Macroparasites and their communities of the European eel *Anguilla anguilla* (Linnaeus) in the Czech Republic

František Moravec and Tomáš Scholz

Institute of Parasitology, Biology Centre of the Czech Academy of Sciences, České Budějovice, Czech Republic

**Abstract:** This paper summarises the results of parasitological examinations of the European eel *Anguilla anguilla* (Linnaeus) in the Czech Republic, carried out at the Institute of Parasitology, Czech Academy of Sciences (previously the Czechoslovak Academy of Sciences) within the period of 50 years (1958–2008). Even though this survey is limited to the Czech Republic, it provides extensive data probably incomparable with any other study anywhere regarding the number of eels examined and parasites found. A total of 723 eels was examined from 42 localities that belong to all of the three main river drainage systems in the country, i.e. the Elbe, Danube and Oder river basins. Of the 31 species of adult and larval macroparasites including Monogenea (4 species), Trematoda (3), Cestoda (3), Nematoda (11), Acanthocephala (5), Hirudinea (1), Copepoda (1), Branchiura (1) and Acariformes (1), most of them (30) were recorded from the Elbe River basin. These parasites can be divided into three main groups regarding their host specificity: parasites specific for eels (26%), non-specific adult parasites occurring also in other fishes (61%) and non-specific larvae (13%). The highest number (19) of parasite species was recorded in the Máchova jezera fishpond system in northern Bohemia. The parasite communities in eels from the individual localities exhibited large differences in their species composition and diversity depending on local ecological conditions.

The parasite fauna of *A. anguilla* in the Czech Republic is compared with that in other European countries. The nematode *Cucullanus egyptae* Abdel-Ghaffar, Bashtar, Abdel-Gaber, Morsy, Mehlhorn, Al Quraishy et Mohammed, 2014 is designated as a species inquirenda.

**Keywords:** parasite fauna, fish, host specificity, species diversity, Elbe River basin, Danube River basin, Oder River basin, Central Europe

Until the exotic, highly pathogenic swimbladder nematode *Anguillicoloides crassus* (Kuwahara, Niimi et Itagaki, 1974) was introduced into European populations of eels *Anguilla anguilla* (Linnaeus) in the early 1980’s, there were few helminthological studies on this species of fish anywhere in the wide freshwater range, irrespective of the considerable value of the European eel fishery (Lacey et al. 1982). Since *A. crassus*, an agent of anguillicoloidiosis, has seriously endangered both eel cultures and natural eel populations in Europe, this parasite has been intensively studied by European researchers. Along with the problem of anguillicoloidiosis, an increased interest to study the parasite fauna of eels as a whole has also been evident in some European countries within recent decades (e.g. Keie 1988, Schabuss et al. 1997, Kennedy et al. 1998, Borgsteede et al. 1999, Kennedy 2001, Sures and Streit 2001, Outeiral et al. 2002, Pilecka-Rapacz and Sobecka 2004, Saraiva et al. 2005, Kristmundsson and Helgason 2007).


Address for correspondence: F. Moravec, Institute of Parasitology, Biology Centre of the Czech Academy of Sciences, Branišovská 31, 370 05 České Budějovice, Czech Republic. Phone +420 38 777 5432; Fax: +420 38 5310388; E-mail: moravec@paru.cas.cz

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
Within broad investigations on the helminth parasites of fishes of the Czech Republic carried out by the researchers of the Institute of Parasitology, Czech Academy of Sciences (previously the Czechoslovak Academy of Sciences), originally in Prague and since 1985 in České Budějovice (see e.g. Moravec 2001, 2013), many eels from different localities were examined during the period of 50 years. Some few partial results of these parasitological examinations have been published (e.g. Ergens 1961, Moravec 1985, Škoríková et al. 1996), but most of the results obtained remain unpublished, even though they represent important information about the species composition of the parasite fauna of eels in the Czech Republic, the distribution of individual species and the diversity of their communities in different localities. Based on the high number of eels examined, this paper presents results of probably the most comprehensive studies on the parasites of this important fish. Therefore, the importance of the data accumulated during 50 years in the Czech Republic goes much beyond this Central European country.

**MATERIALS AND METHODS**

This paper is principally based on helminthological examinations of eels *Anguilla anguilla* from the territory of the Czech Republic, carried out at the Institute of Parasitology, Czech Academy of Sciences (previously the Czechoslovak Academy of Sciences) within the period of 50 years (1958–2008). This material includes macroparasites recorded from 25 eels examined by late Table 1. List of the localities from where eels, *Anguilla anguilla* (Linnaeus), were examined.

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality</th>
<th>No. of eels examined</th>
<th>Year(s) and month(s)</th>
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<tr>
<td>ELBE RIVER BASIN (35 localities)</td>
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<tr>
<td>2</td>
<td>Kamenice River at Hřensko</td>
<td>8</td>
<td>1978, 1979: VII, XI</td>
</tr>
<tr>
<td>3</td>
<td>Ploučnice River near Česká Lipa</td>
<td>24</td>
<td>1994: IX</td>
</tr>
<tr>
<td>4</td>
<td>Ještědský Brook near Ralsko</td>
<td>9</td>
<td>2001, 2002: VI, VIII</td>
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<tr>
<td>5</td>
<td>Metuje River near Náchod</td>
<td>5</td>
<td>1994: X</td>
</tr>
<tr>
<td>6</td>
<td>Seč water reservoir on the Chrudimka River</td>
<td>1</td>
<td>1975: VIII</td>
</tr>
<tr>
<td>7</td>
<td>Úhlavka River near Postoloprty</td>
<td>31</td>
<td>1994: X</td>
</tr>
<tr>
<td>8</td>
<td>Libočanský Brook near Žatec</td>
<td>1</td>
<td>2000: VI</td>
</tr>
<tr>
<td>10</td>
<td>Podhora water reservoir on the Teplá River near Teplá</td>
<td>16</td>
<td>1988: V</td>
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<tr>
<td>12</td>
<td>Vltava River near Zbraslav</td>
<td>13</td>
<td>1988: VII</td>
</tr>
<tr>
<td>14</td>
<td>Vltava River near Temelín</td>
<td>3</td>
<td>1988: IX, X</td>
</tr>
<tr>
<td>15</td>
<td>Lipno water reservoir on the Vltava River</td>
<td>2</td>
<td>1999, 2001: IV, V</td>
</tr>
<tr>
<td>16</td>
<td>Upper Vltava River near Lipno (over the Lipno reservoir)</td>
<td>1</td>
<td>1962: XI</td>
</tr>
<tr>
<td>17</td>
<td>Olsina Brook near Horní Plana</td>
<td>1</td>
<td>1962: II</td>
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<tr>
<td>18</td>
<td>Pond Bagra in České Budějovice</td>
<td>16</td>
<td>1988, 1989: V, VI, VII</td>
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<tr>
<td>19</td>
<td>Pond Jahelník near Dubné</td>
<td>1</td>
<td>1988: X</td>
</tr>
<tr>
<td>20</td>
<td>Sázava River near Číhoř</td>
<td>13</td>
<td>1995: VIII</td>
</tr>
<tr>
<td>22</td>
<td>Želivka water reservoir</td>
<td>31</td>
<td>1988, 1995: V, VI</td>
</tr>
<tr>
<td>23</td>
<td>Tisová near Tachov (warm-water aquaculture of eels near the electric power station)</td>
<td>16*</td>
<td>1989: V</td>
</tr>
<tr>
<td>24</td>
<td>Starý Brook near Kdyně</td>
<td>22</td>
<td>1994: IX</td>
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<tr>
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<td>Úhlavka River near Štětín</td>
<td>7</td>
<td>1994: IX</td>
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<td>Bílá water reservoir on the Starý Brook near Klatovy</td>
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<td>1995: V</td>
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<td>27</td>
<td>Otava River near Štětín</td>
<td>12</td>
<td>1995: VIII</td>
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<tr>
<td>28</td>
<td>Lužnice River near Tábor</td>
<td>10</td>
<td>1994: V</td>
</tr>
<tr>
<td>30</td>
<td>Černovický Brook near Tábor</td>
<td>1</td>
<td>1978: IX</td>
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<tr>
<td>31</td>
<td>Storage ponds at Třeboň</td>
<td>7</td>
<td>1994: X</td>
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<tr>
<td>32</td>
<td>Pond Pohorka near Líšov</td>
<td>4</td>
<td>1985: XI</td>
</tr>
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<td>33</td>
<td>Pond Komorník near Jindřichův Hradec</td>
<td>1</td>
<td>1959: V</td>
</tr>
<tr>
<td>34</td>
<td>Pond Šaloun near Lomnice nad Lužnicí</td>
<td>10</td>
<td>1994: X</td>
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<tr>
<td>35</td>
<td>Malše River near České Budějovice</td>
<td>1</td>
<td>1984: XI</td>
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DANUBE RIVER BASIN (6 localities)

