

Helminth Fauna of Muskrat (Germany)

Subjects: Agriculture, Dairy & Animal Science

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The muskrat is a neozoon species that has occupied many countries of continental North Europe after its introduction from north America as fur animals. Due to its burrowing activity it damages river and canal banks and structures of flood control. For this reason, the eradication of this alien species is recommended. Muskrats are also of parasitological interest since they can act as suitable intermediate hosts for *Echinococcus multilocularis*. On the other hand, little is known on the other helminths that infect muskrats. A total of 130 muskrats of different age groups trapped in different habitats in the Barnim district of the Brandenburg state by a professional hunter were examined for parasites and seven trematodes (*Echinostoma* sp., *Notocotylus noyeri*, *Plagiorchis elegans*, *Plagiorchis arvicolae*, *Psilosostoma simillimum*, *P. spiculigerum*, *Opisthorchis felinus* and four larval cestode species (*Hydatigera taeniaeformis*, *Taenia martis*, *Taenia polyacantha*, *Taenia crassiceps*) were detected. Larval stages of *E. multilocularis* were not found. *O. felinus* was found for the first time in muskrats in Germany. All the named parasites were present in Europe prior to the introduction of muskrats. With a prevalence of 48.9%, *Strobilocercus fasciolaris*, the larval stage of the cat tapeworm, *H. taeniaeformis*, was the most frequent parasite found in adult muskrats.

Keywords: *Ondatra zibethicus* ; helminths ; Federal State of Brandenburg ; Germany

1. Introduction

The muskrat (*Ondatra zibethicus*) is a medium sized semiaquatic, herbivorous rodent which is native to North America and inhabits wetlands, river banks, irrigation channels, lakes, ponds, coastal areas and estuaries. To be protected from predators, muskrats place the entrance to their burrow below of the water level. In shallow water, muskrats construct lodges using plant material. Three female and two male muskrats had been introduced to Bohemia in Czech Republic as fur animal and for hunting purposes. The current muskrat population in Germany is based on these five animals (according to other sources five pairs of muskrats were released ^[1]). Due to its reproduction potential and the migration behavior of this animal species, muskrats had occupied territories in southern Germany already in 1928. Already two years later, muskrats were seen in territories that today belong to Thuringia, Saxony, Saxony-Anhalt and Brandenburg ^[2]. It is documented that muskrats were also released in England but were eradicated later on. Papers on helminth parasites of muskrats in Karelia ^[3] and in Siberia ^[4] suggest that muskrats were also introduced to Russia. Muskrats have also occupied territories in northern Mongolia, north-eastern China, North Korea and Honshu Island of Japan ^[1].

Due to its burrowing activity (it damages river and canal banks and structures of flood control) feeding damage in field crops and feeding on the protected freshwater pearl mussel and other mussel species, the muskrat is listed by the Inventory of Alien Invasive Species in Europe ^[5] as one of the worst invasive species in Europe and is recommended for eradication by the Bern Convention on the Preservation of European Wild Plants and Animals and their Natural Habitats ^[6].

In Germany, foxes, otters, minks, polecats, birds of prey and nowadays raccoons and raccoon dogs are the main predators and this predator-prey-relation reflects on the parasite fauna of muskrats.

Investigations on *Echinococcus multilocularis* in the Brandenburg state of Germany in the 1990s revealed that this zoonotic tapeworm can be found in red foxes ^[7] but the involvement of small mammals as intermediate hosts in the Brandenburg state was not investigated. Already Abuladze ^[8] mentioned findings of larval stages of *E. multilocularis* in muskrats in the 1950th in Russia and listed 42 other intermediate host. Although muskrats are not the first choice of food for red foxes, they might be an indicator for the occurrence of the fox tapeworm since the lifespan of muskrats is longer than that of voles and mice the preferred food of foxes.

The aim of this paper was to examine the helminth fauna of muskrats in the Barnim district of the Brandenburg state of Germany under special attention to cestode metacestodes.

