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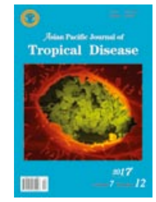

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A comparative study of helminths of raccoon dogs (*Nyctereutes procynoides*) and red foxes (*Vulpes vulpes*) sharing the same territory

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ABSTRACT

Objective: To compare the helminth fauna of raccoon dogs (*Nyctereutes procynoides*) and red foxes (*Vulpes vulpes*) originating from the Uckermark distict, a rural area in the northeastern part of Germany.
Methods: Internal organs of 101 legally hunted raccoon dogs and 144 red foxes were examined for helminths by helminthological dissection.
Results: In total, 18 helminth species were detected of which 14 were present in raccoon dogs and 17 were detected in red foxes. In both host species, *Mesocestoides litteratus*, *Uncinaria stenocephala* and *Toxocara canis* occurred in comparably high prevalences. Significant differences in prevalence were seen in *Isthmiophora melis* and *Alaria alata* that were more often diagnosed in raccoon dogs and *Taenia polyacantha* that was more frequent in red foxes. *Echinococcus multilocularis* was present in both hosts in low prevalence.
Conclusions: Both canid hosts sharing the same territories have a similar helminth spectrum. Differences in prevalence and abundance can be explained with distinct.

1. Introduction

Originating from east Asia raccoon dogs were captured, translocated and returned to the wild as fur animals in the European part of the former Soviet Union between 1927 and 1957. As a result, stable population of this mammal developed in the Ukraine, Belarus and the Baltic republics. Unseen, raccoon dogs migrated west and first specimens were seen in Germany in the 1960th and until 1987 only 58 specimens were hunted in the former GDR[1,2]. In the following years, the hunting bag of raccoon dogs increased rapidly and peaked in the hunting year 2007/2008 to more than 35 000 individuals with the majority bagged in federal countries of Mecklenburg-Pommerantia and Brandenburg[3].

The first study of raccoon dog parasite in Germany was based on 13 carcasses and revealed the presence of 9 endoparasite species that are also common in red foxes in Middle Europe and suggested that raccoon dogs might be hosts for dangerous zoonotic helminths[4]. With findings of *Echinococcus multilocularis* (*E. multilocularis*) and *Trichinella spiralis* (*T. spiralis*) in a further study the role of the raccoon dog as reservoir for zoonotic diseases was proven[5].

There are only few studies in which parasites of raccoon dogs and red foxes originating from a common territory had been comparatively examined[6-8]. The aim of this paper is to compare the helminth fauna of raccoon dogs and red foxes sharing the same environments in the Uckermark district in Germany.

2. Materials and methods

2.1. Origin of the material

The Uckermark, situated in the nort-eastern part of the Brandenburg state, some 60 km north of Berlin, is Germany's biggest rural district covering a territory of 3 058 km^2. The surface of the Uckermark was formed during the last ice-age and is

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characterized by terminal moraines with a maximum altitude of 330 m. The River Oder with its polders borders the Uckermark district from Poland. Apart from smaller streams (Ucker, Randow and Welse) and melioration canals there are a number of lakes and ponds concentrated in the southern half of the district. The total share of surface waters amounts to 4.9%. Roughly two thirds of the area are in agricultural and forestal use. Crop fields with raps, wheat and corn account to 49%, grassland to 10% and forests to 24%. The material of our investigation consisted of internal organs of 101 raccoon dogs and 144 red foxes that were shot, trapped or found dead as a result of animal vehicle crashes. Composition of the material (habitat, sex, age) is shown in Table 1.

Table 1

Habitat, sex and age of 101 raccoon dogs and 144 red foxes from Uckermark district of Brandenburg state examined for parasites.

Category		No. of racoon dogs	No. of Red foxes
Habitat	Forest/crop fields	48	94
	Forest/grassland	28	29
	Oder meadow	25	21
Sex	Male	47	79
	Female	54	65
Age	Juvenile	68	45
	Adult	33	99

2.2. Parasitological procedures

Carcasses of 101 raccoon dogs and 144 red foxes were submitted to the State Veterinary and Food-Control Institute in Frankfurt (Oder). The sender provided information about the origin of the animal and habitat. Age group (adult or juvenile), sex (male or female) was also provided. Internal organs (small intestine, liver, lungs, heart) were removed packed in plastic bags and stored at –18 °C. Examination concentrated on fresh carcasses with complete and intact organs. Only in two sets of raccoon dogs, lungs and hearts were missing. Prior to examination samples were defrosted and rinsed with water to remove blood.

