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# Helminth fauna of the small intestine in the European red fox, *Vulpes vulpes* with notes on the morphological identification of *Echinococcus multilocularis*

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**Abstract.** The small intestines parasite fauna in 561 red foxes from Romania was polyspecific with the predominance of nematodes (91.4%), followed by cestodes (90.7%) and trematodes (15%). The highest intensity of infection was found for cestodes. 3. A total number of 17 species of helminths were found: *Alaria alata, Dipylidium caninum, Echinococcus multilocularis, Mesocestoides lineatus, Taenia polyacantha, T. hydatigena, T. multiceps, T. pisiformis, T. serialis, T. taeniaeformis, T. crassiceps, T. ovis, Ancylostoma caninum, Uncinaria stenocephala, Toxascaris leonina, Toxocara canis* and *Trichuris vulpis*. Ecological niche preference of each parasite species is discussed. A morphological description of *E. multilocularis* isolates from Romania is also given.

**Keywords:** European red fox; Helminths; Romania; *Echinococcus multilocularis.*

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## Introduction

The helminth fauna of the small intestine in the European red fox, *Vulpes vulpes* in Romania was studied only by a few authors and only on a few samples (Gherman et al., 2002; Sikó Barabási et al., 2008; Seres, 2009) and Sikó Barabási et al. (2010) confirmed the presence of *Echinococcus multilocularis* in the foxes in Romania using PCR. The purpose of this paper is to analyze the small intestinal infection with helminths in a large number of samples from foxes and to provide a morphological description of *E. multilocularis* strains from Romania.

## Materials and methods

Between August 2007 and March 2010 we examined small intestine samples from 561 foxes in 15 counties from Transylvania, Romania with various origins (table 1).

**Table 1.** Sources of samples used in this study

| Sources of samples | No of samples |
|---|---|
| county veterinary laboratories | 388 |
| organized hunting | 145 |
| road kills | 28 |
| **Total** | **561** |

Each sample was individually packed and labeled: place of origin, sampling date, age and sex of the animal. For assessing the age of animals we considered: physical development and dentition characteristics (Harris, 1978; Sargeant et al., 1981; Roulichová and Anděra, 2007).

Small intestines were carefully removed from each carcass and subsequently isolated by ligatures (pylorus and ileocecal valve), individually packed and identified. Samples were frozen at -20°C and then placed in freezer at -80°C, 48 hours prior to examination in accordance with international labor protection (Deplazes and Eckert, 1996; Dinkel et al., 1998; Hildreth et al., 2004). Examination of intestinal content was performed according to the methodology described by Deplazes and Eckert (1996; 2001) with the improvements suggested by other authors (Hofer et al. 2000; Duscher et al., 2005; Sikó Barabási et al., 2008). Although the method is time consuming, we consider it necessary because after Dinkel et al. (1998) only 76% of *E. multilocularis* can be found after "classical" necropsy methods. Tackmann et al. (2006) suggest that in case of a weak infection many parasites „could be lost".

The helminths were cleaned three times with sterile distilled water, and after morphological identification and counting, they were deposited in labeled recipients in 10% formalin, or 70% ethanol for further examinations. For the estimation of the intensity of infection with helminths, in each sample the parasites were counted by species and a monitoring system was used:

| | | | |
|---|---|---|---|
| + | = | 1-100 | parasite/sample |
| ++ | = | 101-1,000 | parasite/sample |
| +++ | = | 1,001-5,000 | parasite/sample |
| ++++ | = | 5,001-10,000 | parasite/sample |
| +++++ | = | >10,000 | parasite/sample |

For the morphological identification of *E. multilocularis* the following criteria were considered: shape, size, structure of the scolex with the typical formations (number, form and structure of the rostellar hooks), the presence, shape and contents of the gravid proglotids, shape and orientation of the suckers etc. (Melhorn et al., 1986; Gubányi, 1995; Taira et al., 2003; Eckert and Deplazes, 2004). For defining the ecological niches of the identified helminth species we considered micro-ecological features and the intensity of the infection within the intestinal segments: duodenum, jejunum (sub-divided in three segments, anterior, middle and posterior) and the ileum as described by Caswell (1978) and Nee et al. (1991).

## Results and discussion

From the 561 samples examined, 522 samples (93.0%) were found to harbor helminth parasites (table 2).

