Journal of Helminthology (2004) **78,** 297–303 DOI: 10.1079/JOH2004255

Intestinal helminth parasites in flounder *Platichthys flesus* from the River Thames: an infracommunity analysis

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Abstract

An analysis was undertaken of intestinal helminth communities in flounder *Platichthys flesus* from two sites on the River Thames. A comparison was made between helminth community richness and diversity from these sites at the component and infracommunity levels. At the component community level, a richer and more diverse parasite community was found in flounder from the Tilbury location (marine influence) than that from the Lots Road location (freshwater influence). At the infracommunity level, more parasite species and parasite individuals per host were found at Lots Road and the percentage of similarity values were low at both locations. Helminth species with high prevalence values in the parasite communities of the flounder are the dominant species in any individual fish, harbouring multi-specific infections. The presence of more invertebrate species, which are intermediate hosts in the helminth life cycle in the Thames, fish vagility and the high prevalence and abundance values of *Pomphorhynchus laevis* in the flounder, may explain the differences between the two locations.

Introduction

During the past two decades interest has increased in the analysis of parasite communities. How these communities are structured and which processes are involved in maintaining these structures are two major questions of concern (Holmes, 1986). Few studies, however, provide information suitable for the analysis of the structure and determinant processes of parasite communities, and fewer still contain data on individual hosts, which are essential for an analysis of diversity (Kennedy *et al.*, 1986; Kennedy, 1990). Holmes & Price (1986) arranged the organization levels in parasite communities into a three-tiered hierarchy: host individuals (infracommunity) host populations (component community) and communities of hosts (compound community). At the component community level, results are typically shown as sample summaries of infection parameters, making it difficult to interpret community organization. At the infracommunity level, however, data analysis can reveal possible community interactions, organization and replicability (Esch *et al.*, 1990).

The flounder *Platichthys flesus* is one of eight flatfish species (Pleuronectidae) found in the British Isles and north-west Europe. It is also the only European flatfish to penetrate significant distances into estuaries and to live in freshwater for short periods (Wheeler, 1979). In the River Thames estuary, the flounder is undoubtedly one of the most abundant fish species (Araujo, 1992; Chen, 1994).

The number of metazoan parasite species that a host species supports varies widely from host to host (Price & Clancy, 1983) and from location to location. In Britain, several surveys have been done on the parasite fauna of flounders, and results show much variation in the number of parasites in this host. MacKenzie & Gibson (1970) found 27 macroparasite species in flounder from the Ythan Estuary in Scotland, and Munro (1992) found five different helminth species parasitizing flounder in the River Thames. In their description of flounder parasite

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fauna in the River Thames, El Darsh & Whitfield (1999) reported as many as 24 different species, though their analyses were mainly at the component community level.

Previous surveys of flounders from the Thames estuary have not dealt with infracommunity level analysis, which is essential to understanding helminth community diversity. In an effort to address this deficiency, the present study was focused on analysis at the component and infracommunity levels. The gastrointestinal tract, which is the most favoured habitat for adult metazoan parasites (Mettrick & Podesta, 1974), is the site where parasite interactions are likely to occur. The study therefore concentrates on the intestinal helminth community in flounders collected from two locations on the River Thames.

Materials and methods

Fish and parasite sampling

Flounders were collected from the Tilbury and Lots Road power stations using a dip net in the recovery pool adjacent the power station inject filters. The two sites are approximately 70 km distant from one another. The Tilbury station has a strong marine influence and salinities approach marine levels, whereas Lots Road is further up river and has a mainly freshwater influence (Kinniburgh, 1998). Between July 1994 and August 1995, seven flounder samples were collected from Tilbury and five from Lots Road. Fish were transported live to the laboratory in insulated tanks, killed with a blow to the head and stored at −20°C until examined for helminth parasites. Each fish was weighed, sexed when possible and its pedicle length measured. The abdominal cavity was opened by a ventral longitudinal incision and the organs inspected *in situ* for parasites. Parasites were preserved in 70% ethanol for subsequent species identification.