<table>
<thead>
<tr>
<th>No.</th>
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<th>Year(s) and month(s)</th>
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<tbody>
<tr>
<td>36</td>
<td>Rokytná River near Věmyvšice</td>
<td>3</td>
<td>1986, 1987: V, VI</td>
</tr>
<tr>
<td>37</td>
<td>Mostište water reservoir on the Oslava River near Velké Meziříčí</td>
<td>25</td>
<td>1995: V</td>
</tr>
<tr>
<td>38</td>
<td>Fryšták water reservoir near Zlín</td>
<td>10</td>
<td>1994: IX</td>
</tr>
<tr>
<td>39</td>
<td>Kyjovka River near Koryčany</td>
<td>11</td>
<td>1994: IX</td>
</tr>
<tr>
<td>40</td>
<td>Pond Domaninský near Bystřice nad Pernštejnem</td>
<td>1</td>
<td>1958: XI</td>
</tr>
<tr>
<td>41</td>
<td>Pond Pod mlýnem at Sedlec near Mikulov</td>
<td>9</td>
<td>1995: VI</td>
</tr>
</tbody>
</table>

ODER RIVER BASIN (1 locality)

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality</th>
<th>No. of eels examined</th>
<th>Year(s) and month(s)</th>
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</thead>
<tbody>
<tr>
<td>42</td>
<td>Kružberk water reservoir on the Morava River near Kružberk</td>
<td>8</td>
<td>1996: VI</td>
</tr>
</tbody>
</table>

* small eels two weeks after the import of elvers from England.
Dr. Radim Ergens in 1958–1967, those collected by F. Moravec from 192 eels in the period from 1965–1984 and those collected from 506 eels by F. Moravec and T. Scholz in 1987–2008. Thus, a total of 723 eel specimens was examined from 42 localities that belong to all of the three main river drainage systems in the Czech Republic (see Table 1 and Fig. 1).

The eels were either caught by electro-fishing by the researchers of the Institute or obtained from local fishermen and brought alive to the laboratory, where they were immediately killed and examined fresh. The occurrence of helminths was studied in eels measuring 7–120 cm by the method of a helminthological dissection with emphasis to endoparasites; the presence of ectoparasites (monogeneans) was not followed in all eel specimens examined. The parasites obtained were treated by usual helminthological methods and these materials are mostly deposited in the Helminthological Collection of the Institute of Parasitology, Biology Centre of the Czech Academy of Sciences, in České Budějovice (http://www.paru.cas.cz/en/collections/). Species of parasites are listed alphabetically in each of the higher taxonomic group.

RESULTS

Composition of the fauna of macroparasites of Anguilla anguilla in the Czech Republic

A total of 31 species of macroparasites was found in eels; of these six [Gyrodactylus sp., Crepidostomum metoecus (Braun, 1900), Diplostomum spathaceum (Rudolphi, 1819) metacercariae, Cucullanus truttae Fabricius, 1794, Porrocaecum ensicaudatum (Zeder, 1800) larvae, Echinorhynchus truttae Schrank, 1788 and Argulus foliaceus (Linnaeus, 1758)] represent the first records from eels in the Czech Republic (Table 2).

Monogenea

Gyrodactylus lucii Kulakovskaya, 1951

This is a parasite of Esox lucius Linnaeus and some percid fishes. A single specimen of G. lucii was found on the skin of an eel in the Mácha Lake fishpond system (see Moravec 1985) (August 1982, prevalence 1/7, intensity 1); this represents an accidental infection.

Gyrodactylus sp.

Numerous live and dead specimens of this parasite were found on the gills and fins of eels in the Ohře River near Postoloprty examined in October of 1994, with a prevalence of 26% (8/31) and intensity 30–300 (mean 94) monogeneans per fish. Probably, A. anguilla is only an accidental host for this parasite.

Pseudodactylogyrus anguillae (Yin et Sproston, 1948) and P. bini (Kikuchi, 1929)

In the Elbe River basin, P. anguillae alone was recorded from three localities: Sázava River near Chrčenovice (August 1995: prevalence 54% [7/13], intensity 1–12 [mean...

In the Danube River basin, P. anguillae alone was recorded in one locality: Fryšták water reservoir near Zlín (September 1994: 40% [4/10], 3–65 [21]).

However, the presence of these parasites in other localities cannot be excluded, because no attention was paid to monogenean infections of eels in some localities.

Both P. anguillae and P. bini are pathogenic gill parasites of the Japanese eel Anguilla japonica Temminck et Schlegel in East Asia, from where they were introduced into Europe in the 1970’s. In Europe they quickly spread in the populations of the European eel A. anguilla (see Škoričová et al. 1996). The first record of both parasite species in the former Czechoslovakia is that of late R. Ergens (Institute of Parasitology, Biology Centre, ASCR, České Budějovice, CR – unpubl. data) in October of 1989, who found them to be abundant on small eels (body length 7–18 cm) in a warm-water aquaculture at Tisová, North Bohemia (see Škoričová et al. 1996). The present data show that now both P. anguillae and P. bini are widespread in eel populations in the Czech Republic. Although these parasites were not recorded in 132 eels in the Mácha Lake fishpond system examined until 1977 (Moravec 1985), a sample of eels from the same locality examined in 1994 showed high levels of infection with P. anguillae and P. bini. The situation in this locality reflects the spreading of these parasites in Europe, because the first record of both species in Europe was that of Golovin (1977) in Russia.

**Trematoda**

*Azgyia lucii* (Müller, 1776)

This trematode was found in the stomach of eels in two localities belonging to the Elbe River basin: Mácha Lake fishpond system near Doksý (April 1971: 1/1, 1; September 1971: 7% [1/14], 1; May 1982: 1/5, 1; June 1982: 8% [1/12], 3; August 1994: 13% [2/16], 1); and Orlik water reservoir near Štědrónin (September 1995: 3% [1/38], 9). *Azgyia lucii* was previously reported from eels in the former locality by Moravec (1985).