**Table 2.** The positive samples distribution by county

| County | Examined | Positive | % |
|---|---|---|---|
| AB (Alba) | 23 | 22 | 95.6 |
| AR (Arad) | 19 | 17 | 89.5 |
| BH (Bihor) | 41 | 39 | 95.1 |
| BN (Bistrița) | 53 | 50 | 94.3 |
| BV (Brașov) | 24 | 23 | 95.8 |
| CJ (Cluj) | 36 | 33 | 91.6 |
| CV (Covasna) | 118 | 110 | 93.2 |
| HR (Harghita) | 41 | 40 | 97.6 |
| HD (Hunedoara) | 15 | 15 | 100 |
| MM (Maramureș) | 37 | 36 | 97.3 |
| MS (Mureș) | 36 | 34 | 94.4 |
| SM (Satu Mare) | 63 | 57 | 90.5 |
| SJ (Sălaj) | 18 | 15 | 83.3 |
| SB (Sibiu) | 18 | 15 | 83.3 |
| TM (Timiș) | 19 | 16 | 84.2 |
| **15** | **561** | **522** | **93.0** |

Helminths distribution by taxonomical group was as follows: trematodes (15%), cestodes (90.7%) and nematodes (91.4%). A total number of 17 species of helminths were found (table 3).

*Trematodes*

A single species of trematode was found, *Alaria alata* (figure 1). Although the intensity of parasitism was relatively low in 70 samples (less than 1,000), in 13 samples it exceeded 1,000 and in one single case it was over 10,000 (mesocercariae).

**Table 3.** Prevalence and intensity of helminth infection in foxes from Transylvania, Romania

| Helminth species | Positive (n) | Positive (%) | Intensity of infection + | ++ | +++ | ++++ | +++++ |
|---|---|---|---|---|---|---|---|
| **Trematoda** | **84** | **15.0** | **39** | **31** | **13** | **-** | **1** |
| *Alaria alata* (Goeze, 1782) | 84 | 15.0 | 39 | 31 | 13 | - | 1 |
| **Cestoda** | **509** | **90.7** | **290** | **114** | **68** | **16** | **21** |
| *Dipylidium caninum* (Linnaeus, 1758) | 83 | 14.7 | 50 | 20 | 12 | - | 1 |
| *Echinococcus multilocularis* (Leuckart, 1863) | 27 | 4.8 | 19 | 8 | - | - | - |
| *Mesocestoides lineatus* (Goeze, 1782) | 161 | 28.7 | 38 | 48 | 40 | 15 | 20 |
| *Taenia polyacantha* (Linnaeus, 1758) | 30 | 5.3 | 24 | 3 | 3 | - | - |
| *Taenia hydatigena* (Pallas, 1766) | 46 | 8.2 | 32 | 8 | 5 | 1 | - |
| *Taenia multiceps* (Leske, 1780) | 26 | 4.6 | 23 | 2 | 1 | - | - |
| *Taenia pisiformis* (Bloch, 1780) | 67 | 12.0 | 45 | 16 | 6 | - | - |
| *Taenia serialis* (Gervais, 1847) | 5 | 0.9 | 5 | - | - | - | - |
| *Taenia taeniaeformis* (Batsch, 1786) | 15 | 2.6 | 15 | - | - | - | - |
| *Taenia crassiceps* (Zeder, 1800) | 28 | 5.0 | 23 | 5 | - | - | - |
| *Taenia ovis* (Cobbold, 1869) | 21 | 3.7 | 16 | 4 | 1 | | |
| **Nematoda** | **513** | **91.4** | **356** | **116** | **38** | **3** | **-** |
| *Ancylostoma caninum* (Ercolani, 1859) | 101 | 18.2 | 65 | 31 | 5 | - | - |
| *Uncinaria stenocephala* (Railliet, 1854) | 82 | 15.0 | 55 | 24 | 3 | - | - |
| *Toxascaris leonina* (von Linstow, 1902) | 12 | 4.6 | 9 | 1 | 2 | - | - |
| *Toxocara canis* (Werner, 1782) | 165 | 29.4 | 98 | 37 | 27 | 3 | - |
| *Trichuris vulpis* (Froelich, 1789) | 153 | 27.2 | 129 | 23 | 1 | - | - |

No significant differences were found between sizes (2-3 x 0.6-0.7 mm) of specimens collected in various localities. The highest prevalence was found in Satu Mare (27%), Bihor (24%) and Maramureş (19%). In 23 samples the last part of the duodenum (27.4%) and in 61 samples (72.6%) the first part of the jejunum were infected. In both cases the mesocercariae were main substrate competitors. Four year old foxes were the most infected (45%). The prevalence of infection was higher in female foxes (54%) as in male foxes (46%) but no statistical difference was found. Milesevic et al. (2004) reported a prevalence of 59% for *A. alata* in Croatia in wild boars. The presence of this parasite red foxes from Europe was identified in several countries: Germany (28.3-29.7%), Austria (18.4%), Poland (76.5-88.0%), former Yugoslavia (64.8%) and Bulgaria (2.1%) (Möhl et al., 2009). The high prevalence of the trematode *A. alata* represents a zoonotic risk. Mesocercariae are known to produce viable muscular cysts in several mammalian hosts (pig, wild boar) (Möhl et al., 2009). Humans can acquire the infection by eating insufficiently cooked meat with mesocercariae (Kassai, 1999).

