Journal of Helminthology (2005) **79**, 143–149 DOI: 10.1079/JOH2005276

Helminth communities of the barbel *Barbus barbus* from large river systems in Austria

S. Laimgruber[1], C. Schludermann[1], R. Konecny[1,2]* and A. Chovanec[2]

[1]University of Vienna, Institute of Ecology and Conservation Biology, Althanstrasse 14, 1090 Vienna, Austria: [2]Umweltbundesamt, Spittelauer Lände 5, 1090 Vienna, Austria

Abstract

The composition and diversity of the total and intestinal component endohelminth communities were determined in the cyprinid barbel from three study areas in two large river systems in Austria. Two sample sites in the Danube and one site in the River Drau are the only free flowing stretches of these rivers in Austria. Nine helminth species were identified, with the acanthocephalan *Pomphorhynchus laevis* being dominant in the Danube, with up to 100% prevalence. In the Drau, where the dominant species was the cestode *Bathybothrium rectangulum*, species diversity was higher than in the Danube.

Introduction

Most data on helminth communities in the barbel in Central Europe are derived from the Danube basin and the Elbe (Kritscher, 1955; Ergens & Lucký, 1959; Molnar, 1970; Moravec & Scholz, 1991; Gelnar *et al*., 1996). An extensive study on the parasites of barbel was undertaken in different sites in the Czech Republic, Austria and Hungary by Moravec *et al.* (1997) whereas the population biology, seasonal occurrence and maturation of some helminths from barbel were studied by Scholz & Moravec (1993, 1994, 1996), Moravec & Scholz (1995) and Moravec (1995, 1996). Although the barbel is a most abundant fish species in many European rivers, our knowledge and the understanding of its parasite fauna is still inadequate.

Certain helminths of barbel, mainly acanthocephalans, can occur in high intensities of infection and may cause considerable damage to their fish host (Roberts, 1978). Studies on the parasites of freshwater fish such as the barbel are therefore important not only in pathological or economic aspects of aquaculture and fisheries but also because some of these parasites may serve as sensitive indicators of pollution, providing a useful tool for the assessment of ecological conditions in aquatic habitats (Sures, 2001; Schludermann *et al*., 2003).

The present study, which forms part of a programme on the role of macroparasites as indicators of pollution, is designed to determine the species richness and diversity of helminth communities of the barbel from differing stretches of the rivers Danube and Drau in Austria. Data were used for a comparison of locations with similar ecological conditions but with differing heavy metal concentrations (Schludermann *et al*., 2003).

Materials and methods

Three study sites were selected, with two located in the Danube (Lower Austria) and one in the River Drau (Carinthia) (fig. 1). The Danube is one of the largest river systems in Europe, with a total length of 2850 km and the Austrian part is about 350 km long (Schiemer & Spindler, 1989). The first Danube site is located downstream of Vienna near the inflow of the River Fischa and this section is characterized by large alluvial areas with a diverse system of connected and disconnected back-waters. The second Danube site is located downstream of Melk near the inflow of the River Pielach. Both sites are within the last two free-flowing stretches of the Austrian Danube (Kovacek-Mann, 1992; Humpesch, 1994). The Drau-Rosegg site, a 6.5 km stretch known

*Author for correspondence
Fax: +43 (0)1 4277 9542
E-mail: Robert.Konecny@univie.ac.at

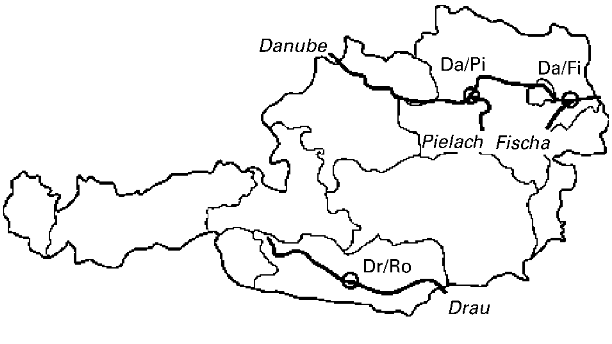

Fig. 1. Location of the three river sites in Austria for collection of barbel between April and November 2001 (after Schludermann *et al.*, 2003) Da/Fi, Danube-Fischa; Da/Pi, Danube-Pielach; Dr/Ro, Drau-Rosegg.