The principal definitive host of *A. lucii* is the northern pike, *Esox lucius*, whereas the European eel serves only as a subsidiary host. It may be supposed that *A. anguilla* acquires the infection by swallowing infected fish, mainly small pike and perch. The occurrence of *A. lucii* in eels seems to be in correlation with the feeding period of the eels.
fish: during the cold season, when the feeding activity of eels almost ceases (Lacey et al. 1982). *A. lucii* was not recorded. In addition to *A. anguilla*, *Perca fluviatilis* Linnaeus and *Sander luciopeca* (Linnaeus) were also recorded as subsidiary hosts of *A. lucii* in the Mácha Lake fishpond system (Moravec 1985).

According to Odening (1976), intermediate hosts of *A. lucii* are various species of freshwater snails of the families Planorbidae, Lymnaeidae, Physidae and Valvatidae.

**Crepidostomum metoecus** (Braun, 1900)

The only locality where this trematode was found in the intestine of an eel was the Ještědský Brook near Ralsko (August 2001: 1/6, 1), belonging to the Elbe River basin.

The main definitive hosts of *C. metoecus* are salmonids, in Europe mostly the brown trout,*Salmo trutta fario* Linnaeus (see Moravec 2004). It is also reported from predatory fishes of some other families such as *Esox lucius* (Esocidae), *Lota lota* (Linnaeae) (Lotidae) or *Perca fluviatilis* (Percidae), which, undoubtedly, acquire the infection of adult trematodes while feeding on small salmonids (Moravec 2004). The finding of adult *C. metoecus* in *A. anguilla* suggests a similar way of transmission, i.e. that the eels acquire this trematode by swallowing small-sized infected trout. In the same locality, *C. metoecus* was recorded from 40% of *S. trutta fario* examined (Moravec 2003). The first intermediate hosts of *C. metoecus* are bivalves (*Pisidium* spp.); amphipods (*Gammarus pulex* (Linnaeus)) and nymphs of aquatic insects (*Ephemera* Linnaeus, *Clomeon Leach, Siphlonurus Eaton*) were recorded as its second intermediate hosts in Europe (see Moravec 2004).

**Diplostomum spathaceum** (Rudolphi, 1819) larv.

Metacercariae of this trematode located in the eye lens of eels were recorded from the following localities belonging to two main river drainage systems:


Danube River basin: Frýšták water reservoir near Zlin (November 1994: 40% [4/10], 1–2 [1]; pond Pod mýněm at Sedlec near Mikulov (June 1995: 3/9, 1–2 [1]).

In the Czech Republic, adults of *D. spathaceum* are common intestinal parasites of gulls (*Larus* spp.) and are exceptionally found in other birds. The first intermediate host is the freshwater snail *Lymnaea (Radix) peregra ovata* (Draparnaud); many fish species belonging to different families (rarely also frogs) serve as the second intermediate host (Vojtek 1974, Moravec 2001, Sitko et al. 2006). According to Moravec (2001), metacercariae of *D. spathaceum* were previously recorded from 50 fish species (mainly cyprinids) in the former Czechoslovakia, but not from *A. anguilla*. Consequently, the present findings of these parasites in eels represent a new host record.

**Taxonomic note:** The taxonomy of species of *Diplostomum* von Nordmann, 1832, including identification of their metacercariae and specificity to the second intermediate host, are not fully resolved. In addition, recent taxonomic studies that combined molecular and morphological data have revealed cryptic diversity in the *Diplostomum* species complex (see e.g. Georgieva et al. 2013, Blasco-Costa et al. 2014, Faltýnková et al. 2014). Therefore, it may well be that metacercariae from eels reported under the name *D. spathaceum* actually belong to more than one species of *Diplostomum*.

**Cestoda**

**Bothriocephalus claviceps** (Goeze, 1782)

This cestode was recorded from eels in the following localities belonging to all three main river drainage systems:


Danube River basin: Fryšták water reservoir near Zlin (November 1994: 40% [4/10], 1–2 [1]; pond Pod mýněm at Sedlec near Mikulov (June 1995: 3/9, 1–2 [1]).

In the Czech Republic, adults of *D. spathaceum* are common intestinal parasites of gulls (*Larus* spp.) and are exceptionally found in other birds. The first intermediate host is the freshwater snail *Lymnaea (Radix) peregra ovata* (Draparnaud); many fish species belonging to different families (rarely also frogs) serve as the second intermediate host (Vojtek 1974, Moravec 2001, Sitko et al. 2006). According to Moravec (2001), metacercariae of *D. spathaceum* were previously recorded from 50 fish species (mainly cyprinids) in the former Czechoslovakia, but not from *A. anguilla*. Consequently, the present findings of these parasites in eels represent a new host record.
Danube River basin: pond Domanský near Bystrice nad Pernštejnem (November 1958: 1/2, 1); Rokytá River near Věmyslice (June 1987: 1/1, 1); Kyjovka Rivulet near Koryčany (September 1994: 18% [2/11], 2–5 [4]); Fryštátk water reservoir near Zlín (September 1994: 30% [3/10], 1); Mostštětě water reservoir on the Oslava River near Velké Meziříčí (May 1995: 16% [4/25], 1–4 [2]).

Oder River basin: Kružberk water reservoir on the Moravice River near Kružberk (June 1996: 5/8, 1–12 [3]).


The present data show that *B. claviceps* is a common and widespread parasite in the Czech Republic, occurring in eels in all the year round. Although it is also present in slowly flowing waters, its highest prevalence was found in larger still-water bodies, such as water reservoirs (Orlik and Fryštátk water reservoirs up to about 40% and 30%, respectively, or Kružberk water reservoir where 5 of 8 eels examined were infected) or large pond systems (Máchů Lake fishpond system up to about 80%). The finding of *B. claviceps* in the Kružberk reservoir represents the first documented record of this parasite in the Oder River basin in the Czech Republic.

This cestode seems to be a specific intestinal parasite of eels and *A. anguilla* has so far been recorded as the only fish definitive host of this species in the Czech Republic (Moravec 2001; present data). *Bothriocephalus claviceps* has also been reported from fish species belonging to other families, but these probably do not serve as true definitive hosts (Scholz 1997). In this connection, it is necessary to mention an interesting finding of adult *B. claviceps* from the intestine of 15% of news *Triturus vulgaris* (Linnaeus) (Caudata) in the small South Bohemian pond Bagr examined in the spring of 1988 and 1989, where also eels infected by this parasite co-occurred (Scholz and Moravec 1998, Žďárská and Nebesářová 1999a, b). This paper provides the first report from the Danube River basin. The present data indicate that *P. macrocephalus* is a common and widespread cestode species in the Czech Republic, occurring in eels mainly in larger rivers, water reservoirs and ponds. The highest prevalence (up to 80%) and intensity (up to 69 specimens) were recorded in the Orlik water reservoir in October 1996, but high levels of infection were also found in some other localities.

This cestode is a specific intestinal parasite of eels (*Anguilla* spp.). The source of *P. macrocephalus* infection for eels are probably both infected copepod intermediate hosts and small forage fishes serving as paratenic hosts (Doby and Jarecka 1966, Willemsen 1967, Scholz et al. 1997). It can be assumed that *P. macrocephalus*, as most other proteocephalidans of the temperate zone, exhibits a pronounced seasonal maturation cycle, but no detailed data on the population biology of this species are available. According to Nie and Kennedy (1991a), growth and maturation of *P. macrocephalus* occurred in early summer in two small rivers in England. At Lake Skadar, Montenegro,
Kajić (1970) recorded mature P. macrocephalus in A. anguilla from January to July and in November, and immature worms during all months, with the highest numbers in May, August and December.

