Richness and diversity of parasite communities in European eels *Anguilla anguilla* of the River Rhine, Germany, with special reference to helminth parasites

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SUMMARY

A total of 121 European eels (*Anguilla anguilla*) from 2 sampling sites on the River Rhine were investigated in respect of their parasite communities. Special attention was given to the swim bladders, intestines, gills and fins of the fish. Twelve different parasite species were found to live in and on the eels. Data from each sampling site were kept separate. Parasites found in descending order of prevalence were: *Anguillicola crassus*, *Trypanosoma granulosum*, *Myxobolus* sp., *Paratenuisentis ambiguus*, *Pseudodactylogyrus* sp., *Bothriocephalus claviceps*, *Myxidium giardi*, *Pomphorhynchus laevis*, *Trichodina* sp., *Raphidascaris acus*, *Acanthocephalus lucii* and *Acanthocephalus anguillae*. Significantly different prevalences were reported for L_3 larvae of *A. crassus*, adult *P. ambiguus*, *B. claviceps* and *Myxobolus* sp. at the 2 sampling sites. The highest number of parasite species was recorded from the intestine, which contained up to 6 different helminths. The coexistence of the acanthocephalans *P. laevis* and *P. ambiguus*, which showed clear patterns of distribution within the intestine of the respective hosts, was reported for the first time. Up to 3 different helminth species were found in the intestine of individual fish. Among those, acanthocephalans were the most prevalent worms with the eel-specific parasite *P. ambiguus* as the dominant species not only of the intestinal but also of the total component communities. Both infra and component communities exhibited low diversity and were dominated by this single species. The evenness reached only approximately 50% or less and it remained unclear why the helminth communities of the eels from the River Rhine with its huge catchment area exhibit such a low parasite diversity and high dominance.

Key words: *Anguilla anguilla*, parasites, acanthocephalans, *Anguillicola crassus*, diversity, richness.

INTRODUCTION

Knowledge of parasites of indigenous fish is of special interest in relation to fish health and understanding of ecological problems. Until now, reports on the parasites of European eels from the River Rhine are rather rare (Würtz, Knopf & Taraschewski, 1998). In view of the commercial interest in eels this is quite remarkable. For example, only few data on the prevalence of the swimbladder nematode *Anguillicola crassus* in eels of the River Rhine have been published as part of studies dealing with different main topics (Hirt, 1996; Würtz, Taraschewski & Pelster, 1996; Würtz, 1997; Würtz *et al*. 1998). Since pathological effects of *A. crassus* on eels have been demonstrated in several studies in recent years (Molnár, Székely & Baska, 1991; Würtz *et al*. 1996; Würtz, 1997), more attention should be focused on the parasitological status of indigenous fish. Due to the increasing emphasis on stocking and management of freshwater fish new parasites could be introduced to new countries and localities (Kennedy, 1993*a*) and these may be harmful to indigenous fish. In addition to *A. crassus*, 3 more eel-specific parasite species (*Pseudodactylogyrus bini*, *Pseudodactylogyrus anguillae*, *Paratenuisentis ambiguus*) are considered to have been introduced recently into European eel populations (Buchmann, Mellergaard & Køie, 1987; Taraschewski *et al*. 1987; Køie, 1988).

Furthermore, the understanding of several aspects of parasite ecology is hindered by a paucity of long-term data on many aspects of host–parasite interactions (Kennedy, 1993*b*). The knowledge of the infection status of fish species could provide a reliable basis for further investigations, as Kennedy (1993*b*) stated that helminth communities are expected to exhibit large and rapid changes in their characteristics over longer periods of time particularly in response to habitat changes. In respect of the River Rhine the lack of data on fish parasites is especially deplorable as this ecosystem has been drastically influenced by straightening and embanking and anthropogenic pollution in former decades. Changes in the diversity and structure of parasite com-

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Table 1. Prevalence (P) in percent, mean intensity (MI) (±S.D.), and abundance (A) (±S.D.) of the parasites of eel from 2 sites of the River Rhine

