Composition and diversity of helminth communities in eels *Anguilla anguilla* in the River Tiber: long-term changes and comparison with insular Europe

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Abstract

Most studies of helminth communities in the European eel *Anguilla anguilla* have been undertaken in the British Isles, and there are very few analyses of community composition and structure from continental Europe. To fill this gap and test the hypothesis that helminth communities in freshwater eels in the British Isles are not typical of those of continental Europe, helminth communities of eels in the River Tiber below Rome were analysed by season using data collected in 1980 and new data from 1996. The intestinal helminth communities in the Tiber eels were species poor and characterized by low diversity. Most eels harboured one or no parasite species and communities were heavily dominated by the acanthocephalan *Acanthocephalus clavula*. Intestinal helminth infracommunity richness and diversity did not differ between seasons within a year or between the same seasons in 1980 and 1996, although some changes in composition were apparent. Intestinal infracommunities from Tiber eels were very similar in characteristics to those analysed from the British Isles, and their temporal changes also showed close similarities to those reported from rivers in the UK. It seems likely therefore that conclusions derived from British studies can be applied to helminth communities of eels on the continent.

Introduction

Most investigations into the structure and dynamics of helminth communities in the European eel *Anguilla anguilla* have been undertaken in the UK and Ireland. These investigations (Kennedy, 1990, 1992, 1993, 1997: Kennedy & Guégan, 1996) have indicated that intestinal helminth communities are species poor and are characterized by low densities, low diversity and high dominance by a single species of helminth, frequently an acanthocephalan. The intestinal helminth communities of freshwater eels appear to be stochastic assemblages, depauperate in character, and most eels are uninfected or harbour only a single species. Long-term changes in community composition may be considerable, whereas diversity may (Kennedy, 1993) or may not (Kennedy, 1997) be more stable.

The extent to which these conclusions may apply to helminth communities of *A. anguilla* throughout its freshwater range is unclear (Kennedy, 1990). Critical comments, especially from referees, have often raised the point that the UK and Ireland are small islands on the extreme edge of the eel's geographical range and so the poverty of the intestinal helminth communities in freshwater may reflect island and biogeographical

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influences. In short, the British Isles may be atypical and so unrepresentative of continental Europe: generalizations based on studies of eel helminths in Britain should not be applied to the continent without more evidence. Although there have been a number of studies on the parasites of eels throughout Europe including Poland (Seyda, 1973; Orecka-Grabda & Wierzbicka, 1994), Yugoslavia (Kazic *et al.*, 1982), Czech Republic (Moravec, 1985), Denmark (Køie, 1988a,b), Italy (Orecchia *et al.*, 1987), Portugal (Saraiva & Chubb, 1989) and Hungary (Molnar & Szekely, 1995), none of these reports contain data on, or analyses of, intestinal helminth infracommunity composition, diversity or long-term changes. The most recent studies of Schabuss *et al.* (1997) from Belgium analyse only component community composition and diversity and those of Kennedy *et al.* (1997) from Italy relate to eels in coastal lagoons of enhanced salinity and not to freshwater localities. To date, there are no published analyses of helminth communities, and especially infracommunities, in freshwater eels from southern and Mediterranean regions of Europe.

The present study was undertaken to fill this gap and forms part of an ongoing investigation (Kennedy *et al.*, 1997) into the parasites of Italian eels. This paper thus presents the results of a study of the composition and diversity of helminth communities of eels in the River Tiber, Italy. This locality was selected: (i) because it is at a latitude of 8°–13° south of the British Isles and so in a different, the Mediterranean, climatic subregion; (ii) because it is reasonably close to the southern limit of the geographical range of the eel in Europe; and (iii) because data on eel helminths in the river were available for comparison from an earlier study undertaken in 1980 (Orecchia *et al.*, 1987). The specific aim of the study was to test the hypothesis that helminth communities in freshwater eels in the British Isles are not typical of those of continental Europe.

Materials and methods

The River Tiber in the region of Rome is at a latitude of almost 42°N, compared to the British Isles which extend from 50° to 55°N. The eel population of the River Tiber is an entirely natural one and there has been no stocking from other localities. A survey of the parasites of eels in the river was carried out over four seasons in 1980 and details of the methods and findings were reported by Orecchia *et al.* (1987). The publication did not provide details or analyses of helminth community structure, but the original infracommunity data sets and representative specimens were made available to us.

In 1996, eels were obtained from commercial fishermen after capture in fyke nets in June (summer sample) and October (autumn sample) from localities corresponding as closely as possible to those of the 1980 survey, i.e. in the main water course of the river south of Rome and near to Ostia Antica. Eels were brought back alive to the laboratory and examined for helminth parasites only by methods similar to those employed by Orecchia *et al.* (1987) and Kennedy (1993) to facilitate comparison. All the major organ systems of the eel except the blood system were examined and all helminths in each eel were identified to species and counted.

