

Prevalence of intestinal nematodes of red foxes (*Vulpes vulpes*) in north-west Poland

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Research

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Abstract

Background: The red fox (*Vulpes vulpes*) is a widely distributed animal in the world. This wild carnivore is also a common host of several dangerous zoonotic parasites, primarily nematodes. Nematodes of red foxes, such as *Toxocara canis* and *Uncinaria stenocephala*, can cause numerous health problems in humans and domesticated animals. The aim of the study was to determine the parameters of occurrence of nematodes in red fox (*Vulpes vulpes*) in north-western Poland.

Methods: The study was carried out in north-western Poland. The research material consisted of 620 red foxes (*Vulpes vulpes*). Parasitological sections of the foxes were taken using the sedimentation and counting technique.

Results: The prevalence of infestations with nematodes was 77.3%, while the mean infection intensity was 20.1 per animal. The presence of *Toxocara canis*, *Toxascaris leonina*, *Uncinaria stenocephala* and *Trichuris vulpis* was noted. The greatest prevalence was presented by *Uncinaria stenocephala* (34.0%). Male and female foxes displayed a similar prevalence of nematodes. Their presence was recorded in the duodenum, jejunum, ileum and caecum of the foxes, and they were significantly more common in the jejunum than in other parts. The most commonly-observed coinfection was between *Uncinaria stenocephala* and *Toxocara canis*.

Conclusions: It can be seen that nematodes are present in high numbers among foxes in north-western Poland. This phenomenon certainly contributes to an increased risk of transmission of parasites to humans and domestic animals, and this can represent a threat to health and even life.

Background

The red fox (*Vulpes vulpes*) is a widely distributed animal in the world (1). From the late 20th century to the first decade of the 21st century, a rapid increase in the number of red foxes has been observed in many European countries (2, 3, 4). The increase in the distribution and density of the red fox in most European countries could be explained by a mortality rate reduction, which is due to an intensive campaigns of vaccination against rabies as well as to the opportunist behaviour of this species (2).

The growth of the fox population has resulted in it expanding to find new habitats. The presence of infected foxes in urbanized areas increases the risk of contact with domestic dogs, and thus a greater risk of infection to humans (5, 6, 7). Infected foxes living in urban and suburban areas can pollute sandpits, parks and squares with their faeces, exposing people to contact with *Toxocara canis* eggs, together with other zoonotic nematode species such as *Toxascaris leonina*, *Trichuris vulpis* and nematodes from the Ancylostomatidae family (8, 9, 10, 11, 12).

Toxocariasis is considered to be the most widespread helminth zoonosis in developed countries. Toxocariasis is responsible for the *visceral* and *ocular larva migrans* syndrome (3, 13, 14). In humans, as paratenic hosts, larvae of *Toxocara canis* do not develop into the adult stage, but migrate throughout the tissues and remain there as L3 arrested larvae for an extended period of time (15).

The number of seropositive cases in children is closely related to the economic status of countries and regions. The prevalence of anti-*Toxocara canis* serum antibody has been estimated at 1–6% in Japan, 2–4% in Denmark, 6% in Austria, 7% in Sweden, 14% in the USA, 22% in Iran, 81% in Nepal (16). Serological tests have revealed the presence of antibodies in a significant percentage of the population in Poland, with the percentage of seropositive people ranging from 18.6–43% depending on the region (17, 18).

The presence of *Toxascaris leonina* and *Trichuris vulpis* nematode larvae in the human body may cause the same symptoms as the presence of *Toxocara canis* larvae (2, 19). Another potential threat to humans is posed by nematodes of the Ancylostomatidae family, such as *Ancylostoma caninum* and *Uncinaria stenocephala* (20). In humans, the invasive larvae of hookworms penetrate the skin and induce symptoms of *larva migrans cutanea* syndrome (21).

Previous findings, the growth in the fox population and the increasing number of diagnoses of parasitic diseases for whom foxes act as a reservoir, emphasise the need for further research into the helminth fauna of these predators. Therefore, the aim of this present study was to determine the parameters of occurrence of nematodes in red fox (*Vulpes vulpes*) in north-western Poland.

