

Abdominal macroparasites of commercially important flatfishes (Teleostei: Scophthalmidae, Pleuronectidae, Soleidae) in northwest Spain (ICES IXa)

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Abstract

This study investigated the helminth fauna of the abdominal viscera and cavity of 484 flatfishes caught in three areas off northwest Spain: the inner third of the Muros Estuary (MI), offshore from the Muros Estuary (ME) and offshore from the Arousa Estuary (AE). The following helminths were found: (a) nematodes—*Cucullanus heterochrous* Rudolphi, 1802, *C. minutus* Rudolphi, 1819, *Anisakis simplex* (Rudolphi, 1819), *Hysterothylacium aduncum* (Rudolphi, 1802), *Contracaecum* sp. and *Capillaria gracilis* Bellingham, 1840; (b) digeneans—*Podocotyle atomon* (Rudolphi, 1802), *P. angulata* (Dujardin, 1845), *Macvicaria soleae* (Dujardin, 1845), *Derogetes varicus* (Müller, 1784), *Lecithochirium rufoviride* (Rudolphi, 1819), *L. musculus* (Looss, 1907), *Synaptobothrium caudiporum* (Rudolphi, 1819), *Zoogonus rubellus* (Olsson, 1868), *Zoogonoides viviparus* (Olsson, 1868), *Rudolphinus crucibulum* (Rudolphi, 1819), *Proctoeces maculatus* (Looss, 1901), *Homalometron galaicus* (Sanmartín, Álvarez, Quinteiro et Paniagua, 1995) and *Lomasoma stephanskii* Dollfus, 1960; (c) cestodes—adult *Bothriocephalus barbatus* Renaud, Gabrion et Pasteur, 1983, *B. gregarius* Renaud, Gabrion et Pasteur, 1983, *Bothriocephalus* sp. and *Bothrimonus nylandicus* (Schneider, 1902), plerocercoids of *Nybelinia lingualis* (Cuvier, 1817), *Grillotia* sp. and unidentified tetraphyllidean plerocercoids; and (d) acanthocephalans—*Acanthocephaloides propinquus* (Dujardin, 1845). Most of these helminths were found in more than one host species and many at more than one capture site. Of the studied hosts, *Microchirus variegatus* and *Platichthys flesus* had the richest helminth communities with 13 species. Within each capture area, the helminth faunas of the various

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host species were similar except *P. flesus* (Linnaeus), which is infected by five helminth species not present in any other host (*Z. rubellus*, *R. crucibulum*, *C. minutus*, *Contracaecum* sp. and *C. gracilis*). There were marked differences between the three areas (particularly between the offshore areas and MI) in the identity of the helminth species present and their abundances, so some of the parasites found may thus be useful markers of different flatfish populations in this area.

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1. Introduction

The flatfishes are an important resource for commercial fisheries throughout the world. In 1999, EEC captures of turbot *Scophthalmus maximus* (Linnaeus) and brill *S. rhombus* (Linnaeus) alone were 6000 and 3000 tons, respectively (Leclercq, 1999). Other commercially important species are the megrim (*Lepidorhombus* spp.), the sand sole, *Solea lascaris* (Risso), and the flounder, *Platichthys flesus* (Linnaeus). Flatfishes are also important in aquaculture. Turbot culture in particular is an increasingly important industry. Of the 3400 tons of turbot produced in the EEC in 1997, 2000 came from Spanish fish farms (Lamour and Leclercq, 1998). In 1998, Spain's production was about 2500 tons (Leclercq, 1999) of which 1818 came from Galicia (NW Spain; PDRA, 1999). Other flatfish species cultivated in various countries, though on a smaller scale, include the halibut (*Hippoglossus hippoglossus* Linnaeus), the plaice (*Pleuronectes platessa* Linnaeus), the common sole (*S. vulgaris* Quensel), sand sole and flounder (Nash, 1998).

The aquaculture industry suffers major economic losses as a result of microbial and parasitic diseases, which in many cases arise as a result of the use of natural waters without adequate filtration or feeding with invertebrates and/or fish caught in natural habitats. It is therefore critically important for aquaculturists to have reliable information about potentially pathogenic organisms that may be present in their region and about the life cycles of these organisms.

Despite the importance of northwest Spain for the production of flatfishes, to date there has been no detailed study of the parasite fauna of the wild flatfishes of this region. We report a study of the abdominal parasites of eight commercially important flatfishes and review the literature on the presence in this area of free-living animal species previously described as potential intermediate hosts of the parasites detected as a basis for future studies of their life cycles in this region.

2. Materials and methods

2.1. Hosts

The host individuals studied (Table 1) come from three areas of the estuaries and the continental shelf off Galicia: (a) offshore from the Arousa Estuary (42°29' N,

Table 1

Flatfish species considered with the number of individuals for each species from each capture area

	Common name in English (Spanish)	Arousa Estuary (AE) ^a	Muros Estuary ^a			Total captures
			MI	ME	Total	
<i>S. maximus</i>	turbot (rodaballo)	80	4	6	10	90
<i>S. rhombus</i>	brill (rémol)	–	11	–	11	11
<i>P. flesus</i>	flounder (platija)	–	18	–	18	18
<i>S. lascaris</i>	sand sole (sortija)	–	18	9	27	27
<i>S. vulgaris</i>	common sole (lenguado)	–	17	–	–	17
<i>L. whiffiagonis</i>	megrim (gallo)	8	3	63	66	74
<i>L. boscii</i>	four-spot megrim (gallo)	117	–	22	22	139
<i>M. variegatus</i>	thickback sole (golleta)	138	–	52	52	190

^a AE, MI and ME: flatfish capture sites (see Fig. 1).

9°2' W; AE in Fig. 1), (b) offshore from the Muros Estuary (42°45' N, 9°26' W; ME in Fig. 1), and (c) on the A Misela bank in the inner third of the Muros Estuary (42°46–47' N, 8°55–57.5' W; MI in Fig. 1). The fish were captured by trawling between December 1986 and December 1993. In most cases, samples were obtained by accompanying local fishermen on normal outings and purchasing fish as caught. Since captures were random and since the natural populations of each species differ in density, sample sizes for each species are different. *Microchirus variegatus* (Donovan) and *L. boscii* (Risso) are abundant on the continental shelf, while *L. whiffiagonis* (Walbaum) and species of the genus *Solea* and *Scophthalmus* are much less frequent (Fariña et al., 1997). In view of the great economic importance of the turbot and its relative scarcity in the natural habitat, we separately collected an additional sample of 80 fish from AE.

2.2. Transport and dissection

During the first few years of this study, captured specimens were killed in situ by a blow to the head, then introduced into individual plastic bags and transferred in ice boxes to the laboratory, where they were kept at 4 °C until dissection (2–3 days at most). From 1991 onwards, the fish were transferred live to the laboratory in seawater transport tanks and maintained in an aquarium with recirculating seawater for at most 3 days before dissection. These fish were killed with an overdose of anaesthetic (MS222, Sigma). Species determinations were done with the aid of Whitehead et al. (1986) and Ben-Tuvia (1990).