*Cestodes*

Twelve species of cestodes were identified in our study. *Mesocestoides lineatus* seems to be the dominating species (28.7%), followed by *D. caninum* (14.7%) and *Taenia pisiformis* (12%). Others species had a prevalence of less than 10%. Results of tapeworms infection in foxes were reported by Reperant (2005) who after examination of 267 animals from Switzerland found domination of *E. multilocularis* (45.7%), followed by *Taenia* spp. (40.8%), *Mesocestoides* spp. (6.4%) and *Dipylidium* spp. (1.9%). *Dipylidium caninum* (figure 2) was identified in 83 samples (14.7%). The intensity of infection was between 1-100 cestodes per sample (60%), in a single case the number exceeded 10,000 specimens (1%). The most infected samples were from Sibiu (39%), Braşov (33%), Covasna (23%) and Harghita (22%). 88.50% were isolated from the last part of the jejunum. Four years old foxes were the most infected (43%). The prevalence of infection was higher in female foxes (55%) as in male foxes (45%). The same differences were described regarding the relationship between the intensity of infection in the two sexes by Vervaeke et al. (2005). *Echinococcus multilocularis* (figure 3) was isolated from 27 foxes (4.8%). The intensity of infection was less than 100 cestodes per sample in 70% of the case. In 8 cases (30%) the intensity was between 114 and 312. Teysseyre (2005) considered that the average infection with *E. multilocularis* in the European red foxes is between 50 and 2,000 specimens/sample.

**Figure 1.** *Alaria alata* - mature form

**Figure 2.** *Dipylidium caninum* - gravid proglotids in feces

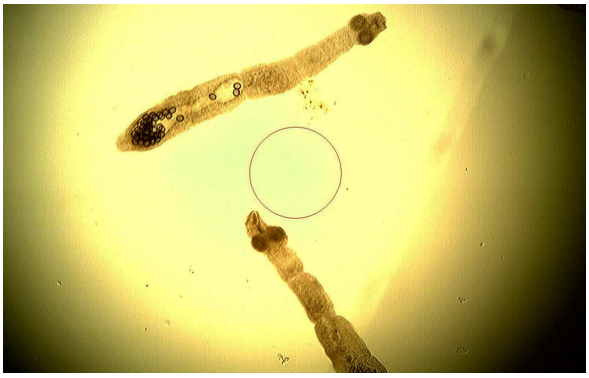

**Figure 3.** *Echinococcus multilocularis* – adults

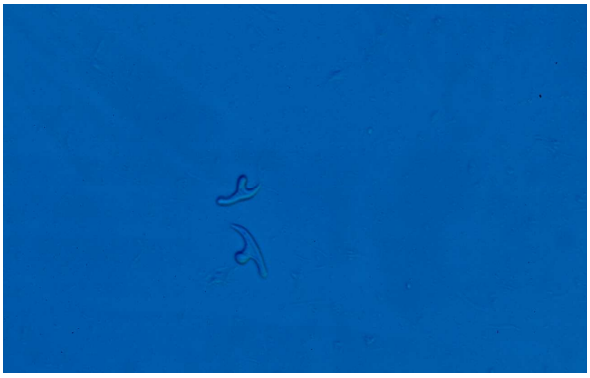

**Figure 4.** *E. multilocularis* – detached small hooks

**Figure 5.** *Mesocestoides lineatus* in the intestinal mucus

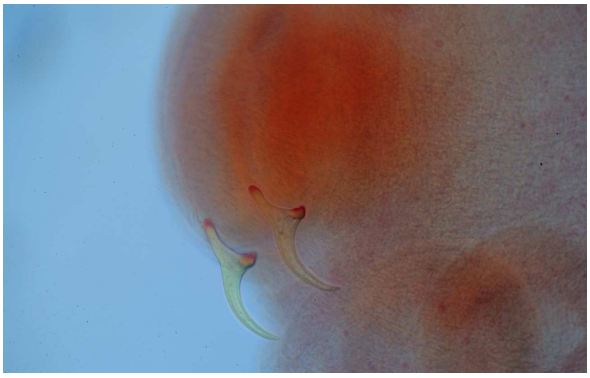

**Figure 6.** *Taenia polyacantha* – rostrum with hooks

During the examination of the 561 samples, 2012 specimens of *E. multilocularis* were collected (table 4). This represents the *E. multilocularis* biomass of the 27 positive samples. From these, 1482 were preserved in formalin and 530 specimens in 70% ethanol for further examinations and analyses, including PCR.