as the 'Rosegger–Schleife', is the only free-flowing part of this river in Austria, which is accompanied by disconnected backwaters (Friedl & Kerschbaumer, 2000). Barbel was found to be one of the most abundant fish species in all selected river stretches (Schiemer & Waidbacher, 1994; Friedl & Kerschbaumer, 2000). It was used as a model fish in the present study not only because of its abundance but also because of the presence of a range of helminth species in barbel in Central Europe (Moravec *et al.*, 1997).

A total of 83 large and medium-sized barbel was collected by electrofishing (Danube-Pielach, Drau-Rosegg) or using dragnets (Danube-Fischa) and bow nets (Danube-Pielach) between April and November 2001. Fish were transported to the laboratory and immediately examined for parasites as previously described by Schludermann *et al.* (2003). The total and caudal length, weight, sex and age were recorded for each fish. The parasitological terminology used follows that of Bush *et al.* (1997). Parasite community diversity and dominance indices were calculated using the Shannon-Wiener index, Shannon-Wiener evenness, Brillouin index, Simpson's index, and Berger Parker index (Magurran, 1988). Data analyses using Kruskal-Wallis, one-way ANOVA, and Post-hoc tests (Bonferroni) were performed using SPSS 10.0.

Results

A total of nine helminth species was identified in barbel from the three river sites. These included four trematodes (*Aspidogaster limacoides*, *Allocreadium isoporum*, *Diplostomum spathaceum*, *Posthodiplostomum brevicaudatum*), three cestodes (*Caryophyllaeus brachycollis*, *Bathybothrium rectangulum*, *Proteocephalus torulosus*), one nematode (*Rhabdochona hellichi*), and one acanthocephalan species (*Pomphorhynchus laevis*). Seven species were found in the intestine, and two species were recovered from the eyes (table 1).

In the Danube-Fischa site, of five helminths recorded, the most dominant species was the acanthocephalan *P. laevis* with a prevalence of 100% and a mean intensity of 177.8. The next most frequent helminth species in the Danube site was the metacercaria of the digenean *D. spathaceum* (prevalence 66.7%, mean intensity 3.7), followed by the nematode *R. hellichi* (prevalence of 27.3% and a mean intensity of 3.4). *Aspidogaster limacoides*, which was the only adult trematode identified, occurred in the intestine with a prevalence of 12.1% and a mean intensity of 2.5. The only cestode species recovered was *C. brachycollis*, with a prevalence of 6.1% and a mean intensity of 4.5.

Eight helminth species were found in the Danube-Pielach site where *P. laevis* was also the dominant species, with a prevalence of 100% and a mean intensity of 111.4, followed by *D. spathaceum* (prevalence 70%). The metacercaria stage of *P. brevicaudatum*, which was found only in this river site, showed a prevalence of 33.3% and adults of *A. isoporum* occurred in 16.7% of infected fish. *Rhabdochona hellichi* showed a higher prevalence (46.7%) in this site compared with 27.3% in the Danube Fischa. The three cestode species recorded, *C. brachycollis*, *B. rectangulum and P. torulosus* all showed relatively low prevalence and intensity levels.

In the Drau-Rosegg site, of the six helminth species recovered, prevalence values of 85% were recorded for *R. hellichi*, *B. rectangulum*, and *D. spathaceum*, with *B. rectangulum* being the dominant species. *Pomphorhynchus laevis* was found in 35% of fish, which is lower than that found in the Danube sites.

Negative binomial distributions were calculated for each parasite species for the three sites (Crofton, 1971a; Magurran, 1988) and the frequency distributions were overdispersed (table 1) with only a few fish harbouring high intensities (Crofton, 1971a,b; Kennedy, 1985; Anderson, 1993).