*Triaenophorus nodulosus* (Pallas, 1781) juv.

Juvenile specimens of this species were recorded from the intestines of eels only twice in two localities belonging to the Elbe River basin: Teplá River at Karlový Vary (July 1965: 1/6, 1) and Mácha Lake fishpond system (August 1994: 6% [1/16], 1). Apparently, eels acquired the infection while feeding on other fishes (probably small *P. fluviatilis*) harbouring the cestode plerocercoids and serving as the second intermediate host of *T. nodulosus*. Larval *T. nodulosus* in *A. anguilla* was previously reported by Vojtek (1961) in the former Czechoslovakia (locality not given) (see also Macko et al. 1993).

**Nematoda**

*Anguillicoloides crassus* Kuwahara, Niimi et Itagaki, 1974

This swim bladder nematode was recorded from the following localities belonging to two main river drainage systems.


Danube River basin: Kyjovka Rivulet near Koryčany (September 1994: 45% [5/11], 1–11 [5]; pond Pod mýlnem in Sedlec near Mikulov (June 1995: 4/9, 3–5 [4]).

This pathogenic parasite of eels was introduced from the Far East into Germany in 1982 (Neumann 1985), from where it quickly spread throughout Europe. Taraschewski et al. (1987) reported it from localities in northern Germany that belong to three main river drainage systems, including the Elbe River estuary. In the Czech Republic, *A. crassus* was first recorded from eels in the Elbe River near Hřensko in June 1991 (Moravec 1992) and later also found in some other localities including those belonging to the Danube basin (Baruš et al. 1996, Moravec 2001). In the Czech Republic, it has not yet been recorded from the Oder River basin, where, however, eels occur rather rarely.

The life cycle of *A. crassus* involves a copepod or os-tracod intermediate host and various aquatic invertebrates (insect larvae, snails) and vertebrates (fishes, amphibians) that serve as paratenic hosts. Eels acquire *A. crassus* infection by feeding on both intermediate- and paratenic hosts, particularly small fishes harbouring *A. crassus* third-stage larvae (Moravec 2013).

**Camallanus lacustris** (Zoega, 1776)


The nematode *C. lacustris* parasitises predominantly fishes of the family Percidae, particularly *Perca fluviatilis*, which serve as definitive hosts. In addition to percids, it is often found in fishes of other families (especially in predatory species), serving apparently only as paradoative or postcyclic hosts (Moravec 2013). It remains unknown whether the infective larvae of *C. lacustris* may develop further and attain maturity in *A. anguilla*, but eels often harbourured gravid (larvigerous) females of this parasite. In the present Czech Republic, this parasite was previously reported from eels in the Elbe River basin (Vltava River in Prague, Elbe River in Poděbrady, Mácha Lake fishpond system) (John 1877, Šrámek 1901, Moravec 1978).

Moravec (1985) observed in eels from the Mácha Lake fishpond system that the values of *C. lacustris* prevalence and mean intensity markedly increased with the body size of this fish host; the highest intensity of infection (235 nematodes) was recorded in an eel measuring 120 cm in length. The intermediate hosts of *C. lacustris* are various species of copepods, whereas some small fishes serve as paratenic hosts (Moravec 2013). Apparently the main source of *C. lacustris* infections in eels is some prey fishes,
particularly small perch. This parasite does not seem to exhibit a pronounced seasonal cycle of maturation (Moravec 1979b, Scholz 1986) and its different developmental stages occurred in eels throughout the year (Moravec 1985).

**Camallanus truncatus** (Rudolphi, 1814)

This species was found only in localities belonging to the Danube River basin: Kyjovka Rivulet near Koryčany (September 1994: 45% [5/11], 1–2 [1]); and Mostišťe water reservoir on the Oslava River near Velké Meziříčí (May 1995: 4% [1/25], 1).

The principal definitive hosts of *C. truncatus* seem to be fishes of the genus *Sander* Oken (*S. lucioperca* and *S. volgensis* Gmelin), but it occurs as well in other percids. Similarly to *C. lacustris*, *C. truncatus* also occurs in many fish species of different families serving probably only as paratenic or postcyctic hosts. In the Danube River basin of the Czech Republic, this parasite was previously recorded from eels in the Svratka River in Brno by Vojtková (1959).

The intermediate hosts of *C. truncatus* are various species of copepods, whereas some small fishes serve as paratenic hosts (Moravec 2013); the latter are probably the main source of infection for eels.

**Cucullanus truttae** Fabricius, 1794

Adults of this species (including ovigerous females) were recorded from eels in one locality belonging to the Elbe River basin: Ještědský Brook near Ralsko (June 2001: 3/3, 1–6 [3]).

*Cucullanus truttae* is an intestinal parasite of salmonids, in Europe mainly of the brown trout *Salmo trutta fario*. Rarely this species was recorded from some predatory fishes of other families, such as *Perca fluviatilis* or *Lota lota*, which probably act only as postcyctic hosts (Moravec 2013). Previously, *C. truttae* was recorded from eels only in Sweden, Ireland, England and Portugal (Törnquist 1931, Conneely and McCarthy 1986, Kennedy 2001, Saraiva et al. 2005). Apparently, also in these cases, eels acquired the *C. truttae* infection secondarily while occasional preying upon the definitive fish hosts of this nematode.

The intermediate hosts of *C. truttae* are larvae of different species of lampreys, in the Czech Republic only the brook lamprey *Lamproptera planeri* (Bloch). However, after the metamorphosis of infected lampreys, the development of *C. truttae* larvae continues further in adult lampreys, in which the nematodes attain their full maturity and may produce eggs (Moravec 2013). Judging from the body size (length 42–54 cm) of eels infected with *C. truttae* in the Ještědský Brook and because the nematodes from eels included ovigerous females, it is almost certain that the source of infection for eels was infected adult lampreys. According to the observations of Moravec (1980), *C. truttae* is found only in brown trout longer than 21 cm; consequently, trouts of this size cannot become a prey for eels.

**Daniconema anguillae** Moravec et Koie, 1987

This parasite of the serosa of swimbladder and intestine of eels was recorded from the localities belonging to the Elbe River basin: Mácha Lake fishpond system (June 1981: 8% [1/12], 1; May 1987: 7% [1/15], 1; August 1994: 25% [4/16], 1–23 [7]; September 1995: 14% [3/22], 1–2 [1]; Ploučnice River near Česká Lipa (September 1994: 4% [1/24], 1); Oře River near Postoloprty (October 1994: 3% [1/31], 1); Sázava River near Chřenské Nové (August 1995: 8% [1/13], 1).

*Daniconema anguillae* is a Holarctic parasite of eels, occurring only in *A. anguilla* in Europe and in *A. rostrata* (LeSeuer) in North America. In Europe, it has been reported only from the Czech Republic, Denmark, Hungary and Lithuania (see Moravec 2013). Its life cycle is unknown, but it may be similar to that in the nematodes of the family Skrjabillanidae, i.e. that the intermediate hosts are blood-sucking branchiurids (*Argulus* spp.), which may be also the source of *D. anguillae* infection for eels. The third-stage larvae of *D. anguillae* occur, sometimes in considerable numbers, in the fins and subcutaneous connective tissue of infected eels (Molnár and Moravec 1994, Molnár and Székely 1995).

**Paraquimperia tenerrima** (Linstow, 1878)

This nematode was recorded from the following localities:


Danube River basin: Rokysná River near Věmýslovice (May 1986: 2/2, 1–9 [5]; June 1987: 1/1, 1).