Same results are reported by Knapp et al. (2008), who found a prevalence of 53% after examining 571 red fox intestines from Central Europe. Concerning the intensity of infection, 91% from the samples had less than 10,000 *E. multilocularis*/sample, and in 9% of the foxes the number of the specimens exceeded 10,000/ sample.

**Table 4.** *Echinococcus multilocularis*- regional distribution of positive samples and intensity of infection

| County (+ samples) | GPS location | Altitude (m) | Sex of host | Age of host | No. of *E. multilocularis* |
|---|---|---|---|---|---|
| AR (2) | 46°02'41"N / 21°17'12"E | 141 | F | 3 | 132 |
| | 46°09'12"N / 21°35'47"E | 162 | M | 2 | 226 |
| BH (6) | 46°52'06"N / 22°04'40"E | 190 | F | 3 | 141 |
| | 46°46'02"N / 21°55'30"E | 123 | F | 4 | 198 |
| | 47°03'18"N / 22°11'05"E | 275 | M | 4 | 33 |
| | 46°45'53"N / 22°10'02"E | 197 | M | 4 | 71 |
| | 47°03'05"N / 22°23'53"E | 586 | M | 4 | 312 |
| | 46°47'54"N / 22°11'59"E | 268 | F | 4 | 9 |
| BN (3) | 47°09'59"N / 24°03'54"E | 267 | M | 4 | 3 |
| | 47°13'54"N / 24°15'28"E | 270 | M | 5 | 8 |
| | 47°15'31"N / 24°18'11"E | 286 | F | 3 | 6 |
| CJ (1) | 47°08'43"N / 23°53'29"E | 232 | F | 4 | 12 |
| CV (2) | 45°55'55"N / 25°33'28"E | 475 | F | 3 | 12 |
| | 45°48'46"N / 25°47'05"E | 507 | M | 4 | 22 |
| HG (1) | 46°20'12"N / 25°06'36"E | 448 | F | 5 | 18 |
| MM (4) | 47°34'10"N / 23°26'25"E | 163 | F | 5 | 12 |
| | 47°39'06"N / 23°22'07"E | 150 | F | 3 | 34 |
| | 47°35'06"N / 23°19'37"E | 173 | M | 4 | 56 |
| | 47°31'59"N / 23°17'47"E | 159 | M | 5 | 79 |
| SM (8) | 47°36'28"N / 22°55'48"E | 171 | F | 4 | 2 |
| | 47°51'03"N / 22°52'40"E | 122 | F | 5 | 118 |
| | 47°51'43"N / 22°47'25"E | 117 | M | 3 | 46 |
| | 47°42'02"N / 22°23'38"E | 126 | F | 5 | 51 |
| | 47°53'29"N / 22°49'59"E | 117 | F | 4 | 212 |
| | 47°54'51"N / 22°53'27"E | 119 | F | 4 | 67 |
| | 47°33'39"N / 22°32'56"E | 116 | M | 4 | 18 |
| | 47°48'02"N / 22°45'55"E | 119 | F | 4 | 114 |
| TOTAL | | | | | **2,012** |

This number of *E. multilocularis* recalculated in biomass values represented a total of 175,897 cestodes. Also high values of infection with *E. multilocularis* were reported by Reperant (2005) after the examination of 267 red foxes in Switzerland (45.7%). In the mentioned study, the intensity of infection was between 1 and 120,020 specimens per host. In 88% of the samples, Reperant found less than 100 *E. multilocularis*, in 9.7% of the samples between 1,000 and 55,000 specimens, and in 1.9% had over 55,000 specimens per examined sample. This last category gave 76% of total biomass of *E. multilocularis.*

Regarding the regional distribution of *E. multilocularis* in our study, from 15 sampled counties, only 8 were positive, with 26 localities. The samples with the highest infection intensity rates were from Satu Mare (31%), Maramureş (23%) and Bihor (23%) (table 5). Analyzing geographic conditions from infected areas, it was found that elevation of these areas ranged between 116 m (Căuaş, Satu Mare county) and 586 m (Aleşd, Bihor county). In infected areas average annual temperature was between 9 and 11°C, and average annual rainfall was 700-900 mm. However, the greater quantity of biomass was in case of Bihor (764 *E. multilocularis* in the 6 positive samples), followed by Satu Mare (628 *E. multilocularis* in the 8 positive samples) and Arad (358 *E. multilocularis* in 2 positive samples). In the counties situated near the border with Hungary, the prevalence of *E. multilocularis* is high. According to Sréter et al. (2003) and Széll et al. (2004) this could be justified by the movement of foxes together with the propagation of the parasite. *Echinococcus multilocularis* was isolated from the last segment of the jejunum, where in 59.2% of the cases was main competitor, in 18.6% it was secondary competitor and in 22.2% it was satellite competitor on the nutritive substrate.