Scrapings from tracheal mucosa were taken and examined for the presence of helminth eggs. With the aid of a syringe 15–20 mL of water was injected into the trachea and trachea and larger bronchi were opened by scissors and washed with tap water. Heart and pulmonary arteries were opened and rinsed with tap water in a large Petri dish. Livers and gall bladders were examined separately for trematodes. For this, liver lobes were cut into 1 cm wide slices, put into water in a large Petri dish and by taking these slices between two fingers flukes were pressed out of the bile ducts. After removal of remnants and discharge of the supernatant flukes were determined and counted. Gall bladders were rinsed with tap water. When no flukes were present the sediment was checked for trematode eggs under a microscope (magnification 100×). Intestines were separated from mesentery and kept at –80 °C for 1 week in order to kill Taeniidae eggs. After thawing, large intestines were separated and its mucosa was checked for helminths and their development stages. Prior to opening of the small intestine its content was flushed with 300–500 mL tap water into a beaker. After a sedimentation time of 20 min the supernatant was discharged and water was refilled. Depending on the content this process was repeated 3–10 times until all food remnants were washed off and the supernatant remained clear. Helminths of each individual host in the sediment were determined by morphology and counted. Most of the scolizes of Taeniidae had incomplete numbers of hooks and few of them [mostly *Taenia crassiceps* (*T. crassiceps*)] lost hooks completely. Nevertheless, differentiation was possible by the diameter of the rostellum and width of the stobila. Differentiation between the two ascarid species was based on the structure and shape of cervical wings and characteristic features of eggs in the distal part of the uterus and the posterior end of male nematodes. However, in juvenile adults that were present in juvenile foxes, differentiation was difficult and for this reason both species were listed together as ascarids.

2.3. Statistical treatment of the data

Prevalence and abundance and their 95% confidence intervals for different parasite species in the two hosts, in different age groups, sexes and habitat were calculated using the software package Quantitative Parasitology 3.0 (QP WEB)[9].

2.4. Ethical statement

Raccoon dogs and red foxes are subject to the Federal Hunting Law of Germany where §22 regulates the closed season. According to the regulation of the implementation of the Hunting Law for the Federal State of Brandenburg hunting on raccoon dogs and red foxes is allowed the whole year trough. Red foxes with offspring have to be spared until the independence of offspring. Raccoon dogs and red foxes were hunted by licensed hunters. Their carcasses were sent to the State Veterinary and Food-Control Institute primarily in connection with a rabies vaccination trial.

3. Results

3.1. The helminth fauna of raccoon dogs and red foxes

The total number of diagnosed helminth species of raccon dogs and red foxes in the Uckermark distict of Brandenburg amounted to 18 [7 trematodes: *Isthmiophora melis* (*I. melis*), *Opisthorchis felineus* (*O. felineus*), *Metorchis bilis* (*M. bilis*), *Pseudamphistomum truncatum* (*P. truncatum*), *Apophallus muehlingi* (*A. muehlingi*), *Plagiorchis elegans* (*P. elegans*), *Alaria alata* (*A. alata*); 4 cestodes: *Mesocestoides litteratus* (*M. litteratus*), *Taenia polyacantha* (*T. polyacantha*), *T. crassiceps*, *E. multilocularis* and 7 nematodes: *Eucoleus aerophilus* (*E. aerophilus*), *Uncinaria stenocephala* (*U. stenocephala*), *Molineus patens* (*M. patens*), *Angyostrongylus vasorum* (*A. vasorum*), *Crenosoma vulpis* (*C. vulpis*), *Toxocara canis* (*T. canis*), *Toxascaris leonina* (*T. leonina*)]. Most of the examined carnivores carried between 2 and 4 different parasite species with maximum numbers of 9 in a red fox and 8 species in a raccoon dog. The examined organs of each 4 hosts were parasite free (Table 2).

Table 2

Number of parasite species found in raccoon dogs and red foxes from Uckermark district.

