragments; range = 0–283, median = 35, interquartile range Q1–Q3 = 20–69 feces/sidewalk). Most of the feces (80.2%) were observed on the ground around trees (area of approximately 1 m^2) and the rest on the tiles of the sidewalk. Although the number of feces/sidewalk was lower in sidewalks next to avenues than in those next to streets ($U_{25;88} = 771.5$, $P = 0.0233$, $median_{avenues} = 25$ and $median_{streets} = 39$), no significant differences were found when analyzing the number of dog feces/sidewalk considering the type of green space ($U_{77;36} = 1251.0$, $P = 0.4071$), the human density in the area ($U_{56;57} = 1415.5$, $P = 0.3012$) or the implementation of control measures ($U_{56;57} = 1573.5$, $P = 0.8994$).

Perception of fecal contamination and associated risks

Park 4 was the most contaminated (Table 1). A total of 358 people were interviewed (67.5% living around the park and 62%

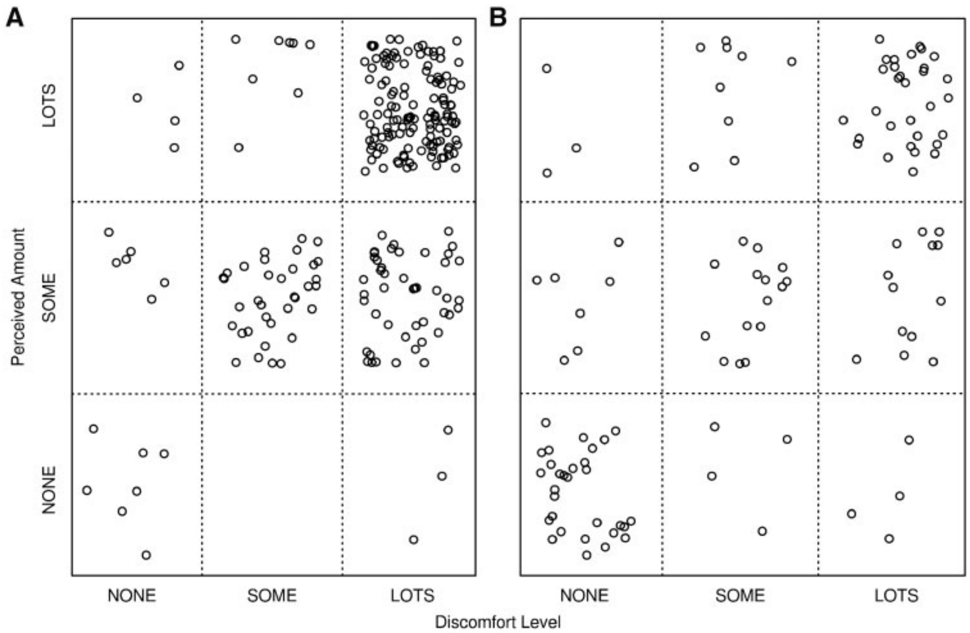

Figure 3: Relationship between the perceived level of fecal contamination and the level of discomfort from opinion survey. (A) Neighbors to the park and (B) infrequent visitors, Buenos Aires city, 2014

owning at least one dog). Of all the people interviewed, 65.6% replied that there were 'many feces' in the park and 68.7% considered the presence of feces 'annoying'. The perceived amount of feces increased with the discomfort level in both residents near the park and sporadic visitors (residents: $\chi^2_{\text{M-H linear trend}} = 53.89$, $P = 0.0000$, $n_{\text{surveyed}} = 241$; sporadic visitors: $\chi^2_{\text{M-H linear trend}} = 31.445$, $P = 0.0000$, $n_{\text{surveyed}} = 116$; Fig. 3). Among the individuals that perceived high levels of fecal contamination, those living near the park reported a 'high level of discomfort' more frequently than sporadic visitors (92% vs. 72%, $\chi^2 = 11.35$, $P = 0.0047$, $n = 185$).