Species richness was calculated for all helminth communities and for intestinal helminths with and without *P. laevis* (tables 2 and 3). In the Danube-Fischa site both Shannon-Wiener (H′) and Simpson's diversity (D) indices showed a low diversity and a high dominance. The Shannon value was close to zero ($H' = 0.128$; evenness ($E) = 0.080$) and the Simpson's value was close to one ($D = 0.957$; $1/D = 1.045$). In contrast, the Drau-Rosegg site had the highest diversity ($H' = 1.196$; $E = 0.668$) and the lowest dominance ($D = 0.342$; $1/D = 2.927$). The Danube-Pielach site shared a medium diversity ($H' = 0.811$; $E = 0.335$) and also a medium dominance ($D = 0.550$; $1/D = 1.823$) The Brillouin index and the Berger-Parker index showed values similar to the Shannon-Wiener and Simpson's indices.

The values of each helminth species were tested separately to examine differences between the three study sites. Only *P. laevis* and *R. hellichi* showed significant differences. The population of *P. laevis* showed significant differences between the two Danube and the Drau sites ($P < 0.001$). There was also a significant difference between the Drau-Rosegg and Danube-Fischa site for *R. hellichi* ($P < 0.001$).

Discussion

The composition and structure of helminth communities in the barbel in the present study were similar to those of Moravec *et al.* (1997), and in the same barbel population data on the use of acanthocephalans as indicators of heavy metal accumulation was also

Table 1. Prevalence, mean intensity, mean abundance, and frequency distribution of the helminth communities of barbel in the Danube-Fischa (A), Danube-Pielach (B), and Drau-Rosegg (C), Austria, between April and November 2001.

Parasite species	Site	Number infected	Number of parasites	Prevalence (%)	Mean intensity (SE ±)	Range	Mean abundance (SE ±)	k-value
Caryophyllaeus brachycollis	A	2	9	6.1	4.5 (3.50)	1–8	0.3 (0.24)	0.02
	B	2	3	6.7	1.5 (0.13)	1–2	0.1 (0.07)	0.10
	C	–	–	–	–	–	–	–
Bathybothrium rectangulum	A	–	–	–	–	–	–	–
	B	1	1	3.3	1.0	1–1	0.03 (0.03)	–
	C	17	326	85.0	19.2 (5.11)	1–76	16.3 (4.60)	0.55
Proteocephalus torulosus	A	–	–	–	–	–	–	–
	B	1	1	3.3	1.0	1–1	0.03 (0.03)	–
	C	2	2	10.0	1.0	1–1	0.1 (0.07)	–
Aspidogaster limacoides	A	4	10	12.1	2.5 (1.19)	1–6	0.3 (0.19)	0.07
	B	–	–	–	–	–	–	–
	C	–	–	–	–	–	–	–
Allocreadium isoporum	A	–	–	–	–	–	–	–
	B	5	15	16.7	3.0 (1.26)	1–7	0.5 (0.28)	0.10
	C	1	12	5.0	12.0	12–12	0.6 (0.60)	0.01
Diplostomum spathaceum	A	22	82	66.7	3.7 (0.78)	1–17	2.5 (0.60)	0.72
	B	21	142	70.0	6.8 (1.76)	1–36	4.7 (1.35)	0.51
	C	17	136	85.0	8.0 (1.53)	1–24	6.8 (1.49)	1.02
Posthodiplostomum brevicaudatum	A	–	–	–	–	–	–	–
	B	10	109	33.3	10.9 (2.46)	1–20	3.6 (1.24)	0.12
	C	–	–	–	–	–	–	–
Rhabdochona hellichi	A	9	31	27.3	3.4 (1.50)	1–15	0.9 (0.48)	0.12
	B	14	1166	46.7	83.3 (32.66)	1–346	38.9 (16.81)	0.10
	C	17	256	85.0	15.1 (2.87)	2–36	12.8 (2.72)	0.82
Pomphorhynchus laevis	A	33	5869	100.0	177.8 (31.49)	7–660	177.8 (31.49)	0.96
	B	30	3342	100.0	111.4 (23.98)	1–604	111.4 (23.98)	0.76
	C	7	14	35.0	2.0 (0.50)	1–4	0.7 (0.26)	0.52

Table 2. Richness and diversity characteristics of the total component communities of helminth parasites of barbel in the Danube-Fischa, Danube-Pielach, and Drau-Rosegg sites, Austria between April and November 2001.