No. of parasites species found	No. of racoon dog			No. of red fox		
	Adults	Juveniles	Total	Adults	Juveniles	Total
0	2	2	4	3	1	4
1	3	8	11	8	13	21
2	8	14	22	12	21	33
3	9	17	26	21	7	28
4	8	14	22	22	2	24
5	2	7	9	16	1	17
6	0	3	3	10	0	10
7	1	2	3	4	0	4
8	0	1	1	2	0	2
9	0	0	0	1	0	1

Raccoon dogs and red foxes harbored 13 and 17 helminth species, respectively (Table 3). Parasites with a high and comparable prevalence in both host species were *M. litteratus*, *U. stenocephala* and *T. canis*/*T. leonina*.

While in red foxes, differentiation between the two ascarid species was not possible due to the young age of the nematodes in some foxes, in raccoon dogs only *T. canis* was found.

Table 3

Prevalence and burden of parasites in raccoon dogs and red foxes in the Uckermark distict, Brandenburg state, Germany.

Parasite species	Racoon dog (n = 101)		Red fox (n = 144)	
	Prevlence (%)	Burden	Prevalence (%)	Burden
I. melis	30.69	1-1200	3.47	1-16
O. felineus	1.98	3-13	5.56	1-72
M. bilis	17.82	1-64	18.75	1-80
P. truncatum	0.00	0	0.69	4
A. muehlingi	0.00	0	0.69	5
P. elegans	0.99	2	0.00	0
A. alata	61.39	1-1335	29.86	1-198
M. litteratus	60.40	1-280	68.06	1-345
T. polyacantha	12.87	1-3	38.89	1-98
T. crassiceps	1.98	1-2	4.86	2-46
E. multilocularis	0.99	52	1.39	12-33
E. aerophilus	18.81*	1-8	28.47*	1-18
U. stenocephala	60.40	1-60	72.22	1-164
M. patens	3.96	1-5	0.69	1
A. vasorum	0.00	0	2.08	2-10
C. vulpis	17.00	1-38	6.25	1-4
T. canis/*T. leonina*	32.71	1-38	47.20	1-71

*: Prevalence of *E. aerophilus* is based on detection of Capillaria like eggs in mucosal scrapings.

I. melis and *A. alata* showed significant higher prevalence and abundance values in raccoon dogs (Table 4). *E. multilocularis* and *M. patens* were present in both hosts but with a low prevalence. There was a higher prevalence in the occurrence of *C. vulpis* in raccoon dogs but this difference was not significant compared to foxes. On the other hand, foxes had significant higher *T. polyacantha* prevalence and abundance (Table 4). The percentage of *T. crassiceps* and *O. felineus* infected foxes was also higher but did not significantly differ from those in raccoon dogs. *P. truncatum*, *A. muehlingi* and *A. vasorum* were only found in foxes while *P. elegans* was only detected in a raccoon dog. Only few hosts of both species were infected with these parasites and also in low numbers only.

3.2. Influence of age

U. stenocephala showed in both age groups of both hosts a prevalence of more than 50%. A comparison of prevalence and abundance of parasites in juvenile and adult raccoon dogs did not show significant differences although there was a tendency that adult specimens had higher prevalence and burden of *I. melis* and *M. bilis* while these parameters were higher for *E. aerophilus*, *C. vulpis* and in juvenile raccoon dogs.

Within the examined fox population, significant higher differences in prevalence and abundance were found for *M. bilis* and *E. aerophilus* in adult foxes, while ascarids were more often found in juvenile foxes. More adult foxes were infected with *A. alata* and *M. litteratus* but there was no significant difference in the abundance of these parasite species (Table 5). A comparison of the helminth prevalence between juvenile and adult raccoon dogs showed only a larger, but insignificant difference in the occurrence of *T. canis* (39.7% *vs*. 18.2%).

Table 5

Parasites of red foxes showed significant difference in prevalence and/or abundance between age groups.