Although some information is presented on helminths from sites other than the intestine, detailed analyses of community structure focused on intestinal helminths at infracommunity level to facilitate comparison with data from the British Isles. Terminology follows the definitions of Bush *et al.* (1997). Infracommunity parameters determined included numbers of helminths per eel, numbers of helminth species per eel and Brillouins' diversity index per eel. Additionally, the Berger-Parker dominance index was calculated for the component community in each season. All indices were calculated as in Magurran (1988). Species were considered specialists if eels were their only or principal definitive host: they were otherwise considered generalists. Comparisons were made using Czekanowski's coefficient and the percentage similarity index as defined in Pielou (1974).

Component helminth communities were first compared in respect of composition and species abundances using data from all four seasons from 1980 and the two seasons in 1996. Subsequent comparisons were made only for intestinal species and for summer and autumn only. Sample sizes for the 1980 survey as given here do not always correspond exactly with those given by Orecchia *et al.* (1987) since in a few cases eels from the 1980 survey were not censused fully and so were ignored. The significance of differences in means was tested with a 't' test, with significance taken at $P = 0.05$.

Results

The mean lengths of the eels examined in 1980 and 1996 did not differ significantly (table 1). The larger sample size in 1980 reflects the fact that the eels were sampled in four seasons compared to two in 1996. Average sample size per season exceeded 40 in both studies.

Six species of helminths were recorded in 1980, of which five were from the intestine (table 1). Four of the species were eel specialists and of the remaining two, *Raphidascaris acus* is commonly found in eels, whereas the caryopyhllaeid cestode is an accidental occurrence. The community was dominated by the acanthocephalan specialist *Acanthocephalus clavula* (Berger-Parker Index = 0.93). All the other intestinal species occurred at low prevalences and formed only a low proportion of the total number of helminths. By 1996 several changes in total species composition were apparent (table 1). There were now nine species present, six of them in the intestine. Seven of the nine species were eel specialists and the remaining two generalist species, *Nicolla gallica* and *Pomphorhynchus laevis,* appear to be accidental occurrences. The invaders *Pseudodactylogyrus anguillae* and *P. bini* were now found on the gills, from which the original inhabitant *Gyrodactylus anguillae* had disappeared. The introduced nematode *Anguillicola crassus* had invaded the population also, and was now almost co-dominant (*pi* 0.35) with *Acanthocephalus clavula* (*pi* 0.41) (table 1). The intestinal community, however, was still dominated by *A. clavula* (table 2) and all the other intestinal species occurred at low prevalence and formed a small proportion of the total number of intestinal helminths.

Table 1. Composition, prevalence and relative abundance of the helminth fauna of eels in the River Tiber.

			Year			
			1980		1996	
Parasite species	Site	Status	Prevalence	*pi*	Prevalence	*pi*
Gyrodactylus anguillae	G	Sp	12.6	0.06	0	0
Pseudodactylogyrus sp.	G	Sp	0	0	16.8	0.02
P. anguillae	G	Sp	0	0	55.4	0.13
P. bini	G	Sp	0	0	28.7	0.07
Nicolla gallica	I	Ge	0	0	1.0	0.001
Bothriocephalus claviceps	I	Sp	2.2	0.004	1.0	0.001
Proteocephalus macrocephalus	I	Sp	0.8	0.002	1.0	0.015
Caryophyllaeidae	I	Ge	0.4	0.001	0	0
Anguillicola crassus	SB	Sp	0	0	66.3	0.352
Pseudocapillaria tomentosa	I	Sp	0	0	1.0	0.001
Raphidascaris acus	I	Ge	3.0	0.007	0	0
Acanthocephalus clavula	I	Sp	52.6	0.93	65.3	0.405
Pomphorhynchus laevis	I	Ge	0	0	1.0	0.001
Total number of parasites				1163		980
No. of eels examined				230		101
Mean length of eels (cm)				26.9		25.8
(± S.D.)				6.0		6.4

G, gills; I, intestine; SB, swim bladder; Sp, specialist; Ge, generalist; *pi*, relative abundance as a proportion of the total number of all helminths of all species in eels.

Table 2. Seasonal changes in prevalence and abundance (± S.D.) of intestinal helminth species only in eels in the River Tiber.