This nematode is a specific intestinal parasite of *A. anguilla*, which is widely distributed in Europe (Moravec 2013). In the Czech Republic, *P. tenerrima* was first recorded by Šrámek (1901) from eels in the Elbe River at Poděbrady. It occurs mainly in small streams and rivers, where it exhibits seasonal cycles of occurrence and maturation (Chubb 1975, Nie and Kennedy 1991b). In the Czech Republic, *P. tenerrima* was recorded from eels during May–July and in September and always gravid females with eggs were also present. The life cycle of *P. tenerrima* remains insufficiently known. Probably aquatic insect larvae, crustaceans or small fishes
serve as intermediate or paratenic hosts (Moravec 1975, 2013, Shears and Kennedy 2005).

**Raphidascaris acus** (Bloch, 1779)

Adults of *R. acus* and larvae in the intestinal lumen of eels were found in the following localities belonging to one main river drainage system.

Elbe River basin: Teplá River at Karlovy Vary (October 1964: 1/2, 1; July 1965: 1/6, 3; September 1965: 1/1, 2; June 1966: 1/3, 3; June 1967: 1/3, 1); Mácha Lake fishpond system (September 1976: 2/5, 2–27 [15]; May 1977: 1/2, 1; September 1977: 7% [1/14], 1; December 1977: 1/1, 1; December 1981: 1/1, 1; September 1990: 1/5, 1); Lužnice River near Lomnice nad Lužnicí (May 1987: 1/2, 2); Vltava River near Zbraslav (July 1988: 31% [4/13], 1–3 [2]); Vltava River near Temelin (October 1988: 1/1, 1); Kamenice River near Hřensko (June 1991: 1/1, 3); Lužnice River near Tábor (May 1994: 30% [3/10], 2–18 [10]; Orlik water reservoir near Štědrin (June 1994: 1/9, 1; October 1994: 1/7, 1; May 1996: 7% [1/14], 1); Úhlavka Rivulet near Stříbro (September 1994: 2/7, 1–2 [2]); Ohře River near Postoloprty (October 1994: 26% [8/31], 1–39 [7]); Libočanský potok near Žatec (June 2000: 1/1, 23); Ještědský Brook near Ralsko (August 2001: 1/6, 1).

*Raphidascaris acus* is a common and widespread parasite in the Czech Republic, where both its adults and larvae have been reported from many fish species in all three main river drainage systems (Moravec 2001). The definitive hosts of *R. acus* are piscivorous fishes belonging to different families, in Europe mainly the pike *Esox lucius* and the brown trout *Salmo trutta fario*, less often other species of salmonids, *Lota lota*, *Perca fluviatilis*, *Sander lucioperca* or *Anguilla anguilla* (see Moravec 2013). However, in addition that eels may serve as definitive hosts for this nematode species, they may also become (as many other fish species) its intermediate hosts (Karmanova 1968). Larvae of this parasite were recorded from the stomach wall of an eel in one locality belonging to the Elbe River drainage system: Úhlavka Rivulet near Stříbro (September 1994: 1/7, 3).

The intermediate hosts of *R. acus* are very many fish species and, in some localities, also amphipods of the genus *Gammarus* Fabricius, which are the source of infection for the definitive host. However, there is also a variety of aquatic invertebrate pre-intermediate and vertebrate post-intermediate paratenic hosts of *R. acus*, of which the latter (mainly fishes and some amphibians) may also serve as source of infection for the definitive host (see Moravec 2013). Adults of *R. acus* (including ovigerous females) were recorded in eels only during late spring and early autumn, whereas samples collected in other seasons comprised intestinal third- or fourth-stage larvae. This corresponds to the pronounced seasonal maturation cycle of *R. acus* observed in other definitive hosts in different localities (Moravec 2013).

**Salmonema ephemeredarum** (Linstow, 1872)

This nematode was found in an eel only once in a locality belonging to the Elbe River basin: Teplá River in Karlovy Vary (July 1965: 1/3, 1). This finding was already reported by Moravec (1967).

The nematode *S. ephemeredarum* is a stomach parasite of salmonids, in Europe mainly of the brown trout *Salmo trutta fario* (see Moravec 2013). Besides salmonids, this parasite is sometimes found in other, mostly predatory or occasionally predatory fishes that acquire accidental infections while feeding on the definitive hosts of *S. ephemeredarum*, i.e. small salmonids. Also in the present case, apparently the eel acquired the *S. ephemeredarum* infection secondarily by occasional preying upon small trouts.

The intermediate hosts of *S. ephemeredarum* are different species of mayflies (Ephemeroptera), whereas some small fishes [*Cottus gobio* Linnaeus, *Barbatula barbatula* (Linnaeus)] may serve as paratenic hosts (Moravec 2013).

**Spinitectus inermis** (Zeder, 1800)

This nematode was found in one locality belonging to the Elbe River basin: Mácha Lake fishpond system (November 1975: 1/1, 4; September 1976: 1/5, 12; December 1976: 1/5, 1; August 1981: 1/1, 2; August 1994: 6% [1/16], 1).

*Spinitectus inermis* is a specific gastrointestinal parasite of the European eel *A. anguilla*. It occurs only locally and is a rather rare parasite of eels in most localities. The intermediate hosts of this nematode are mayflies (Ephemeroptera) (Saraiva et al. 2002). It can be assumed that both infected mayfly intermediate hosts and fish paratenic hosts are the source of infection for eels (Moravec 2013).

**Eustrongylides mergorum** (Rudolphi, 1809) larv.

Larvae of this parasite were recorded from the stomach wall of an eel in one locality belonging to the Elbe River basin: Mácha Lake fishpond system (February 1967: 1/1, 2).

The definitive hosts of *E. mergorum* are different fish-eating birds, whereas aquatic oligochaetes apparently serve as intermediate hosts (Karmanova 1968). Larvae of this nematode occur in a variety of fish species serving as paratenic hosts. Larvae of *E. mergorum* were reported from eels by Moravec (1985) and Kočí (1988) in the Czech Republic and Denmark, respectively.

**Porrocaecum ensicaudatum** (Zeder, 1800) larv.

Larvae of this species were found in the intestinal lumen of an eel in one locality belonging to the Elbe River drainage system: Úhlavka Rivulet near Stříbro (September 1994: 1/7, 3).

Larvae of *P. ensicaudatum* were previously recorded from the intestine and pyloric caeca of *Salmo trutta fario* in the Bystřice River near Olomouc (Danube River basin) (Moravec 1971). The definitive hosts of this nematode are various birds mainly of the family Turdidae. It can be supposed that the nematode larvae only shortly survive in fishes after ingestion of their intermediate hosts, earthworms. Apparently, the European eel is a dead-end host in the circulation of this parasite in the environment.
Acanthocephala

*Acanthocephalus anguillae* (Müller, 1780)

This parasite was found only in the Elbe River basin: Kamenice River near Hřensko (November 1977: 3/5, 1–14 [7]); Ploučnice River near Česká Lipa (September 1994: 13% [3/24], 1–2 [1]); Ohře River near Postoloprty (October 1994: 45% [14/31], 1–25 [6]); Orlik water reservoir near Štěrbrno (October 1994: 7% [1/15], 1; June 1996: 9% [1/11], 1; October 1996: 7% [1/15], 1); Sázava River near Chřenovice (August 1995: 23% [3/13], 2–16 [7]).

