Parasitology International 69 (2019) 75–81

Contents lists available at ScienceDirect

Parasitology International

journal homepage: www.elsevier.com/locate/parint

Intestinal parasites and lungworms in stray, shelter and privately owned cats of Switzerland

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ARTICLE INFO

Keywords:
Toxocara cati
Taenia sp.
Aelurostrongylus abstrusus
Toxoplasma gondii
Risk factors
Zoonotic potential
Environmental contamination

ABSTRACT

Endoparasitic infections represent relevant causes of respiratory and gastrointestinal diseases in cats. The aim of the study was to investigate the occurrence of endoparasites in Swiss cats in order to evaluate the risk of onset of parasitic diseases and potential correlated zoonoses. Therefore 664 faecal samples from privately owned (n = 299), shelter (n = 197) and stray (n = 168) cats were investigated by sedimentation-flotation and 468 samples additionally by the Baermann technique. Overall, 77.4% (n = 130), 21.8% (n = 43) and 11.7% (n = 35) of stray, shelter and privately owned cats, respectively, were positive, with significant differences between the groups. Among infected cats, 58.7% (n = 122) harboured a single, 30.8% (n = 64) two and 10.6% (n = 22) more than two parasite species. *Toxocara cati,* with an infection rate of 18.5% (n = 123), was the most frequently detected parasite. The rates for other intestinal parasites were: *Taenia* sp. 11.1% (n = 74), *Isospora* sp. 8.1% (n = 54), *Capillaria* sp. 4.7% (n = 31), hookworms 1.1% (n = 7), *Giardia duodenalis* 0.8% (n = 5), *Dipylidium caninum* 0.6% (n = 4), *Toxoplasma gondii* 0.6% (n = 4), *Hammondia hammondi* 0.5% (n = 3), *Sarcocystis* sp. 0.2% (n = 1) and *Diphyllobothrium latum* 0.2% (n = 1). First-stage larvae of the lungworm *Aelurostrongylus abstrusus* were found in 2.3% (n = 15) of all samples. The morphological identification of *Taenia* sp., *T. gondii, H. hammondi* and *A. abstrusus* was confirmed by molecular techniques. Overall, cats younger than one year and intact animals were more frequently infected with parasites than older and neutered animals. The observed infection rates were comparable to those from other European studies, except for *Taenia* sp. showing a significantly higher occurrence. This implicates that there is a persistent risk of environmental contamination with parasitic stages especially by stray cats, and a risk of infection for cat owners with potential zoonotic pathogens, emphasizing the need for appropriate parasite control measures.

1. Introduction

Endoparasitic infections of cats represent relevant causes of respiratory and gastrointestinal diseases in cats. The manifestation of clinical signs may depend on the particular parasite species, their abundance, the presence of concurrent multiple infections, and on the age and individual immunological status of the animals. Commonly, kittens and young animals show higher prevalences of infection and of associated clinical diseases [1,2], but also adult and wild felids contribute to environmental contamination and therefore to the maintenance of the life cycles [3]. Furthermore, domestic cats are the main shedders of environmentally resistant stages of potentially zoonotic parasites such as *Toxocara cati* and *Toxoplasma gondii*. Therefore, based on the significant role of cats as pets with close human-bond [4], disease awareness and appropriate information are the main objectives of non-profit organisations like ESCCAP (European Scientific Counsel Companion Animal Parasites) in Europe (www.esccap.org) or CAPC (Companion Animal Parasite Council) in US. Correspondingly, knowledge on infection rates of endoparasites in cats is important for a better management and adequate antiparasitic treatments, in order to foster the health of cats and, accordingly, to prevent zoonotic infections within the frame of the One Health concept [4,5].