Once the abdominal viscera had been extracted, we examined the external surface of the different organs and the abdominal cavity. We separately examined the lumen of the different parts of the digestive tract and each of the adjacent organs. All helminths found were washed in physiological saline, relaxed and fixed in Berland's fluid, then conserved in 70° alcohol until processing for light or electron microscopy by standard procedures in our laboratory (Quinteiro et al., 1992; Álvarez et al., 1994, 1995).

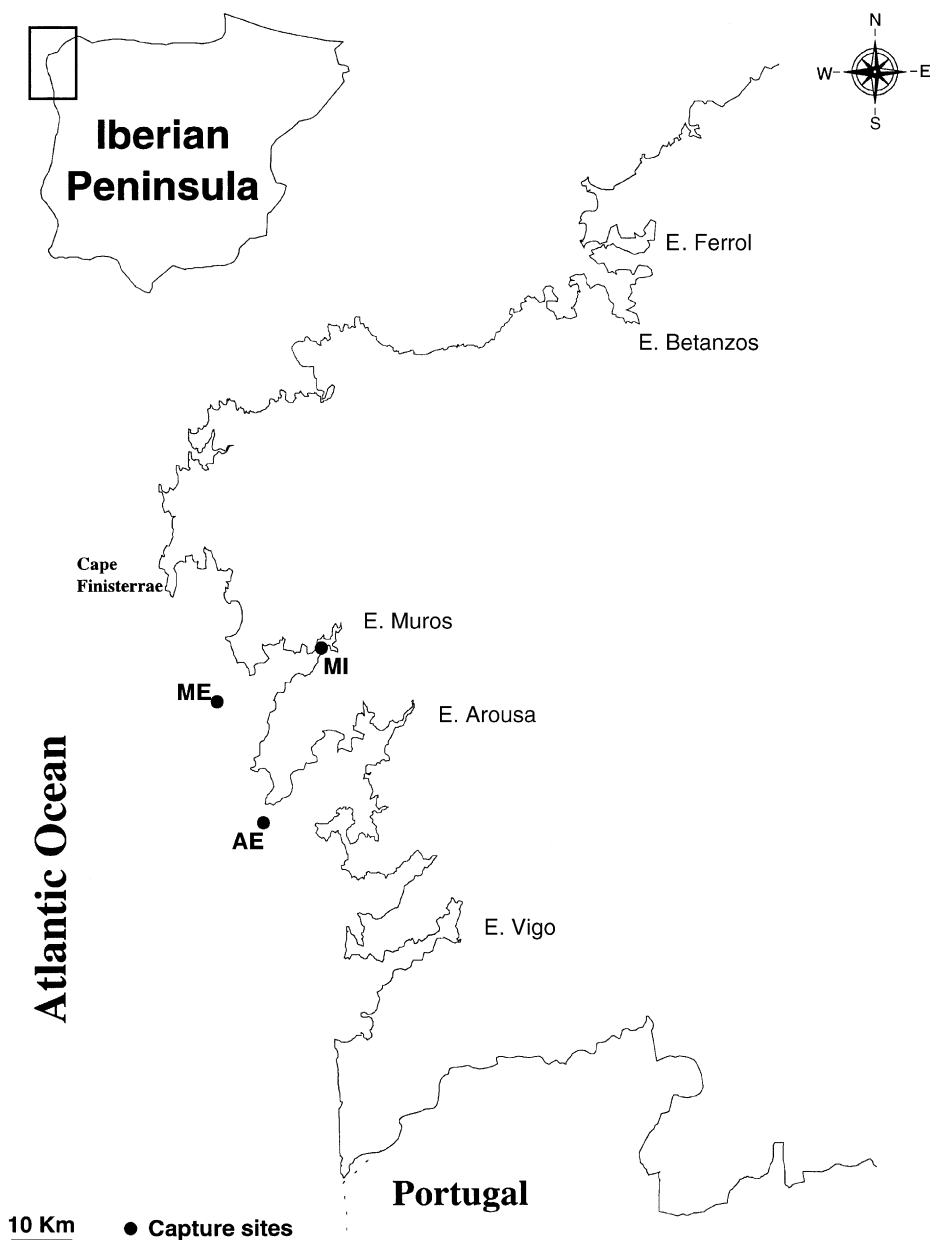


Fig. 1. Map showing the location of the study areas in the northwest Iberian Peninsula and of the three flatfish capture areas (MI—inner part of the Muros Estuary; ME—offshore from the Muros Estuary; AE—offshore from the Arousa Estuary).

2.3. Statistics and abbreviations

Prevalence (P), mean intensity (I_M) and mean abundance (A_M) were determined in accordance with Bush et al. (1997). To assess the statistical significance of the differences between prevalences and mean abundances in the different capture areas and host species, we used Fisher's exact test (GraphPad InStat 1.15 for MS-DOS) and Student's t -test (Microsoft Excel 97), respectively.

Table 2
Helminths detected with the capture areas in which each was found and their locations in the host

Species ^a	Capture sites			Location in host
	MI	ME	AE	
<i>P. atomon</i>	+	—	—	Stomach and intestine
<i>P. angulata</i>	+	—	—	Stomach and intestine
<i>M. soleae</i>	+	—	—	Stomach and intestine
<i>D. varicus</i>	+	—	+	Stomach
<i>L. rufoviride</i>	+	—	—	Stomach and intestine
<i>L. musculus</i>	+	—	—	Stomach and intestine
<i>S. caudiporum</i>	—	+	+	Stomach
<i>Z. rubellus</i>	+	—	—	Stomach and intestine
<i>Z. viviparus</i>	—	+	+	Intestine
<i>R. crucibulum</i>	+	—	—	Intestine
<i>P. maculatus</i>	+	—	—	Intestine
<i>H. galaicus</i>	—	+	+	Intestine
<i>L. stephanskii</i>	—	+	+	Intestine
<i>B. gregarius</i>	+	+	+	Pyloric caeca and intestine
<i>B. barbatus</i>	+	—	—	Pyloric caeca and intestine
<i>Botriocephalus</i> sp.	+	+	+	Pyloric caeca and intestine
<i>B. nylandicus</i>	—	+	—	Intestine
<i>N. lingualis</i> (Plerocercoids)	—	+	+	Free in abdominal cavity or encysted on viscera
<i>Grillotia</i> sp. (Plerocercoids)	+	—	—	Intestine
Tetraphyllidea (Plerocercoids)	+	+	+	Caeca, intestine or abdominal cavity
<i>C. heterochrous</i>	+	—	+	Intestine
<i>C. minutus</i>	+	—	—	Stomach and intestine
<i>Cucullanus</i> sp.	+	—	—	Intestine
<i>Anisakis simplex</i> (L ₃)	—	+	+	Free in abdominal cavity or encysted on viscera
<i>H. aduncum</i> L ₃ adults	+	+	+	Free in abdominal cavity or encysted on viscera. Intestine
<i>C. gracilis</i>	+	—	—	Intestine
<i>Contracaecum</i> sp. (L ₃)	+	—	—	Encysted on outer gut wall
<i>A. propinquus</i>	+	—	+	Intestine
Nematoda gen. sp.	+	—	—	Intestinal lumen
Taxon I (L ₃)				
Cystidicolidae gen. sp. (L ₃) (Taxon II)	—	—	+	Encysted on outer intestinal wall or other viscera, or free in intestinal lumen
Nematoda gen. sp. (Taxon III) (L ₃)	—	+	+	Encysted in hepatic parenchyma

^a L₃ = third stage larva/e.