Location…		LA			RH		
Number of eels examined…		61			60		
Parasites	Site*	P	MI	A	P	MI	A
Anguillicola crassus	SB	83·6	5·3 (4·9)	4·4 (4·9)	76·7	5·0 (4·0)	3·9 (4·1)
Paratenuisentis ambiguus	I	39·3	41·6 (43·9)	16·4 (34·0)	56·7	23·8 (27·5)	13·5 (23·7)
Acanthocephalus lucii	I	1·6	5·0†	0·1 (0·6)	—	—	—
Acanthocephalus anguillae	I	1·6	1·0†	0·0 (0·1)	—	—	—
Pomphorhynchus laevis	I	6·6	14·0 (14·4)	0·9 (4·7)	8·3	4·6 (4·1)	0·4 (1·7)
Raphidascaris acus	I	6·6	3·3 (1·3)	0·2 (0·9)	6·7	2·0 (0·8)	0·1 (0·5)
Bothriocephalus claviceps	I	4·9	3·7 (0·6)	0·2 (0·8)	21·7	4·7 (3·3)	1·0 (2·5)
Myxobolus sp.	F	49·2	N.D.	N.D.	68·3	N.D.	N.D.
Trypanosoma granulosum	B	77·0	N.D.	N.D.	78·3	N.D.	N.D.
Pseudodactylogyrus sp.	G	45·9	N.D.	N.D.	45·0	N.D.	N.D.
Trichodina sp.	G	8·2	N.D.	N.D.	—	—	—
Myxidium giardi	G	19·7	N.D.	N.D.	20·0	N.D.	N.D.

* SB, swimbladder; I, intestine; F, fins; B, blood; G, gills.
N.D., Number of parasites not determined.
—, Not found.
† Only 1 eel infected.

munities of different fish hosts elsewhere have received increasing attention due to the possible application of parasites as indicators of ecosystem integrity and health (Bagge & Valtonen, 1996; Dušek, Gelnar & Šebelová, 1998). According to a recent review (Sures, Siddall & Taraschewski, 1999) up to 150 papers have been published since 1980 that are directly concerned with the relationship between pollution and parasitism. As the lack of parasitological data on wild caught eels has been recognized by different parasitologists, some studies have been published recently (e.g. Køie, 1988; Cone, Marcogliese & Watt, 1993; Kennedy, 1993*b*, 1995, 1997; Barker, Marcogliese & Cone, 1996; Kennedy & Guégan, 1995; Marcogliese & Cone, 1996; Kennedy *et al*. 1996, 1998; Schabuss *et al*. 1997).

The present study was designed to determine species richness and diversity of parasites of European eel from the River Rhine with emphasis on metazoan communities. The infection status and the parasites of eels from 2 different habitats were compared with each other to determine possible small-scale differences concerning the parasite richness and diversity.

MATERIALS AND METHODS

Organism collection and study area

Eels were collected by electrofishing at 2 different sampling sites on the River Rhine in August 1995. The sites were located about 20 km apart from each other. The sites differ in flow rates, stream width and substratum. A total of 61 eels (size: 44·6±6·8 cm, weight: 151±102 g) were caught at a sampling site from the Rhine backwater 'Leimersheimer Altrhein' (LA) with medium velocity and a slushy bottom. Another 60 eels (size: 47·2±9·1 cm, weight: 181±111 g) were sampled in a basin at the Rhine harbour of Germersheim (RH) with a weak current and a stony bottom. The fish were brought back alive to the laboratory, killed and examined immediately. Before opening the body cavity, the eels were checked for parasites in the eye, on the gills and on fins by a stereobinocular and/or a stereomicroscope and the species found were noted (Table 1). After opening the body cavity the eels were examined for helminth parasites by standard methods, all organs being searched. Parasite species and numbers were recorded for all helminths found in the inner organs (Table 1). The swimbladder was searched for adult *Anguillicola crassus* and the wall was checked for larvae (L_3 and L_4) of *A. crassus* using a stereobinocular microscope. As L_3 and L_4 cannot be distinguished from each other perfectly by means of light microscopy, all larvae with a body length exceeding 1·5 mm were counted as L_4 according to the results of Blanc *et al*. (1992). The numbers of the different developmental stages of *A. crassus* were counted and the results are listed in detail in Table 2. The data on *A. crassus* given in Table 1 summarize the numbers of all developmental stages of this nematode. Additionally, blood samples were collected and smears were made and stained with a modified May–Grünwald–Giemsa stain according to Hamers (1995) and checked microscopically for the presence of *Trypanosoma granulosum*.

