

# **RAINBOW TROUT IN SCOTLAND: A BLESSING OR A CURSE?**

## **1.0 INTRODUCTION**

Rainbow trout (*Oncorhynchus mykiss* (Walbaum)) were successfully introduced here from western North America in 1885 (MacCrimmon, 1971), since when their status in the UK and Ireland has been reviewed through questionnaires by Worthington (1940-41) and then by Frost (1974). This paper describes the status of the species in Scotland, in 2002, based on a questionnaire broadly similar to the previous ones. A follow-up investigation of rainbow trout that had escaped from fish farms or stocked angling fisheries was undertaken in the River Earn in Eastern Scotland. More complete details of these studies are provided by Walker (2003a; b).

## **2.0 THE SCOTTISH QUESTIONNAIRE**

Approximately one thousand questionnaires were distributed among anglers, fishery bodies and fish farmers in December 2001 and early January 2002 and 350 replies (35%) were received. More than 70 fishery owners or managers contributed to the survey.

### **2.1 Waters containing rainbow trout**

A total of 305 Scottish waters currently stocked with rainbow trout were identified, compared with 94 found by Frost (1974). The true number is much higher because private fisheries were under-reported, and commercial fisheries often comprised groups of ponds, or lochs. Others are likely to have been missed. Most of the stocked waters were situated in the more populated regions, with few in the Highlands and Islands (Fig 1). To put these numbers into context, there are about 4,000 standing waters in Scotland (> 4 ha) and more than 30,000 overall (Lyle & Smith, 1994).

### **2.2 The stocked fish**

The production of rainbow trout on Scottish fish farms destined for angling in 2001 was 792 tonnes, compared with a total production of 5,466 tonnes (Anon, 2002). However, some fisheries were supplied from other parts of the UK. Therefore, the total amount stocked may have exceeded 1000 tonnes.

Sixty-eight fisheries commented on the size of the fish that they used for stocking. Forty-one (60%) stocked mainly, or solely, fish weighing less than 1 kg. Twenty-four (35%) stocked mainly fish of 1-2 kg and three (5%) stocked fish only greater than 2 kg. Forty fisheries (59%) stocked some fish of this size. Angling captures of rainbow trout weighing more than 5 kg are commonly reported in the press. Very large specimens (10 - 15 kg) also are caught as escaped fish in lochs where there are cage farms eg. in Loch Tay and Loch Earn. These fish may have been eating “waste” pellets.