Methods

The study was carried out in north-western Poland. The research material consisted of 620 red foxes (*Vulpes vulpes*) (236 females, 384 males) obtained as part of a reduction shooting programme.

The research on foxes was carried out using security measures recommended by the WHO (1984). The corpses were frozen at -70 °C to eliminate the invasiveness of *Echinococcus multilocularis* eggs. After four days, parasitological sections of the foxes were taken using sectional methods described by Eckert et al. (22, 23). During sectioning, the small intestine of foxes was isolated and divided into three sections (duodenum, jejunum, ileum) and the sex of the animals was identified based on the gonads. Nematodes were identified according to Stefański and Żarnowski (24) and preserved in 70% alcohol.

The Jaccard coexistence index (J) (25) was used to compare the coexistence of particular species of nematodes, where the feature is the presence of the species in the sample (environment). The values of the indicator will be 100% in cases when two analysed species of nematodes are always found to co-occur, regardless of their number, and 0% when these two species are never observed together.

where: J_{p1p2} - co-existence index between species p1 and p2; a - the number of occurrences of species p1; b - number of occurrences of species p2; c - number of common occurrences of species p1 and p2 in the habitat.

Relative density was calculated as the arithmetic mean of the number of individuals of a particular parasite species per host examined.

The obtained results were analysed using Statistica 10.0. The significance of any differences in the occurrence of individual nematode species with regard to the sex of the host was determined using the Mann-Whitney U-test. The significance of any differences in the occurrence of nematodes in individual sections of the gastrointestinal tract was determined using the Kruskal-Wallis test.

Results

The prevalence of nematodes was 77.3%, while the mean infection intensity was 20.1 per animal. Our data confirm the presence of *Toxocara canis*, *Toxascaris leonina*, *Uncinaria stenocephala* and *Trichuris vulpis* among the tested foxes. Of these, *Uncinaria stenocephala* was the most prevalent nematodes (34.0%) and an intermediate intensity of infection (20.7 per host) (Table 1).

Table 1
Parameters of occurrence of nematodes in red fox

Parasite	Number of Parasites	Number of foxes infected / tested	Prevalence (%)	Intensity of infection		Relative density
				Mean	Range	
<i>Toxocara canis</i>	2284	187/620	30.2	12.2	1–84	3.7
<i>Toxascaris leonina</i>	2747	163/620	26.3	16.9	1–97	4.4
<i>Uncinaria stenocephala</i>	4362	211/620	34.0	20.7	1–96	7.0
<i>Trichuris vulpis</i>	221	74/620	11.9	3.0	1–15	0.4
Nematodes (total)	9614	479/620	77.3	20.1	1-140	15.5

The most common nematode observed in males was *Toxocara canis* (32.0%), while *Uncinaria stenocephala* (37.7%) was most common in females; this difference in prevalence was not statistically significant. In both males and females, the highest mean intensity of infection was by *Uncinaria stenocephala*, which displayed higher intensity in females (21.7 individuals) than males (19.9 individuals). This difference, however, was not statistically significant (Table 2).

Table 2
Incidence of nematodes in red foxes with regard to sex of host

Parasite	Sex of host	Number of Parasites	Number of foxes infected / tested	Prevalence(%)	Mann-Whitney U-test value	Intensity of infection			Relative density
						Mean	Range	Mann-Whitney U-test value	
<i>Toxocara canis</i>	♂	1477	123/384	32.0	Z=-0.44 p = 0.660	12.0	1-84	Z=-1.37 p = 0.172	3.8
	♀	807	64/236	27.1		12.6	1-73		3.4
<i>Toxascaris leonina</i>	♂	1677	106/384	27.6	Z=-0.44 p = 0.662	15.8	1-65	Z=-0.80 p = 0.423	4.4
	♀	1070	57/236	24.2		18.8	1-97		4.5
<i>Uncinaria stenocephala</i>	♂	2428	122/384	31.8	Z=-0.58 p = 0.560	19.9	1-96	Z=-1.69 p = 0.091	6.3
	♀	1934	89/236	37.7		21.7	1-91		8.2
<i>Trichuris vulpis</i>	♂	112	42/384	10.9	Z=-0.22 p = 0.828	2.7	1-15	Z=-1.08 p = 0.280	0.3
	♀	109	32/236	13.6		3.4	1-15		0.5
Nematodes (total)	♂	5694	302/384	78.7	Z=-0.97 p = 0.333	18.9	1-100	Z=-0.15 p = 0.878	14.8
	♀	3920	177/236	75.0		22.2	1-140		16.6