Determination of helminth community structure and statistical treatment

The terms prevalence, mean intensity and abundance were used according to Bush *et al*. (1997).

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Table 2. Prevalence (P) in percent, mean intensity (MI) (±S.D.), and abundance (A) (±S.D.) of different developmental stages of *Anguillicola crassus* in eels

Location…	LA			RH		
Number of eels examined…	61			60		
Anguillicola crassus	P	MI	A	P	MI	A
Total	83·6	5·3 (4·9)	4·4 (4·9)	76·7	5·0 (4·0)	3·9 (4·1)
Adult	56·5	3·6 (3·9)	2·3 (3·6)	70·0	3·3 (2·9)	2·3 (2·9)
L_3	50·8	2·4 (1·9)	1·2 (1·8)	28·3	2·4 (1·5)	0·7 (1·3)
L_4	44·3	2·0 (1·4)	0·9 (1·4)	45·0	2·0 (1·3)	0·9 (1·3)
L_3 and L_4	62·3	3·4 (3·0)	2·1 (2·9)	53·3	2·9 (2·2)	1·6 (2·2)

Measures of community structure and similarity for the endoparasitic helminths detected were those used by Kennedy (1993*b*). The measures of component community and infracommunity structure were: the total number of helminth species (species richness), the Shannon–Wiener Index and its Evenness, Simpson's and Berger–Parker Dominance Index, the mean number of individuals and species per eel and the Brillounin' Index for all eels according to Washington (1984), Magurran (1988) and Mühlenberg (1993). Similarities between the sampling sites were measured using Sörensen's Index (Mühlenberg, 1993) at the component level. The Mann-Whitney U ($P \leqslant 0{\cdot}05$) test was employed to determine significant differences among the numbers of eels being infected by a particular parasite species or developmental stage of *A. crassus* from both sampling sites.

RESULTS

Composition of the parasite community

Data on the parasites found in and on the eels from both sampling sites are summarized in Table 1. Although the eyes of the eels were searched for parasites no eye flukes were recorded. The gills of nearly 50% of the eels were infected with *P. bini* and/or *P. anguillae*. As most of these fish were heavily infested with these monogeneans it seemed neither to be appropriate to count the numbers of each *Pseudodactylogyrus* species nor to discriminate between the species for individual eels. Therefore the prevalence given in Table 1 summarizes the data for eels parasitized with either both or one of both *Pseudodactylogyrus* species. Additionally, *Trichodina* sp. and *Myxidium giardi* were recorded on the gills. Heavy infections by *Myxobolus* sp., *T. granulosum* and *A. crassus* could be found in eels from both sampling sites. Six different species of intestinal helminths were present in the fish: four acanthocephalan species (*P. ambiguus*, *Pomphorhynchus laevis*, *Acanthocephalus lucii* and *A. anguillae*), the nematode *Raphidascaris acus* and the cestode *Bothriocephalus claviceps*. Highest prevalences were recorded for *A. crassus*, *T. granulosum* and *Myxobolus* sp., lowest prevalences were obtained for the 2 *Acanthocephalus* species. *Trichodina* sp., *A. lucii* and *A. anguillae* were found only in eels sampled at LA. Significantly more eels caught at RH were infected by *P. ambiguus*, *B. claviceps* and *Myxobolus* sp. than those fish sampled at LA.