2. Analysis on Results

Of the 130 examined carcasses, 73 contained parasites. Thirty-eight muskrats harbored one parasite species. Two and three different parasite species were found in 27 and 7 muskrats, respectively, and four parasite species were found in a single animal only. Examination of 57 carcasses did not reveal parasites. In 28 (=53.8%) juveniles, 14 (45.1%) subadults and 15 (26.3%) adults no endoparasites were detected.

The endoparasite fauna of muskrats in the Barnim district of the Federal State of Brandenburg consisted of seven trematodes: *Echinostoma* sp. (**Figure 1** and **Figure 2**), *Notocotylus noyeri* (**Figure 3**), *Plagiorchis elegans* (**Figure 4**), *Plagiorchis arvicolae* (**Figure 5**), *Psilotrema simillimum* (**Figure 6**), *P. spiculigerum*, *Opisthorchis felinus* (**Figure 7**) and four larval cestodes (*Hydatigera taeniaeformis* (**Figure 8** and **Figure 9**), *Taenia martis* (**Figure 10** and **Figure 11**), *Taenia polyacantha* (**Figure 12** and **Figure 13**), *Taenia crassiceps* (**Figure 14**) (**Table 1**). Larval stages of *E. multilocularis* were not detected. All trematodes except the bile duct parasite *O. felinus* inhabited the small intestine. Strobilocerci of *H. taeniaeformis* were located in the liver while other metacestodes were found between intestinal lopes in the abdominal cavity.

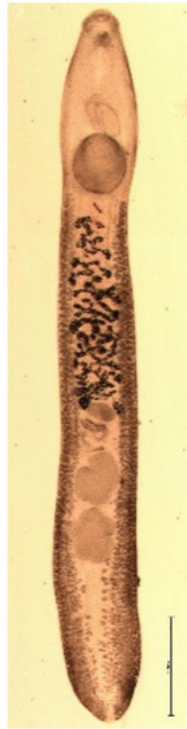


Figure 1. *Echinostoma* sp. total. Bar: 2 mm.



Figure 2. *Echinostoma* sp., anterior end with armed head collar, oral sucker and pharynx. Bar: 200 µm.



Figure 3. *Plagiorchis elegans*. Yolk glands form a bridge prior to the ventral sucker and reach the level of the pharynx. Bar: 500 µm.

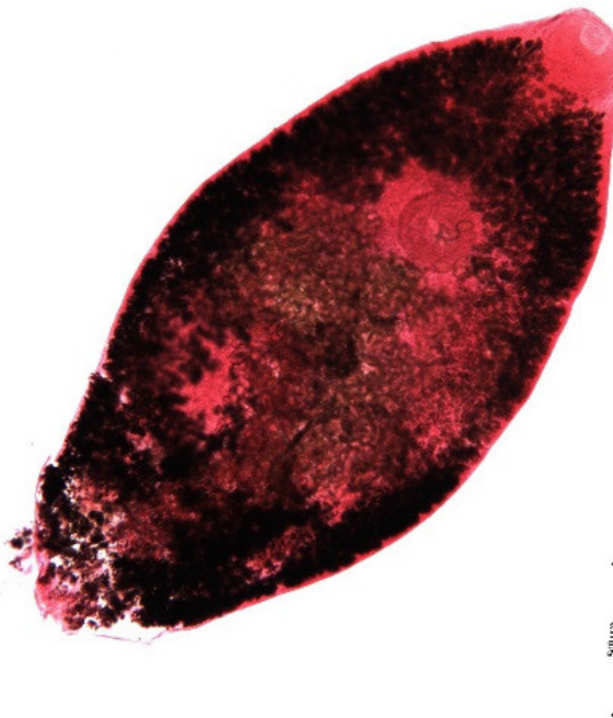


Figure 4. *Plagiorchis arvicolae*. Yolk glands fill most of the body. In unstained fresh specimens the trematode reminds an apple seed. Bar: 500 µm.



Figure 5. *Notocotylus noyeri*. There is no ventral sucker but there are three rows of ventral glands. Testes and ovary are situated at the posterior end. Branches of the uterus reach laterally to yolk glands. Bar: 500 µm.



Figure 6. *Psilosostoma simillimum*. Pharynx and ventral sucker are strikingly larger than oral sucker. Bar: 200 µm.