Table 3
Prevalences (%) of the different helminth species in the eight flatfish species considered

	Capture site ^a	Trematodes												
		<i>P. atomon</i>	<i>P. angulata</i>	<i>M. soleae</i>	<i>D. varicus</i>	<i>L. rufoviride</i>	<i>L. musculus</i>	<i>S. caudiporum</i>	<i>Z. rubellus</i>	<i>Z. viviparus</i>	<i>R. crucibulum</i>	<i>P. maculatus</i>	<i>H. galaicus</i>	<i>L. stephanskii</i>
<i>S. maximus</i>	AE	—	—	—	10.0	—	—	46.3	—	—	—	—	—	—
	MI ^c	—	—	—	—	100	—	—	—	—	—	—	—	—
	ME ^c	—	—	—	—	—	—	16.7	—	—	—	—	—	—
<i>S. rhombus</i>	MI	—	—	—	—	100	—	—	—	—	—	—	—	—
<i>P. flesus</i>	MI	11.1	11.1	38.9	—	—	—	—	33.3	—	5.6	5.6	—	—
<i>S. lascaris</i>	ME ^c	—	—	—	—	—	—	—	—	—	—	—	22.2	—
	MI	66.7	5.6	—	16.7	5.6	5.6	—	—	—	—	—	—	—
<i>S. vulgaris</i>	MI	58.8	11.8	23.5	—	5.9	5.9	—	—	—	—	5.9	—	—
<i>L. whiffiagonis</i>	AE ^c	—	—	—	—	—	—	—	—	—	—	—	—	—
	MI ^c	—	—	—	—	—	66.7	—	—	—	—	—	—	—
	ME	—	—	—	—	—	—	4.8	—	—	—	—	—	—
<i>L. boscii</i>	AE	—	—	—	—	—	—	12.8	—	—	—	—	—	0.9
	ME	—	—	—	—	—	—	9.1	—	—	—	—	—	—
<i>M. variegatus</i>	AE	—	—	—	2.2	—	—	—	—	18.8	—	—	26.1	25.4
	ME	—	—	—	—	—	—	—	—	3.8	—	—	11.5	44.2

^a See Table 1 and Fig. 1.

^b Ac=acanthocephalans.

^c *B. gregarius* in *S. maximus*, *B. barbatus* in *S. rhombus*, the remainder pending electrophoretic studies for identification to species level.

^d Adults; the rest of the anisakids L₃.

^e < 10 individuals examined.

Cestodes					Nematodes						Ac ^b
<i>Bothriocephalus</i> spp. ^c	<i>B. nylandicus</i>	<i>N. linguatilis</i> (P)	<i>Grillotia</i> sp. (P)	<i>Tetraphylidea</i> (P)	<i>C. heterochrous</i>	<i>C. minutus</i>	<i>A. simplex</i> (L ₃)	<i>H. aduncum</i>	<i>Contracaecum</i> sp. (L ₃)	<i>C. gracilis</i>	<i>A. propinquus</i>
93.8	–	–	–	–	2.5	–	–	1.3 ^d	–	–	–
75.0	–	–	–	–	–	–	–	–	–	–	–
50.0	–	–	–	–	–	–	–	–	–	–	–
90.9	–	–	–	–	–	–	–	–	–	–	9.1
5.9	–	–	–	5.6	5.6	55.6	–	–	5.6	5.6	5.6
–	33.3	–	–	11.1	–	–	–	–	–	–	–
5.6	–	–	5.6	11.1	–	–	–	–	–	–	5.6
5.9	–	–	–	5.9	–	–	–	–	–	–	–
–	–	25	–	–	–	–	12.5	12.5	–	–	–
100	–	–	33.3	66.7	–	–	–	33.3	–	–	–
33.3	12.7	–	–	–	–	–	9.5	25.4	–	–	–
13.7	–	1.7	–	–	–	–	8.5	6.0	–	–	2.6
13.6	–	–	–	–	–	–	4.5	13.6	–	–	–
3.6	–	2.2	–	5.8	2.9	–	2.9	7.2	–	–	–
–	–	1.9	–	–	–	–	1.9	–	–	–	–

Table 4
Intensities of infection^a for the different helminth species in the eight flatfish species considered

	Capture site	Trematodes												
		<i>P. atomon</i>	<i>P. angulata</i>	<i>M. soleae</i>	<i>D. varicus</i>	<i>L. rufoviride</i>	<i>L. musculi</i>	<i>S. caudiporum</i>	<i>Z. rubellus</i>	<i>Z. viviparus</i>	<i>R. crucibulum</i>	<i>P. maculatus</i>	<i>H. galai-cus</i>	<i>L. stephanskii</i>
<i>S. maximus</i>	AE	–	–	–	2.8 (1–7)	–	–	4.2 (1–10)	–	–	–	–	–	–
	MI ^c	–	–	–	–	2.5 (1–4)	–	–	–	–	–	–	–	–
	ME ^c	–	–	–	–	–	–	4 (4)	–	–	–	–	–	–
<i>S. rhombus</i>	MI	–	–	–	–	5.6 (1–23)	–	–	–	–	–	–	–	–
<i>P. flesus</i>	MI	1 (1)	3.0 (1–5)	34.1 (1–129)	–	–	–	–	7.0 (1–17)	–	1 (1)	1 (1)	–	–
<i>S. lascaris</i>	ME ^c	–	–	–	–	–	–	–	–	–	–	–	2.0 (1–3)	–
	MI	7.8 (1–22)	1 (1)	–	2.0 (1–3)	5 (5)	1 (1)	–	–	–	–	–	–	–
<i>S. vulgaris</i>	MI	17 (3–78)	2.0 (1–3)	4.5 (1–14)	–	4 (4)	1 (1)	–	–	–	–	2 (2)	–	–
<i>L. whiffiagonis</i>	AE ^c	–	–	–	–	–	–	–	–	–	–	–	–	–
	MI ^c	–	–	–	–	–	1.5 (1–2)	–	–	–	–	–	–	–
	ME	–	–	–	–	–	–	1.7 (1–3)	–	–	–	–	–	–
<i>L. boscii</i>	AE	–	–	–	–	–	–	1.4 (1–3)	–	–	–	–	–	1 (1)
	ME	–	–	–	–	–	–	2.0 (1–3)	–	–	–	–	–	–
<i>M. variegatus</i>	AE	–	–	–	1.3 (1–2)	–	–	–	–	8.2 (1–42)	–	–	3.7 (1–28)	3.2 (1–13)
	ME	–	–	–	–	–	–	–	–	1 (1)	–	–	3.0 (1–8)	3.1 (1–9)

See Table 1 and Fig. 1.