Developmental stages of Anguillicola crassus

Special attention was paid to the infestation of eels with *A. crassus*. Table 2 shows the prevalence of different developmental stages of this nematode. A significantly higher number of eels from the LA was infected by L_3 larvae of this parasite. Although the mean intensity was found to be the same at both sampling sites, a remarkable difference was obvious in respect of the abundance of this stage of *A. crassus*. In contrast, no significant differences could be found for L_4 larvae and adult worms from the sampling sites. The maximum number of *A. crassus* found in individual eels was 22 adult worms for LA and 15 adult worms for RH, respectively. The highest number of larvae (L_3 and L_4) was found to be 13 for LA and 9 for RH.

Component community structure

Summarized data on the helminth component community structure are given in Table 3. Additionally, diversity characteristics of helminth communities from other localities are presented in this table. The sampling site LA showed a higher helminth species richness than RH whereas diversity (Shannon–Wiener & Simpson's Index) was found to be slightly higher at RH. This elevated species richness at LA is only due to the *Acanthocephalus* species, each of them infecting 1 eel, respectively. The evenness was nearly the same at both sampling sites reaching values of about 50% of the maximum theoretical value. Also the Berger–Parker indices are comparable between both sites, due to the dominant eel-specific species *P. ambiguus*. Comparing the component community based on the intestinal helminths the dominance values increase clearly but still they do

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Table 3. Comparison of the diversity characteristics of the helminth communities of eels from the River Rhine and other localities

			Italy*		UK†
	LA	RH	Caprolace	Burano	Clyst 92
Total component communities					
Number of eels	61	60	38	28	44
Number of species	7‡	5‡	3	8	7
Shannon–Wiener Index	0·79	0·84	0·86	1·31	0·79
S–W Evenness	0·41	0·52	0·78	0·63	0·41§
Simpson's Index	1·71	1·80	1·97‖	3·73‖	1·58
Berger–Parker Index	0·74	0·71	0·67	0·54	0·78
Dominant species ¶	*Pa*	*Pa*	*Di*	*Di*	*Pt*
Dominance of intestinal component communities					
Berger–Parker Index	0·92	0·90	0·67	0·71	0·8
Dominant species¶	*Pa*	*Pa*	*Di*	*Di*	*Pt*

* Data from Kennedy *et al*. (1996).
† Data from Kennedy (1993*b*).
‡ Values calculated excluding data on *Pseudodactylogyrus* sp.
§ Value calculated from the data given by Kennedy (1993*b*).
‖ Value calculated from the data given by Kennedy *et al*. (1996).
¶ *Pa*, *Paratenuisentis ambiguus*; *Di*, *Deropristis inflata*; *Pt*, *Paraquimperia tenerrima*.

Table 4. Prevalence (P) in percent of coexistent helminth species in the intestine of eels

Location…	LA	RH
Number of eels examined…	61	60
0 species	57·4	26·7
1 species	27·9	56·7
2 species	11·5	13·3
3 species	3·3	3·3
P. ambiguus and *P. laevis*	6·6	8·3
P. ambiguus and *R. acus*	4·9	5·0
P. ambiguus and *B. claviceps*	3·3	5·0
P. laevis and *R. acus*	3·3	1·7
P. laevis and *B. claviceps*	0·0	1·7
R. acus and *B. claviceps*	1·6	1·7

not differ markedly between sites. Overall, the results do not suggest clear differences in species richness and diversity between both sampling sites. This conformity between the sites is also supported by the Sörensen index which showed a similarity between LA and RH of 85·7%.

Intestinal infracommunity structure

The composition of the intestinal infracommunity was analysed and the results are presented in Tables 4 and 5. Table 5 also contains data from other European localities to facilitate a comparison of the diversity characteristics of the intestinal infracommunity between different countries. The prevalence differs markedly between the 2 sampling sites (Table 4). At site LA, 57·4% of the eels were uninfected whereas 56·7% of the eels caught at RH contained 1 parasite species in the intestine. The proportion of eels with 2 or 3 coexistent helminth species is similar at both sites. The most frequent coexistence of parasites found were eels being infected with *P. ambiguus* and *P. laevis* followed by eels parasitized simultaneously by *P. ambiguus* and *R. acus*. The coexistent acanthocephalans showed clear patterns of distribution within the intestine. While *P. ambiguus* was always detected in the anterior third, *P. laevis* was located in the posterior third of the intestine. One eel (LA) was simultaneously infected with *P. ambiguus* and *A. lucii*. *A. anguillae* occurred without other species in the intestine of another eel caught at LA.

