

This is the final peer-reviewed accepted manuscript of:

Benedetto Morandi, Spencer J. Greenwood, Gary A. Conboy, Roberta Galuppi, Giovanni Poglayen, John A. VanLeeuwen. Endoparasites in dogs and cats diagnosed at the Veterinary Teaching Hospital (VTH) of the University of Prince Edward Island between 2000 and 2017. A large-scale retrospective study. *Preventive Veterinary Medicine*, Volume 175, 2020, 104878.

The final published version is available online at:

<https://doi.org/10.1016/j.prevetmed.2019.104878>

Rights / License:

The terms and conditions for the reuse of this version of the manuscript are specified in the publishing policy. For all terms of use and more information see the publisher's website.

This item was downloaded from IRIS Università di Bologna (<https://cris.unibo.it/>)

When citing, please refer to the published version.

1 **Endoparasites in dogs and cats diagnosed at the Veterinary Teaching Hospital (VTH) of the**
2 **University of Prince Edward Island between 2000 and 2017. A large-scale retrospective study**

3

4 Benedetto Morandi^{a*}, Spencer J. Greenwood^b, Gary A. Conboy^c, Roberta Galuppi^a, Giovanni
5 Poglayen^a, John A. VanLeeuwen^d

6

7 ^a Department of Veterinary Medical Sciences, *Alma Mater Studiorum*-University of Bologna, via
8 Tolara di Sopra 50, 40064, Ozzano Emilia, BO, Italy.

9

10 ^b Department of Biomedical Sciences, Atlantic Veterinary College, Charlottetown, 550 University
11 Ave, Prince Edward Island, C1A 4P3, Canada

12

13 ^c Department of Pathology and Microbiology, Atlantic Veterinary College, Charlottetown, 550
14 University Ave, Prince Edward Island, C1A 4P3, Canada

15

16 ^d Department of Health Management, Atlantic Veterinary College, University of Prince Edward
17 Island, Charlottetown, 550 University Ave, PE C1A 4P3, Canada.

18

19 * **Corresponding author:** benedetto.morandi2@unibo.it

20

21 **Abstract**

22

23 Although many studies on the frequency of endoparasites in dogs and cats in Canada have been
24 reported, seasonal and/or annual patterns are often not evaluated. The frequency and risk factors of
25 endoparasite infections from fecal samples of cats and dogs submitted to the Veterinary Teaching
26 Hospital of the Atlantic Veterinary College, University of Prince Edward Island-Canada were

27 determined, using univariable and multivariable logistic regression analyses. Investigated predictors
28 of endoparasitism available in the 2000 to 2017 database included sex, age, geographic origin and
29 seasonality. A total of 15,016 dogs and 2,391 cats were evaluated for endoparasite status using
30 specific diagnostic tests: direct smear, Baermann, and/or 33% zinc sulfate solution in a standardized
31 centrifugal flotation method. Overall, twelve and eight parasite genera were detected in dogs and cats,
32 respectively. The overall proportional infection was 14.6%, and the cat population showed a higher
33 frequency of positivity to parasites compared to the dog population ($P < 0.001$). The most frequent
34 genera recovered in the whole population (dogs and cats), were *Giardia duodenalis* (5.2%),
35 *Cystoisospora* spp. (3.3%) and *Toxocara* spp. (3.2%). Endoparasitism levels were diagnosed more in
36 feces submitted from young, female intact dogs from PEI compared to the baselines of mature,
37 sterilized male dogs from other provinces, respectively, and diagnoses occurred more often in autumn
38 months than in winter months. There was no significant diagnostic trend across the years for the
39 individual parasites models. The frequency of detected potentially zoonotic parasites in this study
40 highlights the veterinary public health and One Health context of parasitic infections in pets. Although
41 the presented results are not from a random sample and therefore frequency results should be
42 interpreted with caution, the model relationship results may still be relevant. In addition, results are
43 of value to estimate parasite impact and to assist researchers, veterinarians and pet-owners with
44 suitable information to control parasites.

45

46

47 **Keywords:** Veterinary Teaching Hospital, Endoparasites; Fecal examination; Epidemiology; Risk
48 factors; Pets; Canada.

49 **1. Introduction**

50 Parasitic infections are endemic worldwide and have been described as constituting the greatest
51 single worldwide cause of illness and disease in animals and humans (Steketee, 2003). Parasites of
52 companion animals are the cause of several disorders, including anorexia, anemia and diarrhea,
53 mostly in young, old and immunocompromised subjects (Epe, 2009). A wide range of endoparasites
54 are known to cause significant morbidity and mortality in pets, including several species of
55 nematodes, cestodes, trematodes and protists

56 Many species of parasites infect pets, with significant interspecies transmission (Vélez-Hernandez
57 et al., 2014; Zanzani et al., 2014). Companion animals have been shown to transmit zoonotic parasites
58 including, *Giardia duodenalis*, *Cryptosporidium parvum*, *Toxocara* spp., *Echinococcus granulosus*,
59 *Echinococcus multilocularis* and hookworms of various species (Kapel et al., 2006; Antolová et al.,
60 2009; Deplazes et al., 2011; Chen et al., 2012; Macpherson, 2013; Baneth et al., 2016; Kostopoulou
61 et al., 2017). Thus, public health control measures depend on knowing the frequency of these parasites
62 in the population. This zoonotic concern emphasizes the value of routine fecal evaluations for parasite
63 diagnosis in companion animals, even if the sensitivity of a single fecal exam in time can change,
64 depending on parasite biology, fecal examination method, and laboratory technician skill (Broussard,
65 2003). The close contact between pets and humans sharing the same environment increases the
66 transmission risk of different zoonotic diseases (Seah et al., 1975; Chomel and Sun, 2011; Togerson
67 and Macpherson, 2011; Esch and Petersen, 2013; Baneth et al., 2016). The number of dogs and cats
68 in Canada is estimated to be around 8.2 and 8.3 million, respectively. Approximately, 41% of
69 Canadian households have a dog, while 38% have a cat (CAHI, 2019). Therefore, veterinarians play
70 a crucial role in zoonotic risk assessment and communication (Malloy and Embil, 1978; Villeneuve
71 et al., 2015), acting as a main public health operator.

72 Frequency and prevalence of endoparasite species may vary seasonally and from region to region
73 within a country, depending on the biological variation and weather conditions (Oliveira-Sequeira et
74 al., 2002). In a country as large and environmentally diverse as Canada, data from one region may

75 not be applicable to another area of the country, and furthermore, few published papers have explored
76 seasonal patterns of endoparasitism in owned dogs and cats in Canada (Conboy, 2004; Blagburn et
77 al., 2008).

78 This large-scale retrospective study aims to investigate the frequency of endoparasites and the
79 relative risk factors, in owned dogs and cats, from samples submitted to the Veterinary Teaching
80 Hospital (VTH), Atlantic Veterinary College (AVC), University of Prince Edward Island (UPEI),
81 Canada. Where possible, associations between endoparasite infections and age, sex, geographic
82 origin, and seasonality were evaluated, based on availability of animal data.

83 Outcomes originated from this study should be an aid for clinical veterinarians to better educate
84 their clients about parasite occurrence and to use good preventive programs.