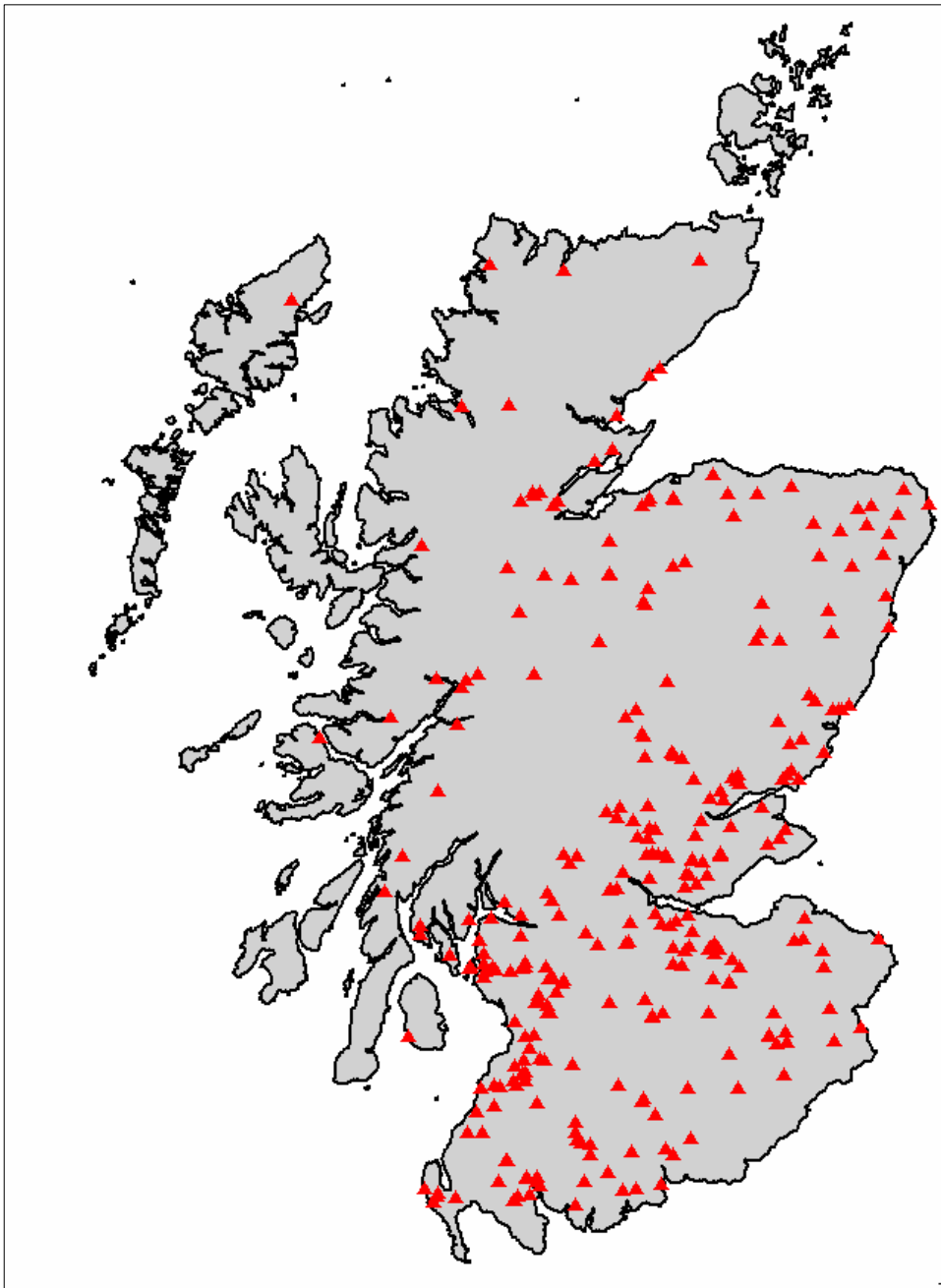


Fig.1. The locations of stocked waters in Scotland holding rainbow trout in 2002

Annual stocking densities ranged to a maximum of about 6,000 fish per ha (Fig. 2). Smaller fisheries tended to be stocked more heavily than larger ones, as noted by Pawson (1982). In the early 1970s, annual stocking densities peaked at about 150 fish per ha (Frost, 1974). She also noted that 'large fish' of 250–305 mm were preferred, which is considerably smaller than current stocking practice. Clearly, the fisheries have become much more intensive and have moved heavily into put-and-take, with little opportunity for natural fish growth.