In opposition to dogs, for which a multitude of parasitological prevalence studies mostly based on coproscopic results have been performed, less data are available for cats. One of the reasons for this difference may be the difficulty of collecting cats' faeces, as privately-owned cats have frequently outdoor access and defecate outside (while free-roaming and stray cats are exclusively outside), precluding faecal sampling for coproscopic analyses. Considering that multiple faecal sampling is recommended to increase sensitivity, the restricted

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https://doi.org/10.1016/j.parint.2018.12.005
Received 5 October 2018; Received in revised form 10 December 2018; Accepted 11 December 2018
Available online 12 December 2018
1383-5769/

availability of fresh faecal samples represents a major limitation. Nevertheless, a number of prevalence studies in cats from various countries have been recently complemented by two large field studies involving overall 1′519 and 1′990 owned cats of 9 and 12 countries, respectively [6,7], allowing an assessment of the current situation in these countries. Little is known about endoparasitism in cats of Switzerland: data are restricted to an older study with a limited number of samples [8], or to a determined area and on a single parasite, such as the ocular nematode *Thelazia callipaeda* [9].

In order to resolve this gap, we investigated the infection rates with intestinal parasites and lungworms, including potentially zoonotic endoparasites, in stray, shelter and privately owned Swiss cats through faecal examination.

2. Material and methods

2.1. Study population

From March to December 2012 and July 2014 to December 2015 a total of 664 faecal samples of Swiss cats were obtained from four different shelters ($n = 197$), from stray cats during neutering campaigns (through rectal examination under general anesthesia) performed in 6 different regions of the country ($n = 168$), and from privately owned cats ($n = 299$). From the latter group, 95 samples were submitted from private persons for study purposes, 133 originated from stationary patients of the Animal Hospital at the Vetsuisse Faculty of the University of Zurich and 71 were obtained from the Diagnostic Unit of the Institute of Parasitology of the University of Zurich. This institute analyses samples from all over the country; also, the Animal Hospital in Zurich is treating all kind of patients for any sort of reasons and has a very large catchment area comprehending urban, semiurban and rural areas; thus, sample collection was considered representative for the whole country.

2.2. Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guides. Objective and design of the study were approved for owned, shelter and stray cats by the owners, shelter administrator and animal welfare organisers of the neutering campaigns, respectively.

2.3. Faecal examination

All samples were stored at 4 °C after collection for a maximum of 5 days. Each sample was first checked macroscopically for adult parasites or parasite parts. Overall 468 samples were analysed with the Baermann-Wetzel technique and with the combined sedimentation/flotation technique using a saturated zinc chloride solution (specific gravity 1.45), while the remaining 196 faecal samples, due to the restricted amount of material (< 6 g), were only analysed with the sedimentation/flotation technique [10]. Parasite stages were photographed and measured by using a digital image processing system (Leica® DM 100 LED, Leica® DFC 420, Leica® LAS 4, Leica Microsystems GmbH, Wetzlar, Germany) and identified using morphological keys [10].

2.4. Molecular diagnostics

All faecal samples of cats positive for first-stage larvae (L1) of *Aelurostrongylus abstrusus* were analysed with a duplex-PCR [11] to exclude a potential co-infection with *Troglostrongylus* sp., after the DNA extraction from isolated larvae with a commercial kit (QIAamp DNA mini kit (QIAGEN no. 51304), QIAGEN GmbH, Hilden, Germany). To distinguish between the morphologically similar *Toxoplasma gondii* and *Hammondia hammondi* oocysts, DNA was extracted from isolated oocysts using a commercial kit (QIAamp DNA stool mini kit (QIAGEN no. 51504), QIAGEN GmbH, Hildem, Germany) after 3 cycles of freezing-thawing and alkaline lysis, according to the manufacturer's instructions. This was followed by a real-time PCR for *Toxoplasma* DNA [12] and a PCR specific for *H. hammondi* [13]. Samples positive for taeniid eggs were analysed by PCR to distinguish between *Taenia* sp. and possible *Echinococcus multilocularis* infections, as previously described [14,15].

2.5. Statistical analysis

Microsoft Excel 2010 for Windows (Microsoft Corporation, Redmond, USA) was used to calculate the means and the standard deviations (SD). The exact binominal 95% confidence intervals (Cl) were calculated according to Clopper and Pearson [16]. Statistical analysis was performed using Windows IBM® SPSS ® Statistics (Version 23): possible correlations between stray, shelter and owned cats their age and sex and corresponding infection rates were calculated by cross-tables and chi-square tests premising available data: overall, age (younger or older than one year) was known for 624 cats, sex and if neutered or not for 642 cats. Differences with $p < .05$ were considered significant.