85

86 **2. Materials & Methods**

87 *2.1 Study population and fecal examination*

88 Between January 1, 2000 and November 17, 2017, fecal samples from privately owned pets from
89 Prince Edward Island or other Canadian Provinces (primarily Atlantic Canadian provinces of Nova
90 Scotia, New Brunswick, and Newfoundland and Labrador) were submitted to the Parasitology
91 Laboratory of Diagnostic Services at the VTH, Atlantic Veterinary College (AVC), University of
92 Prince Edward Island (UPEI) for coprological analyses. The samples represent a mix of routine
93 diagnostic surveillance on clinically normal animals and diagnostic investigations on pets exhibiting
94 clinical signs suggestive of parasitism. Inclusion of a detailed history on sample submission by
95 referring veterinarians was inconsistent such that the true proportion of samples from normal animals
96 and those with clinical signs was unknown. Stored data were organized in a database of variables
97 including; animal species, age, sex, geographic origin (based on home address), date of sample
98 submission, diagnostic technique employed, and tests results. There were substantial missing data for
99 certain variables (e.g. age) because not all relevant data were submitted with the fecal sample.

100 For each sample, parasite eggs, cysts, oocysts and larvae were concentrated from fecal specimens
101 by using a 33% zinc sulfate solution (specific gravity = 1.18) in a standardized centrifugal flotation
102 method (Zajac and Conboy, 2012). Additional methods were employed, including: the Baermann
103 technique for suspected lungworm cases, based on reported clinical signs of coughing and/or dyspnea,
104 to detect the presence of first-stage larvae (L1); and direct smears primarily for trophozoites and cysts
105 of *Giardia duodenalis*, based on reported clinical signs of diarrhea (Zajac and Conboy, 2012). For
106 much of the study period, capillarid eggs were not specifically identified at the Parasitology
107 Laboratory of the VTH. Detection of capillarid eggs in dog fecal samples included *Eucoleus*
108 *aerophilus* and *Eucoleus boehmi* and those in cats would have been *Aonchotheca putorii* and *E.*
109 *aerophilus*.

110

111 2.2 Data management and statistical analysis

112 The initial dataset counted 36,838 rows, representing all the animal species fecal samples which
113 passed through the Parasitology Laboratory at the VTH-Diagnostic Services during the study period.
114 In order to deal with just dogs and cats, all other species were removed from the dataset, leaving
115 24,220 observations. All possible duplicate observations were removed (with the first occurrence of
116 the animal in the dataset retained to enable age risk factor assessment), leaving 17,407 observations,
117 15,016 dogs and 2,391 cats.

118 Two datasets were constructed, one for dogs and one for cats. The first step was to give to each
119 single observation an unequivocal identification number because the numbering system used by the
120 Parasitology Laboratory ran sequentially but reverted back to 1 each year. It was possible to
121 extrapolate the age of each subject by subtracting the date of birth from the date of the visit. In order
122 to make predictor results meaningful and statistically relevant, certain variables were recategorized.
123 The date of testing was used to create season of testing, according to 3-month categories following
124 the astronomical calendar, thus winter was December 21 to March 20; Spring was March 21 to June
125 20; Summer was June 21 to September 20; and Autumn was September 21 to December 20. Age was

126 divided into two categories, \leq one year old and $>$ one year old. The main part of our sample originated
127 primarily from Prince Edward Island and the rest came from other Canadian provinces, so the variable
128 “geographic origin” was dichotomized as PEI and other. Unfortunately, some of the predictor
129 variables presented with missing values which led to a reduction in the number of samples available
130 for those analyses.

131 The frequency of isolated parasites was estimated as the number of positive animals/number of
132 examined animals, in total, and by animal species. Age, sex, animal species, geographic origin
133 (region), year and seasonality were examined as putative risk factors for the commonly isolated
134 parasites using Pearson’s χ^2 test. In order to assess the chance of there being significant differences
135 between the means of the annual numbers of samples from dogs and cats submitted to the VTH during
136 the study period, a Student’s t-test was conducted. Results were considered significant when $P \leq 0.05$.

137 Five multivariable logistic regression analyses were also performed, keeping as our model
138 outcome the combined test results (parasite presence/absence) for dogs and for cats, and one model
139 for each of the 3 most common dog parasites. Backward stepwise regression was employed for the
140 model building, and model fitness was assessed by means of the Hosmer-Lemeshow goodness-of-fit
141 test. Odds ratios (OR) and their 95% confidence intervals (CI) were reported. Testing and analytic
142 control for confounding of model variables was done throughout the model-building process (Dohoo
143 et al., 2009). Interactions between significant model main effects were built and assessed for
144 significant associations with the outcomes of interest. Stata Statistical Software (Release 15, College
145 Station, TX: StataCorp LLC) was utilized for the descriptive statistical analysis and the model
146 building, analyses and evaluations.

147

148 **3. Results**

149

150 *3.1 Descriptive statistics*

151 Between January 1, 2000 and November 17, 2017, a total of 17,407 fecal samples from privately
152 owned companion animals (15,016 dogs and 2,391 cats) were processed in order to detect
153 endoparasites. On average, the frequency of samples submitted was 967.1 per year (SD=347.94), with
154 a range from 580 to 1654. Dogs represented a large majority of the overall samples, with a mean of
155 834.2 submissions per year (SD=290.68; range: 508-1385), whereas cats represented a minority of
156 the overall samples (mean samples per year = 132.8; SD=61.12; range: 64-269). A comparison of the
157 two means resulted in a statistically significant difference on a t-test ($t=3.75$, $P<0.001$).

158 Other information collected at the time of the sample submission is summarized in Table 1. Of the
159 animals with age identified in the database, the proportion of cats less than 12 months of age was
160 twice the proportion for dogs ($P<0.001$). Of the female dogs identified in the database, nearly 2/3rds
161 were spayed, whereas nearly 2/3rds of female cats were not spayed ($P<0.001$). Approximately 60%
162 of male dogs and cats identified in the database were neutered. Regarding the season of the submitted
163 animals to the VTH, 1/3rd of submitted samples for the dogs occurred in spring, and nearly 60% were
164 during spring and summer, whereas 1/3rd of tested cats were in summer, and nearly 60% in summer
165 and autumn ($P<0.001$). Of dogs and cats where the origin was known, approximately 78% were living
166 in PEI ($P<0.001$).

167 The proportion of animals within the entire population found to be infected (eggs, cysts, oocysts,
168 L1, and trophozoites) with at least one parasite genus was 14.6% (95%CI: 0.146 ± 0.0052), with 17.2%
169 (95%CI: 0.172 ± 0.014) and 14.2% (95%CI: 0.142 ± 0.002) from cats and dogs, respectively. This
170 species difference was statistically significant on the Pearson χ^2 -test ($P<0.001$).

171 Table 2 shows the frequency for each parasite genus found separately in the dog and cat
172 populations. Frequent parasites detected, both in dogs and cats, were *Giardia duodenalis* at 5.4% in
173 dogs and 4.18% in cats, followed by *Cystoisospora* spp. at 2.9% and 5.81% in dogs and cats,
174 respectively. Finally, *Toxocara* spp. was detected in 362 dogs and in 196 cats. The remaining genera
175 of parasites were found less frequently.

176 Multiple infections were far less common than those with a single parasite type in both dogs and
177 cats (Table 3). Multiple infections were slightly more common in cats (13.3%) than in dogs (12.5%),
178 although not statistically significant. Out of the 237 dogs with double infections, 103 (43.5%)
179 included *G. duodenalis* and *Cystoisospora* spp. parasites followed by *G. duodenalis* and *Toxocara*
180 *canis* (13.1%). Of the 27 dogs with triple infections, 9 (33.3%) included *G. duodenalis*, *Cystoisospora*
181 spp. and *T. canis* parasites, while only one dog had 4 parasite genera diagnosed: *Crenosoma vulpis*,
182 *T. canis*, *Trichuris vulpis* and *Uncinaria*. Of the 41 cats harbouring two different parasites, 11 (26%)
183 included *Cystoisospora* spp. and *Toxocara cati*, whereas 9 (22%) had capillarids and *Toxocara cati*,
184 and another 9 had *G. duodenalis* and *Cystoisospora* spp. combined infections. Of the 9 cats positive
185 to 3 parasite genera, 4 (44.4%) included capillarids, *Cystoisospora* spp. and *T. cati*. Three cats were
186 positive for 4 parasite genera, with two cats having *Taenia* spp. along with capillarids, *Cystoisospora*
187 spp. and *T. cati*, and the other one harboured *G. duodenalis* instead of capillarids. Only one cat hosted
188 five different parasites, and they were represented by capillarids, *G. duodenalis*, *Cystoisospora* spp.,
189 *Taenia* spp. and *T. cati*.