Figure 7. *Opisthorchis felineus*. Deeply lobed testes are situated at the posterior end. The uterus between ovary and ventral sucker does not overlap intestinal branches.

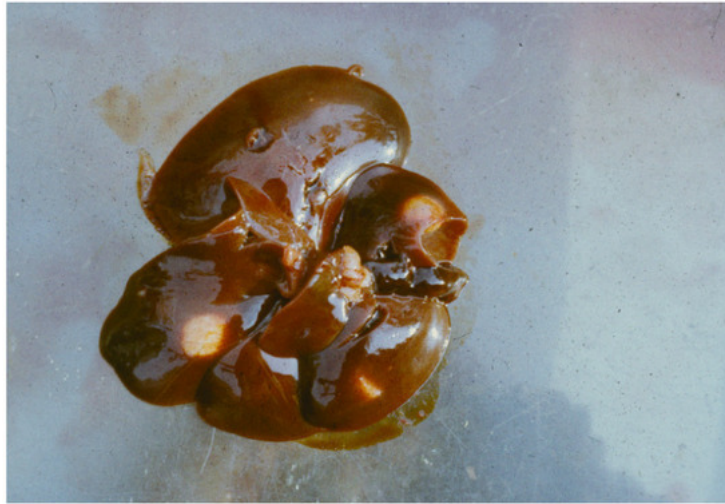


Figure 8. Three cysts of *Strobilocercus fasciolaris* the larval stage of *Hydatigera taeniaeformis* in the liver of a muskrat.



Figure 9. *H. taeniaeformis* scolex.



Figure 10. Larval stages of *Taenia martis* removed from abdominal cavity of a muskrat.

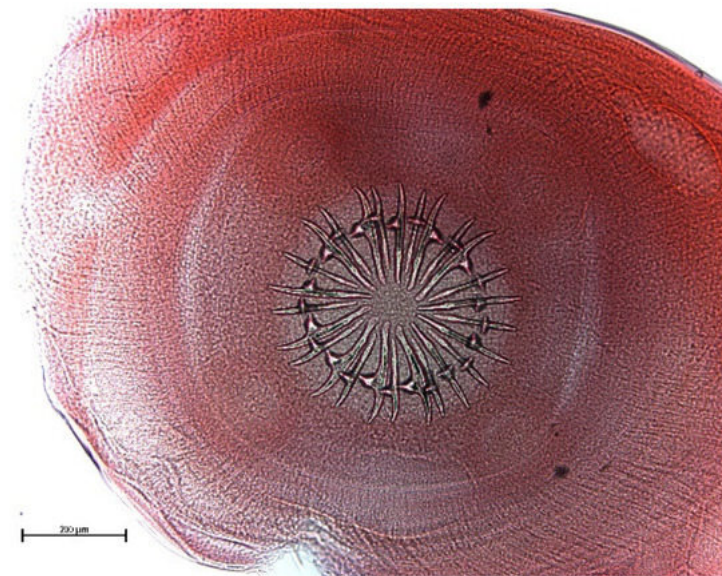


Figure 11. *T. martis* scolex. Bar: 200 μm.



Figure 12. Larval stages of *Taenia polyacantha* removed from thorax of a muskrat.

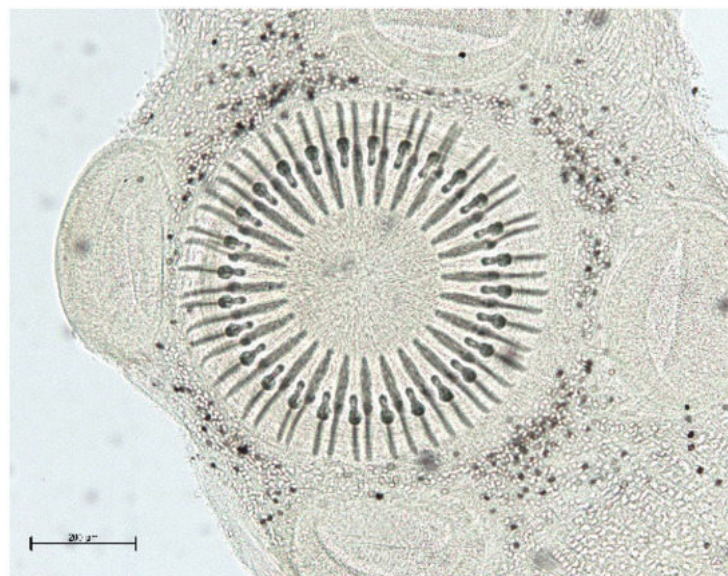


Figure 13. *T. polyacantha* scolex. Bar: 200 μm.