Comparing the diversity characteristics of the intestinal infracommunity it emerges that the mean numbers of helminth individuals as well as of species are nearly the same between both sites (Table 5). Values of Brillouin's diversity index were very low ($< 0{\cdot}1$) and also comparable between both places. Considering infected eels only, the number of helminth species as well as the Brillouin's diversity index increased but remained still comparable between sites.

DISCUSSION

The parasitological examination of the eels from 2 different sites in the River Rhine revealed a total of 12 different parasite species although not all organs and tissues were checked for protozoan parasites (e.g. bile, liver). This number of species is comparable with data on the parasite fauna reported for European eels from Belgium (Schabuss *et al*. 1997), Denmark (Køie, 1988), England (Kennedy, 1993*b*,

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Table 5. Comparison of the diversity characteristics of the intestinal infracommunity of helminth of eels from the River Rhine and other localities

			Italy*		UK†
	LA	RH	Caprolace	Burano	Clyst 92
Number of eels	61	60	38	28	44
Number of helminths					
$\bar{x}$	17·8	15·0	2·6	10·0	5·2
S.D.	37·2	23·9	3·9	11·4	5·0
Number of helminth species (all eels)					
$\bar{x}$	0·6	0·9	0·6	1·1	1·2
S.D.	0·8	0·7	0·8	0·7	0·8
Max	3	3	3	3	4
Number of helminth species (infected eels only)					
$\bar{x}$	1·4	1·3	1·4	1·3	—‡
S.D.	0·6	0·5	0·6	0·6	—‡
Brillouin's Index (all eels)					
$\bar{x}$	0·06	0·07	0·07	0·07	0·09
S.D.	0·17	0·17	0·18	0·18	0·19
Max	0·66	0·67	0·73	0·76	0·92
Brillouin's Index (infected eels only)					
$\bar{x}$	0·43	0·40	0·47	0·50	0·41
S.D.	0·17	0·19	0·14	0·29	0·17

* Data from Kennedy *et al*. (1996).
† Data from Kennedy (1993*b*).
‡ Data not given.

Kennedy, 1997), Ireland (Conneely & McCarthy, 1986) and Italy (Kennedy *et al*. 1996, 1998). The highest number of parasite species was reported for a Danish lake with 27 species (Køie, 1988) and the lowest number was even 0 in one year in the River Otter (England) although 2 years earlier 8 different species were found (Kennedy, 1997). Interestingly, our results also resemble those obtained for American eels (*Anguilla rostrata*) from Canada (Cone *et al*. 1993; Barker *et al*. 1996; Marcogliese & Cone, 1996).

It is most striking that the eels caught in the River Rhine were neither infected by eye flukes (e.g. metacercariae of *Diplostomum* spp.) nor by crustaceans (e.g. *Ergasilus* spp.) which frequently parasitize freshwater eels (Kennedy, 1974; Conneely & McCarthy, 1986; Køie, 1988). Some of the most prevalent helminths found in the present study were eel-specific parasites like *A. crassus*, *P. ambiguus* and *Pseudodactylogyrus* spp., which were all introduced from different regions of the world to Europe.

Both species of the gill monogeneans *Pseudodactylogyrus* are indigenous to Eastern Asia and Australia (Buchmann *et al*. 1987). Køie (1988) reported a prevalence of 20–67 % for *P. anguillae* and approximately 3 % for *P. bini* which resembled the total prevalence determined within this study for the *Pseudodactylogyrus* spp. The acanthocephalan *P. ambiguus* has also only recently been introduced into Europe (Taraschewski *et al*. 1987) from brackish waters of the east coast of the USA where it is a parasite of the American eel. Until now, there are only limited data available on the occurrence of *P. ambiguus* in European eels, acquired in the course of studies investigating heavy metals in fish parasites (Sures, Taraschewski & Jackwerth, 1994; Zimmermann, Sures & Taraschewski, 1999*a*, *b*). While Sures *et al*. (1994) reported a prevalence of 38 % the mean intensity of this acanthocephalan in eels of the River Weser was found to be 17 specimens with a prevalence of 93 % (Zimmermann *et al*. 1999*a*, *b*).