This acanthocephalan is reported from many species of freshwater fishes belonging to different families, but its preferred hosts seem to be numerous cyprinids (Moravec 2004). In the Elbe River basin of the Czech Republic, *A. anguillae* was previously recorded from eels by Šrámek (1901) in the Elbe River at Poděbrady and by Volf and Smišek (1955) in the Sázava and Lužnice Rivers. It has not yet been found in eels of the Danube basin in the Czech Republic (although it was recorded there in other fish hosts) (see Moravec 2001), but Žitňan (1979) listed *A. anguillae* from eels in the Danube River in Slovakia.

The life cycle of *A. anguillae* involves the intermediate host, *Asellus aquaticus* Linnaeus (Isopoda), in which the infective larval stage, the cystacanth, develops (Moravec 2004). The source of infection for eels may be both isopod intermediate hosts and fish definitive (possibly also paratenic) hosts.

*Acanthocephalus lucii* (Müller, 1780)

This acanthocephalan species was recorded from eels in all of the three main river drainage systems.


Danube River basin: Fryšták water reservoir near Zlín (September 1994: 10% [1/10], 1; Mostišťe water reservoir on the Oslava River near Velké Meziříčí (May 1995: 36% [9/25], 2–28 [9]);

Oder River basin: Kružberk water reservoir on the Moravice River near Kružberk (June 1996: 6/8, 2–14 [9]).

This acanthocephalan occurs in many species of freshwater fishes, mainly those which are piscivorous or feeding on macrobenthic invertebrates, belonging to different families (see Moravec 2004). *Percula fluviatilis* seems to be one of the most frequent definitive hosts in Europe (see Moravec 2001). From eels in the Czech Republic, *A. lucii* was previously reported from all three main river drainage systems: the Oder River basin (Moravice River – Dyk and Lucký 1956), the Danube River basin (Svratka River – Vojtěk 1959) and the Elbe River basin (Mácha Lake fishpond system – Moravec 1978, 1985).

The life cycle of *A. lucii* involves an intermediate host, the freshwater isopod *Asellus aquaticus* (see Moravec 2004). The source of infection for eels may be either infected intermediate host isopods (*A. aquaticus*) or prey fishes, most frequently small perch (*P. fluviatilis*) harbouring these parasites.

**Echinorhynchus truttae** Schrank, 1788

This species was recorded from eels only in the Elbe River basin: Kamenice River near Hřensko (November 1978: 1/5, 1; July 1979: 1/3, 1). Adults of *E. truttae* are found mainly in the intestine and pyloric caeca of various salmonids, but also in some fishes belonging to other families. The intermediate hosts of this acanthocephalan are amphipods of the genera *Echinorhynchus* Stebbing, *Gammarus*, *Pontoporeia* Kohlm and *Pallasea* Bate (see Moravec 2013). Cystacanths of *E. truttae* were also recorded in the Czech Republic: in the summer of 1962, these were commonly found in *Gammarus fossarum* Koch from the trout brook Vydří potok (Elbe River basin) in the Šumava Mountains (late V. Baruš, Masaryk University, Brno, CR – unpubl. data; J. Groscha, Institute of Parasitology, Biology Centre, ASCR, České Budějovice, CR – unpubl. data; F. M. – unpubl. data). The source of *E. truttae* infection for eels are probably both the intermediate hosts (mainly *Gammarus* spp.) harbouring the cystacanths and infected fish definitive hosts (mainly small trout) which may become a prey for larger eels.

**Neoechinorhynchus rutili** (Müller, 1780)

This species was recorded from localities belonging to two main river drainage systems.

Elbe River basin: Podhora water reservoir on the Teplá River near Teplá (May 1988: 6% [1/16], 1); Lužnice River near Tábor (May 1994: 10% [1/10], 1); Úhlavka Rivulet near Stříbro (September 1994: 1/7, 1; Ohře River near Postoloprty (October 1994: 3% [1/31], 3); Ještědský Brook near Ralsko (August 2001: 2/6, 1–2 [2]).

Danube River basin: Rokytňá River near Věmýslice (May 1986: 1/2, 2).

This acanthocephalan species is a widely distributed Holarctic parasite mainly of various cyprinids, but it frequently occurs in fishes belonging to other families or even orders (Moravec 2004). In the Czech Republic, *N. ru-
Pomphorhynchus laevis (Müller, 1776)

This acanthocephalan species was recorded from eels only in the Danube River basin: Rokytá River near Věmyšlice (May 1986: 2/2, 5–274 [140]; June 1987: 1/1, 25).

Pomphorhynchus laevis was previously reported from eels of this locality by Moravec and Scholz (1991a,b). Adults of this parasite occur in many fish species of different families, but mainly in cyprinids. The life cycle involves an intermediate host, gammarids of the genera Echinogammarus, Gammarus, Pontogammarus Sowinsky and Corophium Latreille, whereas some small fishes serve as its paratenic hosts (Moravec 2004). Probably some fishes serve only as paratenic or postcylic hosts of N. rutili. It can be assumed that eels become infected with this acanthocephalan mainly by feeding on invertebrate and fish paratenic hosts and on fish definitive hosts.

Hirudinea

Piscicola geometra (Linnaeus, 1761)

This species was occasionally found on eels in Mácha Lake fishpond system (Elbe River basin) examined in 1975–1977 (see Moravec 1985). This ectoparasite is known to occur on many fish species belonging to different families.

Bivalvia

Glochidia gen. sp. larv.

This parasite was recorded only once in the Danube River basin: Mostiště water reservoir on the Oslava River near Velké Meziříčí (May 1995: 6% [1/18], 1). Previously it was reported by Frič (1908) from eels of the Elbe River basin in Bohemia (see Table 2).

Glochidia are larval stages of bivalves of the mussel order Unionida Stoliczka occurring as ectoparasites on many species of fishes. Køie (1988) reported glochidia of Anodonta cygnea (Linnaeus, 1758) from eels in Denmark.

Copepoda

Ergasilus sieboldi Nordmann, 1832

This gill parasite was found only in localities of the Elbe River drainage system: Mácha Lake fishpond system (occasionally recorded from eels in 1975–1977 – Moravec 1985; August 1994: 13% [2/16], 1; Orlik water reservoir near Štědrónin (June 1994: 2/9, 1–3 [2]; October 1994: 7% [1/15], 1; September 1995: 44% [7/16], 1–5 [2]; November 1995: 1/7, 1; May 1996: 7% [1/14], 1; June 1996: 9% [1/11], 3; October 1996: 53% [8/15], 1–5 [2]); Otava River near Štědrónin (August 1995: 8% [1/12], 1).

This ectoparasite occurs on many species of fishes belonging to different families. In eels of the Czech Republic, it was previously reported by Vojtková (1959) from the Svatka River (Danube River basin) and by Moravec (1985) from the Mácha Lake fishpond system (Elbe River basin).

Frič (1873) mentioned the presence of another species, Ergasilus gibbus Nordmann, 1832, a specific parasite of A. anguilla, in eels of the present Czech Republic (Elbe River basin – locality not given). However, E. gibbus is a brackish-water species and, therefore, it is highly probable that in this case, E. sieboldi was misidentified as E. gibbus.

Branchiura

Argulus foliaceus (Linnaeus, 1758)

This temporary ectoparasite was found on gills of an eel in the Mácha Lake fishpond system (Elbe River basin) (August 1982: 1/7, 4); this finding was reported by Moravec (1985).