The presence of nematodes was noted in the duodenum, jejunum, ileum and caecum of the foxes. They were not observed in the other parts of the digestive tract. In general, significantly the most prevalent nematodes were found in the jejunum than in the duodenum or the ileum (Kruskal-Wallis; H = 96.7; p = 0.000) (Table 3).

Table 3

The occurrence of nematodes in red foxes according to location in the intestine

Parasite	Part of the small intestine	Number of Parasites	Number of foxes infected / tested	Prevalence(%)	Kruskal-Wallis value	Intensity of infection			Relative density
						 Please click here to download the original image file  Click here to Correct	Range	Kruskal-Wallis value	
Nematodes	Duodenum	1399	378/620	61.0	H = 96.7 ^A p = 0.000	3.7	1–28	H = 357.5 ^A p = 0.000	2.3
	Jejunum	6883	504/620	81.3		13.7	1-108		11.1
	Ileum	1332	280/620	45.2		4.8	1–48		2.1
<i>Toxocara canis</i>	Duodenum	414	128/620	20.7	H = 50.6 ^A p < 0.001	3.2	1–23	H = 61.7 ^A p = 0.000	0.7
	Jejunum	1582	161/620	26.0		9.8	1–50		2.6
	Ileum	288	64/620	10.3		4.5	1–25		0.5
<i>Toxascaris leonina</i>	Duodenum	429	122/620	19.7	H = 52.0 ^A p < 0.001	3.5	1–20	H = 88.4 ^A p = 0.000	0.7
	Jejunum	2109	147/620	23.7		14.4	1–79		3.4
	Ileum	209	54/620	8.7		3.9	1–12		0.3
<i>Uncinaria stenocephala</i>	Duodenum	556	128/620	20.7	H = 55.8 ^A p < 0.001	4.3	1–28	H = 109.3 ^A p = 0.000	0.9
	Jejunum	3192	196/620	31.6		16.3	1–72		5.2
	Ileum	614	88/620	14.2		7.0	1–35		1.0
<i>Trichuris vulpis</i>	Duodenum	221	74/620	11.9	H = – p = –	3.0	1–15	H = – p = –	0.4
	Jejunum								
	Ileum								
	Caecum								
Presence of statistical significance:									
a - statistically significant at $p \leq 0.05$; A - statistically significant at $p \leq 0.01$									

A significant difference was observed between the occurrence of *Toxocara canis* in the duodenum and ileum and in the jejunum and ileum (Kruskal-Wallis; H = 50.6; $p < 0.001$), *Toxascaris leonina* in the duodenum and ileum and in the jejunum and ileum (Kruskal-Wallis; H = 52.0; $p < 0.001$), as well as *Uncinaria stenocephala* in the duodenum and jejunum and in the jejunum and ileum (Kruskal-Wallis; H = 55.8; $p < 0.001$) (Table. 3).

In the duodenum, the most prevalent nematodes were *Uncinaria stenocephala* (20.7%) and *Toxocara canis* (20.7%); however, the highest mean intensity of infection was displayed by *Uncinaria stenocephala* (4.3 individuals per host) (Table 3). The most prevalent and the highest mean intensity of infection in the jejunum and the ileum were associated with the occurrence of *Uncinaria stenocephala* (31.6%, 16.3 individuals and 14.2%, 7.0 respectively) (Table 3).

Trichuris vulpis (11.9%) was found only in the caecum (11,9%) (Table 3).