Analysis of results

The terms prevalence, mean intensity and abundance of infection were used in accordance with Bush *et al.* (1997). Helminth community analysis was done at two levels: (i) component community (Bush & Holmes, 1986); and (ii) infracommunity (Holmes & Price, 1986). Differences between the number of individual and species of parasites in each locality were measured using the Mann-Whitney U test.

Species richness at the component level was measured as the total number of species in a sample (Southwood, 1987; Magurran, 1988). Diversity was measured using the Shannon-Weiner index and dominance with the Berger-Parker index (Magurran, 1988). Dominant species identity, colonization ability (autogenic or allogenic, Esch *et al.*, 1988) and capacity to infect a wide or narrow range of hosts (specialist or generalist) were also determined (Kennedy, 1975).

At the infracommunity level, the Brillouin index was used as a diversity measure (Magurran, 1988). The similarity (quantitative measure) at the component and infracommunity levels was measured using a percentage of similarity and the Jaccard index was used as a qualitative measure (Magurran, 1988).

Results

A total of 356 fish was examined with individual sample sizes ranging from 21 to 45 fish at Tilbury ($n = 230$) and 26 to 30 at Lots Road ($n = 143$). Twelve helminth species were found in the intestinal lumen of the flounder. The main taxa parasitizing the flounder were Nematoda (5 species) and Trematoda (4 species) (tables 1 and 2). Eleven helminth species were identified from Tilbury (table 1), with *Acanthocephalus anguillae* being the only species not found at this location. The taxonomic groups with the greatest number of species at this location were Nematoda and Trematoda. Seven helminth species were identified from Lots Road (table 2), with more nematode species being found than any other taxonomic group.

At Tilbury, *Pomphorhynchus laevis* and *Cucullanus minutus* were the parasites with the highest prevalence and mean intensity values. *Capillaria* sp. had low prevalence and high mean intensity. All parasites

Table 1. Intestinal helminth fauna in the flounder *Platichthys flesus* from the Tilbury Power Station (number of fish examined = 213).

Parasite species	Number of infected fish	Number of parasites	Prevalence (%)	Mean intensity	Abundance	Variance/mean
Cestoda						
Tetraphyllidean larvae	3	27	1.4	9.0	0.12	23.2
Trematoda						
Podocotyle atomon	8	105	7.3	13.1	0.49	77.9
Helicometra fasciata	1	19	0.5	19.0	0.09	18.7
Lecithaster gibbosus	1	1	0.5	1.0	0.004	1.16
Derogenes varicus	1	6	0.5	6.0	0.03	5.6
Acanthocephala						
Pomphorhynchus laevis	72	563	33.8	7.8	2.6	29.06
Nematoda						
Cucullanus minutus	44	540	20.6	12.3	2.5	57
C. heterochrous	2	3	0.9	1.5	0.014	1.66
Contracaecum sp.	12	22	5.6	1.8	0.10	2.4
Goezia sp.	3	11	1.4	3.6	0.05	5.4
Capillaria sp.	9	230	4.2	25	1.08	103.6

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Table 2. Intestinal helminth fauna in the flounder *Platichthys flesus* from the Lots Road Power Station (number of fish examined = 143).

Parasite species	Number of infected hosts	Number of parasites	Prevalence (%)	Mean intensity	Abundance	Variance/mean
Cestoda						
Tetraphyllidean larvae	3	10	2.1	3.3	0.07	6.8
Trematoda						
Podocotyle atomon	2	9	1.4	4.5	0.06	5.7
Acanthocephala						
Pomphorhynchus laevis	115	1551	80.4	13.5	10.8	46.8
Acanthocephalus anguillae	3	4	1.4	1	0.02	1
Nematoda						
Cucullanus minutus	2	9	1.4	4.5	0.06	7.3
Capillaria sp.	9	221	6.3	24.5	1.5	58.4
Goezia sp.	11	322	7.7	29.2	2.2	31.6

exhibited over-dispersed distributions within the fish population (table 1).