Parasite species	Age group	Prevalence (%)		Abundance	
		Average	95% *CI*	Average	95% *CI*
M. bilis	Juveniles	2.2	0.1; 11.8	0.044	0; 1.33
	Adults	26.3s	17.9; 31.6	3.03s	1.49; 6.16
A. alata	Juveniles	6.7	1.4; 18.3	2.18	0.04; 11.2
	Adults	40.4s	30.7; 50.7	10.30ns	6.17; 18.6
M. litteratus	Juveniles	31.1	18.2; 46.6	16.90	6.9; 40.6
	Adults	84.8s	76.2; 91.4	40.40ns	31.8; 53.0
E. aerophilus	Juveniles	4.4	0.5; 15.1	0.066	0; 0.20
	Adults	39.4s	29.7; 49.7	0.929ns	0.65; 1.62
ascarids	Juveniles	66.7	51.0; 80.0	8.07	4.62; 13.9
	Adults	32.2s	23.3; 45.2	2.25s	1.34; 3.86

s: significant, ns: not significant.

Table 4

Parasites of raccoon dogs and red foxes that showed significant difference in prevalence and/or abundance between the two hosts.

Parasite species	Racoon dog				Red fox			
	Prevalence (%)	95% *CI*	Abundance	95% *CI*	Pravalence (%)	95% *CI*	Abundance	95% *CI*
O. felineus	2.0ns	0.7; 7.0	0.16s	0; 0.57	5.6	2.4; 10.7	0.63	0.09; 3.16
A. alata	61.4s	51.2; 70.9	93.2s	59.4; 154	29.9	22.5; 38.0	7.8	4.62; 13.1
I. melis	30.7s	21.9; 65.5	18.8s	5.0; 76.6	3.5	1.4; 7.7	0.18	0.04; 0.66
T. polyacantha	12.9s	7.0; 21.0	0.18s	0.09; 0.3	37.5	29.6; 45.9	4.1	2.81; 6.71
T. crassiceps	2.0ns	0.2; 7.0	0.03s	0; 0.1	4.9	2.0; 9.8	0.49	0.1; 2.28
C. vulpis	17.0ns	10.2; 25.8	1.18s	0.52; 2.36	6.3	2.9; 11.5	0.13	0.06; 0.24

s: significant; ns: not significant.

3.3. Influence of sex

In raccoon dogs, females compared to males seemed to be more often infected with *I. melis* (37.0% *vs*. 23.4%) and *C. vulpis* (20.4% *vs*. 12.8%) but these differences were insignificant. *M. bilis* showed a twice higher prevalence (25.3% *vs*. 10.8%) in male foxes but this difference was not significant.

3.4. Influence of habitat

According to data submitted by the sender places of bagging could be allocated to three major habitats: forest/crop fields, forest/ grasslands and meadows of the River Oder. Raccoon dogs from crop fields and meadows had significant higher *I. melis* and *A. alata* prevalence and abundance compared to red foxes. Red foxes bagged in grassland habitats showed distinct higher *T. polyacantha* and *U. stenocephala* prevalence and abundance compared to raccoon dogs (Table 6). Both raccoon dogs and red foxes hunted in or next to the meadows of the River Oder showed the highest prevalence and abundance of *O. felineus* and *M. bilis* (Table 7).

Table 6

Differences in prevalence and abundance of intestinal parasites between raccoon dogs and red foxes hunted in different habitats

Parasite	Habitat	Host	Prevalence (%)	95% *CI*	Abundance	95% *CI*
A. alata	Crop fields	Racoon dog	56.2	41.2; 70.5s	58.60s	31.6; 120.0
		Fox	30.1	21.0; 40.0	6.31	3.31; 11.5
	Grasslands	Racoon dog	71.4s	53.1; 86.8	198.00s	99.8; 373
		Fox	17.2	5.8; 35.8	4.60	1.24; 12.6
I. melis	Crop fields	Racoon dog	29.2s	17.0; 44.4	34.40s	5.3; 157.0
		Fox	4.3	1.2; 10.6	0.10	0.02; 0.35
	Grasslands	Racoon dog	39.3s	21.5; 59.4	5.54s	2.29; 15.1
		Fox	3.4	0.1; 16.8	0.55	0; 1.66
T. polyacantha	Grasslands	Racoon dog	10.7s	2.3; 28.2	0.18s	0.04; 0.52
		Fox	51.7	32.5; 70.6	2.80	1.5; 5.1
U. stenocephala	Grasslands	Racoon dog	39.3s	21.5; 59.4	3.00s	1.23; 7.96
		Fox	79.3	60.3; 92.0	14.10	7.86; 26.1

Table 7

Opisthorchiid liver flukes (*O. felineus* and *M. bilis*) in raccoon dogs and red foxes bagged in different habitats.