^a Means; ranges in brackets.

^b Ac = acanthocephalans.

^c *B. gregarius* in *S. maximus*, *B. barbatus* in *S. rhombus*, the remainder pending electrophoretic studies for identification to species level.

^d Adults; the rest of the anisakids L₃.

^e < 10 individuals examined.

Cestodes					Nematodes						Ac ^b	
<i>Bothriocephalus</i> spp. ^c	<i>B. nylandicus</i>	<i>N. linguatilis</i> (P)	<i>Grillotia</i> sp. (P)	<i>Tetraphyllidea</i> (P)	<i>C. heterochrous</i>	<i>C. minutus</i>	<i>A. simplex</i>	<i>H. aduncum</i>	<i>Contracaecum</i> sp.	<i>C. gracilis</i>	<i>A. propinquus</i>	
1 (1)	–	–	–	–	1 (1)	–	–	1 (1) ^d	–	–	–	
1.7 (1–3)	–	–	–	–	–	–	–	–	–	–	–	
20 (20)	–	–	–	–	–	–	–	–	–	–	–	
4.3 (1–7)	–	–	–	–	–	–	–	–	–	–	1 (1)	
1 (1)	–	–	–	3 (3)	1 (1)	6.0 (1–21)	–	–	12 (12)	10 (10)	28 (28)	
–	5.0 (1–10)	–	–	1 (1)	–	–	–	–	–	–	–	
8 (8)	–	–	1 (1)	14.0 (2–26)	–	–	–	–	–	–	7 (7)	
32 (32)	–	–	–	9 (9)	–	–	–	–	–	–	–	
–	–	1 (1)	–	–	–	–	1 (1)	1 (1)	–	–	–	
8.3 (1–21)	–	–	1 (1)	1 (1)	–	–	–	1 (1)	–	–	–	
1.4 (1–4)	1.9 (1–3)	–	–	–	–	–	1.2 (1–2)	4.6 (1–41)	–	–	–	
1.1 (1–2)	–	1 (1)	–	–	–	–	1 (1)	1.1 (1–2)	–	–	1.7 (1–3)	
2.3 (1–3)	–	–	–	–	–	–	3 (3)	3.0 (1–5)	–	–	–	
1.4 (1–2)	–	1 (1)	–	1.3 (1–2)	1.8 (1–4)	–	1 (1)	1 (1)	–	–	–	
–	–	3 (3)	–	–	–	–	1 (1)	–	–	–	–	

Table 5
Mean abundances^a of the different helminth species in the eight flatfish species considered

	Capture site ^b	Trematodes												
		<i>P. atomon</i>	<i>P. angulata</i>	<i>M. soleae</i>	<i>D. varicus</i>	<i>L. rufoviride</i>	<i>L. musculus</i>	<i>S. caudiporum</i>	<i>Z. rubellus</i>	<i>Z. viviparus</i>	<i>R. crucibulum</i>	<i>P. maculatus</i>	<i>H. galaicus</i>	<i>L. stephanskii</i>
<i>S. maximus</i>	AE	–	–	–	0.3 ± 1.0	–	–	1.9 ± 2.8	–	–	–	–	–	–
	MI ^f	–	–	–	–	2.5 ± 1.3	–	–	–	–	–	–	–	–
	ME ^f	–	–	–	–	–	–	0.7 ± 1.6	–	–	–	–	–	–
<i>S. rhombus</i>	MI	–	–	–	–	5.6 ± 6.2	–	–	–	–	–	–	–	–
<i>P. flesus</i>	MI	0.1 ± 0.3	0.3 ± 1.2	13.3 ± 33.5	–	–	–	–	2.3 ± 5.0	–	0.06 ± 0.2	0.06 ± 0.2	–	–
<i>S. lascaris</i>	ME ^f	–	–	–	–	–	–	–	–	–	–	–	0.4 ± 1.0	–
	MI	5.2 ± 7.2	0.1 ± 0.2	–	0.3 ± 0.8	0.3 ± 1.2	0.1 ± 0.2	–	–	–	–	–	–	–
<i>S. vulgaris</i>	MI	9.9 ± 18.7	0.2 ± 0.8	1.1 ± 3.4	–	0.2 ± 1.0	0.06 ± 0.2	–	–	–	–	0.12 ± 0.5	–	–
<i>L. whiffiagonis</i>	AE ^f	–	–	–	–	–	–	–	–	–	–	–	–	–
	MI ^f	–	–	–	–	–	1.0 ± 1.0	–	–	–	–	–	–	–
	ME	–	–	–	–	–	–	0.1 ± 0.4	–	–	–	–	–	–
<i>L. boscii</i>	AE	–	–	–	–	–	–	0.2 ± 0.8	–	–	–	–	–	0.3 ± 1.0
	ME	–	–	–	–	–	–	0.2 ± 0.8	–	–	–	–	–	–
<i>M. variegatus</i>	AE	–	–	–	0.03 ± 0.2	–	–	–	–	1.5 ± 5.9	–	–	1.0 ± 3.1	0.8 ± 2.0
	ME	–	–	–	–	–	–	–	–	0.04 ± 0.2	–	–	0.4 ± 1.3	1.7 ± 2.1

^a Means (ranges).

^b See Table 1 and Fig. 1.

^c Ac = acanthocephalans.

^d *B. gregarius* in *S. maximus*, *B. barbatus* in *S. rhombus*, the remainder pending electrophoretic studies for identification to species level.

^e Adults; the rest of the anisakids L₃.

^f <10 individuals examined.