Regarding the perception of the different issues associated with the presence of feces, the interviewees mentioned the dirtiness (77%), the odor (30.8%), and the health risk to humans (35.6%) and/or to animals (27.4%). Each interviewed was allowed to select more than one option.

The polychoric correlation matrix for the answers about the problems associated with the presence of feces in the park showed that the perception of human health risk and canine health risk were positively correlated ($\rho = 0.71$). The dirtiness as a problem caused by fecal contamination was negatively correlated with the perception of risk for human health ($\rho = -0.49$) and clustered at a greater distance than the odor (Fig. 4).

The perception of the level of fecal contamination and human and canine health risks associated with feces was similar between people who owned a dog and people who did not. Logistic regression analyses showed no relation between pet ownership and perception of human (OR: 1.38, 95% CI: 0.87–2.19) or animal risk health (OR: 1.51, 95% CI: 0.92–2.51).

The perception of risk for human health due to the presence of canine feces in Park 4 increased with the age of the people surveyed (OR = 1.025/year, 95% CI = 1.011–1.041), with similar results for the perception of canine health risk (OR = 1.021/year, 95% CI = 1.005–1.037). Perception of risk for canine health was more likely in women than in men (OR = 1.9841, 95% CI = 1.175–3.438), but this result did not translate to the perception of risk to human health.

Among the 34 dog owners surveyed, suggested measures for the control of canine fecal contamination, 41% ($n = 14$) proposed the use of guards or surveillance personnel, 20% ($n = 7$) proposed education campaigns, 15% ($n = 5$) proposed free bag dispensers in the park for owners to pick up the feces, 15% ($n = 5$) proposed environmental control measures (i.e. dog sectors with fences) and 9% ($n = 3$) answered 'I do not know'.

Parasitological analysis

Parasite species were detected in 58 of the 112 (51.8%) fecal samples collected from Park 4. In 22 of these 58 samples (37.9% of the positive samples), only one species was detected, while the remaining samples harbored two ($n = 20$; 34.5% of the positive samples), three ($n = 10$; 17.2% of the positive samples), four ($n = 5$; 8.6% of the positive samples) or up to five ($n = 1$; 1.7% of the positive samples) different species. Table 4 shows the frequencies observed for each parasite. Helminth eggs were found in 26 of the 112 samples (23.2%), whereas protozoan oocysts/cysts were found in 46 of the 112 samples (41.1%) ($\chi^2 = 5.41$, $P = 0.0200707$).

Discussion

The problem of fecal contamination is present in all cities of the world, but has been evaluated quantitatively in a few studies. Uga (1993) observed 35 feces of dogs and cats per square meter of sandpit in public parks (Hyogo Prefecture, Japan) and shows an urban environment in which the fecal contamination is highly concentrated. Zanzani et al. (2014b) found dog's feces in 86.8% of surveyed subareas in Milan (Italy) and Veneziano et al. (2006) in 98.6% of the studied subareas in Naples (Italy) with a median of 25 feces per transect of 1 km (1 per 40 m). Finally, Rubel and Wisnivesky (2005) observed a median of up to 0.16 feces per square meter in green spaces of the suburbs of Buenos Aires city. In this study, the median of feces per square meter varied from 0 to 0.56 (Sq-17, median = 14 per plot with 5 m by side). Both in the studies carried out in Italy and those

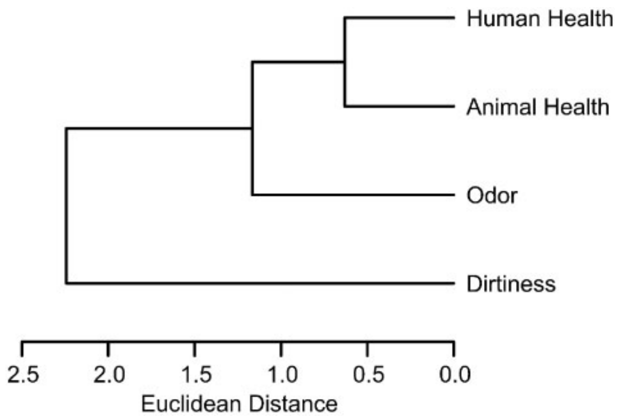

Figure 4: Hierarchical clustering of expressed problems associated with canine fecal pollution, Buenos Aires City, 2014

