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Comparative study of parasite communities in European eel *Anguilla anguilla* from rivers of northern Portugal

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Summary

European eels (*Anguilla anguilla*) from four rivers in northern Portugal were examined for their intestinal helminth communities. Simultaneously macroinvertebrates were collected for determination of biological water quality by the Belgian Biotic Index. Seven species of intestinal helminths were observed in the eels: two cestodes (*Bothriocephalus claviceps* and *Khawia baltica*), four nematodes (*Paraquimperia tenerrima*, *Spinitectus inermis*, *Rhabdochona anguillae* and *Cucullanus truttae*) and one acanthocephalan species (*Acanthocephalus clavula*). Species richness varied between 3 and 4 and all the four communities studied were dominated by one generalist or specialist nematode species. Diversity characteristics of intestinal helminth communities of eels from several lotic systems in Europe were compared to those from rivers from northern Portugal.

Key words: eel; parasites; helminth community; diversity; richness; Portugal

Introduction

The European eel *Anguilla anguilla* L. is an economically important fish that inhabits most European waters, occurring in very different ecological environments.

Only a few studies provide information on the composition and structure of parasite communities of the European eel *A. anguilla* from Portuguese rivers (Carvalho Varela *et al.*, 1984; Saraiva & Chubb, 1989; Saraiva, 1994; Saraiva & Eiras, 1996; Pereira, 2000) and none was carried out at both component and infracommunity levels.

It is well known that the presence or absence of many parasites in an ecosystem depends on a variety of factors including the capability of survival of their intermediate hosts in more or less heavily polluted waters.

The aim of the present study is to compare the intestinal helminth community of the European eel *A. anguilla* from four rivers from northern Portugal with different pollution levels and to analyse the temporal variation in two of them by comparing the data obtained in this study to those obtained in 1994 by Saraiva and in 2000 by Pereira. The authors also compare the characteristics of intestinal helminth communities of eels from several lotic systems in Europe.

Material and Methods

Samples of eels and macroinvertebrates were collected from the rivers Trovela, Covo, Este and Sousa, tributaries of the Lima, Cávado, Ave and Douro systems, respectively (Fig. 1), in each year season (except in spring in the River Este) from November 2001 to July 2002, in order to minimise seasonal fluctuations in the parasite communities.

The eels were captured by electrofishing. A total of 274 eels were examined, 55 (total length: 26.6 ± 6.4 cm, weight: 32.7 ± 23.5 g) from the River Trovela, 79 (25.3 ± 6.3 cm; 30.4 ± 22.7 g) from the River Covo, 47 (23.2 ± 9.2 cm; 29.0 ± 39.1 g) from the River Este and 93 (19.6 ± 3.8 cm; 13.1 ± 8.9 g) from the River Sousa. The fish were transported alive to the laboratory where they were killed, dissected and the digestive tract examined for the presence of helminth parasites. Parasite species were assigned to the categories of generalist or specialist as defined by Bush *et al.* (2001).

Macroinvertebrates were collected (sampling time 10 min) with a hand-net (300 µm mesh size), fixed in 4 % formalin, processed and identified to the taxonomic categories suggested for the calculation of the Belgian Biotic Index (BBI). The Belgian Biotic Index (BBI) of De Pauw and Vanhooren (1983) provides informations about the biological water quality based on the sensitivity of different macroin-vertebrates groups to pollution, and BBI values vary, according to the pollution degree, between 0 (strongly polluted water) to 10 (unpolluted water).