3. Results

Overall, 31.3% (208/664, CI: 27.8–35.0%) of the samples were positive for parasitic stages: this was the case in 77.4% (130/168), 21.8% (43/197) and 11.7% (35/299) of the samples from stray, shelter and owned cats, respectively (Table 1), with significant decrease of infection rates between each of these three groups ($p < .05$). Infections with a single parasite species were significantly more common (58.7%) than infections with two (30.8%) or more than two (10.6%) parasite species. In particular stray cats harboured to a significantly greater extent more than one parasite species compared to shelter and owned cats and only stray cats were simultaneously harbouring more than two parasite species.

Overall, the most frequent parasite was *T. cati,* which was identified in 18.5% (123/664) of the tested samples (Fig. 1). It was the most

Table 1
Faecal samples of Swiss cats ($n = 664$) positive for one, two or more than two endoparasites (CI: 95% Confidence Intervals).

	Owned cats (n = 299)	Shelter cats ($n = 197$)	Stray cats (n = 168)	Total (n = 664)
Positive, n	135	43	130	208
% (CI)	11.7 (8.3–15.9)	21.8 (16.3–28.3)	77.4 (70.3–83.5)	31.3 (27.8–35.0)
Of these				
One parasite species, n	30	35	57	122
% (CI)	10.0 (6.9–14.0)	17.8 (12.7–23.8)	33.9 (26.8–41.6)	58.7 (51.6–65.4)
Two parasite species, n	5	8	51	64
% (CI)	1.7 (0.5–3.9)	4 (1.8–7.8)	30.4 (23.5–37.9)	30.8 (24.6–37.5)
> two parasite species, n	0	0	22	22
% (CI)	0 (0–1.0)	0 (0–1.5)	13.1 (8.4–19.2)	10.6 (6.7–15.6)

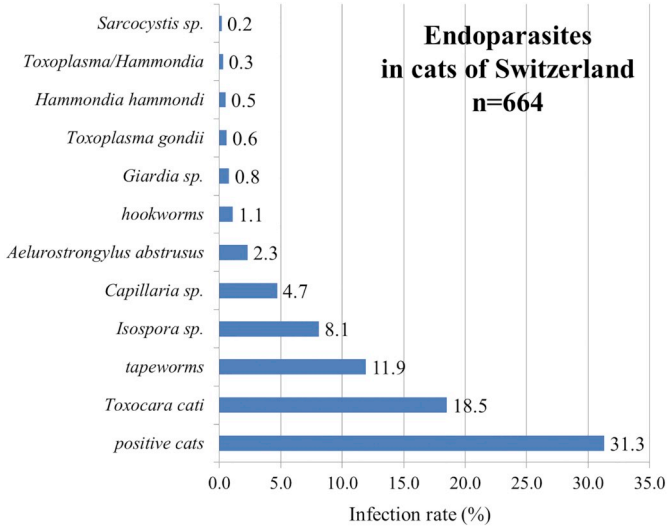

Fig. 1. Infection rates with endoparasites diagnosed in 664 Swiss cats using the Baermann-Wetzel technique and/or combined sedimentation/flotation using a saturated zinc chloride solution (specific gravity 1.45).

frequently found parasite in all three groups, but significantly more often present in stray cats (Table 2). *A. abstrusus* L1 were found in 2.3% (n = 15) of the samples, with 11 positive samples (all from stray cats from which no faeces was available for the Baermann-Wetzel technique) being identified by sedimentation/flotation. With 6.5% (11/168) the infection rate with this parasite was significantly higher in stray cats, compared to 1% (2/197) and 0.7% (2/299) in shelter and owned cats, respectively. Their morphological identification was confirmed by DNA detection positive for *A. abstrusus* and negative for *T. brevior*. *Capillaria* sp. eggs were detected in 4.7% (31/664) of the samples, and significantly more frequent in stray (10.1%) than in owned (2.3%) cats. As no further differentiation was performed, the potential presence of *Capillaria* eggs derived from hunted birds or rodents (intestinal passage) should be also considered.