Table 4: Parasite species detected in canine feces collected in Park 4, Buenos Aires City, 2014

Taxonomic group	Enteroparasite[a]	% (positive samples/*n*)
Helminths	*Ancylostoma caninum*	20.5 (23/112)
	Trichuris vulpis	3.6 (4/112)
	Toxocara canis	1.8 (2/112)
	Taenia spp.	0.9 (1/112)
Protozoa	*Giardia* spp.	16.1 (18/112)
	Cryptosporidium spp.	15.2 (17/112)
	Blastocystis spp.	12.5 (14/112)
	Endolimax nana	11.6 (13/112)
	Cystoisospora canis	8.9 (10/112)
	Chilomastix mesnili	4.5 (5/112)
	Iodamoeba bütschlii	3.6 (4/112)
	Entamoeba spp.	3.6 (4/112)
	Cyclospora spp.	1.8 (2/112)

[a]Species ordered by decreasing prevalence.

conducted previously in Buenos Aires, fecal contamination is higher in areas of greater human density. Our results in this study confirm this relationship again, since the boulevards (public spaces lacking of control measures for the fecal contamination) and the parks without control measures showed higher fecal contamination in green spaces located in areas of high human density.

In squares, the effect of human density was not clear because of the high variability in the number of feces per plot and the absence of squares with control measures in areas of low human density (only square 9).

The effect of human density on fecal contamination would be related to the direct relation between human density and canine density, a relation shown in several studies (Butler and Bingham 2000; Kitala et al. 2001). The canine fecal contamination has been increasing in recent decades in green spaces of Buenos Aires city (Rubel and Wisnivesky 2010; Vaccaro et al. 2012). These increases were consistent with the steady increase of the canine population in Buenos Aires city. The available data showed an estimated minimum of 378 139 dogs in 1994, 425 978 dogs in 2004 and 430 000 dogs in 2016 (Anderson et al. 1996; Bovisio et al. 2006; Government of the City of Buenos Aires 2016). The estimated number of dogs visiting the green spaces of Buenos Aires also showed an increase in the last decade (De Francesco et al. 1998; Pinto et al. 2012) and varied from 150 to 312 in different green spaces (Pinto et al. 2012). The dogs visit the squares every day, which suggests an input of 13.8–28.7 kg of canine feces daily in one hectare (considering 92 g of feces per day per dog, Morgan, Azam, and Pegler 2013).

With respect to sampling of feces in green spaces, our results confirm that ground with or without vegetation concentrate most of the dog feces and therefore may be recommended as place to collect feces. Some authors have proposed that dogs show a preference to defecate on ground or grass rather than tile or concrete (Milkovic, Carbajo, and Rubel 2009; Ferreira et al. 2017).

On the other hand, Atenstaedt and Jones (2011) showed that there are no scientific studies that quantitatively evaluate the effect of campaigns or systematic actions taken to control fecal contamination in public spaces. These campaigns are important because of the reduction of canine fecal pollution provides an efficient way of decreasing the presence of parasites transmissible to the canine and human population in public spaces (Morgan, Azam, and Pegler 2013; Traversa et al. 2014).

The data analyzed in the present study are a quantitative approach to evaluate the environmental measures (those implemented in green spaces considered to be 'controlled') implemented in Buenos Aires city. Since these measures have been implemented unsystematically in different areas of the city over the last decade, the green spaces currently present heterogeneous situations. Because of this, in this study, it was not possible to estimate the relative weight of each environmental measure and our definition of controlled green space included three simultaneous measures: perimeter fencing for night closing, a fenced sector for dogs (a fenced space to allow the dogs to exercise and play without leashes and to contain their waste) and a company devoted to cleaning and maintenance.