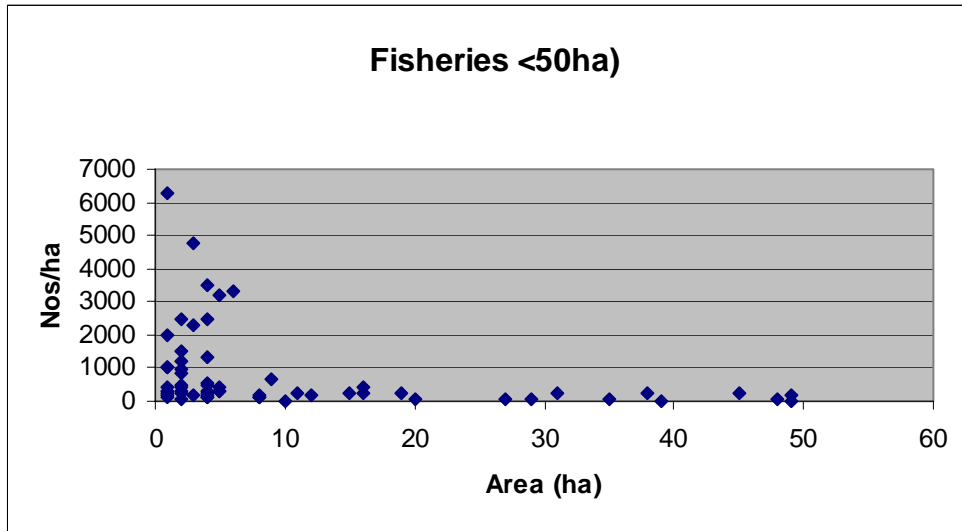


Fig.2 a. Reported annual stocking densities of rainbow trout in 2002

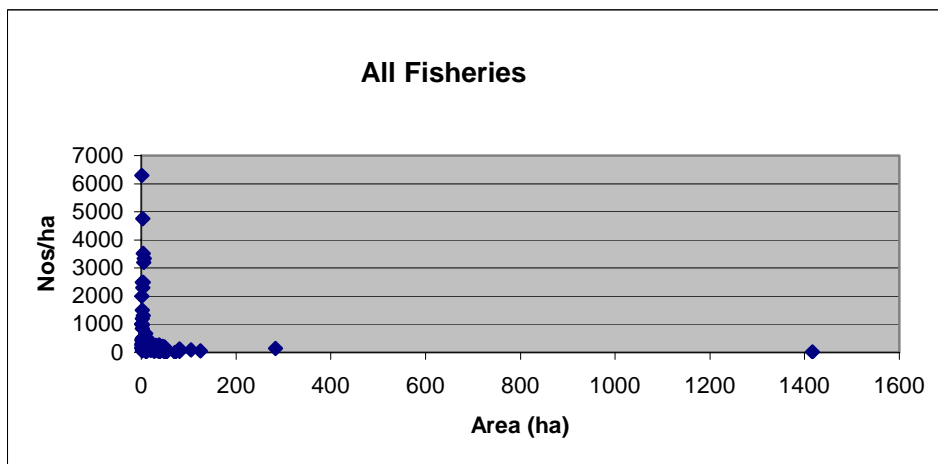


Fig.2b.

### 2.3 Natural reproduction

Nearly all of the respondents were unaware of successful spawning of rainbow trout in Scotland. However, the managers or owners of 14 waters confirmed that some had taken place, although these instances were mainly several years ago, before the regular use of “all-females” and triploids. FRS staff already knew of successful spawning at some other waters (Walker, 2003a). Figure 3 shows the locations of 48 Scottish stillwaters where there have been reports of successful spawning of rainbow trout during the last 35 years. These are categorised as High likelihood where the reports have been validated or are acceptable, and Low likelihood where the presence of small rainbow trout can be explained by escapes from local hatcheries, or fish cages.