Our findings indicate variation in both the frequency of encountering certain pairs of nematodes and the strength of the relationship between them, measured by the Jaccard index (J). The most commonly occurring pairs comprised *Uncinaria stenocephala* and

Toxocara canis (66 joint occurrences, J = 14,2%), and *Uncinaria stenocephala* and *Toxascaris leonina* (40 joint occurrences, J = 9.7%) (Table 4).

Table 4
Frequency of coexistence of individual nematode species in a single host organism

Parasite	<i>Toxocara canis</i>	<i>Toxascaris leonina</i>	<i>Uncinaria stenocephala</i>	<i>Trichuris vulpis</i>
<i>Toxocara canis</i>	187 ¹	3.8 ³	14.2 ³	6.5 ³
<i>Toxascaris leonina</i>	14 ² (2.3)	163 ¹	9.7 ³	6.7 ³
<i>Uncinaria stenocephala</i>	66 ² (10.7)	40 ² (6.5)	211 ¹	7.2 ³
<i>Trichuris vulpis</i>	18 ² (2.9)	17 ² (2.7)	22 ² (3.6)	74 ¹
1 – the number of foxes in which the species of nematode was found;				
2 – the number of co-occurring nematode species (prevalence);				
3 – the Jaccard coexistence index between the species of nematode (%).				

Discussion

In Europe, the most commonly found gastrointestinal nematode in foxes is *Uncinaria stenocephala* (3, 26, 27, 28, 29). Indeed, *Uncinaria stenocephala* was also found to be the most prevalent species in Polish foxes in the present study. Similar prevalence has been demonstrated in studies in northern and southern Poland (1, 30). However, another studies conducted in western and southern Poland showed a significantly lower prevalence of these nematodes (11–35%) (31, 32, 33).

Its prevalence among foxes varies to a great degree between countries, with considerable prevalence observed in Estonia (84.3%) (34), Lithuania (76.9%) (35) and in Italy (75.4%) (27). However, lower prevalence was observed in Ukraine (27.1%) (36), Romania (15.0%) (37), Czech Republic (10.0%) (2), Switzerland (5.3%) (6) and Norway (1.6%) (38).

In Sweden, the prevalence of *Uncinaria stenocephala* in foxes was found to increase from 39.0% in 2008 to 65.0% in 2010 (39). Similar situations were observed in Denmark, from 68.6% in 2006 to 84.1 in 2013 (26, 40). No such relationship was observed in the present study.

In the present study, prevalence of *Toxocara canis* was higher than *Toxascaris leonina*. A similar tendency was observed by Bieńko (41) in previous studies in the same region. However, higher prevalence of *Toxocara canis* was observed than in the present study (42.3%). Bieńko reports that prevalence of *Toxascaris leonina* infection was found to increase more than 12-fold over the test period. This situation may be caused by the availability of food (rodents) in the environment occupied by the foxes. Okulewicz et al. (42) highlight the role of small rodents in the developmental cycle of these nematodes as paratenic hosts, and note that rodents may significantly contribute to the spread of *Toxocara canis* and *Toxascaris leonina* in the environment. Pucek et al. (43) note that most species of rodent display numerical cycles characterised by periodic and rapid changes in density. In the case of forest mice and voles, the seed years of deciduous species (oak, beech, hornbeam) and weather conditions in the winter season have a direct impact on this phenomenon.

High prevalence of *Toxocara canis* and *Toxascaris leonina* in foxes is also influenced by the increasing number of animals infected with the parasite, the large number of eggs excreted to the environment in the faeces of the hosts, and the considerable resistance of eggs to adverse environmental conditions. Given appropriate temperature and humidity conditions, the eggs are known to remain invasive for at least a year (44). Otranto and Deplazes (45) note that *Toxocara canis* infections are generally higher in young foxes (under 6 months of age), although, a relatively high prevalence rate have also been among adult foxes in endemic territories, representing weak immune status against intestinal.