The prevalence of infection was higher in female foxes (59%) than in male foxes (41%). Four year old foxes were the most infected (52%).

**Table 5.** *Echinococcus multilocularis* in different counties

| County | Examined | Positive* | Sex** | | Age** (years) | | | | | | Intensity of infection** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M | F | <1 | 1 | 2 | 3 | 4 | 5 | + | ++ |
| AB | 23 | - | - | - | - | - | - | - | - | - | - | - |
| AR | 19 | 2 (8%) | 1 | 1 | - | - | 1 | 1 | - | - | - | 2 |
| BH | 41 | 6 (23%) | 3 | 3 | - | - | - | 1 | 5 | - | 3 | 3 |
| BN | 53 | 3 (6%) | 2 | 1 | - | - | - | 1 | 1 | 1 | 3 | - |
| BV | 24 | - | - | - | - | - | - | - | - | - | - | - |
| CJ | 36 | 1 (3%) | - | 1 | - | - | - | - | 1 | - | 1 | - |
| CV | 118 | 2 (2%) | 1 | 1 | - | - | - | 1 | 1 | - | 2 | - |
| HR | 41 | 1 (2%) | - | 1 | - | - | - | - | - | 1 | 1 | - |
| HD | 15 | - | - | - | - | - | - | - | - | - | - | - |
| MM | 37 | 4 (15%) | 2 | 2 | - | - | - | 1 | 1 | 2 | 4 | - |
| MS | 36 | - | - | - | - | - | - | - | - | - | - | - |
| SM | 63 | 8 (31%) | 2 | 6 | - | - | - | 1 | 5 | 2 | 5 | 3 |
| SJ | 18 | - | - | - | - | - | - | - | - | - | - | - |
| SB | 18 | - | - | - | - | - | - | - | - | - | - | - |
| TM | 19 | - | - | - | - | - | - | - | - | - | - | - |
| **15** | **561** | **27 (4.8%)** | **11 (41%)** | **16 (59%)** | **-** | **-** | **1 (4%)** | **6 (22%)** | **14 (52%)** | **6 (22%)** | **19 (70%)** | **8 (30%)** |

* % from the total number of examined samples
** % from the positive samples

Morphology analysis of *E. multilocularis* samples showed that individuals had 4-5 small segments, with the opening of genital pore in the first third of the mature proglotid. The gravid uterus was sac-like. Most of the *E. multilocularis* specimens were gravid. The eggs from the gravid proglotids ranged in size 30-50 x 44 μm. The average number of eggs in a gravid proglotid was 160-210, which is consistent with the data of Teysseyre (2005) who is setting this number around 200. In a few mature specimens the hooks of *E. multilocularis* were examined, which were situated on the rostrum or detached from this (figure 4). The size of these hooks was: length of large hooks 30.3-30.4 μm; length of anterior third of large hooks 16.3 μm; length of posterior third of large hooks 17.4 μm; length of small hooks 24.5-25.8 μm; length of anterior third of small hooks 8.6-10.5 μm; length of posterior third of small hooks 18.2-19.6 μm. All dimensions are within the ranges given in OIE (2008).

In the infected samples most of the cestodes found were *Mesocestoides lineatus* (28.7%). The adult forms live in the small intestine of the foxes, and the tetrathyridium form mainly in rodents of Microtidae family, mainly i.e. *Microtus arvalis* with an incidence till 1.4% (Loos-Frank, 1980).

The intensity of infection was balanced: 24% from the analyzed samples had 1-100 specimens, 30% between 101 and 1,000 and 25% between 1,001 and 5,000. However, for 20 samples (12%) the number of *M. lineatus* was higher than 10,000 specimens/sample. Most infected samples were collected from Cluj (47%), Covasna (43%) and Braşov (42%). Length of parasites in low infections was 15-28 cm; generally well developed adult forms were isolated (figure 5). They generally have a round, well developed scolex, without rostrum and hooks. In adult specimens the genital pore was observed in the middle third of the mature proglotids. In the gravid proglotids, the eggs are situated in the interior of the parauterin organ, surrounded with a thick wall. In medium and high infections the cestodes had lengths of 8-15 cm and were commonly young forms. Favorable ecological niche for the development of *M. lineatus* was mostly the middle third (67.9%) and posterior third (32.1%) of jejunum. Four year old (39%) female foxes (56%) were most infected.