During macroscopic exploration, cestode proglottids, identified as *Taenia* sp., were found in 12/664 faecal samples (1.8%), all collected from stray cats. Eggs of *Taenia* sp. were found in 11.1% (n = 74), *Dipylidium caninum* in 0.6% (n = 4), *Diphyllobothrium latum* in 0.2% (n = 1) and hookworms in 1.1% (n = 7) of the faecal samples. Eggs of the latter three parasites were only found in stray cats. PCR performed with the isolated taeniid eggs revealed the presence of *Taenia* sp., and no *E. multilocularis* DNA. *Taenia* sp. was found to a significant greater extent in stray cats, representing the second most common parasite after *T. cati* in this group (63/168, 37.5%), in contrast to 3.0% (6/197) and 1.7% (5/299) in shelter and owned cats, respectively.

Among the protozoa, the most commonly (54/664, 8.1%) identified parasite in this study was *Isospora* sp. (no further differentiation was made). In the groups of shelter and owned cats *Isospora* sp. was the second most frequently detected parasite, with 8.6% (17/197) and 3.0% (9/299), respectively. *Giardia* sp. was found in 0.8% (5/664) of the faecal samples. *Toxoplasma/Hammondia*-like oocysts were detected in 1.35% (9/664) of all examined cats. By molecular analyses, these oocysts could be identified as *T. gondii* and *H. hammondi* in 0.6% (n = 4) and 0.5% (n = 3) of the samples, respectively. In two further samples a differentiation between these two protozoans was not possible due to lack of enough material. *Sarcocystis* sp. was observed in a single (0.2%) sample, obtained from a stray cat during a neutering campaign.

Overall, cats younger than one year were significantly more often infected compared to cats older than one year, females scarcely significantly more often than males, and intact cats significantly more often than neutered ones (Table 4).

Considering the populations of stray, shelter and owned cats separately, there was no significant difference in infection rate related to age or sex of stray cats: in this population 90.9% of cats younger than

Table 2
Endoparasites (intestinal parasites and lungworms) identified in descending occurrence in Swiss stray, shelter and owned cats isolated with the combined sedimentation/flotation technique (n = 664) using a saturated zinc chloride solution (specific gravity 1.45), and the Baermann-Wetzel technique (n = 468).

Parasite species	Stray cats (n = 168)	Shelter cats (n = 197)	Owned cats (n = 299)	Total (n = 664)
Helminths				
Toxocara cati, n	92	18	13	123
% (CI)	54.8 (46.9–62.4)	9.1 (5.5–14.1)	3.0 (1.4–5.6)	18.5 (15.6–21.7)
Taeniidae, n	63	6	5	74
% (CI)	37.5 (30.2–45.3)	3.0 (1.1–6.5)	1.7 (0.5–3.9)	11.1 (8.9–13.8)
Capillaria sp., n	17	7	7	31
% (CI)	10.1 (6.0–15.7)	3.6 (1.4–7.2)	2.3 (0.9–4.8)	4.7 (3.2–6.6)
Aelurostrongylus abstrusus, n	11	2	2	15
% (CI)[a]	6.5 (3.3–11.4)	1.0 (0.1–3.6)	0.7 (0.1–2.4)	2.3 (1.3–3.7)
hookworms, n	7	0	0	7
% (CI)	4.2 (1.7–8.4)	0.0 (0.0–1.5)	0.0 (0.0–1.0)	1.1 (0.4–2.2)
Dipylidium caninum, n	4	0	0	4
% (CI)	2.4 (0.7–6.0)	0.0 (0.0–1.5)	0.0 (0.0–1.0)	0.6 (0.2–1.5)
Diphyllobothrium latum, n	1	0	0	1
% (CI)	0.6 (0.0–3.3)	0.0 (0.0–1.5)	0.0 (0.0–1.0)	0.2 (0.0–0.8)
Protozoa				
Isospora sp., n	28	17	9	54
% (CI)	16.7 (11.4–23.2)	8.6 (5.1–13.5)	3.0 (1.4–5.6)	8.1 (6.2–10.5)
Giardia sp., n	1	2	2	5
% (CI)	0.6 (0.0–3.3)	1.0 (0.1–3.6)	0.7 (0.1–2.4)	0.8 (0.2–1.7)
Toxoplasma gondii, n	0	0	4	4
% (CI)	0.0 (0.0–1.8)	0.0 (0.0–1.5)	1.3 (0.4–3.4)	0.6 (0.2–1.5)
Hammondia hammondi	0	1	2	3
	0.0 (0.0–1.8)	0.5 (0.0–2.8)	0.7 (0.1–2.4)	0.5 (0.1–1.3)
Toxoplasma-like, n	2	0	0	2
% (CI)	1.2 (0.1–4.2)	0.0 (0.0–1.5)	0.0 (0.0–1.0)	0.3 (0.0–1.1)
oocysts				
Sarcocystis sp., n	1	0	0	1
% (CI)	0.6 (0.0–3.3)	0.0 (0.0–1.5)	0.0 (0.0–1.0)	0.2 (0.0–0.8)