190

191 3.2 Univariable analytical statistics

192 Tables 4 and 5 show the differences in proportions of samples diagnosed positive, by factors of
193 interest, for parasitism in general, and for the main parasite genera detected in dogs and cats,
194 respectively. Determination of the Pearson χ^2 -test showed seasonal patterns for *G. duodenalis* in dogs
195 (P=0.03), while there were no significant seasonal differences in cats (P=0.12). Conversely, cats were
196 more likely to be *Cystoisospora* spp. positive during summer than other seasons (P<0.001), whereas
197 the probability of *Cystoisospora* spp. being positive was higher during autumn than other seasons in
198 dogs (P<0.001). For *Toxocara* spp., dogs were more likely to be positive in the autumn than other
199 times of the year (P<0.001), but there were no significantly different proportions among seasons
200 within the feline population (P=0.10).

201 Unfortunately, the dataset had numerous missing values; age, sex and province of origin were
202 included in only 3,247 dogs and 412 cats. For this reduced dataset, younger dogs were parasitized
203 more with *G. duodenalis* than older dogs ($P<0.001$), however this association was not found in cats
204 ($P=0.311$). *Cystoisospora* spp. was significantly more often diagnosed in puppies than adult dogs
205 ($P<0.001$), but age of kittens was not associated with diagnosis of *Cystoisospora* spp. ($P=0.49$).
206 *Toxocara* spp. showed a significantly higher frequency in the young pets of both species (dogs:
207 $P<0.001$ and cats: $P=0.004$).

208 The proportions of animals diagnosed positive for at least one parasite genus, by geographic region
209 (Table 4 and 5), were found to differ significantly in dogs ($P<0.001$) but not in cats ($P=0.29$).
210 No statistical significances were found in the proportions positive for all genera combined, by sexual
211 status, in both cats and dogs. When looking specifically at intact versus sterilized animals, which
212 could change the possibility of exposure to parasites, there was no evidence for significant differences
213 in cats for each of the three common parasites of interest (*G. duodenalis* $P=0.107$, *Cystoisospora* spp.
214 $P=0.724$ and *T. cati* $P=0.09$). Conversely, intact dogs were more likely to be diagnosed infected for
215 *G. duodenalis* ($P<0.001$), *Cystoisospora* spp. ($P<0.001$) and *T. canis* ($P<0.001$) than those that were
216 sterilized.

217 These univariable analytical statistics should be interpreted with caution. The multivariable
218 analytical statistics section provides more definitive results because there is statistical control for
219 confounding of all variables in the final models.

220

221 3.3 Multivariable analytical statistics

222 Based on our 3,242 dog observations with data for the final multivariable logistic regression model
223 (controlling for confounding - Table 6), being older than one year old was a protective factor against
224 a diagnosis of parasitic infections by a factor of 4.3 times (4.3 is the inverse of the OR= 0.232)
225 compared to puppies less than 1 year old. Sterilization, both male and female, was associated with
226 decreased odds of having a parasite diagnosis by a factor of 1.60 compared to intact dogs (while male

227 or female dogs had very similar odds). The province of origin also appeared to have an influence on
228 parasite diagnosis; dogs from Prince Edward Island were 92% more likely to be infected than dogs
229 not from PEI (1.92 is the inverse of the OR=0.521). Without controlling for confounding, 9.2% of
230 PEI dogs were infected versus 4.0% of other dogs. Seasonality indicated that dogs were 65% more
231 likely to be infected in the autumn compared to the winter season baseline (OR=1.65). The significant
232 (P=0.012) trend across the years showed a decreasing odds of diagnosis by a factor of 1.04 or 4% for
233 each additional year within the database (1.04 is the inverse of the OR=0.961).

234 A similar multivariable logistic regression model for cat parasite diagnoses was built through
235 stepwise backward elimination, but age was the only predictor remaining in the model. The odds of
236 being diagnosed positive for at least one parasite genus decreased after the first year of life by a factor
237 of 2.44 (2.44 is the inverse of the OR=0.42; 95%CI: 0.24-0.72), as previously determined in the
238 preliminary univariable logistic regressions for putative risk factors.

239 In order to better understand the epidemiology and risk factors of the 3 common parasites of dogs
240 (*G. duodenalis*, *Cystoisospora* spp. and *T. canis*), a model was built using the frequency of diagnosis
241 for each parasite. No final logistic regression model was possible for *Giardia duodenalis* because no
242 predictor variables remained significant in the final model. Conversely, age was significant (P<0.001)
243 as a predictor for the diagnosis of *Cystoisospora* spp. (Table 7), where a dog being more than 1 year-
244 old was 5.21 time less likely to be diagnosed positive than young dogs. Being sterilized, both for
245 females (OR=3.67) and males (OR=2.42), appeared to be a protective factor compared to the intact
246 female baseline, while intact male dogs had similar odds to intact female dogs. Dog samples coming
247 from outside of PEI were 4.61 times less likely to be diagnosed positive for *Cystoisospora* spp. than
248 dogs from PEI. Additionally, autumn appeared as a risk factor for *Cystoisospora* spp. with an OR=2.76
249 compared to the winter baseline (Table 7). Spring and summer only had trends toward higher risk for
250 *Cystoisospora* spp. infection.

251 The *T. canis* final logistic regression model (Table 8) showed that dogs older than 1-year were
252 close to 6 times less likely of being diagnosed positive for *T. canis* compared to younger dogs.

253 Samples submitted from PEI resulted in 1.7 times higher odds of being *T. canis* positive than other
254 provinces (listed in Table 1), although the odds ratio was not significant (P=0.132), but the variable
255 was retained in the model because it was a confounder for other variables in the final model.
256 Regarding the sexual status, only the castrated male category showed a significant protective
257 association of 2.72 compared to the intact female baseline as with the *Cystoisospora* spp. model, dogs
258 with *T. canis* were 2.67 times more likely to be positive in autumn than the winter baseline (Table 8).
259 There was no significant diagnostic trend across the years for the individual parasites models.

260

261 **4. Discussion**

262 This study of fecal samples of cats and dogs submitted to the Veterinary Teaching Hospital of the
263 University of Prince Edward Island has provided useful annual and seasonal information on their
264 proportional endoparasitic infection levels, as well as risk factors (i.e. year, season, age, sex and
265 region) for endoparasite infections diagnosed within the study population in Canada.

266 The cat population has always been estimated to be larger than the dog population in Canada,
267 however the two populations are nearly equal now, with 8.3 million cats and 8.2 million dogs (CAHI,
268 2019). Conversely, the proportion of dog samples submitted was 7 times higher than cat samples,
269 which was consistent with other studies of similar methodology (Lue et al., 2008; Sánchez-Vizcaíno
270 et al., 2017). In our population, dogs were more often neutered (63.8%) than cats (51.2%), with other
271 studies showing similar owners' attitudes toward pet neutering (Lund et al., 1999; Sánchez-Vizcaíno
272 et al., 2017) in the USA and UK, respectively.