	Danube-Fischa		Danube-Pielach		Drau-Rosegg	
River sites	with *P. laevis*	without *P. laevis*	with *P. laevis*	without *P. laevis*	with *P. laevis*	without *P. laevis*
Total no. of species	5	4	8	7	6	5
Mean no. of species per barbel ± SD	2.12 ± 0.70	1.12 ± 0.70	2.77 ± 0.90	1.77 ± 0.90	3.05 ± 0.83	2.7 ± 0.66
Maximum no. of species per barbel	3	2	5	4	5	4
Mean no. of helminths per barbel ± SD	181.85 ± 179.66	4.00 ± 4.15	159.27 ± 147.07	47.90 ± 94.40	37.3 ± 26.23	36.6 ± 25.82
Maximum no. of helminths/barbel	664	17	681	383	101	100
No. of allogenic species	1	1	2	2	1	1
Shannon-Wiener index (H′)	0.128	1.015	0.811	0.665	1.196	1.124
Evenness (E)	0.080	0.631	0.390	0.320	0.668	0.627
Brillouin index (HB)	0.126	0.965	0.808	0.656	1.179	1.110
Simpson's index (D)	0.957	0.447	0.550	0.674	0.342	0.355
1/D	1.045	2.236	1.819	1.484	2.927	2.820
Berger-Parker (d)	0.978	0.621	0.699	0.811	0.437	0.445
1/d	1.02	1.61	1.43	1.23	2.29	2.25
Dominant species	*Pomphorhynchus laevis*	*Diplostomum spathaceum*	*Pomphorhynchus laevis*	*Rhabdochona hellichi*	*Bathybothrium rectangulum*	*Bathybothrium rectangulum*

Table 3. Comparison of the richness and diversity characteristics of intestinal helminth component communities of barbel in the Danube-Fischa, Danube-Pielach, and Drau-Rosegg sites, Austria between April and November 2001.

	Danube-Fischa		Danube-Pielach		Drau-Rosegg	
River sites	with *P. laevis*	without *P. laevis*	with *P. laevis*	without *P. laevis*	with *P. laevis*	without *P. laevis*
Total no. of species	4	3	6	5	5	4
% of barbels infected	100	45.5	100	53.3	100	90
Mean no. of species per barbel ± SD	1.45 ± 0.56	0.45 ± 0.56	1.77 ± 0.94	0.77 ± 0.94	2.25 ± 0.85	1.90 ± 0.64
Maximum no. of species per barbel	3	2	4	3	4	3
Mean no. of helminths per barbel ± SD	179.36 ± 180.25	1.52 ± 3.22	150.90 ± 144.97	39.53 ± 92.19	30.50 ± 25.20	29.80 ± 24.97
Maximum no. of helminths per barbel	660	15	680	347	93	92
Shannon Wiener index (H′)	0.057	0.927	0.601	0.099	0.882	0.791
Evenness (E)	0.041	0.669	0.335	0.055	0.548	0.491
Brillouin index (HB)	0.055	0.850	0.599	0.094	0.867	0.779
Simpson's index (D)	0.983	0.446	0.611	0.967	0.462	0.483
1/D	1.017	2.244	1.637	1.034	2.166	2.069
Berger-Parker (d)	0.992	0.620	0.738	0.983	0.534	0.547
1/d	1.01	1.61	1.35	1.02	1.87	1.83
Dominant species	*Pomphorhynchus laevis*	*Rhabdochona hellichi*	*Pomphorhynchus laevis*	*Rhabdochona hellichi*	*Bathybothrium rectangulum*	*Bathybothrium rectangulum*