Figure 14. *Taenia crassiceps* scolex.

Of the 73 positive muskrats, 43 were infected with one, 22 with two, 7 with three and one with four helminth species. A total of 40 animals showed Taeniidae metacestodes. Of the 30 cases of liver strobilocercosis, 23 occurred in adult, four in subadult and three in juvenile hosts. In two adult muskrats *H. taeniaeformis* larvae were found in combination with *T. martis* larvae. Eight muskrats (five adults, two subadults and one juvenile) harbored *T. martis*. In addition to the above mentioned mixed infection with *H. taeniaeformis* strobilocerci, another animal showed a combination of *T. martis* and *T. polyacantha*. *T. polyacantha* and *T. crassiceps* metacestodes were found in four and one animal, respectively. All these five muskrats were classified as adults.

Table 1. Helminth findings in muskrats originating from different habitats in the Barnim district.

Habitat	Number of Muskrats Infected with Parasites									
	<i>Echinostoma</i> sp.	<i>Plagiorchis</i> <i>elegans</i>	<i>Plagiorchis</i> <i>arvicola</i>	<i>Notocotylus</i> <i>noyeri</i>	<i>Psilotrema</i> spp.	<i>Opisthorchis</i> <i>felineus</i>	<i>Hydatigera</i> <i>taeniaeformis</i>	<i>Taenia</i> <i>martis</i>	<i>Taenia</i> <i>polyacantha</i>	<i>Taenia</i> <i>cras</i>
Lakes (n = 57)	2	13	0	1	14	0	19	3	3	
Cut off meanders (n = 39)	3	7	0	0	18	1	5	5	1	
Running waters (n = 34)	7	1	1	0	1	0	6	0	0	
Total (n = 130)	12	21	1	1	33	1	30	8	4	

3. Current Insights

The parasite spectrum of muskrats in Europe is relatively poor compared to that of North America. In publications on muskrat parasites from Canada and four US states 35 to 54 different endoparasite species were listed [9]. Examination of helminth fauna of muskrats in the state of Saxony-Anhalt in Germany (n = 80) showed the presence of 15 and 13 different species, respectively [10][11]. In the present material from the Brandenburg State eleven different helminth species were found.

Despite the presence of *E. multilocularis* in final hosts in the Brandenburg state of Germany [7][12][13][14], its larval stage was not detected in muskrats in our material.

The role of muskrats as intermediate hosts of *E. multilocularis* in Germany has been shown in Württemberg (southern Germany) [15] in an area that was known to be endemic for this parasite in foxes [16]. Larval stages of *E. multilocularis* were also found in muskrats hunted in Baden Wuerttemberg [17], Lower Saxony [18], in North Rhine Westphalia [19][20]. In addition, in France, Belgium and the Netherlands muskrats were found to be infected with *E. multilocularis* [21][22][23][24][25].

In our material, larval stages of *E. multilocularis* were not detected. Low prevalence of the adult cestode in final hosts and a relative low number of examined hosts might be the reason.

In the Brandenburg State *E. multilocularis* in red foxes is unevenly distributed. Prevalence in the high endemic focus reached 24% while in the surrounding low endemic area prevalence dropped to 5% [12]. Examination of raccoon dogs revealed a similar picture [13].

Taeniidae metacestodes were most often diagnosed in adult muskrats and there were also few cases of combination of two Taeniidae species. Thus, it is quite unlikely that muskrats ingest taeniid eggs accidentally.