In the Czech Republic, A. foliaceus occurs on the skin of many fish species of different families (Moravec 2001).

Acariformes

Hydrozetes sp.

This ectoparasite was recorded on gills of an eel in the Mácha Lake fishpond system (Elbe River basin) (August 1982: 1/7, 4); this finding was reported by Moravec (1985).

Host categories and specificity of macroparasites of A. anguilla recorded in the present study

Regarding host-specificity, the parasites recorded can be roughly divided into the following groups:

1. Strictly specific species for which eels (Anguilla spp.) serve as the only definitive hosts (as defined by Odening 1976): the monogeneans Pseudodactylus anguillae and P. bini, the cestodes Bothrioccephalus claviceps and Proteocephalus macrocephalus, and the nematodes Paraquimperia tenerrima, Anguillicoloides crassus, Daniconema anguillae and Spinichetus inermis.

2. Species the adults of which also occur in fishes of other families: the monogeneans Gyrodactylus lucii and Gyrodactylus sp., the cestode Trianenophorus nodulosus, the trematodes Azgyia lucii and Crepidostomum metoecus, the nematodes Camallanus lacustris, C. truncatus, Cucullanus truttae, Raphidascaris acus and Salmonoma ephemeredarum, the acanthocephalans Acanthocephalus anguillae, A. lucii, Echinorhynchus truttae, Neoechinorhynchus
hynchus rutili, and Pomphorhynchus laevis, the hirudinean Piscicola geometra, the crustaceans Ergasilus sieboldi and Argulus foliaceus, and the acariform Hydrozetes sp.

Since the present knowledge of the biology of most of these parasites is inadequate, the role of eels in their life cycles remains unknown. It can be only assumed that for some of them (Azygia lucii, C. truttae, R. acus, N. rutili, A. anguillae, A. lucii, E. truttae, P. laevis, P. geometra, E. sieboldi and A. foliaceus) the European eel may serve as a true definitive host, although in many cases infections by these parasites are obtained secondarily, upon feeding on their usual fish definitive hosts. For some other parasites A. anguilla probably serves only as a postcyclic host (C. metoecus, C. lacustris, C. truncatus and S. ephemeridarum), a paradefinitive host in which it cannot reproduce (T. nodulosus) or an accidental facultative host (G. lucii, Gyrodactylyus sp.).

(3) Parasite larvae with a low degree of host specificity, which may infect fishes of different families or orders serving either as intermediate hosts (D. spathaceum, Glochidiutum sp.), paratenic hosts (E. mergorum) or accidental facultative hosts (P. ensicaudatum).

A comparison of these groups shows that although a rather large proportion (26%) of the parasites was represented by the species specific for Anguilla spp., a great majority of them (74%) was formed by non-specific species represented by adults (61%) and larvae (13%). It is of interest that there is no trematode species among the eight parasites specific to eel (two monogeneans, two cestodes and four nematodes) and that three of them (P. anguillae, P. bini and A. crassus) represent introduced species.

Table 2 shows that all of the eight parasites specific for Anguilla spp. were found in the Elbe River basin and all of them, except for one species (Spinitectus inermis), were also recorded from the Danube River basin either in this study or by other authors in the Czech Republic and neighbouring countries. In contrast, only one parasite specific for Anguilla spp. (Bothriocephalus claviceps) was recorded in the Oder River basin, which may be associated with the fact that eels rather rarely occur in this drainage river system (Dyk and Lucký 1957). The presence of non-specific parasites in eels reflects the distribution of these species in other fish hosts. For example, Cucullanus truttae was recorded from eels in the Elbe basin, where it occurs in salmonids, but not from eels in the two other river basins, where C. truttae is absent in salmonids (Moravec 2001).

Parasite communities of A. anguilla in different localities

It is well known that the formation of the parasite fauna of fishes is affected by many external factors; some of them condition the existence of a certain parasite in a given environment, whereas the effects of others are manifested only quantitatively. Consequently, the occurrence of a certain fish parasite in the locality is the result of a synergistic effect of many factors enabling its sometimes complicated developmental cycle to be completed. Therefore, an evaluation of a parasite community in a certain fish host species in a given locality should be based on broad, detailed, long-term observations. However, in this study, the numbers of examined eels from most localities are limited and it is impossible to make a reliable comparison of the parasite communities, both qualitative and quantitative, among all the localities investigated.

Nevertheless, the results obtained indicated marked differences in the numbers of parasite species recorded from eels among some well-sampled localities belonging to the same main drainage system. For example, in the Elbe River basin, the highest number (18) of parasite species was recorded from eels in the Máchá Lake fishpond system, followed by Orlík water reservoir and the Ohře River near Postoloprty (13 species each). Ten species of parasites were found in the Lužnice River near Tábor, seven species in each of the Rivers Ploučnice, Sázava and Otava near Štědrovitín, six species in the Ještědský Brook near Ralsko, five species in the Podhora reservoir near Teplá, Teplá River at Karlovy Vary and Uhlovka Rivulet near Stříbro, four species in the Elbe and Kamenice Rivers near Hlensko, Vltava River near Zbraslav and Temelin, Želivka water reservoir and pond Bagár at České Budějovice, three species in the Želivka River, pond Šaloun near Lomnice nad Lužnicí and storage ponds at Třeboň, two species in the Libočanský Brook near Žatec, Starý Brook near Kdyně, Bílka reservoir near Klatovy and pond Pohorka near Lišov, one species each in the Metuje River near Náhod, Lipno water reservoir and pond Komorník near Jindřichův Hradec. No parasites were recorded from eels in seven other localities (both streams and still waters); however, except for the warm-water aquaculture of eels in Tisová, only individual eel specimens were examined from these localities.

However, the species composition of parasites of eels was usually different even if the same or similar numbers of these organisms were recorded from eels in different localities. For example, of the seven parasite species recorded from eels in the Otava River (P. anguillae, P. bini, P. macrocephalus, P. tenerrima, A. crassus, C. lacustris and A. foliaceus), only three (A. crassus, P. tenerrima and C. lacustris) were found among the six parasites of eels in the Ještědský Brook, where, in contrast, three species (C. metoecus, C. truttae and N. rutili) occurred, which were absent in the Otava River. It is evident that this difference is partly associated with the fact that eels in the Ještědský Brook share the environment with the brown trout (Salmo trutta fario) (C. metoecus and C. truttae are common parasites of salmonids), whereas no salmonids probably occur in the section of the Otava River studied.

Of interest is the proportion of specific and non-specific parasites of eels in the localities. Whereas specific parasites represented about 30–40% of all species recorded in the localities such as the Máchá Lake fishpond system (39%) or the Orlícká water reservoir (31%), from where high numbers of eels were examined in different seasons, in most other localities it ranged from 0 to 25% or from 50 to 100%. Of the specific parasites of eels, the most distributed species was the tapeworm B. claviceps recorded from 24 localities belonging to all the three main river basins; widely distributed were also the tapeworm P. macrocepha-
lus and the nematode *P. tenerrima*, recorded from 14 and 15 localities, respectively, which belong to the Elbe and Danube basins. The pathogenic swimbladder nematode *A. crassus* was recorded from eight localities of the Elbe and Danube basins (see above). On the contrary, the nematode *S. inermis* was found in a single locality (Mácha Lake fishpond system) and the nematode *D. anguillae* only in three localities (Mácha Lake fishpond system and Ohře and Ploučnice Rivers). The composition of non-specific parasites found in eels mostly depended on the character of the locality and other fish species co-inhabiting the environment.

