

# Comparison of the macroparasite communities of wild and stocked brown trout (*Salmo trutta* L.) in the west of Ireland

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## SUMMARY

The aim of the present study was to compare the helminth infra and component communities of wild and stocked brown trout in Lough Feeagh, in the west of Ireland, and also to examine the establishment and development of helminth communities in stocked brown trout. Fish were sampled in May, August and November 1997 and 1998 and an additional sample of wild brown trout was examined in April 1997. In total 217 wild trout and 122 stocked trout were examined. The acanthocephalans *Acanthocephalus clavula* and *Pomphorhynchus laevis* were the first parasite species to infect stocked trout in May 1997. In May 1998 both acanthocephalan species along with the trout specialists *Eubothrium crassum* and *Crepidostomum farionis* were the first to infect trout. Mean species richness values for stocked trout increased from May to November, in 1997 and 1998. For wild trout, mean species richness values increased from April to November, in 1997 and decreased from May to November in 1998. The parasite communities of wild trout were richer than those of stocked trout in May of both years. In August the parasite communities recorded for wild and stocked trout were similar in terms of the number of species present but differed in terms of structure, and in November the parasite communities of stocked trout were richer than those of wild trout.

Key words: trout, infracommunity, component community, acanthocephalan.

## INTRODUCTION

The parasite community ecology of resident brown trout (*Salmo trutta* L.) has received particular attention given their status as the dominant salmonid species in Europe (Bwathondi, 1984; Conneely & McCarthy, 1988; Hartvigsen & Halvorsen, 1993; Molloy, Holland & Poole, 1995; Dorucu *et al.* 1995; Byrne *et al.* 2000). Kennedy & Hartvigsen (2000) tested the hypothesis that the intestinal helminth communities in freshwater brown trout were dissimilar in composition and structure to those in European eels, by examining the component communities from 72 localities and the infracommunities from 34 localities in the British Isles and Norway. Composition of the helminth communities differed significantly between the 2 host groups. However, they identified a suite of 4 commonly occurring trout specialists which gave greater predictability to the trout parasite community composition.

Increasing levels of pollution, habitat decline, and overfishing have increased the importance of fish stocking as a fishery management option (Cragg-

Hine, 1992; Cowx, 1994). However, despite the relative abundance of parasite community studies on brown trout, no study has yet compared the parasite community structure, at any level, of wild and stocked brown trout in the same system. Poynton & Bennett (1985) compared parasites of wild brown trout and stocked rainbow trout in a Hampshire river but this study was limited by small sample sizes and no parasite community parameters were examined. McGuigan & Sommerville (1985) examined the effects of cage culture of rainbow trout on the parasite fauna of Lough Fad in western Scotland. However, this study was more concerned with the aquacultural implications of cage culture rather than parasite community ecology or interactions between wild and stocked trout.

The present study is the only such study to compare, in detail, the parasite communities of wild and stocked brown trout at the component and infracommunity levels in an oligotrophic lake, Lough Feeagh, over 2 successive years, 1997 and 1998. This was facilitated by the sea trout enhancement programme run by the Marine Institute, in which an average of 3500 pond reared brown trout were stocked into Lough Feeagh annually between 1996 and 1998. The establishment and development of the parasite communities in naïve stocked trout

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were examined at the infra and component community levels from the time of first entry of stocked fish into Lough Feeagh.

#### MATERIALS AND METHODS

Lough Feeagh is an oligotrophic freshwater lake of glacial origin located in the west of Ireland. It has an area of approximately 410 hectares, a maximum depth of 43 m and it lies at an altitude of 14 m. The water in Lough Feeagh is soft and distinctly coloured, but transparency is only moderate. pH values range from 6.3 to 7.0 and conductivity values are around 80–90  $\mu\text{S}/\text{m}$ . Surface temperature values are generally within the range 3 °C to 20 °C. Lough Feeagh contains salmon, trout, eels and sticklebacks.

Coloured alphanumerically coded visible implant (V.I.) tags were used to identify fish stocked in Lough Feeagh in 1997 and 1998. Fish stocked in 1997 were tagged with green and red coloured tags and fish stocked in 1998 were tagged with orange coloured tags. Tags were injected dorsally, into the transparent tissue behind the eye of the fish, using a special applicator, according to the procedure described by Kincaid & Calkins (1992). All fish were tagged on their right side. The code used on each V.I. tag is unique to individual fish and the colour referred to a batch of fish. Tagged fish also had their adipose fins removed to facilitate identification.

Beach Seine netting for wild and stocked fish was carried out on 7 occasions on Lough Feeagh between April 1997 and November 1998. Beach seine netting was carried out in accordance with the procedure described by Matthews *et al.* (1997). Once in the laboratory all fish were measured (fork length  $\pm$  0.1 cm) and weighed ( $\pm$  0.1 g). Scales were removed from all wild fish for ageing, and all fish were subsequently frozen. Only 1-year-old wild trout (1+), corresponding to the age of the stocked trout sample were considered for parasitological examination. Beach seine netting surveys carried out around the mouths of the rivers running into Lough Feeagh, suggest that large numbers of juvenile fish enter the lake during their first summer (i.e. as 0+ trout) and over-winter in the lake (Matthews *et al.* 1997).