In accordance with other sources, *Strobilocercus fasciolaris*, the larval stage of the cat tapeworm, *Hydatigera taeniaeformis*, was the most frequent parasite in muskrats (Table 2). Apart from sources mentioned in Table 3, *S. fasciolaris* in muskrats in Germany was previously found by other authors [1][10][26][27][28]. Strobilocerci terminate with a small liquid filled bladder [29]. In Schleswig-Holstein, nearly all 670 examined muskrats were infected [30]. The pseudo segmented *S. fasciolaris* is located in up to cherry sized cysts in the liver parenchyma. Relaxed, it can reach a length of up to 459 mm. The scolex is armed with 30–34 rostellar hooks. Larger and smaller hooks measured 384–420 µm and 240–270, respectively.

Table 2. Prevalence of eleven parasite species found in muskrats in the Barnim district of Brandenburg state (range of intensity is given in brackets). The two species of *Psilotrema* are combined as *Psilotrema* spp.

Age Group	Parasites									
	<i>Echinostoma</i> sp.	<i>Plagiiorchis elegans</i>	<i>Plagiiorchis arvicola</i>	<i>Notocotylus noyeri</i>	<i>Psilotrema</i> spp.	<i>Opisthorchis felineus</i>	<i>Hydatigera taeniaeformis</i>	<i>Taenia martis</i>	<i>Taenia polyacantha</i>	<i>Taenia cras</i>
Adults (n = 47)	8.5 (5–62)	17.0 (1–10)	2.1 (5)	0.0 (0)	17.0 (1–15)	2.1 (12)	48.9 (1–15)	10.6 (1–17)	6.4 (1–69)	(
Subadults (n = 31)	6.5 (1–5)	25.8 (1–8)	0.0 (0)	0.0 (0)	35.5 (1–35)	0.0 (0)	12.9 (1–3)	6.5 (1)	3.2 (5)	
Juveniles (n = 52)	11.5 (1–20)	9.6 (1–2)	0.0 (0)	1.9 (3)	25.0 (1–18)	0.0 (0)	3.8 (1–2)	1.9 (1)	0.0 (0)	
total (n = 130)	9.2 (1–62)	16.2 (1–10)	0.8 (5)	0.8 (3)	24.6 (1–35)	0.8 (12)	23.1 (1–15)	6.2 (1–17)	3.1 (1–10)	(

Table 3. Prevalence of cestode larval stages in muskrats in Germany, Netherlands and Belgium.

Cestode Larval Stage	[10]	[15]	[30]	[11]	[18]	[25]	[24]	This Paper
	n = 630	n = 437	n = 670	n = 80	n = 991	n = 1726	n = 657	n = 130
	Germany	Germany	Germany	Germany	Germany	Netherlands	Belgium	Germany
<i>Echinococcus multilocularis</i>	0	1.8	0	0	4.1	0.1	22.1	0
<i>Hydatigera taeniaeformis</i>	33.17	48.1	99.6	63.75	42.3	44.8	65.8	23.1
<i>Taenia martis</i>	3.02	48.3	0	18.75	3.4	6.1	22.2	10.6
<i>Taenia crassiceps</i>	0.48	0.9	1.1	6.25	2.2	0.3	0.9	0
<i>Taenia polyacantha</i>	0.32	7.3	0	1.25	0.4	0.2	2.6	6.4
<i>Taenia pisiformis</i>	2.38	0	0	0	0	0	0	0
<i>Taenia mustellae</i>		4.8	0	0	0	0	0	0
<i>Mesocestoides</i> sp.	3.79	0	0	0	0	0	0	0

Since muskrats spend most of the time in water, feed mainly on plants growing in water or on bank vegetation (bulrush, iris, sedges, reed grasses, water lilies and others) and only seldom leave the aquatic habitat, there is so far no explanation for the relative high metacestode infection rate. It cannot be excluded that muskrats cover their demand in minerals by ingesting carnivore feces. Other additional sources of calcium and phosphorus would be shells of snails, mussels or crabs. Cats may patrol the banks of water but avoid to enter the water and most probably do not prey on muskrats. Most of the infected muskrats in our material were trapped in lake habitats (Table 1). In Germany, *H. taeniaeformis* is the most frequent feline cestode. In a survey on parasites of feral cats in the Barnim district, between 6 and 30% harbored this tapeworm [31].