The maintenance level of green spaces has also been associated with canine fecal parasite contamination in other studies carried out in parks of Michigan (Ludlam and Platt 1989) and Mar del Plata (Andresiuk et al. 2003). Avcioglu and Balkaya (2011) have observed in green spaces of Erzurum (Turkey) lower contamination with canine parasite eggs transmitted by feces in soils of public parks that have perimeter fencing with respect to those parks without fences.

On the other hand, the owners' attitudes also play a fundamental role in the control of canine fecal contamination. There is general agreement on the fact that the dog waste clean-up policies reduce the fecal and parasite contamination in the urban environments, but nevertheless there is a lack of published data on rates of deposition and removal of dog feces from public places (Morgan, Azam, and Pegler 2013). Some authors have shown through mathematical models that if increases by owners dogs the clean of the feces, the input of parasites into environment decrease significantly (Nijsse et al. 2015).

In the city of Buenos Aires, owners are required to pick up their pets' feces in public spaces since 1987 (Ordinance No. 41831, Government of the City of Buenos Aires 1987) but contraventions are rarely penalized. The public awareness campaigns have been carried out although not periodically nor in all neighborhoods, and the observed percentage of owners who pick up their dogs' feces is around 40% (Rubel and Carbajo 2019). In other cities, the observed percentage of owners who pick up their dogs' feces is variable: 84.4% in Rome and Padua (Italy, Traversa et al. 2014), 59.4% in Exeter and Highcliffe (Great Britain, Webley and Siviter 2000), 56.2% in Vienna (Austria, Arhant and Troxler 2009), 53.5% in Belfast (North Ireland, Wells

2006) and 40.4% in urban environments of Netherlands (Nijsse et al. 2015).

Our results indicate that a large percentage of people perceived the fecal contamination and reported to be annoyed by it. Nevertheless, 77% of the interviewees linked fecal contamination to filth, and only 35% linked the fecal contamination with risks for human health, while even fewer related it to the risk for canine health. Until now, in the official campaigns encouraging owners to pick up their dogs' feces has no mentions the potential transmission of zoonotic parasites and studies in other regions have shown that dog owners are unaware of this risk (DEFRA 2006; Katagiri and Oliveira-Sequeira 2008; Stull 2012) and that a 'minority of people understand that parks could act as a potential source of infection for dogs and people' (Smith et al. 2015). Perhaps due to this lack of knowledge, interviewees mentioned controls with penalties more frequently than educational campaigns or environmental modifications to control canine fecal contamination. However, a campaign that linked canine feces with human toxocariasis had a large impact, reducing the feces in public spaces by 40% in England (DEFRA 2006).

In our study, the perception of the human risks of canine feces was independent of the interviewee's sex but increased with age. Instead, the perception of the risks of canine feces for pets was higher in women. This result implies that campaigns should be focused to target younger and men dog owners.

On the contrary, Nijsse et al. (2015) estimated that young people cleaned their dogs' stools more often than adults in urban environments of Netherlands, which could indicate that they perceive with greater frequency the risks derived from contaminating of the public spaces with canine feces.

With respect to the parasites detected, several of them, such as *Ancylostoma caninum*, *Toxocara canis* and *Giardia* sp., may be pathogenic for humans (McCarthy and Moore 2000; Baneth et al. 2016; Rijks et al. 2016).

The overall prevalence in this study (38.4%) was comparable to that obtained in another previous study (25% positive feces for helminth eggs) in which *A. caninum* was the most prevalent helminth, followed by *Trichuris vulpis* and *T. canis*, in samples collected in squares of Buenos Aires (Rubel and Wisnivesky 2010).

Giardia spp. was the protozoa most frequently detected both in our study and in the 2193 samples of dogs from Southern Greater Buenos Aires analyzed by Fontanarrosa et al. (2006). Several authors have highlighted the importance of this parasite genus in urban environments (Capuano and Rocha 2006; Smith et al. 2014; Zanzani et al. 2014a; Bouzid et al. 2015), although their zoonotic importance remains unclear (Ballweber et al. 2010).