In 1997 samples of wild and stocked fish were collected in May, August and November and an additional sample of wild fish was collected in April. A similar sampling regime was adopted in 1998. However, due to unseasonable rainfall and the resulting high water level in Lough Feeagh, it was not possible to collect a sample of wild fish in April. Samples were taken in so far as possible to reflect seasonal differences in the fish and parasite populations and also as a function of fish availability. November was considered as the winter sample. August was considered as the summer sample, and

May was considered as the spring sample. Two control samples of stocked fish were also taken directly from the rearing ponds, 1 in 1997 ( $n = 72$ ) and 1 in 1998 ( $n = 70$ ), no parasite species were found in any of the control fish.

Fish were defrosted at room temperature and the general condition of the fish and any external lesions were noted. Viscera were removed and rinsed with 0.9% saline, which was kept and separately examined for parasites. The gills, liver, spleen, heart, gonads and swim bladder were all removed and examined for parasites. The body cavity was examined to detect any parasites which might be encysted there. Gonads were used to determine the sex of the fish. It was not possible to sex some juveniles as the gonads were not present. All parasites recovered were fixed in 10% formalin solution. Acanthocephalans were first placed in tap water for 24 h to evert the proboscis. At 24–48 h after fixation, parasites were washed in 70% ethanol and transferred to fresh 70% ethanol with 4% glycerol for long-term storage. Parasites were identified using the standard keys and, where necessary, they were cleared in lactophenol or stained with polyvinyl acetate and lignin pink.

The helminth community was examined at the infra and component community levels. The measures of component community richness used were percentage prevalence, mean abundance and mean intensity, all calculated according to Bush *et al.* (1997). The term component species, as defined by Bush *et al.* (1997), was used to refer to any parasite species which had a prevalence value of 10% or more. Similarities in the parasite communities of wild and stocked fish were calculated using Sorenson's index of similarity at the component community level. The measures of infracommunity richness used were the mean species richness, mean number of individuals and the Brillouin's index of diversity which was calculated for intestinal worms only. The Shannon diversity index was also calculated. All indices used were calculated according to Magurran (1988). One-way analysis of variance was used to compare the abundance values of the 4 most common species (*E. crassum*, *C. farionis*, *P. laevis*, *A. clavula*) between the April 1997 wild trout sample and the remaining wild trout samples. Three-way analysis of variance (ANOVA) was used to examine the relationships between fish status (whether fish were wild or stocked), the month (May, August and November) and year of capture and the abundance of the four most prevalent species. Three-way analysis of variance (ANOVA) was also used to examine the relationships between fish status, the month and year of capture and each of 3 dependent variables, the species richness, the number of individuals, and the Brillouin's index of diversity. In all cases non-normal data were transformed using log transformations, prior to any statistical analysis being undertaken.

## RESULTS

Data summarizing the parasite component communities of wild and stocked trout in each sample month in 1997 and 1998 (April, May, August, November) are presented in Tables 1–4, and data summarizing the parasite component communities of the total wild and stocked trout samples are presented in Table 5. The stocked trout examined in April 1997 and 1998 represent control samples; fish were sampled directly from rearing ponds prior to being released.

*Component community structure**April*

No parasites were found in trout stocked in April 1997 or trout stocked in 1998 (Table 1). This confirms that trout being stocked into Lough Feeagh were initially metazoan parasite-free and that any parasites subsequently found in stocked trout were acquired from that lake. It was not possible to compare the wild 1+ trout sample from April 1997 to any corresponding wild trout sample (as no wild 1+ trout were examined in 1998). However, when the wild 1+ trout sample from April 1997 was compared to the total wild 1+ trout sample (Table 5) *C. farionis* had the highest mean abundance and mean intensity values in both samples. *P. laevis* had the highest prevalence in the total sample and the nematode *Rhabdochona* sp. had the highest prevalence in the April 1997 sample. One-way analysis of variance (ANOVA) showed significant differences in the abundance of *E. crassum* (F ratio = 9.57; D.F. = 1,215;  $P \leq 0.002$ ), *P. laevis* (F ratio = 7.12; D.F. = 1,215;  $P \leq 0.008$ ) and *A. clavula* (F ratio = 7.35; D.F. = 1,215;  $P \leq 0.007$ ) between the April 1997 wild 1+ trout sample and the remaining trout samples.

*May*

Only 2 parasite species, the acanthocephalans *P. laevis* and *A. clavula* were recorded in stocked trout in May 1997 (Table 2). The same 2 acanthocephalan species along with *C. farionis* and *E. crassum* were recorded in stocked trout in May 1998. All species recorded in stocked trout, with the exception of *E. crassum* in 1998 were component species. *A. clavula* had the highest prevalence, mean abundance and mean intensity values in stocked trout in 1997 and 1998. In wild trout the highest component community parameters were recorded for *P. laevis* in 1997 whereas in 1998 *P. laevis* had the highest prevalence, but *C. farionis* had the highest mean abundance and mean intensity values. With the exception of the prevalence and mean abundance values for *P. laevis*, all other component community parameters were higher for the 4 most common

species (*E. crassum*, *C. farionis*, *P. laevis*, *A. clavula*) in 1998.