	Year and season			
	1980		1996	
Parasite species	Summer	Autumn	Summer	Autumn
Nicolla gallica				
Prevalence	0	0	2.4	0
Abundance	0	0	0.024 (±0.16)	0
Bothriocephalus claviceps				
Prevalence	0	0	2.4	0
Abundance	0	0	0.024 (±0.16)	0
Proteocephalus macrocephalus				
Prevalence	0	0	0	1.7
Abundance	0	0	0	0.25 (±1.94)
Pseudocapillaria tomentosa				
Prevalence	0	0	2.4	0
Abundance	0	0	0.024 (±0.16)	0
Raphidascaris acus				
Prevalence	6.8	3.5	0	0
Abundance	0.1 (±0.36)	0.04 (±0.18)	0	0
Acanthocephalus clavula				
Prevalence	58.6	61.4	63.4	65.0
Abundance	5.6 (±14.8)	9.2 (±15.6)	2.5 (±3.0)	4.6 (±9.5)
Pomphorhynchus laevis				
Prevalence	0	0	0	1.7
Abundance	0	0	0	0.02 (±0.13)
No. of eels examined	58	57	41	60
Total no. of helminth species	2	2	4	3
Max. no. of species per eel	2	2	2	2
Berger-Parker Dominance Index	0.98	0.99	0.97	0.94
Dominant species	*A. clavula*	*A. clavula*	*A. clavula*	*A. clavula*

Table 3. Diversity characteristics of the infracommunities of intestinal helminths of the River Tiber.

Characteristics		1980 Summer	1980 Autumn	1996 Summer	1996 Autumn
No. of helminths	x	5.54	9.02	2.61	4.9
	S.D.	14.7	15.5	2.98	9.53
No. of helminth species	x	0.68	0.65	0.71	0.68
	S.D.	0.6	0.52	0.51	0.5
Brillouin's Index	x	0.017	0.001	0.009	0.006
	S.D.	0.066	0.009	0.055	0.047
	Max.	0.346	0.071	0.346	0.366
Percentage of eels infected		61.0	63.1	68.3	66.7
Proportion of eels with 0 or 1 helminth		0.93	0.98	0.97	0.98

Only three species, all intestinal and specialists, were found in both surveys. Comparison between the total communities in 1980 and 1996 based on data in table 1 gives a value for Czekanowski's coefficient of 0.4 and a percentage similarity value of 40%. For intestinal parasites only, values of 0.54 and 95.3% were obtained for the two similarity indices respectively. This difference in the percentage similarity index reflects the overwhelming numerical dominance (0.98 in 1980 and 0.95 in 1996) of *A. clavula* in the intestinal community: the other species contributed to qualitative similarity measures, but little to quantitative ones.

Some differences in intestinal helminth community composition are apparent between seasons (table 2). In 1980, prevalence and abundance of *R. acus* declined from summer to autumn. Changes in both parameters for *A. clavula* over the same period were not significant. In 1996, an increase in *A. clavula* abundance between summer and autumn was evident but not significant. Prevalence levels of *A. clavula* were similar in 1980 and 1996. Although abundance had declined over the period as fewer heavily infected eels were present in 1996, the declines were not significant for the same season. The intestinal helminth community was dominated by *A. clavula* in both seasons in the two years, with the dominance index being similar in all four samples.

Analysis of changes in intestinal helminth infracommunity parameters (table 3) confirms that there was no significant difference in the mean number of helminths per eel from summer to autumn each year, or between 1980 and 1996 for the same season. The mean number of species per eel did not differ significantly between seasons within a year or between years, and the maximum number of species per eel never exceeded two. Mean Brillouin's Index was highest in summer 1980, but values thereafter were lower and of similar magnitude. The large S.D. reflects the small number of eels with two species of helminth, and renders any differences in Brillouin's Index statistically and biologically insignificant. Maximum Brillouin's Index values were similar in three of the samples. These low diversity values reflect the large, and similar, proportion of eels with 0 or 1 species of helminth (= zero diversity) in the samples and the similar prevalence levels.

Discussion

The composition of the helminth communities of eels in the River Tiber is very similar to that reported from numerous localities in the UK and continental Europe, in that all the species reported from eels in the River Tiber have also been reported from eels from freshwater localities in the UK (Kennedy, 1990), Ireland (Conneely & McCarthy, 1986) and a number of countries in mainland Europe (Kazic *et al.*, 1982; Moravac, 1985; Køie, 1988a,b; Saraiva & Chubb, 1989; Molnar & Szekely, 1995; Schabuss *et al.*, 1997). Although species composition and richness vary in detail from locality to locality, helminth communities typically comprise a mixture of specialists and generalists as was reported from the River Tiber. High proportions of uninfected eels and eels infected by a single intestinal species only appear to be characteristic of *A. anguilla* throughout its range and not only in the River Tiber. High levels of dominance of helminth communities by a single species is also a widespread characteristic of eels in the UK (Kennedy, 1990, 1993). Dominance by a species of acanthocephalan, whether the specialist *A. clavula* or a generalist, is clearly not a British or Irish characteristic as Kennedy (1990) tentatively suggested: similar dominance was reported from two of the Belgian rivers studied by Schabuss *et al.* (1997) as well as from the River Tiber.