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

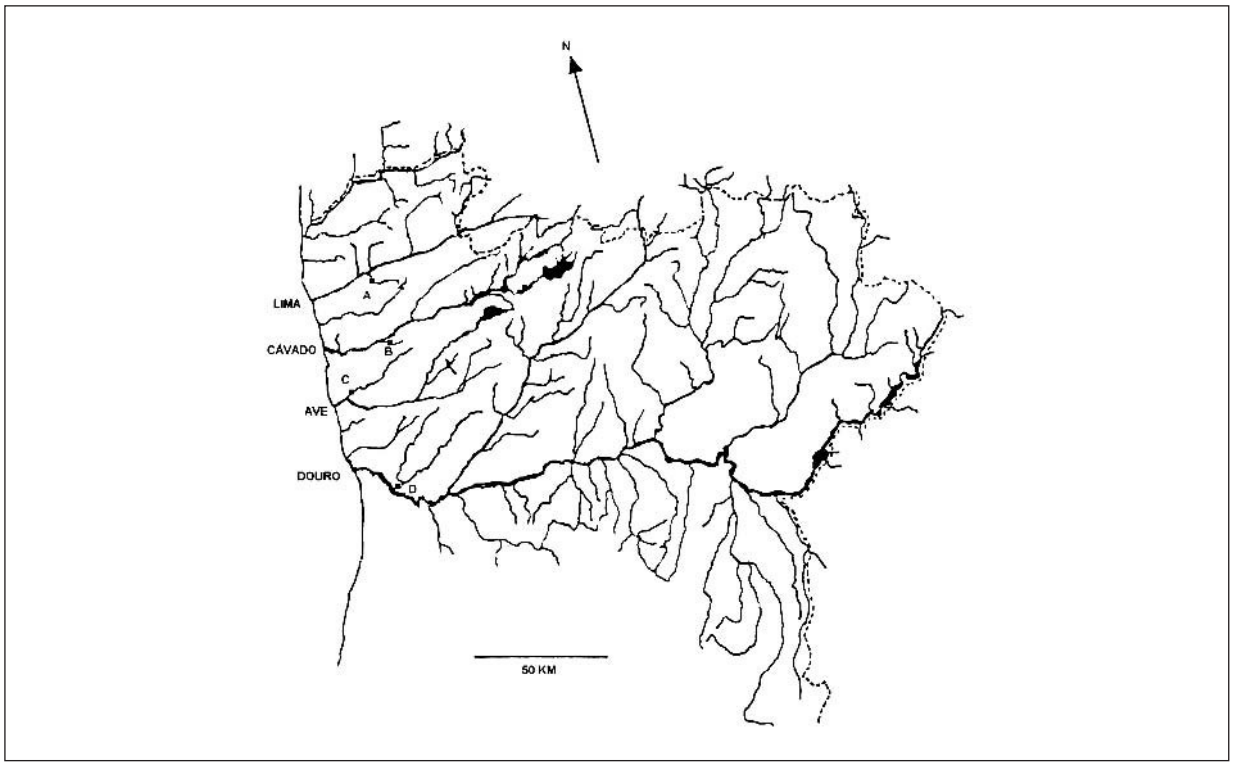

Fig. 1. Location of the sampling sites from the river Trovela (A), the river Covo (B), the river Este (C) and the river Sousa (D) tributaries of the Lima, Cávado, Ave and Douro systems, respectively

(1997).

Characterization of intestinal helminth community structure was carried out at both component and infracommunity levels (*sensu* Bush *et al.*, 1997), using the total number of helminth species (species richness), the Simpson's reciprocal Index (1/D), the Shannon-Wiener Index (H') and its Evenness (Index of Pielou) (E), the Berger-Parker Dominance Index (d), the mean number of parasites and species per eel and the Brillouin´s Index (HB). All these indices were adopted in order to facilitate comparisons with results from other authors and calculated in accordance with Magurran (1989) and Krebs (1999). Component species were defined as those with a prevalence of 10 % or greater in a sample (see Kennedy, 1993). Community similarities between the rivers studied were measured at the component level using Sorensen's Index (qualitative measure) and the Percentage Similarity Index (quantitative measure) (Magurran, 1989; Krebs, 1999).

Results

Composition of the intestinal communities

Data on the intestinal parasites found in eels from the 4 rivers localities are recorded in Table 1.

Seven species of intestinal helminths were observed in the eels: two cestodes (*Bothriocephalus claviceps* and *Khawia baltica*), four nematodes (*Paraquimperia tenerrima*, *Spinitectus inermis*, *Rhabdochona anguillae* and *Cucullanus truttae*) and one acanthocephalan species (*Acanthocephalus clavula*). *P. tenerrima* was the only species detected in all rivers. *B. claviceps* and *C. truttae* were detected in three rivers and the other species were detected in one river only. The highest prevalence and mean abundance in the River Trovela were recorded for *P. tenerrima*, in the River Covo and the River Este for *C. truttae* and in the River Sousa for *R. anguillae*.

The lowest prevalences and mean abundances were obtained for *B. claviceps* in all rivers excluding the River Este where this species was not observed. In this river the lowest prevalence and mean abundance was obtained for *K. baltica*.

Component community structure

Data on the community structure of the intestinal helminths found in eels from the 4 rivers studied are recorded in Table 2.