*August*

The parasite component communities recorded for stocked trout in August of both years contained more species (and were more comparable to the parasite communities recorded for wild trout in August) than the component communities recorded for stocked trout in May. Eight parasite species were recorded in stocked trout in August 1997 and 9 were recorded in 1998, in both years all species recorded were component species (Table 3). Nine parasite species were recorded in wild trout in 1997 and 8 species were recorded in 1998, of these only 5 were component species in 1997 and all were component species in 1998. In 1997 *E. crassum* had the highest prevalence and *Diphyllbothrium ditremum* had the highest mean abundance and mean intensity values in stocked trout and *P. laevis* had the highest prevalence, mean abundance and mean intensity values in wild trout. All component community parameters recorded for *A. clavula* were higher than those recorded for *P. laevis* in stocked trout in 1997 and 1998. In contrast all component community parameters recorded for *P. laevis* in wild trout were higher than those recorded for *A. clavula* in 1998, and in 1997 prevalence and mean abundance values were higher for *P. laevis*.

*November*

The same 9 parasite species were recorded in stocked trout in November 1997 and 1998 and in wild trout in 1998. Seven parasite species were recorded in wild trout in 1997. Five component species were recorded in wild trout in 1997 and 7 component species were recorded in wild trout in 1998. *E. crassum* had the highest component community parameters in 1997 whereas in 1998 *P. laevis* had the highest prevalence value, *A. clavula* had the highest mean abundance value and *E. crassum* had the highest mean intensity value. Four component species were recorded in stocked trout in 1997, compared to 1998 when all species recorded were component species (Table 4). All of the component community parameters recorded for *P. laevis* were higher than those recorded for *A. clavula* in stocked trout in 1997 and 1998 and in wild trout in 1997. The highest component community values were recorded for *P. laevis* in stocked trout in 1997, whereas in 1998 *E. crassum* had the highest prevalence value and *D. ditremum* had the highest mean abundance and mean intensity values.

*Statistical analysis*

Three-way analysis of variance showed significant differences in the abundance of *E. crassum* between wild and stocked trout (F ratio = 28.83; D.F. = 1,305;  $P \leq 0.0001$ ) and between months (F ratio =

Table 1. Helminth component community data for wild and stocked trout from Lough Feeagh in April 1997 and 1998

(IN, intestine; V, viscera; S, stomach; SB, swimbladder; G, gills, % prevalence; A, mean abundance (s.d.); I, mean intensity (s.d.).)

Parasites	Site	April 97 Wild ( <i>n</i> = 29)			April 97 Stocked ( <i>n</i> = 70)			April 98 Wild			April 98 Stocked ( <i>n</i> = 70)		
		%	A	I	%	A	I	%	A	I	%	A	I
<i>Eubothrium crassum</i>	IN	0	0	0	0	0	0	–	–	–	0	0	0
<i>Crepidostomum farionis</i>	IN	48.3	2.7 (3.8)	5.6 (3.7)	0	0	0	–	–	–	0	0	0
<i>Pomphorhynchus laevis</i>	IN	51.7	2.6 (5.1)	5.1 (6.3)	0	0	0	–	–	–	0	0	0
<i>Acanthocephalus clavula</i>	IN	0	0	0	0	0	0	–	–	–	0	0	0
<i>Rhabdochona</i> sp.	IN	55.2	2.5 (3.4)	4.4 (3.4)	0	0	0	–	–	–	0	0	0
<i>Diphyllobothrium ditremum</i>	V	3.5	0.3 (0.2)	1 (0)	0	0	0	–	–	–	0	0	0
<i>Cystidicoloides tenuissima</i>	S	0	0	0	0	0	0	–	–	–	0	0	0
<i>Cystidicola farionis</i>	SB	0	0	0	0	0	0	–	–	–	0	0	0
<i>Discocotyle sagittata</i>	G	0	0	0	0	0	0	–	–	–	0	0	0
<i>Salmincola salmoneus</i>	G	3.5	0.3 (0.2)	1 (0)	0	0	0	–	–	–	0	0	0

Table 2. Helminth component community data for wild and stocked trout from Lough Feeagh in May 1997 and 1998

(IN, intestine; V, viscera; S, stomach; SB, swimbladder; G, gills, % prevalence; A, mean abundance (s.d.); I, mean intensity (s.d.).)

Parasites	Site	May 97 Wild ( <i>n</i> = 32)			May 97 Stocked ( <i>n</i> = 21)			May 98 Wild ( <i>n</i> = 32)			May 98 Stocked ( <i>n</i> = 26)		
		%	A	I	%	A	I	%	A	I	%	A	I
<i>Eubothrium crassum</i>	IN	3.1	0.03 (0.2)	1 (0)	0	0	0	31.3	2.1 (4.9)	6.7 (7)	7.7	0.1 (0.4)	1.5 (0.7)
<i>Crepidostomum farionis</i>	IN	21.9	1.6 (3.9)	7.4 (5.2)	0	0	0	78.1	30.6 (34.5)	39.2 (34.5)	15.4	1 (4)	6.8 (8.9)
<i>Pomphorhynchus laevis</i>	IN	96.9	9.4 (6.7)	9.7 (6.6)	19.1	0.8 (2.3)	4.3 (4)	84.4	8.7 (15.4)	10.3 (16.3)	46.2	1.4 (2.6)	3.1 (3.2)
<i>Acanthocephalus clavula</i>	IN	18.8	0.4 (1.2)	2.3 (1.8)	28.6	1.7 (6.1)	5.8 (10.9)	50	8.8 (20.4)	17.5 (26.4)	57.7	4.1 (6)	7.1 (6.5)
<i>Rhabdochona</i> sp.	IN	0	0	0	0	0	0	9.4	0.2 (0.8)	2.3 (1.5)	0	0	0
<i>Diphyllobothrium ditremum</i>	V	3.1	3 (0.2)	1 (0)	0	0	0	15.6	0.4 (1.2)	2.4 (2.2)	0	0	0
<i>Cystidicoloides tenuissima</i>	S	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cystidicola farionis</i>	SB	3.1	0.03 (0.2)	1 (0)	0	0	0	9.4	1.2 (5.5)	12.7 (25.9)	0	0	0
<i>Discocotyle sagittata</i>	G	3.1	0.1 (0.5)	3 (0)	0	0	0	6.3	0.1 (0.5)	2 (0)	0	0	0
<i>Salmincola salmoneus</i>	G	0	0	0	0	0	0	31.3	0.6 (1.2)	1.8 (1.6)	0	0	0