obtained (Sures, 2001; Schludermann *et al.*, 2003). Overall, nine helminth species were identified, with the barbel specialists being *C. brachycollis* and *B. rectangulum,* (Bykohovskaya-Pavlovskaya *et al.*, 1962; Bates & Kennedy, 1991a,b; Scholz & Moravec, 1994, 1996; Moravec *et al.*, 1997; Zander, 1998; Lyndon & Kennedy, 2001). The residual species were generalists which also inhabit other freshwater fish species (Bykohovskaya-Pavlovskaya *et al.*, 1962; Moravec *et al.*, 1997). Moravec *et al.* (1997) reported a wide range of fish parasites of the barbel from Central Europe and especially for the Danube with a total of 43 species. Kritscher (1955) also examined barbel in Austria with similar results. Other investigations in Poland (Grabda-Kazubska & Pilecka-Rapacz, 1987), northern Spain (Gutiérrez-Galindo *et al.*, 1995), western Serbia (Cakic *et al.*, 1998), and Italy (De Liberato *et al.*, 2002) revealed a similar list of helminths.

At the two Danube sites *P. laevis* was always the most dominant species, with a prevalence of 100% (table 1). Between April 1992 and November 1994, Moravec *et al.* (1997) found comparable values (99% prevalence) in the Danube near Vienna and in Budapest, Hungary. The mean intensity in both Danube sites in the present study was higher than that described by Moravec *et al.* (1997). In the UK Kennedy (1996) examined different fish species in the Otter River with regard to colonization by *P. laevis*. Only in brown trout (*Salmo trutta*) *P. laevis* reaches a prevalence of 100%. In three other fish species, namely bullhead (*Cottus gobio*), flounder (*Platichthys flesus*) and eel (*Anguilla anguilla*) the prevalence values were lower, ranging between 43.6 and 50.0%. In Austria, the Drau-Rosegg site showed a different picture. Amongst the six helminth species recorded, *P. laevis* had a very low prevalence (35%) and a mean intensity of 2.0. A mean intensity of 83.3 for *R. hellichi* and a prevalence of 46.7% in the Danube-Pielach site was higher than that in the Drau site (mean intensity 15.1), whereas in the Danube-Fischa site the corresponding values were a prevalence of 27.3% and a mean intensity of 3.4. Moravec *et al.* (1997) found *R. hellichi* in both Danube sites, i.e. in the Austrian section of the Danube with a prevalence reaching 55%. In the Drau-Rosegg site the nematode species *R. hellichi* showed the highest prevalence (85%) together with *B. rectangulum* and *D. spathaceum*. In the Drau-Rosegg site *B. rectangulum* and *D. spathaceum* showed the highest mean abundance 16.3. The Danube-Fischa site yielded no *B. rectangulum,* and in the Danube-Pielach only one specimen of *B. rectangulum* was recorded. A similar situation was described from both Danube sites investigated by Moravec *et al.* (1997).

In general, the helminth community composition can be explained by the structure and composition of the macrozoobenthos (Dogiel, 1961; Kennedy & Hartvigsen, 2000). The parasite fauna reflects local ecological conditions and there will be distinct differences in the species composition of helminths parasitizing barbel in different study sites. The intermediate hosts for *P. laevis* are gammarids, mostly *Gammarus pulex*, and for *R. hellichi* the trichopteran larva *Hydropsyche* sp. (Dezfuli *et al.*, 1991, 1992; Moravec & Scholz, 1994). The substrate of the two Danube sites in the flat bank regions is fine sediment whereas the deeper regions are dominated by gravel banks. The Danube features a high density of 15 gammarid species (Moog *et al.*, 1991, 1995) and this could explain why barbel in the Danube showed such a high prevalence and intensity of *P. laevis*. Even though the Drau site at the Rosegger-Schleife is the only free-flowing stretch of this river, its original state has been changed by hydraulic engineering. The substrate is now characterized by sediments with large stones (Friedl & Kerschbaumer, 2000). The macrozoobenthos biodiversity here is generally not as high as in the Danube (Moog *et al.*, 1995). In the Drau, insect larvae prevailed (caddisflies, mayflies), and the two gammarid species here played only a secondary role as food items for the barbel and as intermediate hosts for acanthocephalans (Friedl & Kerschbaumer, 2000).

The diversity and dominance indices were calculated for the total component communities of helminths and for the intestinal component community (tables 2 and 3).