The highest helminth species richness and diversity (Simpson´s and Shannon-Wiener Index) were found in the rivers Trovela and Sousa. These rivers exhibited the same species richness and the same number of component species but diversity was higher in the River Trovela due to the occurrence of more identical relative abundances of parasite species, including the dominant species (Berger-Parker Index) which conducted to evenness near the maximum theore-

Table 1. Total number (TN), proportion of species i in the total sample (p_i), prevalence (P), intensity (I) mean (± SD) (min – max) and abundance (A) mean (± SD) of the eel parasites from the rivers studied

Rivers	Trovela					Covo					Este					Sousa				
No. of examined eels	55					79					47					93				
No. of infected eels	22					23					13					44				
Parasites	TN	p_i	P	I	A	TN	p_i	P	I	A	TN	p_i	P	I	A	TN	p_i	P	I	A
B. claviceps	8	0.16	7.3	2.0 (±1.22) (1 – 4)	0.15 (±0.62)	1	0.01	1.3	1*	0.01 (±0.11)						4	0.02	3.2	1.3 (±0.47) (1 – 2)	0.04 (±0.25)
K. baltica											1	0.03	2.1	1.0*	0.02 (±0.15)					
P. tenerrima	22	0.42	20	2.0 (±1.21) (1 – 5)	0.40 (±0.96)	23	0.32	13.9	2.1 (±4.29) (1 – 5)	0.29 (±0.84)	2	0.06	2.1	2.0*	0.04 (±0.29)	24	0.10	10.8	2.4 (±2.6) (1 – 10)	0.26 (±1.14)
S. inemis																83	0.36	16.1	5.5 (±4.15) (1 – 16)	0.89 (±2.63)
R. anguillae																120	0.52	26.9	4.8 (±12.4) (1 – 65)	1.29 (±6.78)
C. truttae	9	0.17	10.9	1.5 (±0.50) (1 – 2)	0.16 (±0.43)	48	0.67	17.7	3.4 (±4.29) (1 – 17)	0.61 (±2.23)	31	0.91	27.7	2.4 (±1.6) (1 – 7)	0.63 (±1.36)					
A. clavula	13	0.25	10.9	2.2 (±1.77) (1 – 6)	0.24 (±0.89)															

* only one infected eel

Table 2. Diversity characteristics of component communities of intestinal helminths of eels from the rivers studied

	Rivers			
Characteristics	TROVELA	COVO	ESTE	SOUSA
No. of species (species richness)	4	3	3	4
No. of component species	3	2	1	3
Simpson´s Reciprocal Index	3.39	1.83	1.20	2.44
Shannon-Wienner Index	1.30	0.69	0.35	1.01
Eveness Index of Pielou	0.94	0.63	0.32	0.73
Berger-Parker Dominance Index	0.42	0.67	0.91	0.52
Dominant species*	*P.t.*	*C.t.*	*C.t.*	*R.a.*

* *P.t.*, *Paraqimperia tenerrima*; *C.t.*, *Cucullanus truttae*; *R.a.*, *Rhabdochona anguillae*

Table 3. Percentage Similarity Index and Sorensen's Index (in parenthesis) between the communities of intestinal helminths of eels from the rivers studied

	Rivers			
Rivers	TROVELA	COVO	ESTE	SOUSA
TROVELA		50 (0.80)	20 (0.57)	12 (0.50)
COVO			73 (0.67)	11 (0.57)
ESTE				6 (0.29)

Table 4. Diversity characteristics of infracommunities of intestinal helminths of eels from the rivers studied

	Rivers			
Characteristics	TROVELA	COVO	ESTE	SOUSA
Mean number of helminths (± SD)	0.95 (±1.52)	0.91 (±3.34)	0.72 (±0.55)	2.48 (±7.31)
Mean number of helminth species (± SD)	0.49 (±0.63)	0.33 (±0.55)	0.32 (±0.56)	0.57 (±0.70)
Maximum number of helminth species per eel	2	2	2	4
Brillouin´s Index				
Mean	0.035	0.013	0.012	0.024
SD	0.111	0.068	0.076	0.096
Max.	0.461	0.366	0.398	0.549
Brillouin´s Index *				
Mean	0.087	0.046	0.057	0.050
SD	0.165	0.125	0.140	0.134
Proportion of eels with 0 or 1 helminth species	0.91	0.96	0.95	0.94

* infected eels only

tical value. Both rivers had a dominant eel-specific species. The lowest helminth species richness and diversity were found in the rivers Covo and Este. These communities showed the same species richness but the number of component species and diversity were lower in the River Este. The low values of diversity and evenness from this river reflect the very high relative abundance of the dominant species (Berger-Parker Index) since this community was composed almost exclusively by *C. truttae* specimens. *C. truttae* was also the dominant species in the River Covo and, for this reason, the River Covo and the River Este were quantitatively (Percentage Similarity Index) the most similar communities studied (Table 3). Qualitatively (Sorensen's Index) the most similar communities were from the River Trovela and the River Covo (Table 3) which reflects the high number of species in common (3). The most dissimilar communities, quantitative and qualitatively, were from the River Este and the River Sousa (Table 3) which is not surprising since these rivers had only one helminth species (*P. tenerrina*) in common and at low relative abundances.