Table 3. Helminth component community data for wild and stocked trout from Lough Feeagh in August 1997 and 1998

(IN, intestine; V, viscera; S, stomach; SB, swimbladder; G, gills, % prevalence; A, mean abundance (s.d.); I, mean intensity (s.d.).)

Parasites	Site	August 97 Wild (n = 47)			August 97 Stocked (n = 15)			August 98 Wild (n = 31)			August 98 Stocked (n = 10)		
		%	A	I	%	A	I	%	A	I	%	A	I
<i>Eubothrium crassum</i>	IN	23.4	2.1 (5.3)	3.1 (7.6)	86.7	12.6 (23.4)	14.5 (24.7)	22.6	2.4 (6.3)	10.6 (9.8)	90	51.3 (86.6)	57 (89.8)
<i>Crepidostomum farionis</i>	IN	31.9	2.5 (7)	7.9 (10.8)	20	1.1 (2.8)	5.3 (4.5)	35.5	2.9 (6.3)	8.3 (8.4)	50	1.6 (2.3)	3.2 (2.3)
<i>Pomphorhynchus laevis</i>	IN	72.3	5.2 (7.3)	7.1 (7.7)	20	0.3 (0.6)	1.3 (0.6)	45.2	3.7 (8.8)	8.1 (11.9)	20	0.5 (1.3)	2.5 (2.1)
<i>Acanthocephalus clavula</i>	IN	25.5	3.2 (11.6)	12.6 (20.9)	40	7.6 (21.6)	19 (32.4)	32.3	4.7 (14.9)	14.6 (24)	30	7.3 (20)	24.3 (34.4)
<i>Rhabdochona</i> sp.	IN	12.8	0.3 (1)	2.5 (1.8)	13.3	0.3 (0.7)	2 (0)	25.8	0.8 (1.6)	3 (1.7)	10	0.2 (0.6)	2 (0)
<i>Diphyllobothrium ditremum</i>	V	8.5	1 (4.3)	11.3 (11.6)	33.3	13.3 (49.2)	40 (84.4)	19.4	1.3 (3.6)	6.7 (5.8)	50	23.7 (48.8)	47.4 (62.8)
<i>Cystidicoloides tenuissima</i>	S	6.4	0.2 (1)	3.7 (2.1)	0	0	0	0	0	0	10	0.1 (0.3)	1 (0)
<i>Cystidicola farionis</i>	SB	0	0	0	13.3	0.1 (0.4)	1 (0)	6.5	0.2 (0.8)	3 (0)	0	0	0
<i>Discocotyle sagittata</i>	G	2.1	0.04 (0.3)	2 (0)	0	0	0	29	0.5 (1.2)	1.8 (1.6)	50	1 (1.3)	2 (1.2)
<i>Salmincola salmoneus</i>	G	4.3	0.6 (0.3)	1.5 (0.7)	13.3	0.1 (0.4)	1 (0)	9.7	0.1 (0.3)	1 (0)	10	0.1 (0.3)	0.1 (0.3)

Table 4. Helminth component community data for wild and stocked trout from Lough Feeagh in November 1997 and 1998

(IN, intestine; V, viscera; S, stomach; SB, swimbladder; G, gills, % prevalence; A, mean abundance (s.d.); I, mean intensity (s.d.).)

Parasites	Site	November 97 Wild (n = 14)			November 97 Stocked (n = 23)			November 98 Wild (n = 31)			November 98 Stocked (n = 25)		
		%	A	I	%	A	I	%	A	I	%	A	I
<i>Eubothrium crassum</i>	IN	78.6	6.4 (7.7)	8.2 (7.9)	96	8.4 (6.6)	8.8 (6.5)	22.6	2.4 (6.3)	10.6 (9.8)	84	4.7 (5.1)	5.6 (5.1)
<i>Crepidostomum farionis</i>	IN	7.1	0.1 (0.3)	1 (1)	8	0.1 (0.4)	1 (1.5)	35.5	2.9 (6.3)	8.3 (8.4)	52	7.4 (19)	14.2 (24.8)
<i>Pomphorhynchus laevis</i>	IN	50	3.9 (5.8)	7.9 (6.1)	100	13.9 (13.3)	13.9 (13.3)	45.2	3.7 (8.8)	8.1 (11.9)	68	5 (8.8)	7.4 (9.9)
<i>Acanthocephalus clavula</i>	IN	14.3	0.2 (0.4)	1.5 (0.7)	20	1.4 (5)	6.8 (10.2)	32.3	4.7 (14.9)	14.6 (24)	52	3.4 (7.5)	6.5 (9.5)
<i>Rhabdochona</i> sp.	IN	0	0	0	4	0.04 (0.02)	1 (0)	25.8	0.8 (1.6)	3 (1.7)	48	2 (3.3)	4.3 (3.57)
<i>Diphyllobothrium ditremum</i>	V	64.3	2.4 (4.3)	3.7 (5)	64	2.5 (3.8)	3.9 (4.2)	19.4	1.3 (3.6)	6.7 (5.8)	64	9.2 (18.8)	14.4 (22.1)
<i>Cystidicoloides tenuissima</i>	S	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cystidicola farionis</i>	SB	0	0	0	8	0.7 (2.5)	9 (0)	6.5	0.2 (0.8)	3 (0)	20	1.4 (5.2)	6.8 (10.8)
<i>Discocotyle sagittata</i>	G	21.4	0.3 (0.6)	1.3 (0.6)	4	0.04 (0.2)	1 (0)	29	0.5 (1.2)	1.8 (1.6)	44	1 (1.7)	2.2 (1.9)
<i>Salmincola salmoneus</i>	G	7.1	0.1 (0.3)	1 (0)	8	0.1 (0.4)	1.5 (0.7)	9.7	0.1 (0.3)	1 (0)	20	0.3 (0.61)	1.4 (0.6)