Parasite	Host	Habitat	Prevalence (%)		Abundance	
			Mean	95% *CI*	Mean	95% *CI*
O. felineus	Raccoon dog	Cropfields	0.0	0.0; 7.4	0.00	-
		Grasslands	3.6	0.1; 18.3	0.46	0; 1.39
		Oder meadows	4.0	0.1; 20.4	0.12	0; 0.36
	Red fox	Cropfields	2.1	0.3; 7.5	0.03	0; 0.09
		Grasslands	0.0	0.0; 11.9	0.00	-
		Oder meadows	28.6	11.3; 52.2	4.14	0.48; 17.9
M. bilis	Raccoon dog	Cropfields	10.4	3.5; 22.7	0.92	0.23; 3
		Grasslands	14.3	4.0; 32.7	0.54	0.11; 1.18
		Oder meadows	36.0	18; 57.5	4.12	1.1; 12.9
	Red fox	Cropfields	10.6	5.2; 18.7	0.97	0.3; 2.87
		Grasslands	24.1	10.3; 43.5	1.10	0.35; 4.14
		Oder meadows	47.6	25.7; 70.2	8.60	2.15; 23.3

4. Discussion

Little is known about the parasite fauna of raccoon dogs in the original homelands. From Japan, four trematode, two cestode, twelve nematode and three acantocephalan species were reported[10-12]. Three trematode, one cestode and nine nematode species were detected in raccoon dogs in Korea[13-15]. Forty-six species of helminths were found in raccoon dogs on the territory of the former Soviet Union[16] and a comparison of helminth species in of raccoon dogs from Far-East of Russia, Volga Delta and Europe revealed a total of 54 species[17]. Our results showed that raccoon dogs in the new environment have lost their original helminths and acquired helminths of hosts sharing the same habitats. Differences in prevalence and abundance of these parasites in the two hosts can be explained by their lifestyle and preferred diet. Both host species are not specialized on any particular diet and are food generalists and opportunistic omnivores. In general, the fox is a more active predator and consumes more often vertebrate prey while the raccoon dog frequently eats invertebrates, carrion and plants[18-22].

A study carried out in the state of Mecklenburg-Pomerania that borders to the Uckermark district and has similar geo-ecological features found that voles were the preferred food for red foxes while raccoon dogs consumed more often mice and shrews and only raccoon dogs preyed on amphibians[23]. This explains why raccoon dogs were more often infected with helminths in which life cycle amphibians play a role. In our case these are *I. melis* and *A. alata*. Comparison of the parasite fauna of raccoon dogs and red foxes in Lithuania[6], Denmark[7] and Poland[8] gave similar results.

The triheteroxenous life cycle of *I. melis* includes the pulmonate water snails *Lymnaea stagnalis* as first, and amphibians but also freshwater fish as second intermediate hosts. Regarding the final host, it is of low host specific and was recorded in at least 40 different mammals[24]. Personal experience showed that raccoon dogs in spring patrol roads along spawning waters of amphibians to feed on remnants of frogs and toads killed by cars. A study of amphibian parasites in the Brandenburg state of Germany showed that 36% of frogs harbored echinostomatid metacercariae and 15% were infected with metacercariae of *A. alata*[25].

The first intermediate hosts in the polyheteroxenous life cycle of *A. alata* are planorbid snails. Subsequent cercariae shed by these snails enter the body of tadpoles and become mesocercariae in their body cavity. Adult frogs but also several frog-eating reptiles, birds and mammals serve as paratenic hosts. The adult trematode can develop only in the intestines of canids. The wide range of paratenic hosts is the reason that *A. alata* is also frequently found in red foxes. However, there is a difference in prevalence in prevalence between juvenile and adult foxes. The potential human pathogen *A. alata* came into focus of researchers after repeated finding of its metacercariae in carcasses of wild boars[26,27].