The characteristics of the intestinal infracommunities of the River Tiber eels are also very similar to those reported from localities in the UK and Ireland. The measures of helminth community structure in the River Tiber eels fall within the range of values reported from rivers in the UK (Kennedy, 1993, 1997). Indeed, these communities from the River Tiber are poorer than those from many localities in the British Isles and the maximum value of infracommunity richness in the intestine recorded in the River Tiber (two) is quite characteristic of Irish eels but is below the normal value of three recorded from British eels (Kennedy & Guégan, 1996). This is somewhat unexpected, as it might have been predicted that helminth communities in eels from warmer latitudes in the Mediterranean sub-region would have been richer since the eels remain more active and feed more over winter. Thus, the helminth communities of eels in the River Tiber are depauperate in nature and similar to those reported from the UK and Ireland, from other localities in continental Europe and indeed also from *A. rostrata* in North America (Marcogliese & Cone, 1993, 1996; Cone *et al.*, 1993). They differ from the communities reported from *A. reinhardtii* in tropical Queensland, which are richer and more diverse and are seldom dominated by one species and never by an acanthocephalan (Kennedy, 1995). In respect of helminth community composition and characteristics, the two species of Atlantic eel are similar to each other and differ markedly from the species of Pacific eel.

The data from the present investigation also provide some indication of the extent to which helminth community composition and diversity in the eels of the River Tiber have changed over time. The period covered by the present study, 16 years, is actually longer than those of the long term studies of helminth communities of eels in the River Clyst (13 years) and River Otter (12 years) in Britain (Kennedy, 1993, 1997) although samples were taken over several years in Britain and not just at two points. In both rivers, Kennedy (1993) found evidence of considerable changes in species composition, due mainly to colonizations, and richness of intestinal helminth communities in eels. These changes were much greater than those in diversity and dominance, and it was suggested that there was an underlying stability in community structure.

Changes in total community composition were evident in the helminths of eels of the River Tiber also, and similarity between the communities in 1980 and 1996 was low (40%). The major changes in helminth community composition involved the appearance of *A. crassus* in the swimbladder and *P. anguillae* and *P. bini* on the gills. *Anguillicola crassus* is a recent introduction to Europe and has spread widely and rapidly throughout the continent since the mid 1980s: its appearance in the River Tiber by 1996 was thus to be expected. The loss of *G. anguillae* from the gills of the eels in the River Tiber is believed to be due directly to inter-specific competition between it and the species of *Pseudodactylogyrus* (Kennedy & Di Cave, 1998). None of these three species, however, are believed to interact with the intestinal helminth community.

Changes in the intestinal helminth communities in the River Tiber eels over the period affected composition rather than structure of the community. The species that disappeared after 1980 and appeared in 1996 were rare in respect of both prevalence and abundance. They had an impact on the composition of the community, reflected in the low (0.54) value of the qualitative Czekanowski coefficient. The percentage similarity index, however, is a quantitative measure and so is much more affected by the abundance of species, and this indicated a very high level of similarity (95.3%) over the period. The infracommunity parameters also indicated a remarkable constancy of intestinal helminth community structure and diversity over the period. It is the overwhelming dominance of the intestinal helminth community by *A. clavula* that is responsible for this stability and constancy, since the changes in presence and absence of rare species have minimal impact on community structure. This bears some resemblance to the situation in the River Clyst, where the intestinal helminth community was also heavily (Berger-Parker index >0.7) dominated by a single species in most years and where richness and diversity parameters were unexpectedly similar at the start and end of the investigation there. Dominance by a single species was less overwhelming in the River Otter and the intestinal community there was more affected by the introduced species which were not always rare (Kennedy, 1997). These changes must in some way reflect environmental and management changes in the River Tiber, but the constancy of community structure supports the suggestion of Kennedy & Guégan (1996) that there are stabilizing determinant processes operating in the communities.

In respect therefore of component community composition and dominance and of infracommunity richness and diversity, helminth communities of eels in the River Tiber are very similar to those in the British Isles and in other parts of Europe. Moreover, the temporal changes that occurred in the helminth communities of eels in the River Tiber also show close similarities to those reported from rivers in the UK. It therefore seems likely that conclusions on helminth community structure based on investigations of eels in the British Isles can be applied to helminth communities of eels in both northern and southern Europe. The hypothesis that helminth communities in freshwater eels in the British Isles are not typical of those of continental Europe can be refuted.

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