Table 5. Total helminth component community data for wild and stocked trout samples from Lough Feeagh in 1997 and 1998

(IN, intestine; V, viscera; S, stomach; SB, swimbladder; G, gills, % prevalence; A, mean abundance (s.d.); I, mean intensity (s.d.).)

Parasites	Site	Total Wild ( <i>n</i> = 217)			Total Stocked ( <i>n</i> = 122)		
		%	A	I	%	A	I
<i>Eubothrium crassum</i>	IN	26.3	2.2 (5.9)	8.1 (8.9)	56.6	8.5 (28.6)	15 (36.9)
<i>Crepidostomum farionis</i>	IN	40.1	6.4 (17.2)	15 (23.8)	22.1	2 (9.1)	9.1 (17.9)
<i>Pomphorhynchus laevis</i>	IN	70.4	5.4 (8.7)	7.7 (9.5)	51.6	4.4 (8.9)	8.5 (10.9)
<i>Acanthocephalus clavula</i>	IN	25.8	3 (11.4)	11.7 (20.2)	39.3	3.7 (10.9)	9.3 (15.9)
<i>Rhabdochona</i> sp.	IN	14.7	0.5 (1.7)	3.5 (2.8)	13.1	0.5 (1.7)	3.4 (3.3)
<i>Diphyllobothrium ditremum</i>	V	15.2	0.9 (3.3)	5.7 (6.6)	34.4	6 (24.1)	17.4 (38.9)
<i>Cystidicoloides tenuissima</i>	S	4.1	0.6 (4.5)	14.1 (18.2)	0.8	0.01 (0.1)	1 (0)
<i>Cystidicola farionis</i>	SB	3.2	0.2 (2.2)	7.5 (11.6)	7.4	0.4 (2.6)	6 (8.2)
<i>Discocotyle sagittata</i>	G	11.5	0.2 (0.7)	1.9 (1.3)	13.9	0.3 (0.9)	2.1 (1.7)
<i>Salmincola salmoneus</i>	G	10.6	0.2 (0.6)	1.6 (1.2)	8.2	0.1 (0.4)	1.3 (0.5)

Table 6. Sorenson's index of similarity between wild and stocked trout in May, August and November of 1997 and 1998

		Wild			
		1997	May	August	November
Stocked	May		0.15	0.14	0.17
	August		0.08	0.47	0.37
	November		0.61	0.63	0.42
		Wild			
		1998	May	August	November
Stocked	May		0.19	0.34	0.50
	August		0.14	0.42	0.32
	November		0.41	0.60	0.66

36.18; D.F. = 2,305;  $P \leq 0.001$ ) but not between years. Significant differences in the abundance of *C. farionis* existed between wild and stocked trout (F ratio = 14.41; D.F. = 1,305;  $P \leq 0.0002$ ), between months (F ratio = 4.59; D.F. = 2,305;  $P = 0.01$ ) and between years (F ratio = 34.61; D.F. = 1,305;  $P \leq 0.0001$ ).

For *P. laevis* significant differences in abundance existed between wild and stocked trout (F ratio = 16.12; D.F. = 1,305;  $P \leq 0.0001$ ), between months (F ratio = 7.84; D.F. = 2,305;  $P \leq 0.0005$ ) and between years (F ratio = 10.9; D.F. = 1,305;  $P \leq 0.001$ ). For *A. clavula* significant differences in the abundance existed between years (F ratio = 14.0; D.F. = 1,305;  $P \leq 0.0002$ ) but not between months or between wild and stocked trout.

Summary data on the parasite communities of wild and stocked trout in Lough Feeagh are presented in Table 5. Ten parasite species were identified in wild and stocked brown trout. *D. ditremum* was allogenic and the remaining 9 species were auto-genic. *D. ditremum* was also the only larval species present. *P. laevis* had the highest overall prevalence

value in wild trout and *C. farionis* had the highest mean abundance and mean intensity values. *E. crassum* had the highest overall prevalence and mean abundance values in stocked trout and *D. ditremum* had the highest mean intensity value. Eight component species were recorded in wild trout, and 7 were recorded in stocked trout. The nematodes *Cystidicola farionis*, and *Cystidicoloides tenuissima* were non-component species in wild and stocked trout and the copepod *Salmincola salmoneus* was also a non-component species in stocked trout. Stocked trout had the highest prevalence values for *E. crassum*, *D. ditremum*, *A. clavula*, *Cystidicola farionis* and *Discocotyle sagittata*, and wild trout had the highest prevalence values for the remaining 5 species. At the component community level Sorenson's index was used to examine the parasite community similarity between wild and stocked trout for each month in 1997 and 1998 (Table 6). In 1997 the highest level of community similarity recorded between wild and stocked trout occurred in August; however, the highest overall level of community similarity occurred between wild trout in August and stocked