273 The results presented in this paper show a relatively low frequency of fecal endoparasites in pets;
274 17.2% of the examined cats and 14.2 % of the dogs were shown to be infected with at least one
275 parasite genus. A conference abstract of a nationwide study on dogs with constant or regular access
276 to the outdoors, carried out in Italy by Brianti et al. (2018), reports twice the percentage of our survey.
277 However, the samples submitted to the VTH in our study were from a population of dogs that would

278 have been a mix of animals from urban, suburban and rural areas and included both clinically normal
279 animals and those exhibiting clinical signs of disease.

280 Cats were significantly more parasitized than dogs in our study population, likely due to the higher
281 likelihood of cats being free to roam outdoors compared to dogs, thereby increasing the probability
282 of contact with infectious parasitic stages from environmental sources. This is opposite to the results
283 of Barutzki and Schaper (2011), in a similar large-scale study carried out on fecal samples from
284 German dogs and cats submitted to a Veterinary Laboratory for parasitological examination. On the
285 contrary a survey carried out in Italy by Riggio et al. (2013) showed the same discrepancy in parasite
286 prevalence of 35% and 31% in cats and dogs, respectively. Additionally, Tamponi et al. (2017)
287 pointed out a higher infection risk in cats compared to dogs in companion animals living in Sardinia
288 region, an Italian Mediterranean Island; unfortunately, no hypotheses were provided. Compared with
289 other Canadian studies, we found a lower frequency of infection, which again may be due to our study
290 population being from VTH submissions rather than a random sample. Most other Canadian study
291 results are from western Canada (Stull et al., 2007; Bridger and Whitney, 2009; Joffe et al., 2011) or
292 Ontario and Quebec (Shulka et al., 2006; Blagburn et al., 2008) or from shelter dogs and cats
293 (Villeneuve et al., 2015). However, in a country as large as Canada, data and risk factors from one
294 region could be different from another region.

295 The final model result of dogs coming from provinces other than Prince Edward Island having
296 significantly lower odds of being positive for parasites is also likely due to differences in the many
297 host, agent and environmental factors that affect the probability of a dog harboring parasites in a
298 country as large and heterogeneous as Canada.

299 Proportionately, all Canadian studies have shown that *G. duodenalis* and *Toxocara* spp. are the
300 most common parasites infecting cats and dogs (Seah et al., 1975; Malloy and Embil, 1978; Shulka
301 et al., 2006; Villeneuve et al., 2015). The infection risk for *G. duodenalis* in Europe is reported to be
302 approximately 25% and 20% in dogs and cats, respectively (Epe et al., 2010) by using antigen snap-
303 tests. Carlin et al. (2006) reported a lower infection rate than Epe et al. (2010) but still higher than the

304 present study; 15.6% among dogs tested, and 10.8% among cats. utilizing the same diagnostic test
305 used by Epe et al. (2010). These two European studies with the snap-test likely have higher estimates
306 because antigen can be detected even after the organism has been eliminated. Our lab does perform
307 *G. duodenalis* diagnosis by zinc sulfate solution, having a Se=86%, Sp=98%, which is similar to the
308 snap-test of Se=91%, Sp=96%. Additionally, Uehlinger et al. (2017) have demonstrated the reliability
309 of ZnSO₄ floatation technique compared to snap antigen-test. Both *G. duodenalis* and *Toxocara* spp.
310 parasite species are responsible for human infections. It is estimated that about 200 million people in
311 Asia, Africa and Latin America have shown giardiasis clinical manifestations (Feng and Xiao, 2011).
312 Regarding human toxocariasis, Lee et al., (2014) reported 10% seroprevalence in North America from
313 a meta-analysis.

314 According to some studies, monoparasitism appears to be much more common than polyparasitism
315 in pets presented to a teaching hospital (Kirkpatrick, 1988; Sudan et al., 2015), monoparasitism
316 (38.1%) was less frequent than polyparasitism (46.7%). Additionally, the low socio-economic
317 conditions can affect the host-parasite relationship, leading to more pet scavenging for food and
318 therefore more parasite exposure (Schurer et al., 2014).

319 Regarding seasonal variation in endoparasite frequency, submitted samples from dogs more
320 frequently harboured parasites during autumn in our study for the main endoparasites found, whereas
321 cats were much more frequently and significantly diagnosed in summer just for *Cystoisospora* spp.
322 Dogs may have increased likelihood of exposure during the summer months when there are longer
323 days with more light, and the fact that people and their dogs spend more time outside, leading to more
324 diagnosed infections in autumn. Favourable climatic conditions occurring during the summer may
325 also allow for better parasite development within the environment and hosts. Seasonal effects on
326 parasitism may reflect parasitic responses to changes in photoperiod, leading to lower shedding in
327 winter (Polley and Thompson, 2009).

328 In Italy, the seasonal pattern was studied only for *G. duodenalis* and only for dogs, where a higher
329 prevalence was found in winter (Bianciardi et al., 2004). A similar result was found in Argentina in

330 the late winter (Fontanarrossa et al., 2006). Similar seasonal results were obtained by Kirkpatrick
331 (1988) in dogs of Pennsylvania in the 1980s, whereas no seasonality was detected by Nolan and Smith
332 (1995) in the following decade in the same area. Due to the historic nature of these surveys in
333 Pennsylvania, and the effects of climate change on parasite and host physiology, their results should
334 be interpreted with caution (Polley and Thompson, 2009).

335 Regarding dog-level risk factors associated with being positive for parasites, the logistic model built
336 for dogs indicated that neutering was associated with 60% lower parasitic infections compared to
337 intact animals. Possible reasons for this association (not causal) could be that sterilization may reduce
338 the natural instinct of dogs to roam in search of a mate, thereby reducing exposure to parasitic
339 infections. Additionally, owners who sterilized their pets could be more likely to prevent roaming
340 and to use preventative anti-parasitic products or treat dogs for parasites than those who did not.

341 The observed trend across the 18 years of this large-scale retrospective study found a significant
342 decrease in the number of parasite-positive dogs (Table 6). This trend likely reflects an increased
343 awareness among dog owners about parasitic diseases, increased use of deworming and preventative
344 protocols, and the improved efficacy of new products on the market (Palmer et al., 2010). The odds
345 of being positive for parasites decreased by 4% each year, which is in agreement with other studies
346 (Barutzki and Schaper, 2013; Sudan et al., 2015; Tamponi et al., 2017).

347 The final logistic model for all parasites combined in cats showed only that age was a putative risk
348 factor. The odds of a cat being positive for at least one parasite genus was 2.44 times less in adults
349 compared to kittens, likely due to parasite-specific immunity that is usually acquired with age, and
350 the eventual single or repeated exposures to parasites during the mature life of a cat (Ramirez-Barrios
351 et al., 2004). In Canada, cats come into heat any time between January and October, although they
352 are focused around the longest day of the year in June (Bronwyn Crane personal communication).
353 Dogs are not seasonal, with the exception of the Basenji breed. All other breeds usually have a 6-
354 month inter-estrus interval and heats are randomly spread throughout the year.

355 The two genus-specific parasite models in dogs, for *Cystoisospora* spp. and *T. canis* (Tables 7-8),
356 found similar results compared to the model built for predictors associated with the presence/absence
357 of at least one parasite (Tables 6). With these genera making up a large portion of the parasites found
358 in the dogs in the dataset, it is not surprising to find these similarities in results. Due to the smaller
359 number of dogs specifically with *T. canis* infections, sterilized females and geographic origin were
360 no longer significantly associated with infection, but the odds ratios were similar to the model for
361 combined parasite presence.