[a] 468 cats were testes by the Baermann-Wetzel technique. *A. abstrusus* was the only lung worm identified.

Table 4
Infection rates of stray, shelter and privately owned cats with parasites in correlation with age, sex and spaying (CI: 95% Confidence Intervals; n.a.: not applied). Significant differences among categories are marked with *.

Variable	Categories	Stray cats (n = 168) %, CI (n/tot)	Shelter cats (n = 197)[a] %, CI (n/tot)	Owned cats (n = 299)[a] %, CI (n/tot)	Total (*n* = 664)[a] %, CI (n/tot)
Age	< 1 year	90.9% (78.3–97.5%) (40/44)	32.8% (21.3–46.0%) (20/61[a])	25.8%* (15.8–38.0%) (17/66[a])	45.0%* (37.4–52.8%) (77/171[a])
	> 1 year	72.6% (63.8–80.2%) (90/124)	15.0% (9.0–23.0%) (17/113[a])	8.3% (5.0–12.9%) (18/216[a])	27.6% (23.5–32.0%) (125/453[a])
Sex	Male	75.4% (63.1–85.2%) (49/65)	20.5% (12.0–31.6%) (15/73[a])	9.4% (5.5–14.8%) (16/170[a])	26.0% (21.2–31.3%) (80/308[a])
	Female	78.6% (69.5–86.1%) (81/103)	21.3% (14.0–30.2%) (23/108[a])	15.4% (9.6–23.1%) (19/123[a])	36.8%* (31.6–42.2%) (123/334[a])
Spaying	Intact m/f	n.a.	25.3% (16.2–36.4%) (20/79[a])	21.7%* (13.4–32.1%) (18/83[a])	50.9%* (45.4–56.4%) (168/330[a])
	Spayed m/f	n.a.	17.6% (10.8–26.4%) (18/102[a])	8.1% (4.8–12.6%) (17/210[a])	11.2% (7.9–15.3%) (35/312[a])

[a] Discrepancies regarding the sums are given by unknown data for single individuals.

one year and 72.6% of cats older than one year harboured parasites; 78.6% of the female and 75.4% of the male animals were infected. The whole stray cat population was considered as intact. Among shelter cats there was a not significant difference concerning age, with higher infection rates in cats younger than one year than in older ones. No significant difference related to sex or between intact or neutered individuals was observed. Also in the privately owned cats group, individuals younger than one year harboured significantly more often parasites than older animals. No significant difference was found between males and females. However, in this group intact cats were significantly more often infected than neutered ones (Table 4).

4. Discussion

The here presented findings obtained through analysis of faecal samples from 664 Swiss cats with different origin and lifestyle represent so far the most extensive parasitological study on cats performed in Switzerland. With an overall parasite infection rate of 31.3%, this result is absolutely comparable with the rates (30.8%) recently obtained in a study performed with 613 owned cats from 12 European countries [7].

Samples of stray cats were overall more often positive for parasitological stages and were, accordingly, also harbouring more often two or more different parasite species. This highlights the major epidemiological role of stray cats in environmental contamination with parasitic stages, both serving as infection source for other felids (free-roaming and privately owned cats with outdoor access) and contributing to the establishment of reservoirs in intermediate and paratenic hosts. They therefore fundamentally contribute to the spread and endemicity of parasites [3], including endoparasites with zoonotic potential.