The most prevalent parasite was *A. crassus*, introduced to Europe in the early 80s probably with infected eels from Taiwan (Taraschewski *et al*. 1987; Køie, 1988). This swimbladder parasite was found in approximately 80 % of the eels, a level in good agreement with other studies on the occurrence of *A. crassus* in Europe. Würtz *et al*. (1998) reported prevalences between 60 and 72 % for the River Rhine near Karlsruhe. Similar prevalences were also reported from other countries as this parasite spread rapidly across the continent. *A. crassus* can now be found over almost the whole of Europe (Moravec, 1992) and its successful establishment seems only to be restricted by the natural ambient temperature regimes (Knopf *et al*. 1998). Interestingly, we found a significantly higher prevalence of the 3rd-stage larvae (L_3) of this parasite at the backwater sampling

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site (LA), although there were no significant differences in levels of the other developmental stages of this nematode. To explain the higher prevalence of L_3 one may assume that there is a higher number of infected intermediate hosts – most likely paratenic hosts – in the backwater of the River Rhine compared with the river basin. As the mean intensity of infection with L_3 is the same at both sampling sites, it becomes clear that the number of L_3 ingested by each eel which feeds on the respective intermediate host is similar. Thus, it seems possible that the number of infected intermediate hosts is higher at the backwater compared to the basin. As the known number of possible intermediate and paratenic hosts is still increasing (Székely, 1996; Székely, Pazooki & Molnar, 1996), the finding presented here cannot be sufficiently explained at the moment, and this unequal distribution of the L_3 needs further investigations.

Although most of the previous studies on eel parasites in Europe have focused on metazoans we have also recorded some protozoan parasites which reached prevalences of up to 80 % (*T. granulosum*). Køie (1988) also reported up to 100 % prevalence for *T. granulosum* in the blood of eels. Again, as compared to Køie (1988), the prevalence of the myxosporeans *Myxobolus* sp. and *Myxidium giardi* are relatively high in the eels caught in the River Rhine. While the prevalence did not differ between both sampling sites for *T. granulosum* and *M. giardi*, the number of eels infected with *Myxobolus* sp. was markedly higher in the basin compared to the backwater. In contrast, *Trichodina* sp. was found only in those eels caught in the backwater of the river. Anyway, it becomes clear from the species found in the eels of both sites that the most frequent and prevalent parasites were metazoans. Therefore it seems appropriate that most of the studies dealing with eel parasites disregard protozoans but concentrate on parasitic worms (Conneely & McCarthy, 1986; Kennedy *et al*. 1992; Cone *et al*. 1993; Barker *et al*. 1996; Marcogliese & Cone, 1996).

Concerning metazoans infecting fish the emphasis has been put on intestinal helminths which represent the richest parasite communities as most species of helminths were found in the intestine (Kennedy, 1993*b*, 1997; Kennedy *et al*. 1996). In the present study the highest number of different parasite species was recorded from the intestine of eels, which contained up to 6 different helminths. Among these, acanthocephalans were the most prevalent worms with *P. ambiguus* as the dominant species not only of the intestinal but also of the total component communities. Therefore we support the opinion of Kennedy (1990) who concluded that eels were usually dominated by a single parasite species which is frequently an acanthocephalan species and most often a generalist but could also be a specialist. We describe for the first time *P. ambiguus* as the most dominant parasite in eels which is an eoacanthocephalan species and is considered a specialist. In a long-term study Kennedy (1997) also described eel specialists as the dominant species, although none of these dominant specialists were acanthocephalans. Thus, the appearance of an acanthocephalan species as an eel specialist may be the reason for the very low diversity of the parasite communities in this study. Both infra- and component communities exhibited a low diversity and were dominated by this single species.