Infracommunity structure

Data on the infracommunity structure of the intestinal hel-

Table 5. Macroinvertebrates observed, number of taxonomic categories and biotic index in the studied rivers localities

		Trovela	Covo	Este	Sousa
PLECOPTERA	Leuctridae	8			
	Nemoura	3			6
TRICHOPTERA	Ecnomidae	2			
	Glossomatidae	9			
	Hydropsychidae	9	7	3	10
	Philopotamidae	14			
	Phryganeidae	2			
	Polycentropodidae				7
	Rhyacophilidae	4	1		18
	Psychomyiidae	12	2		
EPHEMEROPTERA	*Baetis*	74	128	12	32
	Caenis		39		22
	Centroptilum	14			10
	Ephemera		15		18
	Ephemerella	27			
	Ephoron	26	23		
	Habrophlebia				2
	Heptagenia	1			9
	Potomanthus	1			
	Procloeon			3	1
ODONATA	Coenagrionidae	1			
	Corduliidae		3		2
	Lestidae	1			
	Libellulidae	2			
COLEOPTERA	Dryopidae	2			
	Dytiscidae	2			
	Elmidae	108	8		
	Gyrinidae	5			
	Haliplidae	1			
	Helodidae	1			
	Hygrobiidae	4			
MOLLUSCA	Bithynidae		2		19
	Neritidae				2
	Pisidium				11
CRUSTACEA	*Gammarus*	2			
MEGALOPTERA	Sialidae	1			
HEMIPTERA	*Gerris*	3	3		
	Vellidae	2			
DIPTERA	Chironomidae	22	55		67
	Culicidae	3	2		1
	Empididae	2			
	Limoniidae	8	1		5
	Tabanidae	2	6		3
	Simulidae	3			
HIRUDINAE	Hemiclepsis	3			
OLIGOCHAETA	Lumbricidae	18			
	Lumbriculidae	83	56		11
	Tubificidae		3		
PLATHELMINTA	*Dugesia*	14	2		1
	Polycelis		1		
TOTAL OF SYSTEMATIC UNITS *		32	16	3	18
BIOTIC INDEX (BI)		10	8	4	9

* The systematic units with one specimen only are not quantifying to the calculation of the BI

Table 6. Diversity characteristics of component communities of intestinal helminths of eels from several lotic systems in Europe

Characteristics	Portugal			England		Ireland			Poland		Germany			
	Saraiva (1994)[1]		Pereira (2000)[1]	Kennedy (1993)	Kennedy (2001)[2]	Conneely & McCarthy (1986)[1]		Kennedy & Moriarty (2002)	Seyda (1973)[1]	O-G& W[3] (1994)[1]	Sures *et al.*(1999)[4]		Sures & Streit (2001)	
	R. Este 1988	R. Este 1989	R. Sousa	R. Cyst 1979 to 92 (min. – max.)	R. Exe System (min. – max.)	R. Abbert	R. Drimneen	R. Shannon	R. Odra	R. Odra	R. Rhine[5]		R. Rhine[5]	
No. of species (sp. richness)	5	5	6	0 – 9	3 – 10	5	7	1 - 5	6	5	6	4	4	6
No. of component species	2	3	3	0 – 3	1 – 5	3	4	1	6	3	1	2	1	6
Simpson´s Reciprocal Index	3.05	3.37	2.30	0 – 2.67	1.33 – 3.08	2.88	2.54	1.00 – 1.15	2.63	3.85	1.18	1.25	1.23	2.12
Shannon-Wienner Index	1.32	1.32	0.97	0 – 1.04	0.46 – 1.28	1.88	1.68	0.04 – 0.30	1.84	2.07	0.39	0.44	0.42	1.11
Eveness Index of Pielou	0.82	0.82	0.54	0 – 0.95 [1]	0.41 – 0.89	0.81	0.60	0 – 0.17	0.71	0.89	0.22	0.32	0.30	0.62
Berger-Parker Dominance Index	0.48	0.38	0.52	0 – 0.88	0.44 – 0.88	0.40	0.50	0.93 – 1.00	0.57	0.34 – 0.30	0.92	0.90	0.90	0.67
Dominant species*	*P.t.*	*C.t.*	*R.a.*	*A.c., P.t., B.c.*	*P.t., S.i., P.l.*	*P.t.*	*P.l.*	*A.l.*	*A.a.*	*A.a, A.l.* (co-dominance)	*P.a.*	*P.a.*	*P.a.*	*P.a.*