At Lots Road, differences in the infection parameters between the parasites were more extreme than at Tilbury (table 2) with *P. laevis* having high prevalence and mean intensity values. Both *Capillaria* sp. and *Goezia* sp. had low prevalence and higher mean intensity values.

Component community level

Parasite species richness analysis between locations

More helminth species were found in flounder from Tilbury than from Lots Road ($W = 41493$; $P < 0.05$) (table 3). More individual parasites, however, were found in fish from Lots Road ($W = 43202$; $P < 0.05$). The helminth community from Lots Road had a higher Berger-Parker index value than that from Tilbury, meaning that diversity was greater in helminth communities from Tilbury than those from Lots Road (see Shannon-Weiner index values). The dominant helminth species in flounder from both locations was *P. laevis*. All parasite species were autogenic species. Flounder helminth communities exhibited 50% similarity and a large proportion of this similarity was due to the high prevalence and mean intensity of *P. laevis* at both locations.

Table 3. The helminth community at the component level in the flounder *Platichthys flesus* from the power stations of Tilbury and Lots Road.

	Tilbury	Lots Road
No. fish examined	213	143
No. infected fish	123	109
No. parasite species	11	7
No. individual parasites	1527	2126
No. allogenic species	0	0
No. autogenic species	11	7
Berger-Parker index	0.37	0.73
Dominant parasite species	*P. laevis*	*P. laevis*
Dominant species	Generalist	Generalist
Shannon-Wiener index	2.15	1.15
% similarity	0.49	
Jaccard index	0.5	

Parasite richness analysis in individual flounder

The number of helminth species found in flounder from Tilbury ranged between 4 and 7. Berger-Parker index values were variable in the different samples from this location and *P. laevis* and *C. minutus* were the dominant species (table 4).

At Lots Road, worm burdens in the flounder were higher than at Tilbury, but the number of species was lower. The Berger-Parker index value was higher in three of five samples examined and *P. laevis* was the dominant species in all samples (table 5).

Infracommunity level

The mean number of helminth species per host at Tilbury was lower than one (table 6) with the exception of August 1995, and the percentage of hosts with zero or one parasite species varied from 76.2% (August 1995) to 100% (October 1994). The mean number of parasites per fish examined was variable, with the highest value observed in May 1995 and the lowest in July of the same year. The highest Brillouin index value was observed in July 1995 and the lowest in July 1994. The percentage similarity between parasite infracommunities in the total sample was 23.2 ± 39.7 and the Jaccard index value was 0.12 ± 0.30. In individual samples, the percentage similarity did not reach 50%, though values higher than 40% were recorded in October and November of 1994, and in June and July of 1995 (table 6).

With the exception of July 1995, the mean number of helminth species per fish examined at Lots Road was lower than one. The percentage of individual hosts with zero or one helminth species varied from 55.5% (August 1995) to 100% (July 1995). The mean number of individual helminths per fish in these samples was higher than at Tilbury (table 7), and ranged from 1.1 (July 1995) to 32.5 (August 1995). The percentage similarity between parasite infracommunities in the total sample was 23.8 ± 32.1 and the Jaccard index value was 0.41 ± 0.42. In individual samples the percentage similarity was higher than at Tilbury, but the infracommunity diversity was lower.

Dominance at the parasite infracommunity level

Parasite species with high infection levels (prevalence and abundance) are the most common dominant species

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Table 4. The helminth infracommunity in the flounder *Platichthys flesus* from the Tilbury Power Station from July 1994–August 1995.

Year/month	Number of fish examined	Number of infected fish	Number of individual parasites	Number of parasite species	Berger-Parker index	Dominant species
1994						
July	30	14	131	4	0.78	*C. minutus*
October	30	12	188	4	0.94	*P. laevis*
November	45	24	377	7	0.49	*P. laevis*
1995						
May	30	18	373	7	0.44	*C. minutus*
June	27	18	161	4	0.78	*C. minutus*
July	30	20	128	6	0.74	*C. minutus*
August	21	17	165	4	0.68	*P. laevis*

Table 5. The helminth infracommunity in the flounder *Platichthys flesus* from the Lots Road Power Station from July 1994–August 1995.