The calculation of indices without *P. laevis* yields a completely different picture showing that one dominant species can change the results totally. The present study confirmed the statement that parasite communities of freshwater fish generally show a low diversity and thus exhibit a high dominance by a single species (Kennedy *et al.*, 1986).

Acknowledgements

This work was funded by the Austrian Science Fund (FWF project number P14548-B.) We wish to express our grateful thanks to Dr Wolfgang Honsig-Erlenburg and Mag. Gerald Kerschbaumer from the Kärnter Institut für Seenforschung and the local fishery authorities at the River Drau. We are also grateful to Dr Gerald Zauner, University of Agricultural Sciences (BOKU) Vienna, the Company PROFISCH, and Mr Otto Eggendorfer, community of Fischamend for their support at the Danube locations. We also would like to thank Dr Andrea Hanus Illnar and Mr Andreas Knieschek, Umweltbundesamt for heavy metal analyses and Dr Michael Stachowitsch for critical comments on the manuscript.

References

Anderson, R.M. (1993) Epidemiology. pp. 75–116 *in* Cox, F.E.G. (*Ed.*) *Modern parasitology.* Oxford, Blackwell Scientific Publications.

Bates, R.M. & Kennedy, C.R. (1991a) Potential interactions between *Acanthocephalus anguillae* and *Pomphorhynchus laevis* in their natural hosts chub, *Leuciscus cephalus* and the European eel, *Anguilla anguilla*. *Parasitology* **102**, 289–297.

Bates, R.M. & Kennedy, C.R. (1991b) Site availability and density-dependent constraints on the acanthocephalan *Pomphorhynchus laevis* in rainbow trout, *Oncorhynchus mykiss* (Walbaum). *Parasitology* **102**, 405–410.

Bush, A.O., Lafferty, K.D., Lotz, J.M. & Shostak, A.W. (1997) Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *Journal of Parasitology* **83**, 575–583.

https://doi.org/10.1079/JOH2005276 Published online by Cambridge University Press

Bykhovskaya-Pavlovskaya, I.E., Gusev, A.V., Dubinina, M.N., Izyumova, N.A., Smirnova, T.S., Sokolovskaya, I.L., Shtein, G.A., Shul'man, S.S. & Epshtein, V.M. (1962) *Key to parasites of freshwater fish of the USSR.* Jerusalem, Israel, Program for Scientific Translations 1964.

Cakic, P.C., Hegedis, A.E., Kataranovski, D.S. & Lenhardt, M.B. (1998) Endohelminths of Mediterranean barbel, *Barbus peloponnesius petenyi*, in running waters of West Serbia (Yugoslavia). *Folia Zoologica* **47** (Suppl. 1), 81–85.

Crofton, H.D. (1971a) A quantitative approach to parasitism. *Parasitology* **62**, 179–193.

Crofton, H.D. (1971b) A model of host–parasite relationship. *Parasitology* **63**, 343–364.

De Liberato, C., Berrilli, F., Di Cave, D., Russo, R., Tancioni, L. & Kennedy, C.R. (2002) Intestinal helminths of Italian barbel, *Barbus tyberinus* (Cypriniformes: Cyprinidae), from the Tiber River and first report of *Acanthocephalus clavula* (Acanthocephala) in the genus *Barbus*. *Folia Parasitologica* **49**, 246–248.

Dezfuli, B.S., Zanini, N. & Reggiani, G. (1991) *Echinogammarus stammeri* (Amphipoda) as an intermediate host for *Pomphorhynchus laevis* (Acanthocephala) parasite of fishes from the River Brenta. *Bollettino di Zoologia.* **58**, 267–271.

Dezfuli, B.S., Bosi, G. & Rossi, R. (1992) The ultrastructure of the capsule surrounding *Pomphorhynchus laevis* (Acanthocephala) in its intermediate host *Echinogammarus stammeri* (Amphipoda). *Parassitologia* **34**, 61–69.

Dogiel, V.A. (1961) *Parasitology of fishes*. Edinburgh and London, Oliver and Boyd.