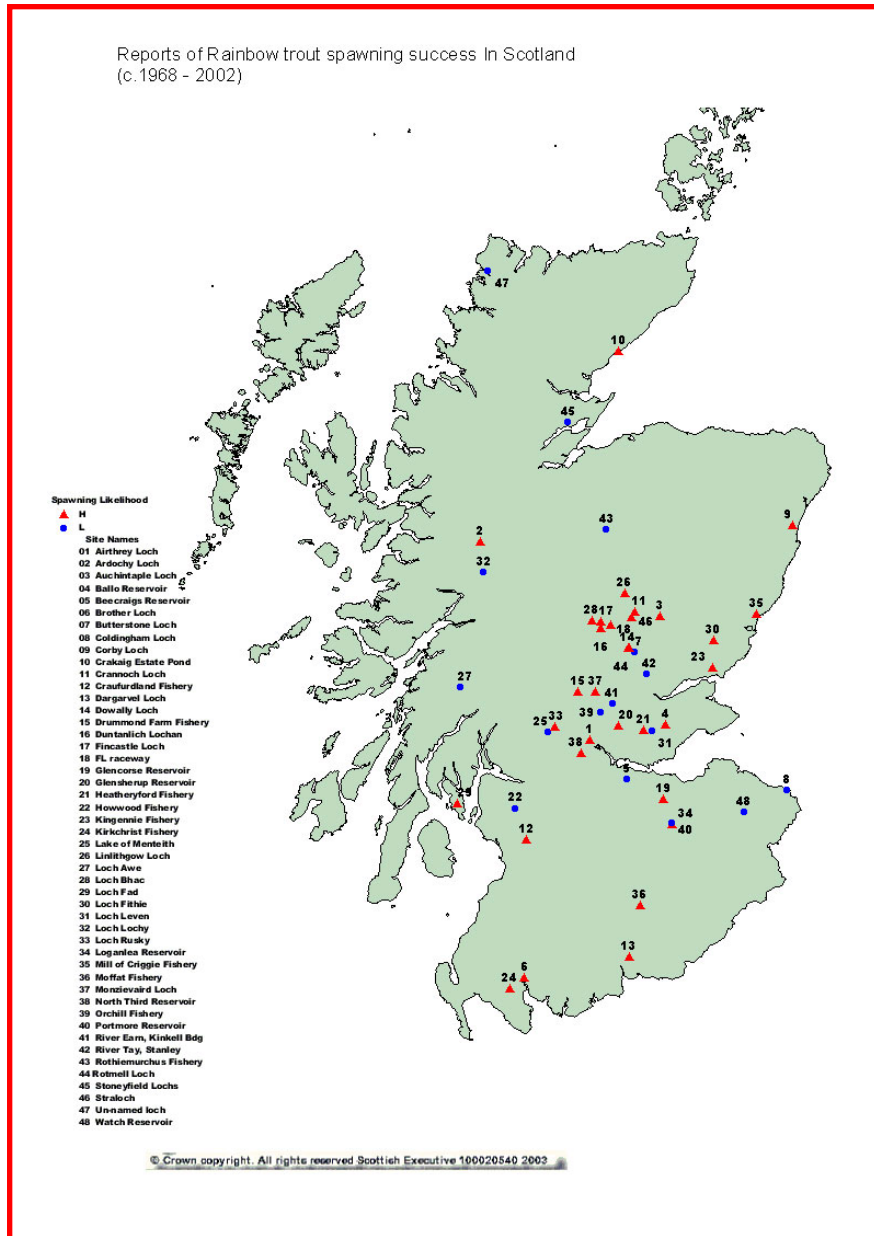


Fig.3. Reports of spawning success of rainbow trout in Scottish stillwaters

## 2.4 Escaped fish

Escaped rainbow trout were observed in 54 rivers or streams, seven freshwater and three sea lochs/estuaries. The River Awe and Loch Awe were mentioned 37 times, followed by the River Earn and Loch Earn (25 times), the River Tweed and tributaries (23 times) and the River Tay and Loch Tay (19 times). All areas where escaped fish were common were close to fish farms. Several people expressed their concern about possible ecological impacts of rainbow trout on native salmonids and the River Earn System was investigated as a case study.