Cryptosporidium spp. was detected in our study with similar prevalence as *Giardia* spp., in coincidence with results of other authors (Ferreira et al. 2017). In contrast, *Giardia* spp. was detected more frequently in canine feces than *Cryptosporidium* spp. in the studies carried out by Rinaldi et al. (2008) and Smith et al. (2014).

Fontanarrosa et al. (2006) only detected *Cryptosporidium* spp. in 5 of the 2193 samples, but the samples analyzed were not collected from public spaces but were fecal samples sent by veterinarians to a diagnostic laboratory.

Some authors have founded that the prevalence of *Cryptosporidium* spp. is higher in dogs that attend parks (Wang et al. 2012) and other authors have found a positive association between protozoan infections in dogs and the frequency of visits to the parks and the number of visited parks (Smith et al. 2014).

Cystoisospora canis was detected with similar frequency in this study and that carried out by Fontanarrosa et al. (2006), 8.9% and 11.9% of fecal samples, respectively.

Finally, *Sarcocystis* sp. was not detected in our study but it was detected in the one carried out by Fontanarrosa et al. (2006). In contrast, *Endolimax nana*, *Chilomastix mesnili*, *Iodamoeba bütschlii*, *Entamoeba* sp., *Cyclospora* sp. and *Blastocystis* sp. were not observed by Fontanarrosa et al. (2006), but were detected in our study.

Comparisons between different studies are difficult because the samples analyzed by the different authors differ regarding their number, origin (soil, feces of identified animals or feces collected in public spaces), spatial and temporal scale, types of parasites diagnosed (protozoa, helminth, both) and diagnostic methods used.

Our results showed that protozoa were more prevalent than helminths in the fecal samples studied, although other studies have shown the opposite (Ramírez-Barrios et al. 2004; Fontanarrosa et al. 2006; Katagiri and Oliveira-Sequeira 2008). This result cannot be generalized to other sites of Buenos Aires city or to other cities of Argentina because the park studied is located in a neighborhood with medium to high economic level and thus most dogs seemed to be domiciled dogs and not stray dogs.

In the study carried out by Katagiri and Oliveira-Sequeira (2008) in the State of São Paulo, Brazil, helminths were more frequent in fecal samples from stray dogs than in samples from domiciled dogs. On the other hand, some authors have suggested that the predominance of protozoan infections versus helminthic infections could be due to the sustained increase in the use of anthelmintic drugs (Bugg et al. 1999; Ferreira et al. 2017) or ineffective drugs, such as the simultaneous use of praziquantel-pyrantel-febantel (Matos et al. 2015).

In agreement with other studies, our results showed that green spaces are potential sources of infection for the dog population and for zoonosis transmission (Wang et al. 2012; Smith et al. 2014; Ferreira et al. 2017). The green spaces have simultaneously high levels of canine fecal contamination, high parasitic prevalences for different species and high number of dogs that daily attend. In different urban contexts, such as neighborhoods with houses, the most important source of infective stages for zoonosis transmission varies, since dogs can defecate mainly at home backyards or gardens (Smith, Hagstad, and Beard 1984; Habluetzel et al. 2003) or on sidewalks (Rubel and Wisnivesky 2005).

This is the first study in the city of Buenos Aires that: (i) confirms that environmental control measures decrease canine fecal contamination of public green spaces, (ii) shows that a large percentage of dog owners do not associates canine fecal contamination with the transmission of parasites and (iii) recommend that campaigns to control fecal contamination should focus in the young and men dog owners.

Both the environmental control measures and the behavioral changes are keys in fecal contamination control.

As already discussed by other authors, the complexity of this environmental problem calls for a One Health approach (Paul, King, and Carlin 2010; Zinsstag et al. 2012; Traversa et al. 2014), with public policies that articulate measures of different kinds. Research at the local level, collaboration between researchers, practitioners and public health authorities, and coordinated actions between government agencies, professional associations and other social actors are all needed to build sustainable zoonoses control strategies.

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