Since no long-term observations in the localities under investigation (except for the Mácha Lake fishpond system – see Moravec 1985) were conducted throughout the year and only small numbers of eels from the majority of localities were examined, any quantitative comparisons, both within a given locality and between different localities, were not considered as they would be misleading.

**DISCUSSION**


According to Borgsteede et al. (1999), at least 64 species of macroparasites were known to occur in eels from 13 European countries at that time, but now this number, within the whole range of *A. anguilla*, may be estimated to be around 100. The number (31) of parasite species recorded from eels in the freshwater localities of the Czech Republic is considerably higher as compared with those recorded in freshwater localities in other countries, where the numbers of species are less than 20, but usually only about 10 (see e.g. Borgsteede et al 1999 for survey). The highest number (35) of macroparasites of eels was reported from Denmark, but this figure concerns eels from freshwater, brackish-water and marine localities (Köie 1988, Borgsteede et al. 1999).

Since the species composition of the parasite fauna of eels is considerably influenced by the presence of non-specific parasites co-occurring in fishes of other families in the same localities (see above), the most interesting and important is the distribution of the parasites specific for eels (*Anguilla* spp.). It has been mentioned above that eight specific species were recorded in this study. An additional specific parasite of the European eel, the nematode *Rhabdochona anguillae* Spaul, 1927, is known to occur only in the streams of Spain and Portugal (Spaul 1927, Saraiva and Moravec 1998); it is also reported from eels in Bulgaria (Margaritov 1968), but this record should be verified, because other *Rhabdochona* spp., parasites of other fishes, may be accidentally found in *A. anguilla* serving as a post-cyclic host (e.g. *R. pashi* Baylis, 1928 from eels in Egypt – Moravec 1974). *Rhabdochona anguillae* seems to be restricted in its distribution to southern Europe only. A morphologically very similar species, *R. keralensis* Moravec, Sheeba et Kumar, 2012, is a specific parasite of *Anguilla bengalensis* (Gray) in India (Moravec et al. 2012).

Amin et al. (2008) described *Acanthocephalus rhinensis* Amin, Thelen, Mündeler, Taraschewski et Sures, 2008 from *A. anguilla* in the Rhine River, Germany. Even though other hosts of this acanthocephalan remain unknown, because of its rarity in eels from the type locality, Amin et al. (2008) assumed that *A. anguilla* is only an accessory host that may play a marginal role in the circulation of this parasite in the environment. Therefore, *A. rhinensis* cannot be considered as a specific parasite of eels. Moreover, the taxonomy of some species of *Acanthocephalus* Koehler, 1771 and *Echinorhynchus* Zoega in Müller, 1776 parasitising European freshwater fishes seems to be somewhat confused and, consequently, the validity of *A. rhinensis* needs a verification.

In addition to the above-mentioned specific parasites of European eels in freshwaters, there are specific macroparasites occurring in this fish host in the brackish and marine localities, represented by the monogenean *Gyrodactylus anguillae* Ergens, 1960, the trematodes *Deropristis infaia* (Molin, 1859) and *Bucephalus anguillae* Špakulová, Macko, Berrilli et Dezfuli, 2002, the nematode *Goezia anguillae* Lèbre et Petter, 1983, the acanthocephalan *Paratenusentis ambiguus* Van Cleave, 1921 and the copepod *Ergasilus gibbus*. It may be that also the nematode *Cucullanus egyptiae* Abdel-Ghabar, Bashtar, Abdel-Gaber, Morsy, Mehllhorn, Al Quraishy et Mohammed, 2014, recently described from *A. anguilla* from off the coast of the Gulf of Suez (Red Sea, Egypt) (Abdel-Ghabar et al. 2014) is a specific parasite of eels, but it is poorly described and not clearly distinguished by morphometrical features from its congeners; therefore, it should be considered a *species inquirenda*.

**Taxonomic note:** Špakulová et al. (2002) described a new trematode species, *Bucephalus anguillae* (Bucephalidae) from *A. anguilla* in a brackish-water fish farm on the Italian coast of the Adriatic Sea; later this species was also reported from eels in the coastal lagoons of Tunisia (Abdallah and Maamouri 2002) and in Corsica, France (Filippi et al. 2010). This species is probably identical with *Gasterostomum fimбриatum* Molin, 1859 (different from *G. fimбриatum* Siebold, 1848 from *Perca* sp. and *Sander* sp., which was synonymised with *Bucephalus polymorphus* Baer, 1827 by Wagener 1858) from the same host (*A. anguilla*) in northern Italy (Padova) near the Adriatic coast (Molin 1859).

In contrast to the composition of specific parasites of *A. anguilla* in freshwaters, the group of specific parasites of this fish in brackish and marine waters includes two trematode species, one acanthocephalan species and one copepod species; no specific trematodes, acanthocephalans or copepods occurred in eels from freshwater localities. Of
the six specific parasites in brackish and marine localities, one (P. ambiguus) represents a species introduced into Europe from North America (Taraschewski et al. 1987).

The group of non-specific adult parasites of eels is rather variable in different localities and mostly depends on the composition of the local fish fauna, because eels acquire the infection by these parasites while feeding on their fish definitive hosts or infected invertebrate or fish intermediate/paratenic hosts. This group of parasites is highly variable as to the species composition, which differs considerably from one locality to another and with respect to the characteristics of the environment. In addition to the parasite species recorded from eels in this study, other adult non-specific parasites were found in this host in freshwater localities in other countries, for example, the trematodes Pseudocapillaria tomentosa (Dujardin, 1843) and Philometra cyprinirutili (Creplin, 1825), the acanthocephalan Acanthocephalus clavula (Dujardin, 1845) and many others. In marine and brackish-water environments, this group of non-specific parasites of eels is represented by a large number of trematode species (e.g. species of Derogenes Lühe, 1900, Hemisaria Rudolphi, 1809, Lecithochirium Lühe, 1901, Lechiochirium Lühe, 1901, Limodor uterum Bray, 1987 and Podocotyle Dujardin,1845), some nematodes (e.g. species of Cucullanus Müller, 1777 and Hysterohylysmion Ward et Magath, 1917), acanthocephalans [e.g. some of Echinorhynchus spp. and Acanthocephaloides incassatus (Molin, 1858)] and the isopod Gnathia maxillaris (Montagu, 1804), which currently occur in other marine and brackish-water fishes.

Non-specific parasite larvae recorded from eels in the Czech Republic have been represented only by four species (Table 2), but this group of parasites includes others, which were found in eels in freshwaters of other European countries, for example, larval Ligula intestinalis (Linnaeus, 1758) and Diplostomum spp. or the nematode larvae of Contraccum spp., Cosmoecephalus obvelatus (Creplin, 1825), Paracuraria adunca (Creplin, 1846), Spiroxyx contortus (Rudolphi, 1819) and Streptocara spp. Adults of all of these species, except for S. contortus maturing in turtles, are parasites of fish-eating birds. In the marine and brackish-water environments, this group includes some larval cestodes (Grillotia sp., ‘Tetraphyllidea’ gen. sp.) and nematodes, such as Anisakis simplex (Rudolphi, 1809), Hysterohylysmion spp. or Pseudoterranova decipiens (Krabbe, 1878) (e.g. Outeiral et al. 2002, Moravec 2013), the definitive hosts of which are elasmobranchs, marine fishes and marine mammals.

The parasites of the European eel, their life cycles and ecology still remain insufficiently known and it is highly desirable to pay further attention to this highly interesting group of parasitic organisms.

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