One of these parasites is *T. cati*, the most frequently detected parasite in our study and throughout Europe [1,6,7,17–20], independently of the examined cat population, with overall prevalences between 16.5% and 27.1%. Our results (overall infection rate: 18.5%) therefore come close to the studies where cats from 9 (19.7%) and 12 (16.5%) European countries, respectively, were examined [6,7]. *Toxocara cati* was identified in more than half of the stray cats (54.8%) in the present study. Lack of anthelmintic treatments and nutrition highly relying on hunting activity with ingestion of infected paratenic hosts may explain the high parasitism observed [17,21]. Among paratenic hosts, rodents are suggested to play a fundamental role, particularly in urban areas, with seroprevalence rates i.e. for *Toxocara* spp. in Switzerland up to 20% [22], therefore representing an important source of infection for stray and free-roaming cats. However, as transmission of *T. cati* also occurs during lactation and through direct ingestion of eggs from immediate surroundings, it is not surprising that also the infection rate in shelter animals is high. In opposition to dogs, coprophagia with false positive results can be excluded for cats [23].

Regarding taeniids as the second most frequently detected parasite group, the infection rate with *Taenia* sp. was significantly higher compared to other European studies, in which prevalences were as low as 1.3% and 1.1% [7], or maximally reaching a rate of 6.5% in single countries. Our result was mostly traceable to the group of the stray cats, in which *Taenia* sp. was the second most common parasite (infection rate 37.5%). We identified all cestodes as *Taenia* sp., excluding therefore the occurrence of *E. multilocularis,* although prevalence for this parasite in Swiss foxes can be as high as 67%, i.e. in recreational areas [24], which may represent also the most attractive roaming area for cats. Accordingly, in intermediate hosts acting also as preys for cats, both *Taenia* sp. and *E. multilocularis* were frequently found [22,25]. Nevertheless, *E. multilocularis* prevalence in European cat populations is generally below 1% [5,26], confirming that cats are less susceptible to this parasite than foxes or dogs [27] and therefore supposed to play a minor role in the transmission of this potentially dangerous zoonotic parasite [5]. The reason why the infection rate with *Taenia* sp. in household but also in stray cats from other countries than Switzerland, (i.e. from Germany (2.5%) [17] or Spain (4.3%) [21]), is significantly lower or why taeniids are even not found (i.e. Italy) [20], is not clear. Different techniques, i.e. McMaster [7] versus centrifugal flotation techniques [6] performed with different solutions of varying specific gravity may explain these discrepancies. The use of a saturated zinc chloride solution with high specific gravity (1.45) like the one used in the here presented study may account for a higher sensitivity for detection of taeniid eggs.

The infection rate (2.3%) with the only lungworm, *A. abstrusus,* detected in Swiss cats was very similar to the one of shelter cats from the Netherlands [28], or to a mixed cat population from Italy [20]. Affected cats can be asymptomatic, show unspecific signs or are classically presented with respiratory problems [29,30]. The currently most diffused diagnostic method for detection of lungworms is the Baermann technique [10,31]. However, intermittent or suspended larval excretion [29,32] and also restricted availability of fresh faecal samples represent major limitations for the diagnosis of lungworm infections with larval excretion. Serological tests can overcome this issue [33]. As advanced, the results may also highly vary depending on the study population: in a multicentre study with owned cats performed in 12 European countries, where the same procedures were adopted, lungworm prevalence varied from 0.8–35.8% [7]. We statistically confirmed that *A. abstrusus* infection rates are higher in stray (6.5%) than in owned (0.7%) cats and we verified the absence of other metastrongylid lungworms than *A. abstrusus* in Swiss cats. As for taeniid infections, alimentation predisposes stray cats to higher rates of infection compared to other cats.