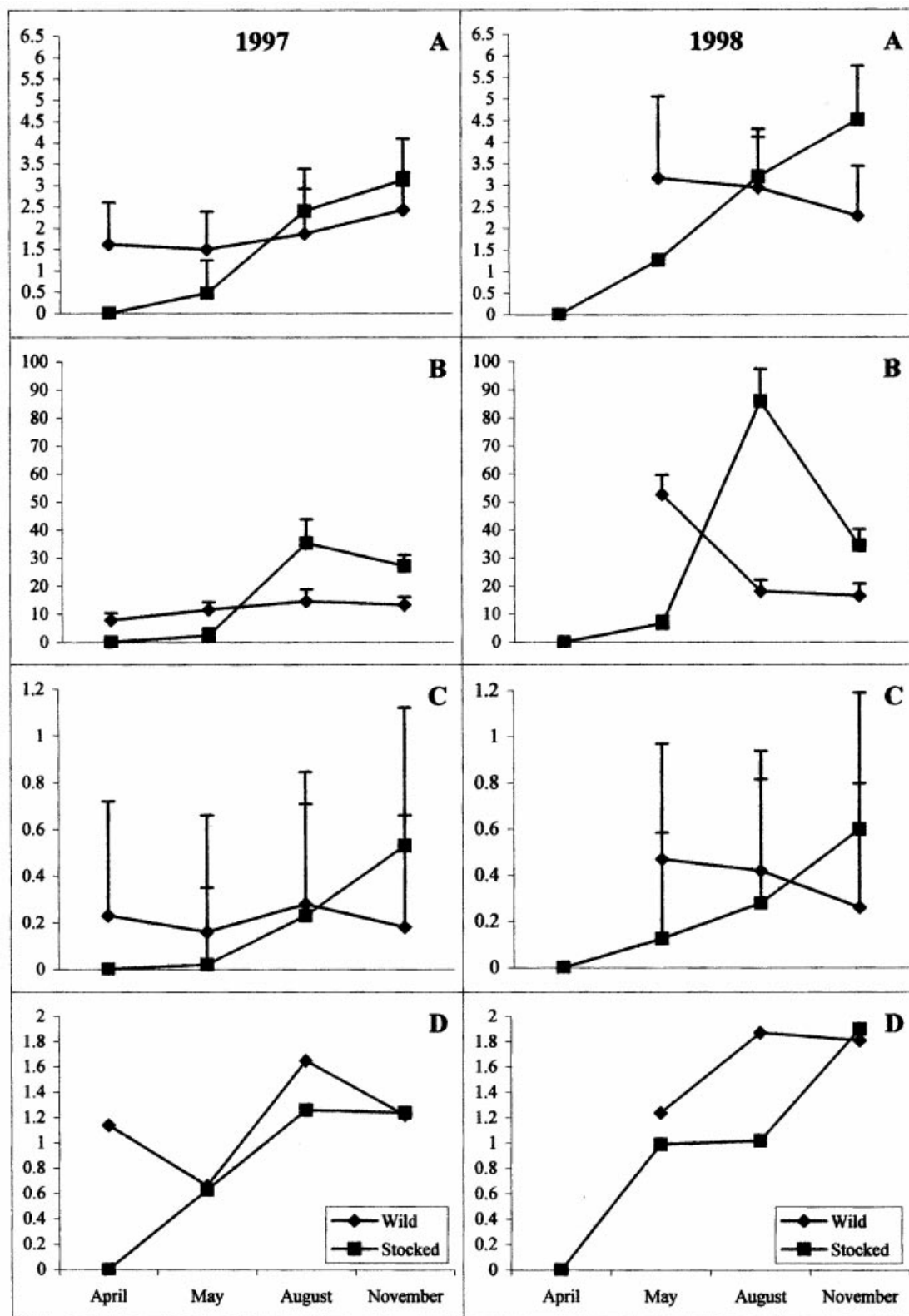


Fig. 1. Infracommunity parameters for wild and stocked fish from Lough Feagh in 1997 and 1998. (A) Mean species richness; (B) mean number of individuals; (C) Brillouin's index (intestinal worms only); (D) Shannon diversity index. Standard error (S.E.) bars are shown where necessary and, for purposes of clarity, only positive standard error bars have been shown.

trout in November. In 1998 the level of community similarity between wild and stocked trout increased from May to a peak in November. The Sorenson's

index value recorded in November was the highest parasite community similarity value recorded in 1998.

### *Infracommunity structure*

Nine wild trout and 16 stocked trout (excluding the control samples) harboured no metazoan parasites. Values for the mean species richness, mean number of individuals, Brillouin's index of diversity (intestinal worms only) and the Shannon diversity index are presented in Fig. 1. In 1997 and 1998, values for the mean species richness and the mean number of individuals for stocked trout increased from zero in April, when fish were first put into Lough Feeagh, to values comparable with the corresponding wild trout samples in August and to values in excess of those recorded for wild trout in November. A similar situation occurred for the Brillouin's index of diversity values recorded for stocked trout in 1998; however, in 1997 values for the Brillouin's index of diversity for wild trout were higher in all months than for the corresponding stocked trout sample (Fig. 1). Values for the Shannon diversity index for stocked trout also increased from zero in April; however, in 1997 values peaked in August and decreased in November, whereas in 1998 values peaked in November. In wild trout, values for the Shannon diversity index peaked in August 1997 and 1998. In all cases with the exceptions of the mean species richness value for wild trout in November 1997 and the Shannon diversity index value for stocked trout in August 1997 infracommunity parameters were higher in 1998.