Year/month	Number of fish examined	Number of infected fish	Number of individual parasites	Number of parasite species	Berger-Parker index	Dominant species
1994						
July	30	29	126	2	0.99	*P. laevis*
November	26	25	494	5	0.76	*P. laevis*
1995						
February	30	26	584	3	0.76	*P. laevis*
July	30	17	33	1	1.0	*P. laevis*
August	27	12	869	3	0.68	*P. laevis*

Table 6. Characteristics of the helminth infracommunity in the flounder *Platichthys flesus* from the Tilbury Power Station from July 1994–August 1995.

Year/month	Flounder length (cm)	Mean helminth indiv/host (± sd)	Mean helminth species/host (± sd)	Mean Brillouin index values (± sd)	Mean % similarity (± sd)	% of hosts with 0 or 1 helminth species
1994						
July	9.36 ± 4.7	4.3 ± 14.7	0.7 ± 0.8	0.011 ± 0.04	29 ± 37	80
October	9.9 ± 3.6	6.2 ± 15.0	0.4 ± 0.5	0.0	44 ± 49	100
November	11.6 ± 4.3	8.4 ± 17.7	0.68 ± 0.7	0.014 ± 0.04	48 ± 47	86.6
1995						
May	11.6 ± 2.7	12.4 ± 37	0.8 ± 0.9	0.020 ± 0.05	27 ± 42	90
June	12.7 ± 1.9	9.0 ± 17.1	0.8 ± 0.7	0.022 ± 0.06	43 ± 43	85.2
July	13.1 ± 2.6	4.2 ± 6.0	0.8 ± 0.6	0.026 ± 0.06	42 ± 45	86.6
August	13.1 ± 1.0	7.8 ± 12	1.04 ± 0.7	0.020 ± 0.05	39 ± 45	76.2
Total	11.6 ± 3.7	7.1 ± 19.3	0.73 ± 0.7	0.017 ± 0.04	23.2 ± 39.7	86.6

Table 7. Characteristics of the helminth infracommunity in the flounder *Platichthys flesus* from the Lots Road Power Station from July 1994–August 1995.

Year/month	Flounder length (cm)	Mean helminth indiv/host (± sd)	Mean helminth species/host (± sd)	Mean Brillouin index values (± sd)	Mean % similarity (± sd)	% of hosts with 0 or 1 helminth species
1994						
July	12.8 ± 2.3	4.2 ± 3.8	1 ± 0.2	0.009 ± 0.03	98 ± 5	96.6
November	13.4 ± 3.1	19 ± 30	1.5 ± 0.4	0.010 ± 0.03	57 ± 45	80.7
1995						
February	13.6 ± 2.5	18.3 ± 31.4	1.06 ± 0.6	0.032 ± 0.06	67 ± 36	80
July	13.6 ± 1.4	1.1 ± 1.4	0.56 ± 0.5	0.0	35 ± 47	100
August	14.1 ± 1.4	32.5 ± 25.3	1.5 ± 0.6	0.060 ± 0.08	54 ± 39	55.5
Total	11.5 ± 1.9	14.8 ± 24.9	1.04 ± 0.6	0.021 ± 0.05	23.8 ± 32.1	83.3

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at infracommunity level in single or multi-specific infections. In general, parasites with high prevalence in the samples were more dominant than those with low prevalence values. For example, at Tilbury, *P. laevis* and *C. minutus* were present in a large number of sampled flounder (high prevalence) and were the most frequently dominant species at the infracommunity level (table 8). A similar situation occurred at Lots Road where *P. laevis* parasitized a large number of flounder, and was the most frequently dominant species at the infracommunity level. *Goezia* sp. and *Capillaria* sp. did not have high prevalence, but they were peculiarly dominant at the infracommunity level when present in multi-specific infections (table 8). It should be noted that the mean number of helminth species (rs = 0.364; $P < 0.0001$; $n = 356$) and the number of individual parasites (rs = 0.253; $P < 0.0001$; $n = 356$) was found to increase with host length.