*Taenia polyacantha* (figure 6) lives in the small intestine of foxes; its larval forms in microtids, mostly in *Arvicola terrestris* and *Clethrionomys glareolus* (Haukisalmi and Hentotten, 1993; Teysseyre, 2005; Cerqueira et al., 2007).

In our study, this parasite was found in 30 samples (5.3%). The infection rate in 80% of the samples was low (1-100). Positive samples were from Maramureş (24%), Satu Mare (21%), Cluj (17%) and Bihor counties (5%). The number of rostellar hooks varies between 52 and 62. Regarding the ecological niche *T. polyacantha* populated in a proportion of 77% the middle third of the jejunum, and in 23% its anterior third. It was mostly satellite competitor. A similar proportion of distribution was described by Seres (2009) namely 78% in the middle third of the jejunum and 22% in the anterior third. Male foxes were more infected (60%).

*Taenia hydatigena* was found in 46 samples (8.2%). This cosmopolitan parasite is found in the small intestine of dogs, foxes, wolves and other wild carnivores with the intermediate host represented by domestic and wild ruminants (Letková et al., 2008). In 67% of the samples, infection was low (<100 cestodes per sample), in 31% infection was between 100 and 5,000 specimens; in a single case intensity was over 5,000. There were no significant differences between the cestode size and intensity of infection. Most infected samples were from Braşov (21%), Sibiu (17%) and Harghita counties (17%). Favorable ecological niche for the development of *T. hydatigena* was the anterior third (in 78.2% of the cases) and the middle part (21.8%) of the jejunum. In both cases in substrate competition this species was within secondary category. Four years old (48%) female foxes (57%) were most infected.

*Taenia multiceps* was present in 26 samples (4.6%). Intensity of infection was under 100 specimens/sample in 88% of the cases. Most infected samples were from Sibiu (17%), Timiş (11%) and Harghita (10%) counties. Favorable ecological niche for the development of *T. multiceps* proved to be the middle third of the jejunum (79.2%) or the posterior third (20.8%). In both cases in substrate competition the species was on secondary category. Four years old (58%) female foxes (42%) were the most infected.

*Taenia pisiformis* was found in 67 samples (12%). Intensity of infection was mostly low, under 100 cestodes per sample (67%). The intensity of infection did not influence the morphology and development of the cestode (Beveridge and Rickard, 1975). Most infected samples were from Harghita (24%), Cluj (19%) and Sibiu counties (17%). The characteristic ecological niche in all cases was the middle third of the jejunum, where in the substrate competition *T. pisiformis* played a secondary role. Four years old (63%) female foxes (49%) were the most infected.

The cestode *Taenia serialis* was identified in only 5 (0.9%) samples collected from Covasna (2), Bistriţa (1), Harghita (1) and Timiş counties (1). Intensity of infection was very low, in all cases under 100 specimen/sample. *Taenia serialis* was uniformly present in the anterior third and middle third of the jejunum, like satellite competitor. Four years old (80%) female foxes (60%) were the most infected.

*Taenia taeniaeformis* is a parasite of the small intestine of foxes with its larval forms in microtid rodents, mostly *A. terrestris* (Pétavy et al., 2003; Reperant et al., 2009). It was identified in 15 samples (2.6%). Intensity of infection never reached 100 cestodes per sample. Most infected samples were from Alba (9%), Bistriţa (9%), Sălaj (6%) and Sibiu counties (6%). Favorable ecological niche for its development was the anterior third (68.3%) and the middle third (31.7%) of the jejunum, where it was a satellite competitor. Female foxes (73%) and three years old (53%) were mostly infected.

*Taenia crassiceps* is parasitic in the small intestine of foxes and the larval development takes place in microtid rodents, mostly *M. arvalis*, producing neurocysticercosis (Rietschel, 1981; Hoberg et al., 1999). The cestode was identified in 28 samples (5%). Intensity of infection in 82% of the cases was low (<100 specimens/sample). Most infected samples were found in Satu Mare (14%), Maramureş (14%), Cluj (11%) and Sălaj counties (11%). Favorable ecological niche for the development of *T. crassiceps* is the middle third of the jejunum (68%) and respectively the anterior third (32%), where commonly they were satellite competitors. Similar results are described by Seres (2009) who found the favorable ecological niches to be the middle

third of the jejunum in 70% of the cases and the anterior third in 30%. Females (61%) and 3-4 years of age foxes (32-32%) are most intensely parasitized.