In the mentioned Europe-wide cat study [7] capillarid (*Capillaria aerophila*) and metastrongylid lungworm infections were simultaneously identified in more than half of the analysed cats and it was

hypothesised that a common transmission pathway may explain such co-infections, based on ingestion of paratenic host species shared in their life cycles. We observed both, capillarid and *A. abstrusus* infections, significantly more frequently in the stray than in the other two examined cat populations. *Aelurostrongylus abstrusus* infections are induced by direct ingestion of infected gastropods or paratenic hosts, while the life cycle of capillarids is supposed to rely on ingestion of earthworms and of potential further paratenic hosts (including, among others, rodents) [34,35]. As intestinal passages of *Capillaria* eggs from hunted birds or rodents were not excluded, and considering the high detection rate of taeniid infections, altogether this indicates that despite good care and nutrition, cats maintain their hunting habits. Our study additionally showed that mixed infections are significantly more frequent in stray cats, in particular combined infections with *T. cati* and taeniids ($n = 37$), or *T. cati* and capillarids ($n = 12$), or the combination of all three of them ($n = 6$) (results not shown). Also cats infected with lungworms were frequently co-infected with intestinal parasites (with *T. cati,* n = 3; with taeniids, n = 3; with both of them, n = 3). Furthermore, the cestodes *Dipylidium caninum* and *Diphyllobothrium latum* and hookworms were detected in a limited number of stray cats only. All these parasites include intermediate and paratenic hosts in their life cycle, i.e. fleas, fishes, rodents or earth worms, which are possibly more accessible and attractive to stray than other cats. A broader diet based on a wide range of different preys is therefore supporting stray cats to be at higher risk for infections.

In the here examined shelter cats cestode and nematode infection rates were not significantly different from those in owned cats. Robben et al. (2004) found a prevalence of gastrointestinal parasites of 52.5% in shelter cats in the Netherlands, which is higher than the one found in shelter cats of our study (21.8%). A possible explanation is the rigorous anthelmintic treatment plan in the participating shelters of our study, as every cat entering the shelter was dewormed. However, anthelmintic treatments do not affect protozoan infections, and this may explain the high percentage of cats positive for *Isospora* sp. (8.6%). This would as well apply for *Giardia* sp. cysts. The occurrence of *Giardia* sp. in our study is most likely underestimated, as we only used the sedimentation/flotation technique, with a lower sensitivity compared to coproantigen detection [17,36] or the Sodium acetate-Acetic acid-Formalin-Concentration (SAFC) technique [37]. Overall, *Isospora* sp. was the most frequent protozoan parasite and significantly more frequent in stray cats, while other protozoa were rare. *Giardia* sp. is frequently identified as the most common protozoan parasite [36,38], though its clinical relevance in asymptomatic cats remains questionable [39] and its zoonotic importance is limited, as cats are more frequently infected with cat specific isolates [40]. In contrast, cats (and wild felids) are the only source of *T. gondii* oocysts, responsible for contamination of the environment. *Toxoplasma gondii* is a higly prevalent zoonosis worldwide and relevant for immunocompromised individuals and for foetuses during primary infections in women. In our study, a total of four cats were excreting *T. gondii* oocysts, while three cats were excreting the morphologically similar *H. hammondi* oocysts, which are not known to produce disease neither in animals nor in humans. Interestingly, the four confirmed *T. gondii* positive cats were all owned cats and therefore in closer contact with humans than i.e. stray cats, potentially representing a high zoonotic potential. With an infection rate of at least (without considering the two not specified isolates) 1.3% (CI: 0.4–3.4%) in owned cats, this rate was more than ten times higher (0.11%, CI: 0.07–0.16) than the one determined in a comprehensive study including over 24′000 cats from Germany and other European countries [41]. In a previous study from Switzerland, only one of 252 analysed cats (i.e. 44 stray cats, 171 pet cats, 37 cats with gastrointestinal disorders) was shedding *T. gondii* oocysts, corresponding to a prevalence of 0.4% (95% CI: 0.0–2.2%) [42]. In another study from Germany a prevalence of 0.77% (CI: 0.60–0.98%) was observed, however no molecular differentiation between *T. gondii* and *Hammondia* was performed [36]. In further previously mentioned studies, no *T. gondii*-like oocysts were identified [6,7,20,43]. The reasons for these discrepancies are unclear, but could be searched in the short patency of *T. gondii,* and difficulties in detecting and identifying these small oocysts in faecal samples. In a similar manner, also *Sarcocystis* sp. sporocysts were observed in 0.2% (our study) – 0.3% of cats [36], while not described in the other studies.