Cestodes					Nematodes						Ac ^c
<i>Bothriocephalus</i> spp. ^d	<i>B. nylandicus</i>	<i>N. lingualis</i> (P)	<i>Grillotia</i> sp. (P)	Tetraphyllidea (P)	<i>C. heterochrous</i>	<i>C. minutus</i>	<i>A. simplex</i>	<i>H. aduncum</i>	<i>Contracaecum</i> sp.	<i>C. gracilis</i>	<i>A. propinquus</i>
3.7 ± 2.5	–	–	–	–	0.03 ± 0.2	–	–	0.01 ± 0.1 ^c	–	–	–
1.3 ± 1.3	–	–	–	–	–	–	–	–	–	–	–
10.0 ± 11.0	–	–	–	–	–	–	–	–	–	–	–
3.9 ± 2.2	–	–	–	–	–	–	–	–	–	–	0.1 ± 0.3
0.06 ± 0.2	–	–	–	0.2 ± 0.7	0.06 ± 0.2	0.3 ± 5.7	–	–	0.7 ± 2.8	0.6 ± 2.4	1.6 ± 6.6
–	1.7 ± 3.4	–	–	0.1 ± 0.3	–	–	–	–	–	–	–
0.4 ± 1.9	–	–	0.1 ± 0.2	1.6 ± 6.1	–	–	–	–	–	–	0.4 ± 1.6
1.9 ± 7.8	–	–	–	0.5 ± 2.2	–	–	–	–	–	–	–
–	–	0.2 ± 0.5	–	–	–	–	0.1 ± 0.4	0.1 ± 0.4	–	–	–
8.3 ± 11.0	–	–	0.3 ± 0.6	0.7 ± 0.6	–	–	–	0.3 ± 0.6	–	–	–
0.5 ± 0.8	0.2 ± 0.7	–	–	–	–	–	0.1 ± 0.4	1.2 ± 5.2	–	–	–
0.2 ± 0.4	–	0.02 ± 0.1	–	–	–	–	0.1 ± 0.3	0.1 ± 0.3	–	–	0.04 ± 0.3
0.3 ± 1.0	–	–	–	–	–	–	0.1 ± 0.0	0.4 ± 0.2	–	–	–
0.05 ± 0.2	–	0.02 ± 0.1	–	0.07 ± 0.3	0.1 ± 0.4	–	0.03 ± 0.2	0.1 ± 0.3	–	–	–
–	–	0.06 ± 0.4	–	–	–	–	0.02 ± 0.1	–	–	–	–

3. Results

The helminths found, their distributions in the capture areas and their sites of infection within each host species are listed in Table 2. Prevalence, mean intensity and mean abundance are listed in Tables 3–5.

For reasons of space, results for three larval nematodes are listed here instead of in the tables: (a) taxon I in *S. lascaris* from MI which, in view of morphology, may be the L₃ of one of the two species of the genus *Cucullanus* present in our fish ($P=5.6$, $I_M=1$ and $A_M=0.1$); (b) taxon II, of the family Cystidicolidae, in *M. variegatus* from AE ($P=2.2$, $I_M=1$ and $A_M=0.02$); and (c) taxon III, unidentified, in *M. variegatus* from AE ($P=3.6$, $I_M=39$ and $A_M=1.4$) and ME ($P=3.8$, $I_M=2.5$ and $A_M=0.1$).

The helminth communities observed in each host species vary among the three capture areas. Within each capture area, however, the helminths infecting the different hosts are notably similar with one exception. Of the 13 parasite species detected in *P. flesus* (MI), five were not detected in any other host species in any of the three capture areas: *Zoogonus rubellus* (Olsson, 1868), *Rudolphinus crucibulum* (Rudolphi, 1819), *Cucullanus minutus* Rudolphi, 1819, *Capillaria gracilis* Bellingham, 1840, and *Contracaecum* sp.

For two host species, the number of individuals considered was sufficient for statistical comparisons between capture areas ($n \geq 15$ individuals per capture area, see Table 1). Significant differences ($p \leq 0.05$) were observed only between ME and AE in the following helminths from *M. variegatus*: (a) *Zoogonoides viviparus* (Olsson, 1868) for P and A_M ; (b) *Homalometron galaicus* (Sanmartín et al., 1995) for P and A_M ; (c) *Lomasoma stephanskii* Dollfus, 1960 for P and A_M ; and (d) nematode taxon II L₃ in *M. variegatus* for A_M . In all cases except *L. stephanskii*, the highest values were for AE.

4. Discussion

4.1. Digenea

Podocotyle atomon (Rudolphi, 1802) (Opecoelidae) has a Holarctic distribution although we are not aware of any previous reports of its presence in the Mediterranean. Køie (1983) considers it to be a brackish-water species. In the present study, we detected this species in the Muros Estuary, where salinity is lower than in the open ocean but is greater than 30‰ and thus cannot be considered brackish.

P. atomon is specific for its first intermediate host, the gastropod mollusc *Littorina saxatilis* (Olivier) (Køie, 1981, 1983). Its second intermediate hosts are various crustaceans, including isopods of the genera *Idotea* and *Sphaeroma*, the amphipods *Melita palmata* (Montagu) and *Gammarus* spp. and the decapod *Crangon crangon* (Linnaeus) (Gollasch and Zander, 1995). The snail and the crustaceans are all present on the western coast of the Iberian Peninsula (Román and Pérez, 1979; Erlandsson et al., 1998; Cabral, 2000), and all except the genus *Idotea* have been recorded as part of the diet of *S. vulgaris* (*S. solea*) in the estuary of the River Tagus (Tajo, Tejo) (west coast of Portugal; Cabral, 2000); these are firm candidates to be the second intermediate hosts of this parasite in Galicia.

Due to the taxonomical controversy between certain species of genus *Podocotyle*, we do not have reliable data on the life cycle of *P. angulata* (Dujardin, 1845). As suggested by Bartoli and Boudouresque (1997) for the opecelid *Macvicaria alacris* (Looss, 1901) (likewise an opecelid), it is possible that this species has a life cycle similar to that of *P. atomon*, with a prosobranch mollusc as first intermediate host and one or more species of crustaceans as second intermediate host(s). On the Galician coast, adult *P. angulata* has previously been reported in the European eel, *Anguilla anguilla* (Linnaeus) (Outeiral et al., 2001).

A similar life cycle may likewise be postulated for *M. soleae* (Dujardin, 1845), a specific parasite of *P. flesus*. It only occurs irregularly in other hosts (*Callionymus lyra* Linnaeus and *S. vulgaris*) in which it is typically smaller with smaller reproductive organs and eggs (Gibson and Bray, 1982; our own unpublished data). Its appearance in *S. vulgaris* in the present study can thus be considered accidental.

Another species about whose life cycle we have no information is *L. stephanskii* (Fellodistomidae). This species is present in *M. variegatus* and *L. boscii* on the continental shelf though it is rare in the latter. It has also been observed in *Conger conger* ([Artedi] Linnaeus) and *Lophius piscatorius* Linnaeus from the same areas (Quinteiro, 1990).

In *Proctoeces maculatus* (Looss, 1901), the first intermediate host is a bivalve mollusc: *Mytilus edulis* (Linnaeus), *M. galloprovincialis* (Lamarck) or *Ischadium recurvum* (Rafinesque) (Bower et al., 1994). The second intermediate host may be a bivalve such as *M. edulis*, *M. galloprovincialis*, *Crassostrea gigas* (Thunberg) or *Scrobicularia plana* (da Costa), a gastropod such as *Patella caerulea* Linnaeus, *Rissoa* spp. and *Tricolia pulla* (Linnaeus) or a polychaete (*Leptonereis glauca* Claparède, *Nereis* spp.) (Le Pommelet et al., 1997). We consider that its presence in *P. flesus* and *S. vulgaris* is accidental and that its principal definitive hosts in the study area might be gobiids (*Gobius* spp.) and labrids (*Symphodus* spp.), which have been previously reported as such by Le Pommelet et al. (1997). Its occasional presence in *P. flesus* and *S. vulgaris* may be attributable to the ingestion of gobiid and/or labrid larvae or juveniles which form part of their usual diet (Iglesias, 1983; Costa, 1988; Hostens and Mees, 1999; Beyst et al., 1999; Cabral, 2000). It is probable that its most important first and second intermediate hosts on the Galician coast are mussels *Mytilus* spp. which are intensively cultivated in the estuaries. It is present, at low intensity and prevalence, in mussels from the estuaries of Arousa, Muros, Betanzos (Lorbé) and Vigo (Robledo et al., 1994; Villalba et al., 1997) (see Fig. 1), as well as that of Aveiro in Portugal (Teia-dos-Santos and Coimbra, 1995), constituting a potential problem for the industry since massive infections may be lethal. The principal symptoms are deficient intestinal absorption (with consequent loss of body weight and thus commercial value), parasitic castration and abductor muscle weakness (hindering fixation to the substrate) (Villalba et al., 1997; Bower et al., 1994).