Discussion

The flounder is carnivorous and generally an opportunistic feeder consuming whatever appropriate and acceptable food item is most abundant. The size, abundance and distribution of organisms in the environment are the main factors determining its choice of prey (Chen, 1994). The number of helminth species identified from samples taken at Tilbury and Lots Road differed. Since no differences were recorded in host length between the locations (tables 6 and 7), this difference may be due to other reasons. A partial explanation may be the higher diversity of invertebrates acting as intermediate hosts and preyed upon by flounders in marine-influenced waters (Holmes, 1986; Esch *et al.*, 1990). In the Thames tideway, a wider range of invertebrates used by flounders as a food resource is present at West Thurrock and Tilbury (Huddart 1971; Sedgwick, 1978; Jarrah, 1992) than in the upper Thames (Battersea and Tedington) (Chen, 1994). Digeneans require invertebrates as intermediate hosts to complete their life cycle and thus the distribution of invertebrates determines the presence of digeneans in flounders. For nematodes, differences in infection levels at both locations may be related to the distribution of flounder along the river in the case of direct life cycle species (*Cucullanus minutus* and *C. heterochrous*) (MacKenzie & Gibson, 1970). In species with indirect life cycles, infection levels may be related to intermediate host distribution (*Capillaria* sp., *Contracaecum* sp. and *Goezia* sp.) (Sprent, 1983; Williams & Jones, 1994).

Almost all intestinal helminths found in this survey are marine rather than freshwater in origin. In previous surveys, *P. laevis* in flounders from the Thames had been assumed to be the marine/estuarine strain of this parasite because of its need for an intermediate host species and its microhabitat (Munro, 1992; Munro *et al.*, 1989, 1990). The freshwater strain of *P. laevis,* however, has been recently detected by Guillen-Hernandez & Whitfield (2001) though its prevalence and mean intensity are lower than those of the marine/estuarine strain. *Acanthocephalus anguillae* is the only flounder intestinal helminth identified in the survey that can be considered a freshwater element in the flounder helminth community.

This freshwater parasite is poorly represented in the flounder helminth community even when both micro- and macroparasites are considered (El-Darsh & Whitfield, 1999). This may be a result of poor tolerance towards salinity changes, of its free-living larval stages. Alternatively, it may be due to fish migration into the lower estuary, where they are infected by marine parasites.

Component level parasite richness and diversity

As a catadromous species, the flounder can be infected with parasites from both freshwater and marine environments, and changes in the helminth intestinal community composition are related to parasite tolerance for the osmotic shock that accompanies this environmental change (MacKenzie & Gibson, 1970; Esch *et al.*, 1990). The absence of marine and freshwater intermediate hosts, ectoparasite stenohalinity conditions and the effect of salinity changes on parasite eggs and free larval stages are some of the main factors affecting the number of parasites

Table 8. Helminth species infracommunity dominance in the flounder *Platichthys flesus* from the Tilbury and the Lots Road power station sites on the River Thames. The table indicates the number of fish hosts with a parasite species, and the number of times this species dominates the infracommunity.

	Tilbury		Lots Road		Multispecies infections in the flounder	
Helminth species	Present	Dominant	Present	Dominant	Present	Dominant
Podocotyle atomon	5	4	2	1	3	1
Podocotyle sp.	3	3	–	–	1	0
Helicometra fasciata	1	1	–	–	1	1
Lecithaster gibbosus	1	1	–	–	1	0
Derogenes varicus	1	1	–	–	–	–
Tetraphyllidean larvae	3	1	3	2	4	2
Pomphorhynchus laevis	72	65	115	98	31	9
Acanthocephalus anguillae	0	0	3	1	2	0
Cucullanus minutus	44	41	2	2	18	6
Cucullanus heterochrous	2	0	–	–	–	–
Contracaecum sp.	12	10	–	–	9	2
Capillaria sp.	9	7	9	5	16	9
Goezia sp.	3	1	11	9	13	9

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in brackish waters (Möller, 1978). Flounders are known to migrate from the upper to the lower estuary and *vice versa* throughout the yearly cycle (Chen, 1994). There also appear to be 'resident' populations at both sampling locations, since differences in the number of parasite species at the component level are very clear, and no differences were found in length composition between the two locations.