*Taenia ovis* was found in 21 samples (3.75%), what demonstrates that foxes from infected areas can consume organs from dead sheep. confirming the hypothesis of Flueck and Jones (2006) of a sylvatic cycle. The intensity of infection in 76% cases was <100 cestodes/sample. Most infected samples were collected from Sibiu (28%) and Braşov counties (17%). Favorable ecological niche for the development of *T. ovis* was the distal third of the jejunum, where it was a satellite competitor. Female foxes (52%) around 4-5 years of age (43-43%) were the most infected.

*Nematodes*

*Toxocara canis* (29.4%) had the highest prevalence, followed by *Trichuris vulpis* (27.2%) and other nematodes. The prevalence of different species of nematodes in the red fox varies by geographical area. Reperant (2005) highlights the dominance of *Uncinaria stenocephala* (79.0%), followed by *T. canis* and *Toxocara leonina* (both in total 73.8%) and with a lower prevalence *T. vulpis* (8.6%).

*Ancylostoma caninum* was found in 101 samples (18%), with an intensity of infection of 1-100 nematodes/sample (64%). Most of the infected samples were from Hunedoara (60%), Alba (39%) and Mureş counties (39%). Favorable ecological niche for the development of the parasite was mostly in the middle third of the jejunum, having a secondary role in the substrate competition. Four year old (39%) female foxes (66%) were mostly infected. Prevalence of *U. stenocephala* was 15% with 82 positive samples. The intensity of infection was usually low, with <100 nematodes/sample (67%). Most infected samples were in Mureş (33%), Hunedoara (33%) and Alba (30%). The favorable ecological niche was the posterior third of the duodenum and the anterior third of the jejunum (secondary competitor). Four year old (48%) females (56%) were mostly infected. Vervaeke et al. (2005) found no significant difference between the two sexes.

*Toxascaris leonina* and *T. canis* represents the most important nematodes in foxes from Romania. *Toxascaris leonina* was identified in 12 samples (4.6%). Intensity of infection was predominantly low (in 75% of the samples). Most of the infected samples were from Braşov (8%), Mureş (6%) and Sibiu (6%). Favorable ecological niche for the development of the *T. leonina* was the distal part of the jejunum, where in the substrate competition was a secondary or satellite competitor. Highest infection rates were found in females (58%) and less than 1 year old foxes (59%). *Toxocara canis* was found in 165 (29.4%) of the samples. The intensity of infection was generally low, with <100 parasites/sample (59%); in 64 cases the number exceeded 100 specimens (38.78%) or 5,000 specimens (2%). The highest prevalence was recorded in Harghita (56%), Hunedoara (53%) and Timiş counties (47%). The ecological niche was the first (38%) and the last third (62%) of the jejunum. For the substrate, *T. canis* was competing with *A. alata* (8:2). Most infected category were 4 (36%) and 3 (34%) years old females (54%).

*Trichuris vulpis* was present in 27.2% (n=153) of the analyzed samples. Intensity of infections was generally low, with <100 nematodes/sample (84%). Highest prevalence was recorded in Mureş (44%), Bistriţa (43%) and Bihor counties (41%). The favorable ecological niche for the development of the parasite is the posterior third of jejunum and the ileum where *T. vulpis* was a satellite competitor. Female foxes (54%) of four (35%) and three (34%) years old were the most infected.

Extensive helminth prevalence studied in foxes from Europe were performed by several authors. Di Cerbo et al. (2008) examined 645 foxes from the Italian Alps and found 15 species of parasites with an overall prevalence of 84.5%. Of the 219 foxes examined in Belgium the infection level was 62.6% and in Switzerland (n=267) of 95.1% (Reperant, 2005; Vervaeke et al., 2005). Similar findings were published by Teysseyre (2005) who found 75.4% of the examined red fox with polyparasitism with the dominance of cestodes (50%), followed by nematodes (48%). Eira et al. (2006) showed that for an infection

prevalence of 90.32% the total biomass of helminths was 7,620 and composed of 20 species. A review of epidemiological studies from Central and Eastern Europe is shown in table 6.