Cysticercus talpae, the larval stages of *T. mustellae* (syn. *T. tenuicollis*) is often situated in 3–5 mm oval shaped thin-walled cysts under the liver capsule of rodents and insectivores. Less often they can be found in the body cavity, under the skin or in the kidneys. The rostellum of the scolex is equipped with 44–50 or more hooks. Large and small rostellar hooks have nearly the same length, 170–190 and 210 µm, respectively. Apart from muskrats, *C. talpae* was found in bank

voles, yellow necked mice, harvest mice, short tailed and common voles in Germany [32]. Final hosts of *T. mustelae* are weasels and other members of mustelids. This bladder worm was not found in own material.

Other metacestodes listed in **Table 3** are situated in the body cavities not causing visible host reactions. *Cysticercus longicollis*, the larval stage of *T. crassiceps*, were found in the thorax of an adult muskrat trapped in one of the lakes. This larval stage multiplies in the intermediate host by budding. *C. longicollis* is a 2–4 mm long egg shaped, thin walled bubble with an invaginated scolex. Rostellar hooks in numbers between 30 and 36 were arranged in two circles and measured 180–197 and 130–151 µm, respectively. Rostellar hooks of both types had strikingly long blades. Budding took place at the larger end, opposite of the scolex. The infected muskrat harbored 37 fully developed bladder worms, some of them were with buds. Previously, *C. longicollis* was detected also in a swelling between skeleton muscles [11]. Canids were listed as main and martens, badgers and cats as accidental final hosts for *T. crassiceps* [33]. In the Brandenburg state, *T. crassiceps* was found in raccoon dogs and red foxes in a prevalence of 2 and 5%, respectively [14].

T. polyacantha is another canid specific cestode with a large spectrum of rodents, including muskrats, as intermediate hosts. The larval stage of *T. polyacantha* was up to 10–12 mm long, with an invaginated scolex that bore up to 60 rostellar hooks arranged in two circles. The prevalence of *T. polyacantha* in final hosts, red fox and raccoon dog hunted in the neighboring Uckermark district added up to 40 and 13%, respectively [14].

T. martis, also known under its synonyms *T. intermedia*, *T. melesi*, *T. sibirica*, is a cestode of mustelids. Its larval stage with a white, bilaterally flattened, elongated body with fringed margins was situated in the abdominal cavity without any viewable host reaction. The invaginated scolex was armed with 28 rostellar hooks arranged in two circles. Larger hooks were 175–195 µm and smaller hooks were 130–145 µm long, respectively. Both hooks stroke due to comparably small blades and relatively strong roots. Apart from muskrats, the larval stage of *T. martis* was found in Germany also in beavers [34]. In Germany, the adult cestode was previously found in stone martens [15], otters [35] and beech martens [36].

Allegedly, larvae of *T. pisiformis* and tetrathyridia of *Mesocostoides* sp. that were found in the liver parenchyma [10] most probably, were misdiagnosed early stages of *S. fasciolaris*, since *C. pisiformis* is usually found in the mesenterium and *Mesocostoides* tetrathyridia are located free in abdominal and thoracic cavities of intermediate hosts [15]. In our opinion, these stages could also be *C. talpae*.

As far as we know, the recent muskrat population in Germany go back to five to ten specimen that were released in Bohemia [1] and examination showed that the trematode, *Quinqueserialis quinqueserialis*, seems to be the only species that has traveled with infected muskrats from America to Europe and was able to establish the life cycle in the new habitats. *Qu. quinqueserialis* is a frequent parasite of muskrats in America and planorbid snails of the genus *Gyraulus* are the intermediate hosts. Experimental infections showed that at least 15 rodents are susceptible for an infection and produced fertile trematodes [37]. In Germany, this notocotylid species was found in muskrats in Saxony-Anhalt [10][11] and Lower Saxony [38]. In addition, apart from muskrats, *Qu. quinqueserialis* was also found in a brown rat in Saxony-Anhalt [39]. It has not been detected in our material from Barnim district.

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