The life cycle of opisthorchiid liver flukes, *O. felineus*, *M. bilis* and *P. truncatum* as well as the heterophyid intestinal trematode *A. muehlingi* includes cyprinid fish as second intermediate hosts. The lower prevalence of *O. felineus* compared to *M. bilis* in both host species can be explained with the rare occurrence of *Bithynia leachii*, the first intermediate host of *O. felineus*. An earlier study of liver parasites showed that nearly 30% of red foxes in the Uckermark district were infected with *M. bilis* and only 4% harbored *O. felineus* but *P. truncatum* has not been detected[28]. Within their major habitats (grasslands, crop fields and meadows of the River Oder there were no big differences in prevalence and abundance of opisthorchiid liver flukes between the two host species. However, animals bagged in the meadows of the River Oder had significant higher prevalence and abundance of *O. felineus* and *M. bilis* compared to those hunted in grasslands and crop fields.

The reason for the low prevalence of *P. truncatum* and *A. muehlingi* might be that carnivores are poor host for these flukes. Out of 1 551 red foxes from Brandenburg state and Berlin only 11 harbored *P. truncatum* and only in low numbers[28-30]. *A. muehlingi* has a wide spectrum of fish-eating birds and mammals as final hosts and were mainly found in gulls, pelicans, cormorants and loons[31]. *A. muehlingi* metacercariae were found in 14% of roach from waters of the city of Berlin[32] and a recent study on fish parasites in the Oder River reported 50%–100% prevalence in vimba, rudd, bleak and bream[33]. The adult stage of *A. muehlingi* was only once diagnosed in a red fox in Germany[34].

P. elegans that was found in one raccoon dog only is an accident parasite of carnivores. It has been reported from dogs, jackals, foxes, raccoon dogs and cats in the former Soviet Union[16] but it is more common in birds and insectivorous mammals and also in reptiles. Mosquitoes and other water related insects are the second intermediate hosts in the triheterogenous aquatic lifecycle. Little is known about *P. elegans* in final hosts in Germany. *P. elegans* was found in 15 out of 114 muskrats trapped in the Brandenburg state[35]. Raccoon dogs and muskrats become infected accidently when ingesting insect larvae while drinking.

The diet of both host species reflected also on the prevalence of *T. polyacantha* and *T. crassiceps* that have rodents as natural intermediate hosts and were more often detected in red foxes showing prevalence of 39% and 5%, respectively compared to raccoon dogs with a prevalence of 13% and 2%, respectively. Also in the comparative studies in Lithuania, Denmark and Poland, red foxes were more often infected with these *Taenia* species than raccoon dogs[6-8]. According to literature data from European countries metacestodes of these cestodes have been found mainly in voles, lemmings and muskrats but not in insectivorous shrews. In a survey carried out in Germany subsequent larval stages were detected only in the common vole (*Microtus arvalis*) and only in low prevalence[36].

Although occurring in low prevalence, *E. multilocularis* as a dangerous human pathogen deserve special attention. As *T. polyacantha* and *T. crassiceps* the so called "fox tapeworm" has a similar spectrum of natural intermediate host. Prevalence in both final hosts were at low levels of 1.0% and 1.4%, respectively. This is comparably low compared to a study carried out in Latvia where the prevalence of *E. multilocularis* in raccoon dogs and red foxes amounted to 8.1% and 17.1%, respectively[37]. The first records of *E. multilocularis* in raccoon dogs in Germany were in two out of 74 (= 2.7%) animals originating from Uckermark and the bordering Barnim district. Both harbored *E. multilocularis* in large numbers[5]. A larger study of *E. multilocularis* including 966 raccoon dogs from northern districts of the Brandenburg state revealed 60 positive cases that were unevenly distributed. The estimated true *E. multilocularis* prevalence for the Uckermark district ranged from 0% to 12%[38]. An uneven distribution of *E. multilocularis* is also known for the fox population in Brandenburg where a high endemic area with a prevalence of 24% is surrounded by an area with low prevalence of 5%[39].