Comparing data about the correlation of age, gender or neutering status with positivity for parasitic stages is complex. There is, like in the presented study, a general trend of higher parasitic detection in animals of younger age [1,17,19,20,36]. Single studies described young age as a risk factor especially for *T. cati* infections [6,18], others for lungworm infections [7,44], while in others studies, cats older than one year were more frequently infected with lungworms and/or hookworms [6,18,19]. The lifestyle may account fundamentally for these differences, as outdoor cats were constantly found at higher risk than indoor cats [6,18,20,30], a fact directly correlated to higher prevalences in stray cats, which all have outdoor access with contact to infected intermediate or paratenic hosts. This contributes to explain the absence of significant age differences in the stray cat population of our study, in opposition to owned cats younger than one year, being more frequently infected than older cats. Age may have an influence on hunting success, with older cats having more experience, but younger cats being more curious for preys and more successful due to higher agility.

In our study, there is interestingly a significant difference between males and females, with latter ones being overall more frequently infected with parasites; however, subdividing the analysed cats into the three subgroups (stray, shelter, owned), this difference was no longer significant, reflecting the frequent findings of an absent gender difference [7,18,19,30]. The difference obtained when analysing the neutering status of cats, with intact animals (overall, and among owned cats) more frequently infected with parasites, is attributable to the population of stray cats (all intact) and the fact that owned cats are mostly neutered, but the ones that are not neutered are contemporaneously more frequently infected with parasites: these animals are probably hunting more and are also less under owner control and not i.e. subject to deworming treatments, comparably to stray cats. However, no data on anthelmintic treatments were obtained for this study.

For organisational matters the samples were collected over two different time periods with an interruption of 18 months: as we are not aware of factors that could have influenced the infection rates meanwhile we did not consider the two sampling periods separately. Instead, investigating different cat populations using differing diagnostic methods represents an important limitation when comparing data of different studies. The adopted techniques and the quality and quantity of the faecal material used for examination are relevant, leading to varying sensitivities and specificities. As an example, for the detection of lungworm infections Lacorcia et al. [45] compared different methods using the Baermann technique as the reference allocating to this method a 100% sensitivity, while Olsen et al. [46] compared the Baermann technique with a new lung digestion method performed after necropsy, obtaining a sensitivity of 87% for the same technique. In our study, we had a very limited amount of faecal material especially from stray cats, and in these cases we only performed a sedimentation/flotation method. Interestingly, although the Baermann technique is usually considered superior, in a previously performed study in Italy all 40 cats positive for *A. abstrusus* by the Baermann technique were confirmed also by flotation with zinc sulfate solution with a specific gravity of 1.350 [2]. Evidently, all these methods depend on L1 shedding in faeces, which is not the case for serological methods detecting i.e. antibodies and which are very useful for epidemiological studies [33].

5. Conclusion

The results of this study confirm the presence of the most common intestinal parasites and lungworms in Swiss cats and highlight the fact

that the stray cat population is principally contributing to environmental contamination and, therefore, directly or indirectly through intermediate and paratenic hosts, to infections also of shelter and owned cats. As a result of the close contact between these latter animals to their keepers and owners, a risk of transmitting zoonotic parasites needs to be considered, underlining the importance of regular faecal examination and anthelminthic treatments, as advised e.g. by ESCCAP (European Scientific Counsel Companion Animal Parasites, www.esccap.org) and other organisations promoting a healthy cohabitation between pets and their owners.

Acknowledgements

The authors thank the organisation NetAP (Network for Animal Protection) for allowing EZ to accompany them during neutering campaigns of stray cats to collect samples. The technical support of Francesca Gori, Stefan Müller, Nina Gillis-Germitsch and the team of the Diagnostic Unit of the Institute of Parasitology at the Vetsuisse Faculty of the University of Zurich is gratefully acknowledged. We also want to thank Dr. Felix Grimm for his help with the biomolecular methods. Furthermore, the authors wish to thank the animal keeper teams of the participating shelters and of the Animal Hospital at the Vetsuisse Faculty of the University of Zurich for collecting faecal samples.

Conflict of interest

The authors have no conflict of interest to declare.

Funding

This work was partially supported by a grant from Bayer Animal Health GmbH.

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