### *Statistical analysis*

In all analyses, the April samples for wild and stocked trout have been excluded, as only 1 wild trout sample was taken and the stocked trout were taken from rearing ponds as a control sample.

### *Species richness*

No significant differences in species richness existed between stocked and wild fish. The interactions between month and year and year and fish status (wild or stocked) were also non-significant. However there were significant differences in the species richness recorded between months (F ratio = 46.38; D.F. = 2,298;  $P \leq 0.0001$ ) and between years (F ratio = 46.25; D.F. = 1,298;  $P \leq 0.0001$ ). The interactions between month and fish status (F ratio = 44.54; D.F. = 2,298;  $P \leq 0.0001$ ) and between month year and fish status (F ratio = 7.72; D.F. = 2,298;  $P \leq 0.0005$ ) were also significant.

### *Number of individuals*

No significant differences in the number of individuals were recorded between years. The interactions between fish status and year and between fish status, month and year were also non-significant. Signifi-

cant differences in the number of individuals were recorded between fish status (F ratio = 13.54; D.F. = 1,326;  $P \leq 0.0003$ ) and between months (F ratio = 11.02; D.F. = 3,326;  $P \leq 0.0001$ ). The interactions between fish status and month (F ratio = 57.7; D.F. = 2,236;  $P \leq 0.0001$ ) and between month and year (F ratio = 9.48; D.F. = 2,326;  $P \leq 0.0001$ ) were also significant.

### *Brillouin's index*

No significant differences in the Brillouin's index of diversity existed between stocked and wild fish. The interactions between year and month and year and fish status were also non-significant. Significant differences in the Brillouin's index of diversity existed between years (F ratio = 20.7; D.F. = 1,294;  $P \leq 0.0001$ ) and months (F ratio = 41.81; D.F. = 2,294;  $P \leq 0.0001$ ). However, the interactions between month and fish status (F ratio = 29.88; D.F. = 2,294;  $P \leq 0.0001$ ) and between year, month and fish status (F ratio = 3.39; D.F. = 2,294;  $P \leq 0.03$ ) were significant.

## DISCUSSION

Few workers have examined the parasite fauna of wild and stocked trout (Aderounmu, 1966; Wootten, 1973; Poynton & Bennett, 1985; McGuigan & Sommerville, 1985), and none have examined parasite community parameters in any detail. Aderounmu (1966) showed that 12 species were found in wild trout and 7 species were found in hatchery-reared trout. Similarly, Wootten (1973) demonstrated that the parasite fauna of stocked rainbow trout from the raceways in Hanningfield reservoir was a reduced version of the parasite fauna found in the adult fish from the reservoir. In this case prevalence and mean intensity values were provided. Poynton & Bennett (1985) examined the parasitic infections of wild and cultured brown trout and cultured rainbow trout. This study was more concerned with the identity of parasite species and their potential interactions with cultured fish, rather than parasite community dynamics. McGuigan & Sommerville (1985) compared the parasite faunas of cultured rainbow trout, eels and wild fish in a eutrophic freshwater loch in the west of Scotland. They demonstrated a number of differences in the prevalence and intensity values recorded for some parasite species between wild and stocked trout. The aim of this study, however, was to examine the effects of intensive fish farming on a Scottish loch in terms of disease and parasites. Correspondingly, sample fish were maintained in cages, artificially fed and treated with therapeutic products when necessary. Therefore the present study is the first, to exclusively examine the parasite infra and component communities of wild and stocked trout living 'freely' in a natural lake.



Stocked trout were put into Lough Feeagh in late March/early April in each of 2 successive years, giving them about 1 month to acclimatize, and to become infected with parasites before the first fish samples were taken in May. The first parasite species to infect stocked trout in 1997 were the acanthocephalans *A. clavula* and *P. laevis*. The brown trout is considered to be the preferred definitive host of *P. laevis* in Ireland. In contrast, *A. clavula* uses the freshwater eel *Anguilla anguilla* as its preferred definitive host and only occurs occasionally in trout. Both species of acanthocephalan were also the first to infect the stocked trout put into Lough Feeagh in 1998, along with *E. crassum* and *C. farionis* which both use trout as their preferred definitive host. The parasite component communities recorded for wild fish in May 1997 and 1998 were richer than those recorded for stocked fish. The parasite component community recorded in stocked fish was made up of the 4 most prevalent species found in wild fish, which agrees with the findings of Hartvigsen & Halvorsen (1993) who showed that the parasite species infecting recently introduced salmon parr were the most prevalent species in the adjoining lake. The occurrence of the 4 most prevalent species recorded in wild trout, in the stocked trout samples in May 1997 and 1998 also agrees with the findings of Kennedy & Hartvigsen (2000), who examined the intestinal helminth communities of brown trout from 72 localities in Ireland, England and Norway and identified a group of 4 species which occurred commonly in trout and gave a better degree of predictability to the parasite community. However, in the present study only 3 of the 4 species recorded in May were specialists in trout. The occurrence of *E. crassum* and *C. farionis* in stocked trout in May 1998 and not in May 1997 was probably related to a general increase in the abundance of *E. crassum* and *C. farionis* in Lough Feeagh (as recorded in the wild trout samples from May 1997 and 1998).