362 As previously indicated, the main limitation to the interpretation of the study results is that
363 endoparasite data from diagnostic laboratories often carry a selection biases, in that they are based on
364 incomplete data submitted, and they reflect the situation in well-cared for animals that are being
365 checked for endoparasite. Our results from the fecal analyses provide an overview about the
366 frequency of which endoparasites are diagnosed in dogs and cats. Despite the selection biases, the
367 results of the risk factor analyses may still reflect relationships found in a randomly selected
368 population. In particular, the longitudinal nature of this dataset provided results regarding annual and
369 seasonal patterns. An additional limitation is the imperfect sensitivities of the tests utilized by the
370 laboratory which would likely lead to under-estimates of the frequency of infection.

371 Based on the public health concern of our results, control measures need to be considered for both
372 *Toxocara* spp. and *G. duodenalis*. Prevention of initial contamination of the environment can be
373 achieved by eliminating patent infections in dogs and cats, and/or preventing defecation by pets in
374 public areas unless owners clean up after their pets. Furthermore, education of the public on proper
375 hygiene prior to ingestion of food is important (Overgaauw and van Knapen, 2013). As *G. duodenalis*
376 is only minimally zoonotic, it may be necessary to treat and isolate positive dogs (or isolate their fecal
377 matter) in order to protect other dogs and cats from infection and to prevent environmental
378 contamination with potentially zoonotic cysts (Bowman and Lucio-Forster, 2010).

379 Future research that compares longitudinal data from other parts of Canada or North America
380 would help to corroborate the results found from the VTH database in PEI. Furthermore, evaluating

381 if owners' attitudes toward parasitic infections affect the probability of parasite infections in pets in
382 PEI or elsewhere would also be helpful.

383

384 **5. Conclusion**

385 This secondary-data study provides an impression of the parasitic infection status in submitted
386 fecal samples from dogs and cats in Prince Edward Island and other Canadian provinces, during an
387 eighteen-year period. Endoparasitism was diagnosed less commonly in mature, sterilized male dogs,
388 from other provinces compared to the baseline of young, female intact dogs from PEI, and diagnoses
389 occurred more often in autumn months than in winter months. *G. duodenalis*, *Cystoisospora* spp. and
390 *Toxocara* spp. were the three most common genera of parasites found in dogs, and the same
391 significant risk factors were also found in the models for the last two parasites. Only age was a
392 significant risk factor to fecal parasitism in cats in the dataset, with young cats having higher
393 endoparasitism levels compared to mature cats.

394 Although these data represent only the group of concerned pet owners who used the services of a
395 referral veterinary teaching hospital, it is still relevant to obtain information about the presence of
396 parasites, especially in relation to the zoonotic potential of pets sharing the same environment with
397 human beings. These concerned pet owners are likely more intimately sharing their environment with
398 their pets than owners who are less concerned about their pets. Knowing the trend of parasitic
399 infections across the geography, years, seasons, species, sexual status and age provides a perspective
400 to clinicians and researchers that can guide them when estimating the risk and impact of parasites and
401 when communicating control measures using a One Communication concept (Cipolla et al., 2015).

402

403 **Acknowledgements**

404 The authors wish to thank Nicole Buchanan, Janet Saunders, Bob Maloney and Jenny Yu for their
405 time and expertise provided in building the dataset. Funding to support the primary author's PhD

406 program degree and the time to conduct this study was provided by PhD program in Veterinary
407 Science at the Department of Veterinary Medical Science-*Alma Mater Studiorum*-University of
408 Bologna.

409

410 **References**

411 Antolová, D., Reiterová, K., Miterpáková, M., Dinkel, A., Dubinský, P., 2009. The first finding of
412 *Echinococcus multilocularis* in dogs in Slovakia: an emerging risk for spreading of infection.
413 *Zoonoses Public Health*. 56 (2), 53-58. doi: 10.1111/j.1863-2378.2008.01154.x.

414 Baneth, G., Thamsborg, S.M., Otranto, D., Guillot, J., Blaga, R., Deplazes, P., Solano-Gallego, L.,
415 2016. Major parasitic zoonoses associated with dogs and cats in Europe. *J. Comp. Pathol.* 155,
416 S54-S74. doi: 10.1016/j.jcpa.2015.10.179.

417 Barutzki, D., Schaper, R., 2011. Results of parasitological examinations of faecal samples from cats
418 and dogs in Germany between 2003 and 2010. *Parasitol. Res.* 109, S45–S60. doi 10.1007/s00436-
419 011-2402-8.

420 Barutzki, D., Schaper, R., 2013. Age-dependant prevalence of endoparasites in young dogs and cats
421 up to one year of age. *Parasitol. Res.* 112, S119-S131. doi: 10.1007/s00436-013-3286-6.

422 Bianciardi, P., Papini, R., Giuliani, G., Cardini, G., 2004. Prevalence of *Giardia* antigen in stool
423 samples from dogs and cats. *Rev. Med. Vet.* 155, 417-421.

424 Blagburn, B., Schenker, R., Gagne, F., Drake, J., 2008. Prevalence of intestinal parasites in
425 companion animals in Ontario and Quebec, Canada, during winter months. *Vet. Ther.* 9, 169-175.

426 Bowman, D.D., Lucio-Forster, A., 2010. Cryptosporidiosis and giardiasis in dogs and cats: veterinary
427 and public health importance. *Exp. Parasitol.* 124, 121-127. doi: 10.1016/j.exppara.2009.01.003.

428 Brianti, E., Arfuso, F., Cringoli, G., Di Cesare, A., Falsone, L., Ferroglio, E., Frangipane Di
429 Regalbono, A., Gaglio, G., Galuppi, R., Genchi, M., Iorio, R., Kramer, L., Lia, R.P., Manfredi,
430 M.T., Morganti, G., Perrucci, S., Pessarini, C., Poglayen, G., Otranto, D., Rinaldi, L., Scala, A.,
431 Solari Basano, F., Varcasia, A., Venco, L., Veneziano, V., Veronesi, F., Zanet, S., Zanzani, S.A.,
432 2018. Italian nationwide survey on endoparasites of dogs. XXX Congresso SoIPa, Milano, 26-29
433 giugno. ISBN 978-88-943575-0-9.

434 Bridger, K.E., Whitney, H., 2009. Gastrointestinal parasites in dogs from the Island of St. Pierre off
435 the south coast of Newfoundland. *Vet. Parasitol.* 162, 167-170. doi: 10.1016/j.vetpar.2009.02.016.

436 Broussard, J.D., 2003. Optimal fecal assessment. *Clin. Tech. Small. Anim. Pract.* 18, 218-230. doi:
437 10.1016/S1096-2867(03)00076-8

438 Canadian Animals Health Institute, 2019. [https://www.cahi-icsa.ca/press-releases/latest-canadian-](https://www.cahi-icsa.ca/press-releases/latest-canadian-pet-population-figures-released)
439 [pet-population-figures-released](https://www.cahi-icsa.ca/press-releases/latest-canadian-pet-population-figures-released) (accessed 23 May 2019).

440 Carlin, E.P., Bowman, D.D., Scarlett, J.M., Garrett, J., Lorentzen, L., 2006. Prevalence of *Giardia* in
441 symptomatic dogs and cats throughout the United States as determined by the IDEXX SNAP
442 *Giardia* test. *Vet. Ther.* 7, 199-206.

443 Chen, J., Xu, M.J., Zhou, D.H., Song, H.Q., Wang, C.R., Zhu, X.Q., 2012. Canine and feline parasitic
444 zoonoses in China. *Parasit. Vectors.* 5, 152. doi: 10.1186/1756-3305-5-152.

445 Chomel, B.B., Sun, B., 2011. Zoonoses in the bedroom. *Emerg. Infect. Dis.* 17, 167-172. doi:
446 10.3201/eid1702101070.