Higher prevalence of *Toxocara canis* than *Toxascaris leonina* has also been found in other countries, including Denmark (59.4% and 0.6%) (40), Italy (52.6% and 0%) (27), Slovakia (25.8% and 17.5%) (46) and Kyrgyzstan (30.4% and 5.9%) (47). However, a higher prevalence of *Toxascaris leonina* than *Toxocara canis* has been found in some countries, including Sweden (respectively 65.0% and 30.0%) (39), Turkey (65.0% and 20.0%) (48), Greenland (41.8% and 0.0%) (49) and Norway (12.9% and 1.6%) (38). The exceptions are the studies from the Czech Republic, where the prevalence of both species in foxes was equal (2).

The parasite with the lowest prevalence in this study was *Trichuris vulpis*. This was supported by the results of Karamon et al. (1) in Poland, who reported foxes infected with this nematode from 1.3% in south-east Poland to 4.4% in the north of the country. High prevalence have been reported only in southern Poland (64.4%) (50). Interestingly, this parasite was not found in central Poland (51).

In other European countries, the prevalence of *Trichuris vulpis* among foxes varied considerably. 12.3% of tested foxes were found to be infected in Italy (27), 7.0% in Sweden (39), 5.5% in Switzerland (6), 4.8% in Ukraine (36) and 1.6% in Norway (38). However, *Trichuris vulpis*, which is localized in the large intestine, was very often not taken into consideration during post-mortem parasitological investigations because surveillances in foxes were often limited to the small intestine (1).

In the present study, similar levels of occurrence of nematodes were observed between males and females. Similarly, previous studies have also failed to note any difference in occurrence based on sex (2, 30, 52).

Unfortunately, it is difficult to find suitable comparisons for the results of the present study as literature regarding the occurrence of nematodes in individual sections of the digestive tract of foxes is scarce. The nematodes *Toxocara canis* and *Toxascaris leonina* prefer to colonise the duodenum and jejunum, and are significantly less commonly observed in the ileum. *Uncinaria stenocephala* colonises the jejunum far more readily than the duodenum or ileum. One exception of the nematodes studied herein is *Trichuris vulpis*, which was observed only in the caecum, suggesting that this the preferred site of occurrence. Similar prevalence was obtained by Fiocchi et al. (27), in the caecum of seven foxes (12.3%).

Uncinaria stenocephala most commonly occurs with *Toxocara canis* (J = 14.2%) or *Toxascaris leonina* (J = 9.7%). *Toxocara canis* and *Toxascaris leonina* were found to co-occur in only 14 foxes (J = 3.8%). This may indicate that these two species of parasites share an antagonistic relationship or are in competition with each other. The high prevalence of *Toxocara canis* among foxes and pets may lead to a low prevalence of *Toxascaris leonina* and *vice versa* (39). However, Jankovska et al. (2) report the co-occurrence of these two nematode species 70.6% of tested foxes in Czech Republic.

High prevalence of nematode has been observed in foxes inhabiting the region of north-west Poland. A number of studies suggest that the occurrence of geohelminths is associated with climate conditions (temperature, air and soil humidity, mean annual rainfall) that extend the lifespan of their free-living developmental stages (1, 2, 53, 54, 55). The region of north-west Poland is situated close to the sea, has substantial forest cover and a temperate climate, as well as a total annual rainfall of 500–800 mm and a mean annual temperature of 7–9 °C, as well as significant air humidity, indicating that this area supports the development of parasites. These conditions certainly increase the threat to health, and even the life, of humans and their pets by increasing the risk of transmission of parasites; this risk is further increased by the growing numbers of foxes living nearby, which search for new places to live in areas inhabited by humans.

Conclusions

This study has shown that nematodes are present in high numbers among foxes in north-western Poland. This phenomenon certainly contributes to an increased risk of transmission of parasites to humans and domestic animals, and this can represent a threat to health and even life.

Abbreviations

J: the Jaccard coexistence index

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Study conception and design was carried out by AT and BP. Manuscript preparation was carried out by AT, BP, ATM and RP. Laboratory work was performed by AT. All authors read and approved the final manuscript.

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