The component communities of wild and stocked trout in August 1997 and 1998 were similar in terms of composition, but different in terms of structure. *E. crassum* had the lowest component community parameters in stocked trout in May 1998 yet in August it dominated the community. The next most dominant species in stocked trout in August 1998, the larval cestode *D. ditremum*, was absent in May. The increase in the component community parameters of *E. crassum* and *D. ditremum* was consistent with a peak recruitment period in midsummer (Kennedy, 1996). The dominance of *A. clavula* over *P. laevis* in stocked trout, and the dominance of *P. laevis* over *A. clavula* in wild trout in August suggests that both groups of fish were feeding preferentially on different intermediate hosts, *Asellus meridianus* in the case of stocked trout and *Gammarus duebeni* in the case of wild trout. However, O'Grady (1983), working on brown trout in central Ireland,

could not find any significant differences in the proportions of *Asellus* and *Gammarus* consumed by wild and stocked trout.

Overall the component parasite communities recorded for stocked trout in November 1997 and 1998 were richer than those recorded for wild trout. Only the component community parameters recorded for *D. sagittata* in 1997, the mean abundance and mean intensity values recorded for *A. clavula* in 1998 and the mean intensity value recorded for *E. crassum* in 1998 were higher for wild trout. The mean abundance and mean intensity values recorded for *E. crassum* in stocked trout in 1997 and 1998 decreased sharply from August to November. This is in agreement with the findings of Kennedy (1996) who demonstrated a large midsummer increase in *E. crassum* as a result of recruitment, followed by a substantial drop. Wyatt & Kennedy (1988) demonstrated that a number of copepod species had distinct seasonal occurrences, and different species peaked in abundance from spring to autumn. It is likely that a combination of the same seasonal changes in the abundance of copepod intermediate hosts and a significant increase in parasite mortality (and subsequent loss from the fish host) were responsible for the drop in the mean abundance and mean intensity values recorded for *E. crassum*.

When the total parasite component communities of wild and stocked trout were examined wild trout had the highest prevalence values for 5 of the 10 parasite species they had in common. The composition of the total parasite component community recorded for stocked brown trout was almost identical to that recorded for wild trout; however, in terms of community structure some differences existed between them. Stocked trout had substantially higher prevalence, mean abundance and mean intensity values for *E. crassum* and *D. ditremum*, and wild trout had higher values for *C. farionis*. This suggests that stocked trout were feeding on more planktonic organisms, probably planktonic copepods, which are the intermediate hosts of *E. crassum* and *D. ditremum* (Kennedy & Burrough, 1978), and wild trout were feeding on more benthic invertebrates, which are the probable intermediate hosts of *C. farionis*. A number of studies have examined the diets of wild and stocked fish (Sosiak, Randall & McKenzie, 1979; O'Grady, 1983; Johnsen & Ugedal, 1986; Kelly-Quinn & Bracken, 1989) and all have shown that stocked fish ultimately adopt a normal diet, although the length of time taken to do this differs. Sosiak *et al.* (1979) working on salmon parr and O'Grady (1983) working on brown trout demonstrated that stocked fish initially favoured food items on or near the surface of the lake. O'Grady (1983) also suggested that competition with resident fish might result in trout being forced from the benthic feeding areas and having to feed near the surface. Thus, stocked fish are considered to

feed on more items on or near the surface resulting in higher prevalence and mean abundance values for *D. ditremum* and *E. crassum*.

Few workers have examined helminth infracommunities of fish (Kennedy *et al.* 1997; Marcogliese & Cone, 1998; Molloy *et al.* 1995), similarly, few workers have examined the parasite communities of wild and stocked fish (McGuigan & Sommerville, 1985; Vidal-Martinez *et al.* 1998); however, none have compared infracommunity parameters between wild and stocked fish in a natural environment. In both years the infracommunity values recorded for stocked trout reflect the fact that they were only released into Lough Feeagh in late spring. Values for the mean species richness, mean number of individuals, and diversity indices all increased from May to August. Such increases were consistent with the development of the helminth community in stocked trout. The helminth infracommunities of stocked trout in 1997 and 1998 went from being poorer than those recorded for wild trout in May, to being comparable with the infracommunities recorded for wild trout in August, and higher than the infracommunities recorded for wild trout in November.

Vidal-Martinez *et al.* (1998) compared the parasite communities and presented some infracommunity data for wild and caged *C. urophthalmus* over a 7-month period. A total of 17 parasite species were recorded from the wild fish sample and 10 species were recorded from the caged fish sample. A maximum of 13 parasite species were recorded from the wild fish sample in April. The pattern demonstrated for caged *C. urophthalmus* fish was similar to that demonstrated for stocked trout in Lough Feeagh, in that the number of parasite species increased over the course of the study. However, unlike the situation in Lough Feeagh, the number of parasites recorded in a caged fish in any month never equalled or exceeded the number of parasites recorded in wild fish. This study was also not directly comparable to the study in Lough Feeagh, as stocked *C. urophthalmus* were fed an artificial diet, and maintained in artificial cages. They had free access to all planktonic copepods and their parasites but not to benthic intermediate hosts. Consequently it would be impossible for caged *C. urophthalmus* to adopt a 'fully wild' parasite fauna.

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