We found only a single immature individual of *R. crucibulum* (Bucephalidae) in *P. flesus*. Like *P. maculatus*, the first intermediate host is mussel (Matthews, 1973). The second intermediate hosts are demersal fishes including flatfishes. The adult is specific for *C. conger* so that our finding of an immature specimen that is free in the intestinal lumen should be considered accidental. This species has not yet been reported from mussels in Galicia; however, it has been detected at low prevalence in the Aveiro Estuary in Portugal

(Teia-dos-Santos and Coimbra, 1995). Pathological effects in mussels are similar to those of *P. maculatus*.

Derogenes varicus (Müller, 1784) is very widely distributed in subarctic and temperate regions (Køie, 1983). It is characteristic of oceanic waters and a marked generalist as regards the definitive host, occurring in more than 100 species of demersal and benthic fishes (Køie, 1979; Paperna, 1995) and cephalopods of the genus *Sepia* (Køie, 1979). In our area, the most frequent definitive hosts are *Trisopterus luscus* (Linnaeus), *Trigla lucerna* Linnaeus and *Hyperoplus lanceolatus* (Le Sauvage) (Quinteiro, 1990), and less frequently, the eel *A. anguilla* (Outeiral et al., 2001) and flatfishes (Quinteiro, 1990). The first intermediate host is a prosobranch mollusc of the genus *Natica* (Køie, 1979). *Natica alderi* Forbes forms part of the benthic fauna of our coasts, as do species of the genera *Calanus*, *Acartia*, *Balanus* and *Pagurus* (Román and Pérez, 1979; López-Jamar et al., 1984; González-Gurriarán and Olaso, 1987; Braun et al., 1990), which Køie identifies as second intermediate hosts of *D. varicus*, among other planktonic and benthic invertebrates. Species of the genus *Acartia* are reported to form part of the diet of *S. maximus* on the west coast of Ireland (Tully and Céidigh, 1989). The transport hosts of *D. varicus* are small fishes (gobiids and juveniles of other species) that form part of the diet of the piscivorous definitive hosts (Køie, 1979; Zander et al., 1993).

We detected three species of the family Hemiuridae: *Lecithochirium rufoviride* (Rudolphi, 1819), *L. musculus* (Looss, 1907) and *Synaptobothrium caudiporum* (Rudolphi, 1819). The distribution of *L. rufoviride* and *S. caudiporum* is Lusitanian, while that of *L. musculus* additionally extends to the Pacific. *L. rufoviride* and *L. musculus* are not habitual parasites of flatfishes but rather of anguilliforms though they have been found in other large predatory fish, such as *S. rhombus* and *L. piscatorius* (Gibson and Bray, 1986). This is in accordance with their low prevalence in all species except *S. maximus* and *S. rhombus* whose importance as fish predators is greater. Finally, it is interesting to note that *L. musculus* may in fact be a complex of two sibling species as deduced from its enzyme banding pattern (Vilas et al., 2000).

The first intermediate hosts of *L. rufoviride* are gastropods of the genus *Gibbula* (Gibson and Bray, 1986; Køie, 1990). Little is known about the life cycle of *L. minutus*, but like *L. rufoviride*, its second intermediate hosts are species of the genus *Gobius* and *Pomatoschistus*. *L. rufoviride* also occurs in labrids. *Pomatoschistus* species are a habitual part of the diet of *S. rhombus* in Belgium (Beyst et al., 1999) and of *P. flesus* (Costa, 1988) and *S. senegalensis* Kaup (Cabral, 2000) in the Tagus Estuary in Portugal. These small fish are very abundant on the Galician coast (Tenore et al., 1982; Iglesias, 1983; Fariña et al., 1997) especially in the estuaries. *Gibbula cineraria* Linnaeus is a possible first intermediate host of *L. rufoviride* on our coasts.

H. galaicus (Apocreadiidae) was described in *M. variegatus* by Sanmartín et al. (1995) as *Apocreadium galaicus*. Cribb and Bray (1999) synonymized the genus *Apocreadium* with *Homalometron*. This is the first report of this species in *S. lascaris*. The life cycle of this species remains unknown. As far as we know, it is restricted to the Galician coast although it should be stressed that there have been few detailed studies of the parasite fauna of flatfishes off Portugal, northern Spain and western France (Bay of Biscay).

Within the family Zoogonidae, we found *Z. viviparus* and *Z. rubellus*. *Z. viviparus* occurs throughout the northern hemisphere except in the Black Sea. Its first intermediate

host is a gastropod of the genus *Buccinum* (Køie, 1976; Bray, 1986). Its second intermediate hosts include lamellibranch molluscs such as *Nucula sulcata* Brown, *Corbula gibba* (Olivieri) and *Venus striatula* (da Costa), gastropods such as *Cythara attenuata* Montagu and *Nassarius incrassatus* (Ström), starfish such as *Ophiura ophiura* (Linnaeus) (Køie mentions its junior synonym *O. texturata* Lamarck), *O. albida* Forbes, *Amphiura filiformis* (Müller) and *A. chiajei* Forbes, the sea urchin *Psammechinus miliaris* (Müller) and polychaetes such as *Pectinaria koreni* (Malmgren) and *Ammotrypane aulogaster* Rathke. All of the species mentioned except *C. attenuata* are present on the northwest coast of the Iberian Peninsula (Tenore et al., 1982; López-Jamar and Mejuto, 1986) where they may likewise act as second intermediate hosts.

The life cycle of *Z. rubellus* is similar to that of *Z. viviparus*, with the gastropod *N. reticulatus* (Linnaeus) as first intermediate host, and various echinoderms (e.g. *P. miliaris*) and polychaetes (*Nereis* spp.)—all present on the Galician coast—as second intermediate hosts. Polychaetes of the genus *Nereis* form an important part of the diet of *P. flesus* in the Tagus Estuary in Portugal (Costa, 1988), and it is probable that the same is true in the Muros Estuary, which would explain the relatively high prevalence of this species in *P. flesus* in MI.