447 Cipolla, M., Bonizzi, L., Zeconi, A., 2015. From “One Health” to “One Communication”: the
448 contribution of communication in Veterinary Medicine to Public Health. *Vet. Sci.* 2, 135-149. doi:
449 10.3390/vetsci2030135.

450 Conboy, G.A., 2004. Natural infections of *Crenosoma vulpis* and *Angiostrongylus vasorum* in dogs
451 in Atlantic Canada and their treatment with milbemycin oxime. *Vet. Record* 155, 16-18.
452 <http://dx.doi.org/10.1136/vr.155.1.16>

453 Deplazes, P., Van Knapen, F., Schweiger, A., Overgaaauw, P.A.M., 2011. Role of pet dogs and cats
454 in the transmission of helminthic zoonoses in Europe, with a focus on echinococcosis and
455 toxocarosis. *Vet. Parasitol.* 2011, 182, 41-53. doi: 10.1016/j.vetpar.2011.07.014

456 Dohoo, I., Martin, W., Stryhn, H. 2009. Model-building strategies, in: Dohoo, I., Martin, W., Stryhn,
457 H. (2nd Eds.), *Veterinary Epidemiologic Research*. VER Inc. Charlottetown, PEI-Canada, pp. 365-
458 394.

459 Epe, C. 2009. Intestinal nematodes: biology and control. *Vet. Clin. North. Am. Small. Anim. Pract.*
460 39, 1091-1107. doi: 10.1016/j.cvsm.2009.07.002.

461 Epe, C., Rehker, G., Schnieder, T., Lorentzen, L., Kreienbrock, L., 2010. *Giardia* in symptomatic
462 dogs and cats in Europe - results of a European study. *Vet. Parasitol.* 173, 32-38. doi:
463 10.1016/j.vetpar.2010.06.015.

464 Esch, K.J., Petersen, C.A., 2013. Transmission and epidemiology of zoonotic protozoal diseases of
465 companion animals. *Clin. Microbiol. Rev.* 26, 58-85. doi:10.1128/CMR.00067-12.

466 Feng, Y., Xiao, L., 2011. Zoonotic potential and molecular epidemiology of *Giardia* species and
467 giardiasis. *Clin. Microbiol. Rev.* 24, 110-140. doi: 10.1128/CMR.00033-10.

468 Fontanarroza, M.F., Vezzani, D., Basabe, J., Eiras, D.F., 2006. An epidemiological study of
469 gastrointestinal parasites of dogs from Southern Greater Buenos Aires (Argentina): Age, gender,
470 breed, mixed infections, and seasonal and spatial patterns. *Vet. Parasitol.* 136, 283-295. doi:
471 10.1016/j.vetpar.2005.11.012.

472 Joffe, D., Van Niekerk, D., Gagné, F., Gilleard, J., Kutz, S., Lobingier, R., 2011 The prevalence of
473 intestinal parasites in dogs and cats in Calgary, Alberta. *Can. Vet. J.* 52, 1323-1328.

- 474 Kapel, C.M.O., Torgerson, P.R., Thompson, R.C.A., Deplazes, P., 2006. Reproductive potential of
475 *Echinococcus multilocularis* in experimentally infected foxes, dogs, raccoon dogs and cats. Int. J.
476 Parasitol. 36, 79-86. doi: 10.1016/j.ijpara.2005.08.012.
- 477 Kirkpatrick, C.E., 1988. Epizootiology of endoparasitic infections in pet dogs and cats presented to a
478 veterinary teaching hospital. Vet. Parasitol. 30, 113-124.
- 479 Kostopoulou, D., Claerebout, E., Arvanitis, D., Ligda, P., Voutzourakis, N., Casaert, S., Sotiraki, S.,
480 2017. Abundance, zoonotic potential and risk factors of intestinal parasitism amongst dog and cat
481 populations: The scenario of Crete, Greece. Parasit. Vectors. 10, 43. doi: 10.1186/s13071-017-
482 1989-8.
- 483 Lee, R.M., Moore, L.B., Bottazzi, M.E., Hotez, P.J., 2014. Toxocariasis in North America: a
484 systematic review. PLoS Negl. Trop. Dis. 8, e3116. doi: 10.1371/journal.pntd.0003116
- 485 Lund, E.M., Armstrong, P.J., Kirk, C.A., Kolar, L.M., Klausner, J.S., 1999. Health status and
486 population characteristics of dogs and cats examined at private veterinary practices in the United
487 States. J. Am. Vet. Med. Assoc. 214, 1336-1341.
- 488 Lue, T.W., Pantenburg, D.P., Crawford, P.M., 2008. Impact of the owner-pet and client-veterinarian
489 bond on the care that pets receive. J. Am. Vet. Med. Assoc. 232, 531-540. doi:
490 10.2460/javma.232.4.531.
- 491 Macpherson, C.N.L., 2013. The epidemiology and public health importance of toxocariasis: a
492 zoonosis of global importance. Int. J. Parasitol. 43, 999-1008. doi: 10.1016/j.ijpara.2013.07.004.
- 493 Malloy, W.F., Embil, J.A. 1978. Prevalence of *Toxocara* spp. and other parasites in dogs and cats in
494 Halifax, Nova Scotia. Can. J. Comp. Med. 42, 29-31.
- 495 Nolan, T.J., Smith, G., 1995. Time series analysis of the prevalence of endoparasitic infections in cats
496 and dogs presented to a veterinary teaching hospital. Vet. Parasitol. 59, 87-96.

497 Oliveira-Sequeira, T., Amarante, A.F.T., Ferrari, T.B., Nunes, L.C., 2002. Prevalence of intestinal
498 parasites in dogs from Sao Paulo State, Brazil. *Vet. Parasitol.* 103, 19-27.
499 [https://doi.org/10.1016/S0304-4017\(01\)00575-1](https://doi.org/10.1016/S0304-4017(01)00575-1).

500 Overgaaouw, P.A.M, van Knapen, F., 2013. Veterinary and public health aspects of *Toxocara* spp.
501 *Vet. Parasitol.* 193, 398-403. <https://doi.org/10.1016/j.vetpar.2012.12.035>.

502 Palmer, C.S., Robertson, I.D., Traub, R.J., Rees, R., Thompson, R.C.A., 2010. Intestinal parasites of
503 dogs and cats in Australia: the veterinarian's perspective and pet owner awareness. *Vet. J.* 183,
504 358-361. doi: 10.1016/j.tvjl.2008.12.007.

505 Polley, L., Thompson, R.C.A., 2009. Parasite zoonoses and climate change: molecular tools for
506 tracking shifting boundaries. *Trends Parasitol.* 25, 285-291. doi: 10.1016/j.pt.2009.03.007.

507 Ramirez-Barrios, R.A., Barboza-Mena, G., Munoz, J., Angulo-Cubillan, F., Hernandez, E., Gonzalez,
508 F., Escalona, F., 2004. Prevalence of intestinal parasites in dogs under veterinary care in
509 Maracaibo, Venezuela. *Vet. Parasitol.* 121, 11-20. doi.org/10.1016/j.vetpar.2004.02.024.

510 Riggio, F., Mannella, R., Ariti, G., Perrucci, S., 2013. Intestinal and lung parasites in owned dogs and
511 cats from central Italy. *Vet. Parasitol.* 193, 78-84. <https://doi.org/10.1016/j.vetpar.2012.11.026>

512 Sánchez-Vizcaíno, F., Noble, P.J.M., Jones, P.H., Menacere, T., Buchan, I., Reynolds, S., Dawson,
513 S., Gaskell, R.M., Everitt, S., Radford, A.D. 2017. Demographics of dogs, cats, and rabbits
514 attending veterinary practices in Great Britain as recorded in their electronic health records. *BMC*
515 *Vet. Res.* 13, 218. doi: 10.1186/s12917-017-1138-9.