Data analyses at the infracommunity level showed that the mean number of parasite species per fish is higher at Lots Road than at Tilbury. This is a consequence of the constant presence of *P. laevis* in the fish host, but also highlights the differences in the analyses at the infracommunity and component community levels. Diversity values at the infracommunity level in the intestinal helminth community of flounder are lower than those reported by Kennedy *et al.* (1986) and Kennedy (1993) for *Anguilla anguilla*, a catadromous host from the UK (0.19 ± 0.22 and 0.16 ± 0.24 respectively).

Seasonality in the intensity of feeding behaviour of flounder (Wheeler, 1979) can produce differences in the number of intestinal helminths. A comparison between samples of flounder collected at the same time in both locations, showed differences in the number of parasitic worms. Since *P. laevis* is the dominant helminth species in Lots Road, this difference in the number of helminth individuals is likely to be related to the abundance of *Gammarus zaddachi* along the river. In the upper Thames, *G. zaddachi* is the main source of food for the flounder, and *P. laevis* is the dominant species both at the component community level and in individual samples from this part of the river. High *P. laevis* dominance values in this part of the river indicate intensive feeding of flounder on *G. zaddachi*, and consequently a low richness and diversity in the helminth community.

At Tilbury, *P. laevis* was not as dominant as in the flounder from Lots Road. Munro *et al.* (1998) point out that the *P. laevis* marine-estuarine strain life cycle is completed mainly within the salinity-delineated distribution of *G. zaddachi*, and the infection pattern is essentially controlled by the movement of potential hosts through this region of the estuary. Probably the low infection levels at Tilbury are the result of the substitution of *G. zaddachi* by *G. salinus* as intermediate host in this part of the estuary, since this is the limit of the *G. zaddachi* distribution towards the coast. It is also where *G. salinus* abundance begins to increase suggesting that the limits of the distribution of intermediate hosts are critical points in the distribution of *P. laevis*. Additionally, the presence of *C. minutus* as a dominant species in four of seven flounder samples from Tilbury indicates either a change in host feeding habits, or seasonality in the number of infective stages during the spring and summer.

Esch *et al.* (1988) pointed out that helminth communities in the same fish species often show low degrees of similarity in composition, number and dominance between localities. In the British Isles, helminth communities in freshwater fish are thought to be chance assemblages rather than structured organizations (Kennedy *et al.*, 1986). In brackish waters, helminths able to tolerate variable salinities are likely to be widespread as they stand a better chance of being introduced into new locations by fish straying when returning to freshwater habitats. These tolerant helminths are likely to be responsible for the similarity in the intestinal helminth communities from Lots Road and Tilbury (Esch *et al.*, 1988).

The constant presence of *P. laevis* in individual samples of flounder from Lots Road resulted in a high percentage similarity at both component community and infracommunity levels. At the component community level at Tilbury, dominance alternated between *P. laevis* and *C. minutus*, while at Lots Road *P. laevis* was the only dominant species at this level. In contrast, at the infracommunity level almost any species can be dominant in multispecies infections at either of the sampling locations. Variability in the similarity and dominance values of helminths between samples of flounder from the same location confirms the fortuitousness of species composition and abundance in flounder helminth communities. Differences in the feeding habits of flounder throughout the annual cycle are indicated by the fact that the highest similarity values occurred between flounder samples from the same locality taken in the same season, even when collected in different years.

The results of the present survey agree with those of El-Darsh & Whitfield (1999) in that they indicate that flounder vagility and feeding habits determine differences in the helminth communities of flounder along the river. However, the infracommunity level analysis demonstrates the random nature (based on low similarity values and high variation in dominant species identity) of flounder helminth communities, which contrasts with the apparent stability observed in a previous component community level study (El-Darsh & Whitfield, 1999).

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(Accepted 10 June 2004)