Ergens, R. & Lucký, Z. (1959) *Dactylogyrus dyki* n. sp. auf den Kiemen der Barbe (*Barbus barbus* (L.)). *Acta Societas Zoologicae Bohemicae.* **23**, 351–353.

Friedl, T. & Kerschbaumer, G. (2000) *Forschungsprojekt Ökosystem Flusskraftwerk Rossegg-St. Jakob, Stand und Zukunftsperspektiven der Bewirtschaftung*. Kärntner Institut für Seenforschung.

Gelnar, M., Koubkova, B., Plankova, H. & Jurajda, P. (1996) Report on metazoan parasites of fishes of the river Morava with remarks on the effects of water pollution. *Helminthologia* **31**, 47–56.

Grabda-Kazubska, B. & Pilecka-Rapacz, M. (1987) Parasites of *Leuciscus idus* (L.), *Aspius aspius* (L.) and *Barbus barbus* (L.) from the river Vistula near Warszawa. *Acta Parasitologica Polonica* **3**, 219–230.

Gutiérrez-Galindo, J.F., Lacasa-Millán, M.I., Castellá-Espuny, J. & Munoz-López, E. (1995) Helminths of *Barbus meridionalis meridionalis* Risso, 1826 in north-eastern Spain. *Acta Parasitologica* **40**, 140–141.

Humpesch, U.W. (1994) Quantitative Erfassung des Makrozoobenthos der Stromsohle in der freien Fleißstrecke der österreichischen Donau – Bodenstruktur, Besiedlungsdichte und Besiedlungsstruktur. pp. 109–125 *in* Kinzelbach, R. (*Ed.*) *Limnologie aktuell, biologie der Donau*. Stuttgart-Jena-New York, Gustav Fischer Verlag.

Kennedy, C.R. (1985) Interactions of fish and parasite populations: to perpetuate or pioneer? pp. 1–20 *in* Rollinson, D. & Anderson, R.M. (*Eds*) *Ecology and genetics of host-parasite interactions*. Academic Press, London.

Kennedy, C.R. (1996) Colonization and establishment of *Pomphorhynchus laevis* (Acanthocephala) in an isolated English river. *Journal of Helminthology* **70**, 27–31.

Kennedy, C.R. & Hartvigsen, R.A. (2000) Richness and diversity of intestinal metazoan communities in brown trout *Salmo trutta* compared to those of eels *Anguilla anguilla* in their European heartlands. *Parasitology* **121**, 55–64.

Kennedy, C.R., Bush, A.O. & Aho, J.M. (1986) Patterns in helminth communities: why are birds and fish different? *Parasitology* **93**, 205–215.

Kovacek-Mann, H. (1992) Vergleichende populationsdynamische Untersuchung von Barbe (*Barbus barbus*, L. 1758) und Rußnase (*Vimba vimba*, L. 1758) im Donaustauraum Altenwörth und der angrenzenden Fließstrecke in der Wachau unter besonderer Berücksichtigung der Ernährungsökologie. PhD thesis, Universität für Bodenkultur, Vienna, Abteilung für Hydrobiologie, Fischereiwirtschaft und Aquakultur.

Kritscher, E. (1955) Beitrag zur Kenntnis der Fischparasiten der Trattnach und des Innbachs bei Bad Schallerbach (O.Ö.). *Jahrbuch des Österreichischen Musealvereins* **100**, 373–389.

Lyndon, A.R. & Kennedy, C.R. (2001) Colonisation and extinction in relation to competition and resource partitioning in acanthocephalans of freshwater fishes of the British Isles. *Folia Parasitologica* **48**, 37–46.

Magurran, A.E. (1988) *Ecological diversity and its measurement*. London, Cambridge University Press.

Molnar, K. (1970) Beiträge zur Kenntnis der Fischparasitenfauna Ungarns VI. Cestoda, Nematoda, Acanthocephala, Hirudinea. *Parasitologia Hungarica* **3**, 51–76.