516 Schurer, J.M., Ndao, M., Quwezance, H., Elmore, S.A., Jenkins, E.J., 2014. People, pets, and
517 parasites: one health surveillance in Southeastern Saskatchewan. *Am. J. Trop. Med. Hyg.* 90:
518 1184-1190. doi: 10.4269/ajtmh.13-0749

519 Seah, S.K.K., Hucal, G., Law, C., 1975. Dogs and intestinal parasites: a public health problem. *Can.*
520 *Med. Assoc. J.* 112, 1191-1194.

521 Shulka, R., Giraldo, P., Kraliz, A., Finnigan, M., Sanchez, A.L., 2006. *Cryptosporidium* spp. and
522 other zoonotic enteric parasites in a sample of domestic dogs and cats in the Niagara region of
523 Ontario. *Can. Vet. J.* 47, 1179-1184.

524 Steketee, R.W., 2003. Pregnancy, nutrition and parasitic diseases. *J. Nutr.* 133, 1661S-1667S. doi:
525 10.1093/jn/133.5.1661S.

526 Stull, J.W., Carr, A.P., Chomel, B.B., Berghaus, R.D., Hird, D.W., 2007. Small animal deworming
527 protocols, client education, and veterinarian perception of zoonotic parasites in western Canada. *Can.*
528 *Vet. J.* 48, 269-276.

529 Sudan, V., Jaiswal, A.K., Shanker, D., Kanojiya, D., Sachan, A. 2015. Prevalence of endoparasitic
530 infections of non-descript dogs in Mathura, Uttar Pradesh. *J. Parasit. Dis.* 39, 491-494. doi:
531 10.1007/s12639-013-0383-5.

532 Tamponi, C., Varcasia, A., Pinna, S., Melis, E., Melosu, V., Zidda, A., Sanna, G., Pipia, A.P., Zedda,
533 M.T., Pau, S., Brianti, E., Scala, A., 2017. Endoparasites detected in faecal samples from dogs and
534 cats referred for routine clinical visit in Sardinia, Italy. *Vet. Parasitol. Reg. Stud. Reports.* 10, 13-
535 17. doi.org/10.1016/j.vprsr.2017.07.001.

536 Torgerson, P.R., Macpherson, C.N.L., 2011. The socioeconomic burden of parasitic zoonoses: Global
537 trends. *Vet. Parasitol.* 182, 79-95. doi:10.1016/j.vetpar.2011.07.017.

538 Uehlinger, F.D., Naqvi, S.A., Greenwood, S.J., J. McClure, J.T., Conboy, G., O'Handley, R.,
539 Barkema, H.W., 2017. Comparison of five diagnostic tests for *Giardia duodenalis* in fecal samples
540 from young dogs. *Vet. Parasitol.* 244, 91-96. doi.org/10.1016/j.vetpar.2017.07.030

541 Vélez-Hernández, L., Reyes-Barrera, K.L., Rojas-Almaráz, D., Calderón-Oropeza, M.A., Cruz-
542 Vázquez, J.K., Arcos-García, J.L., 2014. Riesgo potencial de parásitos zoonóticos presentes en
543 heces caninas en Puerto Escondido, Oaxaca. *Salud. Publica. Mex.* 56, 625-30.

- 544 Villeneuve, A., Polley, L., Jenkins, E., Schurer, J., Gilleard, J., Kutz, S., Conboy, G., Benoit, D.,
545 Seewald, W., Gagné, F. 2015. Parasite prevalence in fecal samples from shelter dogs and cats
546 across the Canadian provinces. *Parasit. Vectors.* 8, 281. doi: 10.1186/s13071-015-0870-x.
- 547 Zajac, A.M., Conboy, G.A., 2012. Fecal Examination for the Diagnosis of Parasitism, in Zajac, A.M.,
548 Conboy, G.A. (8th Eds.), *Veterinary Clinical Parasitology*, John Wiley & Sons, Inc. pp. 3-164.
- 549 Zanzani, S.A., Gazzonis, A.L., Scarpa, P., Berrilli, F., Manfredi, M.T., 2014. Intestinal parasites of
550 owned dogs and cats from metropolitan and micropolitan areas: prevalence, zoonotic risks, and
551 pet owner awareness in Northern Italy. *Biomed. Res. Int.* doi: 10.1155/2014/696508.

552 **Highlights:**

- 553 • Parasites occur even in owned companion animals under veterinary care
- 554 • Cats are significantly more frequently diagnosed positive for parasites than dogs
- 555 • Two of the three most frequently diagnosed parasite genera in dogs are zoonotic or
556 potentially zoonotic: *Toxocara* and *Giardia*, respectively
- 557 • Parasites were significantly more likely to be diagnosed in young dogs in PEI in autumn in
558 the first years of the laboratory results, compared to mature sterilized dogs outside of PEI
559 during other times of the year

Table 1: Descriptive statistics of predictors, by category, for 15,016 dogs and 2,391 cats diagnosed at the Atlantic Veterinary College from 2000-2017, along with comparisons between dogs and cats.

Predictors	Categories	Dogs (%)	Cats (%)	P-Value
Age*	≤12 months	709 (21.8)	164 (39.8)	<0.001
	>12 months	2,538 (78.2)	248 (60.2)	
	Total	3,247	412	
Sexual status*	Male	641 (19.7)	86 (21.4)	<0.001
	Female	534 (16.5)	110 (27.4)	
	Castrated male	1,047 (32.2)	127 (31.6)	
	Sterilized female	1,025 (31.6)	79 (19.6)	
	Total	3,247	402	
Geographic origin*	PEI	2,479 (76.3)	362 (87.7)	<0.001
	Others**	769 (23.7)	51 (12.3)	
	Total	3,248	413	
Seasonality	Winter	2,905 (19.3)	497 (20.8)	<0.001
	Spring	4,564 (30.4)	503 (21)	
	Summer	4,162 (27.7)	686 (28.7)	
	Autumn	3,385 (22.6)	705 (29.5)	
	Total	15,016	2,391	

*Predictors with missing values. PEI= Prince Edward Island. **Other Provinces include (Alberta, British Columbia, New Brunswick, Nova Scotia, Newfoundland and Labrador, Ontario, Quebec, and Saskatchewan). P-value based on the Pearson χ^2 -test.

Table 2: Frequency of the endoparasites found in 15,016 dogs and 2,391 cats diagnosed at the Atlantic Veterinary College during 2000-2017.

	Parasites	Dogs (n=15,016)		Cats (n=2,391)		Total %
		n	%	n	%	
Nematoda	<i>Ancylostoma</i>	110	0.73	1	0.04	0.63
	<i>Angiostrongylus vasorum</i>	145	0.97	-	-	
	Capillarids*	17	0.11	24	1.00	2.35
	<i>Crenosoma vulpis</i>	280	1.86	-	-	
	<i>Toxascaris leonina</i>	17	0.11	2	0.08	0.11
	<i>Toxocara canis/cati</i>	362	2.41	196	8.2	3.21
	<i>Trichuris vulpis</i>	64	0.43	-	-	
	<i>Uncinaria</i>	114	0.76	1	0.04	0.66
Trematoda	<i>Alaria</i>	27	0.18	-	-	
Cestoda	<i>Taenia</i>	17	0.11	21	0.88	0.22
Protozoa	<i>Giardia duodenalis</i>	811	5.4	100	4.18	5.23
	<i>Cystoisospora</i>	437	2.91	139	5.81	3.31

*Includes *Aonchotheca putrorii* and *Eucoleus aerophilus* (cats) and *Eucoleus aerophilus* and *Eucoleus boehmi* (dogs).