M. litteratus gave a completely different picture. This cestode was found in raccoon dogs and red foxes with a high prevalence (68% and 60%, respectively). While in juvenile and adult raccoon dogs the prevalence did not differ significantly (56% and 70%, respectively) adult foxes harbored *M. litteratus* more frequent than juvenile foxes (85% and 31%, respectively). The life cycle of this cestode is not fully disclosed. *Mesocestoides* larval stages (tetrathyridia) were found in amphibians, reptiles, birds and rodents but it is unclear how these animals became infected. It was believed that cysticercoids found in oribatid mites in a place with high *Mesocestoides* prevalence in foxes were larval stages of this tapeworm[40]. However, own experience showed that oribatid mites measuring less than 1 mm are unable to crack the egg containing paruterin organ of gravid *Mesocestoides* segments. Attempts to infect rodents with oncospheres from paruterine organs failed and none of the rodents developed tetrathyridia[41]. *Mesocestoides* tetrathyridia were found in mice and voles in Germany in the same low percentage as those of *T. polyacantha* and *T. crassiceps*[36]. In a more recent study, tetrathyridia were detected in six out of 257 small rodents in Berlin[42]. Considering this high prevalence in both raccoon dogs and red foxes, it has to be assumed that the life cycle of *M. litteratus* differs from the those of above mentioned Taenia species. It is conceivable that a coprophagic insect (beetle) is involved and that the life cycle is facultative triheteroxenic.

All three detected lungworms are biohelminths and can also be found in dogs. The most dangerous of these nematodes for dogs is *A. vasorum*, the French heartworm. Intense research on the distribution of this nematode in Germany has started only in recent years and were concentrated on dogs[43-46]. The prevalence of coproscopically positive dogs was low in general but reached 7.4% in animals with clinical symptoms[45]. In our material only two foxes harbored *A. vasorum* and none of the raccoon dogs were infected. In the Havelland district in western Brandenburg, 9% of foxes were diagnosed positive for *A. vasorum* but raccoon dogs gave negative results[47]. Also in other studies *A. vasorum* was not detected in raccoon dogs[5,48]. The highest *A. vasorum* prevalence (48.6%) was found in red foxes in Denmark[49]. Since slugs and snails are the intermediate host for *A. vasorum* and frogs can be involved in the live cycle as paratenic hosts, it would be expected that raccoon dogs rather than red foxes would be infected.

C. vulpis that has a similar life cycle with land snails included as intermediate hosts was found in a comparable high prevalence of 17% in raccoon dogs and only in 6% of examined red foxes. For this reason, a low susceptibility or even resistance of raccoon dogs to *A. vasorum* can be suspected.

The hookworm *U. stenocephala* was the most frequent nematode in both host species. Final hosts can acquire the infection by ingesting the infective larval stage or via infected paratenic hosts.

An additional mode of infection is when the infective 3rd stage larva under conditions of sufficient moisture penetrates the skin of the hosts. This would explain why raccoon dogs and red foxes have comparable *Uncinaria* prevalence.

Ascaris were frequent (> 30%) in both host species. Infection routes of *T. canis* were investigated in detail in the middle of last century[50-53]. Under natural conditions it is most likely that adult wild carnivores become infected via rodents functioning as paratenic hosts. There is a good reason for this since *T. canis* DNA was detected in 8 (3.1%) out of 257 mice and voles captured in outskirt districts of Berlin city with high fox densities and, the *T. canis* ELISA seroprevalence in these small rodents added up to 14.2%[42]. The transplacental and transmammary infection explains why juvenile hosts in our study showed higher ascarid prevalence and burdens.

Although it was not subject of our study, it is noteworthy that muscle samples of foxes and raccoon dogs were included in a *Trichinella* survey[53]. Out of 360 samples from raccoon dogs, 5 (1.4%) were positive for *T. spiralis* but all animals from Uckermark district were tested negative. A larger survey that included muscle samples from 1 527 raccoon dogs hunted all over the Brandenburg state revealed a prevalence of 1.9%[54]. This study also detected *Trichinella britovi* and *Trichinella pseudospiralis* apart from the more common *T. spiralis*. Red foxes showed a lower *Trichinella* prevalence. Out of 7 103 tested foxes from all over Brandenburg state *T. spiralis* was found only in 5 (0.07%) animals[55].

Raccoon dogs and red foxes sharing the same habitats have a similar helminth spectrum. Differences in helminth prevalence and abundance can be explained with different lifestyle, food preference and utilization. Both hosts are sources for helminto-zoonoses, like alveolar echinococcosis, opisthorchiidosis, toxocarosis (larva migrans visceralis), alariosis and are a reservoir for trichinellosis.

Conflict of interest statement

We declare that we have no conflict of interest.

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