Moog, O., Nesemann, H. & Waidbacher, H. (1991) Makrozoobenthos-Zönosen ausgewählter Standorte der Donau zwischen Strom-Km 2203 und 2170. *Erweiterte Zusammenfassung, Deutsche Gesellschaft für Limnologie (DGL), Jahrestagung* **1991**, 290–294.

Moog, O., Humpesch, U.H. & Konar, M. (1995) The distribution of benthic invertebrates along the Austrian stretch of the River Danube and its relevance as an indicator of zoogeographical and water quality patterns: part 1. *Archiv für Hydrobiologie*, Suppl. **101**, Large Rivers, 9, 2, 121–213.

Moravec, F. (1995) Trichopteran larvae (Insecta) as the intermediate hosts of *Rhabdochona hellichi* (Nematoda: Rhabdochonidae), a parasite of *Barbus barbus* (Pisces). *Parasitology Research* **81**, 268–270.

Moravec, F. (1996) The amphipod *Gammarus fossarum* as a natural true intermediate host of the nematode *Raphidascaris acus*. *Journal of Parasitology* **82**, 668–669.

Moravec, F. & Scholz, T. (1991) Observation on the biology of *Pomphorhynchus laevis* (Zoega in Müller, 1776) (Acanthocephala) in the Rokytná River, Czech and Slovak Federative Republic. *Helminthologia* **28**, 23–29.

Moravec, F. & Scholz, T. (1994) Seasonal occurrence and maturation of *Neoechinorhynchus rutili* (Acanthocephala) in barbel, *Barbus barbus* (Pisces), of the Jihlava River, Czech Repuplic. *Parasite* **1**, 271–277.

Moravec, F. & Scholz, T. (1995) Life history of the nematode *Rhabdochona hellichi*, a parasite of the barbel in the Jihlava River, Czech Republic. *Journal of Helminthology* **69**, 59–64.

Moravec, F., Konecny, R., Baska, F., Rydlo, M., Scholz, T., Molnar, K. & Schiemer, F. (1997) *Endohelminth fauna of barbel,* Barbus barbus *(L.), under ecological conditions of the Danube basin in Central Europe*. Czech Republic, Academia Praha.

Roberts, R.J. (1978) *Fish pathology.* London, Bailliere Tindall.

Schiemer, F. & Spindler, T. (1989) Endangered fish species of the Danube River in Austria. *Regulated Rivers: Research and Management* **4**, 397–407.

Schiemer, F. & Waidbacher, H. (1994) Naturschutzerfordernisse zur Erhaltung der typischen Donau-Fischfauna. pp. 247–265 *in* Kinzelbach, R. (*Ed.*) *Limnologie aktuell, biologie der Donau.* Stuttgart-Jena-New York, Gustav Fischer Verlag.

Schludermann, C., Konecny, R., Laimgruber, S., Lewis, J.W., Schiemer, F., Chovanec, A. & Sures, B. (2003) Fish macroparasites as indicators of heavy metal pollution in river sites in Austria. *Parasitology* **126**, 61–69.

Scholz, T. & Moravec, F. (1993) Finding of *Proteocephalus* sp. larva (Cestoda: Proteocephalidae) in *Sialis lutaria* (Insecta: Megaloptera). *Acta Societas Zoologicae Bohemicae* **57**, 159–160.

Scholz, T. & Moravec, F. (1994) Seasonal dynamics of *Proteocephalus torulosus* (Cestoda: Proteocephalidae) in barbel (*Barbus barbus*) from the Jihlava River, Czech Republic. *Folia Parasitologica* **41**, 253–257.

Scholz, T. & Moravec, F. (1996) Seasonal occurrence and maturation of *Bathybothrium rectangulum* (Cestoda: Amphyicotylidae) in barbel *Barbus barbus* of the Jihlava River, Czech Republic. *Parasite* **3**, 39–44.

Sures, B. (2001) The use of fish parasites as bioindicators of heavy metals in aquatic ecosystems: a review. *Aquatic Ecology* **35**, 245–255.

Zander, C.D. (1998) *Parasit-Wirt-Beziehungen: Einführung in die ökologische parasitologie*. Berlin, Heidelberg, New York, Springer-Verlag.

(Accepted 15 December 2004)