Table 3: Proportions of single and multiple parasitism infections in 2,128 positive dogs and 412 positive cats diagnosed at the Atlantic Veterinary College from 2000-2017

# of different parasitism	Positive dogs (n=2,128)		Positive cats (n=412)		Total %
	n	%	n	%	
1	1,863	87.55	358	86.89	87.4
2	237	11.14	41	10.19	9.95
3-4	28	1.31	12	2.91	1.58
5	-	-	1	0.25	0.04

Table 4: Frequency of the three main parasite genera in dogs, by age group, sex, geographical origin and seasonality of diagnosis, diagnosed at the Atlantic Veterinary College from 2000-2017.

Independent variables/category	No. of tested dogs	No. of positive dogs (%)			
		<i>Toxocara canis</i>	<i>Giardia duodenalis</i>	<i>Cystoisospora</i> spp.	All genera
Age group*					
≤12 months	709	47 (6.6)	57 (8)	43 (6.1)	146 (20.6)
>12 months	2,538	21 (0.8)	22 (0.9)	21 (0.8)	112 (4.4)
Total	3,247	132 (4.1)	79 (2.4)	64 (2)	258 (7.9)
Sexual status*					
Male	641	25 (3.9)	30 (4.7)	19 (3.0)	82 (12.8)
Female	534	23 (4.3)	21 (3.9)	27 (5.1)	72 (13.5)
Sterilized female	1,025	12 (1.2)	18 (1.8)	7 (0.7)	51 (5)
Castrated male	1,047	8 (0.7)	9 (0.9)	11 (1.1)	52 (5)
Total	3,247	68 (2.1)	79 (2.4)	64 (2.0)	257 (7.9)
Geographical origin*					
Prince Edward Island	2,479	60 (2.4)	67 (2.7)	61 (2.5)	227 (9.2)
Other	769	8 (1.0)	12 (1.6)	3 (0.4)	31 (4)
Total	3,248	68 (2.1)	79 (2.4)	64 (2.0)	258 (7.9)
Seasonality					
Winter	2,905	83 (2.9)	171 (5.9)	55 (1.8)	474 (16.3)
Spring	4,564	76 (1.7)	212 (4.7)	106 (2.3)	558 (12.2)
Summer	4,162	74 (1.8)	225 (5.4)	151 (3.6)	568 (13.6)
Autumn	3,385	129 (3.8)	203 (6.0)	125 (3.7)	528 (15.6)
Total	15,016	362 (2.4)	811 (5.4)	437 (2.9)	2,128 (14.2)

*Variables containing missing values

Table 5: Frequency of the three main parasites genera in cats, by age group, sexual status, geographical origin and season of diagnosis, diagnosed at the Atlantic Veterinary College from 2000-2017.

Independent variables/category	No. of tested cats	No. of positive cats (%)			
		<i>Toxocara cati</i>	<i>Giardia duodenalis</i>	<i>Cystoisospora</i> spp.	All genera
Age group*					
≤12 months	164	22 (13.4)	6 (3.7)	9 (5.5)	36 (21.9)
>12 months	248	13 (5.2)	5 (2.0)	10 (4.0)	26 (10.5)
Total	412	35 (8.5)	11 (2.7)	19 (4.6)	62 (15.0)
Sexual status*					
Male	86	5 (5.8)	4 (4.6)	2 (2.3)	12 (14.0)
Female	110	13 (11.8)	4 (3.6)	7 (6.4)	23 (20.9)
Sterilized female	79	2 (2.5)	-	2 (2.5)	4 (5.1)
Castrated male	127	8 (6.3)	3 (2.4)	6 (4.7)	15 (11.8)
Total	402	28 (7.0)	11 (2.7)	17 (4.2)	54 (13.4)
Geographical origin*					
PEI	362	33 (9.1)	11 (3.0)	15 (4.1)	56 (15.5)
Other	51	2 (3.9)	-	4 (7.8)	6 (11.8)
Total	413	35 (8.5)	11 (2.7)	19 (4.6)	62 (15.0)
Seasonality					
Winter	492	44 (8.9)	23 (4.7)	14 (2.8)	73 (14.8)
Spring	505	30 (5.9)	14 (2.8)	14 (2.8)	55 (10.9)
Summer	701	53 (7.6)	25 (3.6)	62 (8.8)	142 (20.2)
Autumn	693	69 (9.9)	38 (5.4)	49 (7.1)	142 (20.5)
Total	2,391	196 (8.2)	100 (4.2)	139 (5.8)	412 (17.2)

*Variables containing missing values. PEI= Prince Edward Island

Table 6: Predictors of the final logistic regression model of factors associated with parasites presence in 3,242 dogs diagnosed at the Atlantic Veterinary College from 2000-2017.

<i>Predictors</i>	Odds Ratio	95%CI	P-value	Overall P-value
Year	0.961	0.931-0.991	0.012	
Age*				
≤12 months	baseline	baseline	-	
>12 months	0.232	0.174-0.311	<0.001	
Sexual status*				
Female	baseline	baseline	-	
Male	0.978	0.687-1.392	0.904	0.026
Sterilized female	0.627	0.419-0.938	0.023	
Castrated male	0.624	0.419-0.931	0.021	
Geographic origin*				
PEI	baseline	baseline	-	
Others	0.521	0.351-0.774	0.001	
Seasonality				
Winter	baseline	baseline	-	
Spring	1.201	0.781-1.845	0.404	0.011
Summer	1.461	0.974-2.191	0.067	
Autumn	1.647	1.076-2.523	0.022	

* Variables containing missing values; PEI= Prince Edward Island. P-value based on the Wald test

Table 7: Predictors of the final logistic regression model of factors associated with *Cystoisospora* spp. presence in 3,242 dogs diagnosed at the Atlantic Veterinary College from 2000-2017.

<i>Predictors</i>	Odds Ratio	95% CI	P-value	Overall P-value
Age*				
≤12 months	baseline	baseline	-	
>12 months	0.192	0.108-0.341	<0.001	
Sexual status*				
Female	baseline	baseline	-	
Male	0.577	0.314-1.062	0.077	0.005
Sterilized female	0.272	0.113-0.652	0.004	
Castrated male	0.413	0.195-0.876	0.021	
Geographic origin*				
PEI	baseline	baseline	-	
Others	0.217	0.065-0.676	0.009	
Seasonality				
Winter	baseline	baseline	-	
Spring	2.181	0.844-5.634	0.107	0.042
Summer	2.399	0.960-5.993	0.061	
Autumn	2.759	1.074-7.085	0.035	

*Variables containing missing values; PEI=Prince Edward Island. P-value based on the Wald test

Table 8 Predictors of the final logistic regression model of factors associated with *Toxocara canis* presence in 3,242 dogs diagnosed at the Atlantic Veterinary College from 2000-2017.

<i>Predictors</i>	Odds Ratio	95% CI	P-value	Overall P-value
Age*				
≤12 months	baseline	baseline	-	
>12 months	0.168	0.094-0.297	<0.001	
Sexual status*				
Female	baseline	baseline	-	
Male	0.948	0.524-1.713	0.860	0.012
Sterilized female	0.589	0.277-1.250	0.168	
Castrated male	0.368	0.157-0.862	0.021	
Geographic origin*				
PEI	baseline	baseline	-	
Others	0.558	0.262-1.191	0.132	
Seasonality				
Winter	baseline	baseline	-	
Spring	0.756	0.309-1.850	0.541	<0.001
Summer	1.232	0.566-2.681	0.598	
Autumn	2.674	1.270-5.628	0.010	

*Variables containing missing values; PEI=Prince Edward Island. P-value based on the Wald test.