[1]Values calculated from data given by the authors; [2]Values calculated from data given by the author from localities with a sample size equal or higher to 15 eels; [3] O-G & W - Orecka-Grabda and Wierbicka; [4]Values recalculated for intestinal helminths only; [5]Values from 2 sampling sites* *A.a., Acanthocephalus anguillae; A.c., Acanthocephalus clavula; A.l., Acanthocephalus lucii; B.c., Bothriocephalus claviceps; C.t., Cucullanus truttae; P.a., Paratenuisentis ambiguus; P.l., Pomphorhynchus laevis; P.t., Paraquimperia tenerrima; R.a., Rhabdochona anguillae; S.i., Spinitectus inermis*

minths found in eels from the 4 rivers are recorded in Table 4.
The highest values of mean number of helminths/eel, as well as the highest values of mean and maximal number of species/eel, were observed in the River Sousa. These results reflect the occurrence in this river of the two more abundant species (*R. anguillae* and *S. inermis*) (see Table 1) and it was the only river where one eel was infected with 4 helminth species. In general, the diversity characterristics of infracommunities analysed, including the Brillouin´s Index, were low in all rivers. These results were associated with the low percentage of eels infected with two or more helminth species (less than 10 %) and with the low values of mean intensity and mean abundance observed.

Biological water quality
Data on the macroinvertebrates collected and values of the Belgian Biotic Index obtained in the 4 rivers are recorded in Table 5.
The River Trovela had the richest and the River Este the poorest benthic macroinvertebrate community. The biological water quality analysis showed that the River Trovela (BI = 10) and the River Sousa (BI = 9) were not polluted in the study area, the River Covo (BI = 8) was slightly polluted but the River Este (BI = 4) was heavily polluted. Since the macroinvertebrate community richness of the River Sousa is similar to that observed in the River Covo (as can be seen by the number of systematic units) a similar degree of pollution could be expected in these rivers. The differrence observed can be explained by the presence and absence of Plecoptera, which is the most sensitive group to pollution, in the River Sousa and in the River Covo, respectively.

Discussion

Altogether 7 different intestinal helminth parasites occurred in the eels with different richness between the rivers: 4 species were found in the rivers Trovela and Sousa, while 3 species were detected in the rivers Covo and Este. In the River Este the presence of one specimen of *K. baltica* in one sample only and the knowledge of its preference for other host species (Chubb *et al.*, 1997) seems to indicate this specie is accidental in this host. Comparison of the present data with those obtained by Saraiva (1994) in the same locality of the River Este, and Pereira (2000) in the same locality of the River Sousa, it can be seen that the intestinal helminth community richness decreased in these two rivers in recent years.
The intestinal helminth communities' richness from Portuguese eels are within the range obtained in the majority of studies conducted on eels from lotic systems in other European countries (Table 6), since the most frequent values reported are 5 and 6 or, according to Kennedy (1990), 3.
The 4 communities studied were dominated by one generalist or specialist nematode species. These results support the opinion of Kennedy (1990) that eel helminth communities are usually dominated by a single parasite species. In all the studies conducted in Portugal, nematode species dominate the intestinal helminth community of eels. In Poland and Germany, the dominant species were always acanthocephalan, and in England and Ireland, both groups were observed.
The dominance and diversity indexes values observed in the intestinal helminth communities of eels from the rivers from northern Portugal are similar to those observed in lotic systems in Europe (Table 6). The dominance value was low and diversity indexes were high in unpolluted water (River Trovela and River Sousa) and the dominance value was very high and diversity indexes were very low in heavily polluted water (River Este).
The proportion of eels that were uninfected or harboured a single helminth species was very high, and the mean number of species per eel was low in all the rivers studied. These results are in accordance with those from Kennedy (1990, 1993) who found that in the majority of localities over 80 % of the eels were uninfected or infected with 1 species of helminth only and the mean numbers of species per eel seldom exceeded 1.
The mean values of Brillouin's index are very low in all the studied rivers but similar to those obtained by Kennedy *et al.* (1986).
The geographical distribution of intermediate hosts is an important factor influencing the occurrence of parasites. Eels are opportunistic feeders, feeding on almost any available organism. In unpolluted water, communities are richer and there are more food species available and conesquently intestinal helminth communities tend to be more varied. However, other factors could be responsible for the community structure variation. The introduction of new species is an example, as probably happens in the River Rhine where the low diversity and high dominance due to *P. ambiguus* (Sures *et al.*, 1999; Sures & Streit, 2001) was probably caused by the recent introduction of this species into Europe.

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