Comparing the diversity characteristics of the eels caught in the River Rhine with data from Italian lakes (Kennedy *et al*. 1996) the potential to build up a diverse community does not appear to be realised for the eels investigated here. The evenness reaches only approximately 50 % and less, whereby values of up to 100 % were described for lakes in Italy (Kennedy *et al*. 1996). Consistently, the values of the Berger–Parker dominance indices for the total as well as for the intestinal component communities were markedly higher in the present study compared to the data from Italian lakes. Thus, there is a high potential for a more diverse helminth community of the eels from the River Rhine. This is similar to the situation described by Kennedy (1993*b*) for the River Clyst in England with an evenness of 41 % in 1992 and a Berger–Parker dominance index of 0·78 and with the data from the River Tiber (Kennedy *et al*. 1998). Poulin (1996) reported a negative correlation between community evenness and parasite abundance among fish hosts. That means, when parasites are very abundant the respective community comprises a few core species and some rare species. To obtain a higher community evenness more species of generalists (e.g. digeneans and nematodes) and accidentals have to be acquired which both act as rare species. As the data on the helminth communities for the rivers Tiber and Rhine are similar to the situation described for eels of British rivers one can agree with the conclusion that the results derived from British studies can be applied to helminth communities of eels from continental Europe (Kennedy *et al*. 1998). Anyway, it remains unclear why the helminth communities of the eels from the River Rhine with its huge catchment area exhibit such a low parasite diversity and high dominance.

Slight differences emerged on the intestinal infracommunity level comparing our data with data from Italy and England. While the mean number of helminths is markedly higher in the River Rhine compared with the River Clyst in 1992 (Kennedy, 1993*b*), with the River Tiber (Kennedy *et al*. 1998) and with the lakes Caprolace and Burano (Kennedy *et al*. 1996) the mean number of helminth species (considering all eels as well as infected eels only) is comparable between all sites. Also, no clear differences emerged concerning the diversity, the values

of the Brillouin's index (considering all eels as well as infected eels only) were low, but nearly the same at all sites. Therefore the intestinal infracommunities in eels from different countries and regions in Europe were very similar in their characteristics.

The eel-specific cestode *B. claviceps* was reported to be the most frequently occurring species over a period of 9 years in eels of the River Otter in England (Kennedy, 1997). Following *P. ambiguus* this tapeworm was also the most abundant helminth in our study. The only intestinal nematode was the generalist *R. acus* occurring less frequently than *B. claviceps* in the eels of the River Rhine. The presence of the *Acanthocephalus* species *A. anguillae* and *A. lucii* seems just to be accidental as they occur in only 1 eel each with low numbers of specimens. The most frequently co-occurring helminths were the acanthocephalans *P. laevis* and *P. ambiguus*. It was conspicuous that *P. laevis* was always detected in the posterior part of the intestine while *P. ambiguus* was attached in the anterior part of the alimentary tract. Additionally, the individuals of *P. laevis* were smaller than their conspecifics usually detected in chub (*Leuciscus cephalus*) or barbel (*Barbus barbus*) from the River Rhine (unpublished data). This resembled results of Kennedy (1996) who found no gravid *P. laevis* in eels, while gravid females were detected e.g. in brown trout (*Salmo trutta*). Therefore it seems possible that also in Germany the formation of distinct strains of *P. laevis* takes place as reported for this parasite in Britain (e.g. Kennedy, 1984; Kennedy, Bates & Brown, 1989).

The present investigation provides a baseline for further studies on parasite communities of eels from the River Rhine and adjacent waters. Alterations in the helminth communities in eels may reflect a pollution incident although they certainly do not allow a clear indication of the nature of possible environmental changes. The need for more sustained measurements over the long-term remains (Kennedy, 1997) to distinguish natural community changes (background fluctuations) from fluctuations due to pollution or environmental impacts.

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