4.2. Eucestoda

Within the Order Trypanorhyncha, we found *Nybelinia lingualis* (Cuvier, 1817) and an undetermined *Grillotia* species. These species use mesoplanktonic organisms (copepods, amphipods, ostracods and chaetognaths; Dollfus, 1976) as first intermediate hosts. The second intermediate hosts are small teleosts and cephalopods. On the continental shelf off Galicia, the second intermediate hosts of *N. lingualis* are the cephalopods *Todaropsis eblanae* Ball and *Illex coindetti* Verany (Pascual et al., 1996) and various species of predatory fish, including *C. conger*, *L. piscatorius*, *Trachurus trachurus* (Linnaeus) and flatfishes (Quinteiro, 1990). These fishes are infected by ingestion either of the first intermediate host or of other fish or cephalopods. The definitive hosts are elasmobranchs. We have not been able to identify the *Grillotia* specimens to the species level, and thus cannot be certain about its life cycle. However, it is probably similar to that of *N. lingualis* in this region since it appears to occupy a very similar niche as regards definitive host species and location in the hosts. Dollfus (1976) cites the presence of plerocercoids of the genus *Grillotia* in the cephalopod *Sepia officinalis* Linnaeus. In the estuaries of Muros and Arousa, we have detected plerocercoids of the same *Grillotia* species in various species of demersal fish and its definitive host in MI is *Raja undulata* Lacepède (Peris, 2000; Sanmartín et al., 2000a).

Proceroids of tetraphyllideans occur in many types of benthic invertebrates (as first intermediate host; Euzet, 1959) and in elasmobranchs as definitive host. We have not been able to determine the species found in this work, but we know that the adult forms of *Onchobothrium uncinatum* Rudolphi, 1819, *Phyllobothrium lactuca* (Rudolphi, 1819), *Acanthobothrium benedeni* Löemberg, 1889 and *Echeneibothrium beauchampi* Euzet, 1959 all occur in *R. undulata* in MI (Sanmartín et al., 2000a).

Bothriocephalus scorpii (Müller, 1776) (Pseudophyllidea) is a complex of species that are highly specific for their definitive host (Morand et al., 1995). Thus, *B. barbatus*

Renaud, Gabrion et Pasteur, 1983 infects *S. rhombus*, while *B. gregarius* Renaud, Gabrion et Pasteur, 1983 infects *S. maximus*. We are not aware of the reports of electrophoretic studies of *B. scorpii* from other flatfishes and have thus designated the *Bothriocephalus* specimens that we isolated from other flatfishes as *Bothriocephalus* spp. The intermediate hosts of *B. barbatus* and *B. gregarius* are calanoid copepods such as *Eurytemora velox* (Lilljeborg), *Acartia discaudata* (Giesbrecht) and *A. clausi* Giesbrecht (Robert and Gabrion, 1991). *B. gregarius* additionally needs a gobiid of the genus *Pomatoschistus* as paratenic host, while *B. barbatus* passes directly from the intermediate to the definitive host. As mentioned above, the copepods of the genus *Acartia* and the gobiids of the genus *Pomatoschistus* are present on the Western Iberian coast.

Bothrimonus nylandicus (Schneider, 1902) (Cyathocephalidea) is another complex made up of two morphologically identical species (Renaud and Gabrion, 1988). Since we have not performed electrophoretic studies and since Renaud and Gabrion did not name their species, we have retained the name *B. nylandicus* to designate the cestodes found in *S. lascaris* and *L. whiffiagonis*. *Bothrimonus* species use gammarid amphipods as intermediate hosts (Sandemann and Burt, 1972). Many of these amphipods (including *Gammarus locusta* Linnaeus) are frequent on the western Iberian coast, and as mentioned above, form part of the diet of some flatfish species.

4.3. Nematoda

Anisakis simplex (Rudolphi, 1819) (Anisakidae) characteristically occurs in deep waters (Cannon, 1977a), and indeed in the present study, we detected this species only in AE and ME (approximately 200 m below sea level). However, it occasionally appears in fishes captured in the inner part of the Arousa Estuary (Sanmartín et al., 2000b and unpublished data), which has a relatively deep central channel and water which is much more similar to that of the open ocean, since it receives much greater upwellings of North Atlantic Central Water than the Muros Estuary. Its first intermediate hosts are planktonic euphausiid crustaceans. In our region, it uses several species of fish and cephalopod as second intermediate hosts (Pascual et al., 1995; Sanmartín et al., 2000b), while the definitive hosts are dolphins and small whales (Abollo et al., 1998).

The anisakid *Hysterothylacium aduncum* (Rudolphi, 1802) was present in all three capture areas. Its first intermediate hosts are benthic invertebrates, such as chaetognaths (Øresland, 1986), gammarid amphipods, calanoid copepods, polychaetes and barnacles, as well as invertebrate-feeding fish such as the anchovy (González, 1998; Navone et al., 1998). Its second intermediate hosts are piscivorous fishes, such as *Merluccius merluccius* (Linnaeus), *T. trachurus* and salmonids. On the northwestern Iberian coast, *L₄* are present in species including *C. conger*, *L. piscatorius*, *Pollachius pollachius* (Linnaeus), *Boops boops* (Linnaeus) and *Scomber scombrus* Linnaeus (Quinteiro, 1990). *L₃* are found in these species and in others including *Micromesistius poutassou* (Risso), *Gobius niger* Linnaeus, *Symphodus cinereus* (Bonnaterre) and *T. trachurus* (Quinteiro, 1990; Peris, 2000).

According to Anderson (2000), the definitive hosts of the species of *Contracaecum* are birds and mammals associated with various types of aquatic habitat. The intermediate hosts include coelenterates, ctenophores, molluscs of all types, polychaetes and crusta-

ceans. The *Contracaecum* larvae found in the present study were similar to the type-II larvae described by Cannon (1977b) and were thus probably *Contracaecum spiculigerum* Müller, 1777, a parasite of seabirds.

C. heterochrous Rudolphi, 1802 (Gibson, 1972; Køie, 2000) and *C. minutus* (Gibson, 1972) are specific for flatfishes. However, the prevalences and intensities obtained for these two species in the present study were very low (Tables 3 and 4), and this species has also been found in other fish in this area (*Gobius* spp., *A. anguilla* and *C. lyra*) (Peris, 2000) with similar or higher prevalences and intensities to those observed in the present study. The intermediate hosts used by this species include various polychaetes of the genus *Nereis* (Køie, 2000) which are likewise present on our coasts.

The life cycle of *C. minutus* is not entirely clear. Gibson (1972) suggests that the cycle is direct, with the L₂ phase encysting in the viscera of the definitive host itself (*P. flesus*), as it occurs with *C. chabaudi* Le-van-Hoa et Pham-Ngoc-Khue, 1967. However, Gibson was unable to demonstrate the presence of L₂ in *P. flesus*. In disagreement with Gibson, Ivashkin and Khromova (1975) considered polychaetes to be obligate intermediate hosts of this species. The most recent studies of Køie (1999, 2000) have revealed that *C. heterochrous* and *C. cirratus* Müller, 1777 use invertebrates and small fishes as intermediate hosts. This suggests that the direct cycle of *C. chabaudi* is the exception rather than the rule within this genus, and until more complete information is available, we are inclined to favour the hypothesis of Ivashkin and Khromova.