**Table 6.** Helminth fauna of *Vulpes vulpes* in Central and Eastern Europe

| Species | Prevalence (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Greece [1,2] | Italy [3,4] | Poland [5,6] | former Yugoslavia [7] | Bulgaria [11] | Germany [8] | Slovakia [9] | Hungary [10,11] | Romania [12,13] | This study |
| Total (n) | 83,6 (314) | 83,7 (283) | 66,1 (165) | (532) | (243) | 66,8 (1300) | (302) | 87,3 (59) | 92,4 (77) | 93,0 (n=561) |
| *A. alata* | 1.6 | | 56.7 | 65 | 2 | | | 48.5 | 31.2 | 15.0 |
| *D. caninum* | 3.2 | 57.3 | | | | 0.2 | 1.99 | 46 | 16.8 | 14.7 |
| *M. lineatus* | 73.6 | 45.4 | 71.2 | 62 | 41 | 54.1 | 61.23 | 73 | 76.6 | 28.7 |
| *T. crassiceps* | 0.3 | | | 51 | 27 | 17.7 | | 7-24 | 68.8 | 5.0 |
| *T. hydatigena* | 0.9 | | | 2 | 0.4 | | | 1 | 10.4 | 8.2 |
| *T. multiceps* | | | | | | | | | | 4.6 |
| *T. pisiformis* | | | | 22 | 1 | 0.15 | | 4 | | 12.0 |
| *T. polyacantha* | | | | 16 | 17 | | | 3 | 59.7 | 5.3 |
| *T. serialis* | | | | | | 0.15 | | 0.6-1 | | 0.9 |
| *T. taeniaeformis* | | | | | | | | | | 2.6 |
| *E. multilocularis* | | | 13.9 | | | | 10.6 | | | 4.8 |
| *Taenia* spp. | | | 29.7 | | | | 20.86 | 2.9-33.8 | | |
| *A. caninum* | 5.1 | | 6.7 | 15 | 6 | | 5.63 | 1-4 | 10-33.8 | 18.2 |
| *T. canis* | 28.6 | 9.1 | 19-34 | 44 | 50 | | 25.82 | 12-26.5 | 20-36.4 | 29.4 |
| *T. leonina* | 2.5 | | 17.55 | | | | | | | 4.6 |
| *T. vulpis* | 8.0 | | 10.3 | 20 | | | 6.9 | 2 | | 27.2 |
| *U. stenocephala* | 43.9 | 39.1 | 25-36 | 44 | 40 | | 1.98 | 11.8-72 | 34-39 | 15.0 |

1.- Haralabidis et al. (2003)
2.- Papadopoulos et al. (1997)
3.- Calderini et al. (2009)
4.- Magi et al. (2009)
5.- Pilarczyk et al. (2005)
6.- Borecka et al. (2009)
7.- Pavlovic et al. (1997)
8.- Pfeiffer et al. (1997)
9.- Letková et al. (2006)
1o.-Takács (2001)
11.-Széll et al. (2004)
12.- Seres (2009)
13.- Gherman et al. (2002)

Prevalence, intensity of infection and spread of parasites in the intestine is in a close correlation. Calderini et al. (2009) showed that in central Italy *Dipylidium* spp. and *Mesocestoides* spp. were codominant in foxes. Eira et al. (2006) draws attention over the association of helminths in the small intestine, like *U. stenocephala* with *T. canis* or *Mesocestoides* spp. with *A. alata*. Caswell (1978) and Hanski (1982) grouped parasites in main, secondary and satellites competitors. Main competitors are usually in small number as species (2-5) but with high intensity of infection (over 1,000 specimens). For secondary competitors there may be more species (4-8) localized in the same intestinal segment but usually with an average intensity of infection (100-500 specimens). Satellite competitors are usually species (2-12), with a reduced intensity of infection in the intestinal segment (1-50 specimens). An overview of our findings is shown in table 7.

**Table 7.** Ecological niches and substrate competition of helminths of foxes in our study

| Ecological niches | Main competitor | Secondary competitor | Satellite competitor |
|---|---|---|---|
| Duodenum | *Alaria alata* | *Uncinaria stenocephala* | - |
| Anterior jejunum | *Alaria alata*<br>*Toxocara canis* | *Taenia hydatigena*<br>*Uncinaria stenocephala* | *Taenia polyacantha*<br>*Taenia serialis*<br>*Taenia taeniaeformis*<br>*Taenia crassiceps*<br>*Toxocara leonina* |
| Middle jejunum | *Mesocestoides lineatus* | *Taenia hydatigena*<br>*Taenia multiceps*<br>*Taenia pisiformis*<br>*Ancylostoma caninum* | *Taenia polycantha*<br>*Taenia serialis*<br>*Taenia taeniaeformis*<br>*Taenia crassiceps*<br>*Toxocara leonina* |
| Posterior jejunum | *Mesocestoides lineatus*<br>*Toxocara canis*<br>*Echinococcus multilocularis* | *Dipyllidium caninum*<br>*Taenia multiceps*<br>*Trichuris vulpis*<br>*Toxocara leonina*<br>*Echinococcus multilocularis* | *Echinococcus multilocularis*<br>*Taenia ovis*<br>*Toxocara leonina* |
| Ileonum | *Trichuris vulpis* | - | - |

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