No data are available on the life cycle of *C. gracilis*. Its definitive hosts are predatory fishes of the families Gadidae, Cottidae, Pleuronectidae, Anarhichadidae and Macrouridae (Moravec, 1987). In Galicia, it is observed not only in *P. flesus*, but also in *Ciliata mustela* (Linnaeus) (Peris, 2000), *Gaidropsarus mediterraneus* (Linnaeus) and *T. luscus* (Quinteiro, 1990).

The larvae of the family Cysticolidae detected in the present study may be of *Cristitectus congeri* Petter, 1970, the adult of which is specific for *C. conger*. Similar specimens have been found in many fish species along the Galician coast (Quinteiro, 1990; Peris, 2000; Sanmartín et al., 2000a,b). The life cycle of *C. congeri* is not known, but those of various other species of this family have been described (Choudhury and Dick, 1998; Anderson, 2000; Martorelli et al., 2000) whose first intermediate hosts are decapods, amphipods, copepods or aquatic larvae of insects, while various fishes and cephalopods have been described as second intermediate or paratenic hosts (Sanmartín et al., 2000a,b; Gestal et al., 1999).

4.4. *Acanthocephala*

The cycle of *Acanthocephaloides propinquus* (Dujardin, 1845) is not known although Belghyti et al. (1994) cite a personal communication by de Buron, who achieved a successful experimental infection of the amphipod *Caprella acutifrons* Latreille which seems to be a synonym of *C. penantis* (Leach). All of the Echinorhynchidae, whose cycles are currently known, use crustaceans as intermediate hosts (De Buron and Golvan, 1986). *C. acutifrons* has not been reported to date from the Western Iberian coast, but *C. equilibria* Say is present (López-Jamar et al., 1984) and may possibly be the intermediate host in our region.

4.5. Helminth communities

Total helminth species richness was much higher in the inner part of the Muros Estuary than in the open ocean areas (21 in MI against 15 in AE and 11 in ME). Only *B. gregarius*, the undetermined *Bothriocephalus* spp., *H. aduncum*, the tetraphyllidean plerocercoids and the type-III nematode larvae were observed in all three areas. *D. varicus*, *A. propinquus* and *C. heterochrous* were observed in both AE and MI; another seven species were observed in both AE and ME; *B. nylandicus* was observed only in ME; while the 14 remaining species were observed only in MI (Table 2).

The fact that species richness was highest in MI is attributable at least in part to the presence of five species exclusive to *P. flesus*. Indeed, species richness in *P. flesus* was identical to that in *M. variegatus* despite the fact that capture effort was much higher for this latter species (Poulin, 1998); thus, the value for *P. flesus* may in fact be an underestimate. Indeed, the observed differences between AE and ME may be partially attributable to the higher capture effort for *M. variegatus*, *L. boscii* and *S. maximus* in AE (see Table 1).

Most of the species that were not present in all three areas are digeneans and cestodes. Of the digeneans, species of the family Opecoelidae were present in MI only. Of the hemiurids, *L. rufoviride* and *L. musculus* were present only in MI, while *S. caudiporum* was present only in AE and ME. However, *L. rufoviride* infects *C. conger* from the Galician continental shelf (Quinteiro et al., 1987; Quinteiro, 1990), so its absence among the flatfishes of AE and ME is probably not due to the absence of infective metacercariae but more likely to differences in the trophic chains of conger eel and the different species of flatfishes. Of the Fellodistomidae, *L. stephanskii* was found in AE and ME and *P. maculatus* in MI. This latter result may be related to the presence of mussel cultivation rafts in the estuaries, providing *P. maculatus* with abundant intermediate hosts. Finally, of the Zoogonidae, *Z. rubellus* was only found in MI (in *P. flesus*), while *Z. viviparus* was present in AE and ME (though with significantly higher mean abundance and prevalence in AE). Considering the cestodes, in AE and ME, we found plerocercoids of *N. lingualis*, while in MI, we only found the *Grillotia* species. *B. nylandicus* (the adult phase) was found only in ME.

All the aforementioned species may be useful as indicators of the origin of fish. Indeed, *N. lingualis* and *Grillotia* sp. have already been used to distinguish between various conger populations in our region (Sanmartín et al., 2000b). In this study, we also used *H. aduncum* and *Contracaecum* sp. and the presence/absence of *A. propinquus*. In the hosts considered in the present study, however, *H. aduncum* and *A. propinquus* were present in all three sampling areas. More suitable indicator species for these hosts would therefore be *A. simplex* and *Contracaecum* sp., although as mentioned, the former occurs in various fish species within the Arousa Estuary.

4.6. Helminths in aquaculture

Three factors contribute to the pathogenic effects of helminths and other parasites in cultured fish: stress due to crowding and manipulation, the cultivation system used and the diet. In crowded conditions that are very common in farms, fish produce corticoids

(Sindermann, 1990), and in some species, pheromones (Williams and Jones, 1994), both with an immunosuppressive effect. This favours the appearance of massive infections by species that cause little harm to their host in the natural environment but that, under these conditions, may cause severe disease and even death.

The importance of diet can be illustrated by several examples. In the mid-1980s, there was an outbreak of *B. scorpii* (probably *B. gregarius*) in a turbot farm near our capture areas, which resulted in severe economic losses (Devesa, 1996). A second outbreak, this time of *A. simplex*, occurred at approximately the same time in another farm in the same area (unpublished data). Both species are transmitted in the food chain, and at the time the outbreaks occurred, farmed turbot were fed on fresh blue whiting (*M. poutassou* Risso, 1826) and sand eels (*H. lanceolatus* Le Sauvage, 1824), which are both very abundant in the area. Outbreaks stopped when industrial feeds for turbot farming were introduced. Karlsbakk et al. (2001) has described an experimental case with high mortalities in cod (*Gadus morhua*) postlarvae fed on natural zooplankton due to several helminth and arthropod species and has revised a number of literature reports of lethal helminth infections of very young fish, both cultured and wild, fed with natural zooplankton.

The importance of the culture system is closely related to diet. In a tank system, it is possible to use water filters to keep organisms from the external environment out of the tanks, preventing their ingestion by the fish. Furthermore, filters also prevent the entry of infective stages of many parasites that search for new hosts by active swimming (for example, trematode cercariae, copepod larvae, etc.). In contrast, when netpens directly submerged in the sea are used, invertebrates and even small fish from the environment can enter freely, making a strict control of the diet of the cultured fishes practically impossible. Netpens are the usual system for salmonids, and their use for several species that had hereto been cultivated in tanks, including pleuronectiforms such as turbot and halibut, is being studied experimentally. It is thus possible that helminths that are now considered unimportant as fish farm pathogens might cause economic problems in the future.

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