## 3.0 CASE STUDY

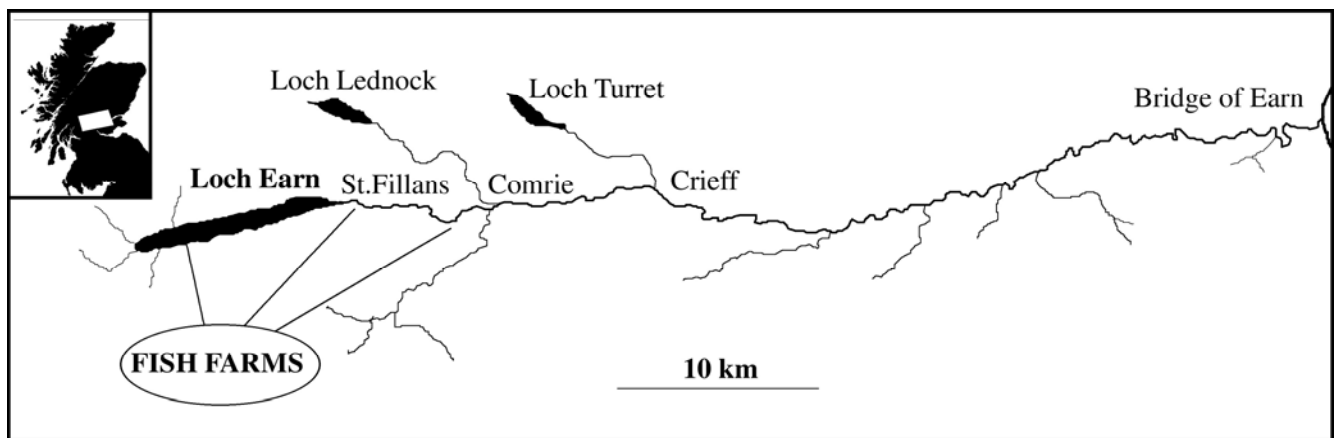


Fig.4. The River Earn System in Eastern Scotland

The objectives were to establish:

- the current extent and sources of rainbow trout escapes in the River Earn System,
- their size, age, sex composition and maturity status,
- their seasonal diet and
- any evidence of successful spawning.

The River Earn (Figure 3) is the lowest major tributary of the River Tay. The main river exits Loch Earn, a large mesotrophic loch, 10 km in length, situated in mountains to the west of Comrie and St Fillans and meanders east through rich arable and pastoral farmland to meet the River Tay estuary at Bridge of Earn. There is a cage farm containing rainbow trout near the top end of Loch Earn and two land-based fish farms, fed by lades from the river, between St Fillans and Comrie. The lower of the fish farms also contains ponds catering for angling. Loch Earn is a popular multi-watersports venue and angling fishery which is accessible to salmon (*Salmo salar* L.) and sea trout (*S. trutta* L.), but is fished more frequently for stocked and natural brown trout and escaped rainbow trout. It also contains Arctic charr (*Salvelinus alpinus* (L)). Several

small lochs and ponds in the Earn catchment are stocked with rainbow trout. The outflowing river supports fishing for salmon, sea trout, brown trout and grayling (*Thymallus thymallus* (L.)).

### **3.1 Methods**

Gill-nets (15 –120 mm stretched mesh) were used to obtain fish from Loch Earn (29 August). Smaller numbers were collected by angling. Samples of rainbow trout and some brown trout were obtained from the river by angling between Loch Earn and Crieff. Stomach contents were assessed by overall displacement volume and then by proportion of the various food items, following Hynes (1950) and others, and were identified only to broad groups. Most of the gill-netted fish were used initially for disease monitoring. (Walker 2003b). Some qualitative electro-fishing also was undertaken, mainly to obtain fish for disease monitoring.

### **3.2 Trout numbers and size**

Details of the monthly and length distributions of the sampled fish are given in Tables I and II. Total samples of 215 rainbow trout and 25 brown trout were collected between May and December 2002 and late April to June 2003. The size ranges of the rainbow trout obtained from the loch and the river were broadly similar (overall length range 122 – 456 mm). The brown trout samples from the loch and from the river also were broadly comparable, although the numbers were smaller (overall range 121 – 685 mm). Most of the brown trout larger than about 350 mm were of stocked origin (based on fin erosion and scale examination).

### **3.3 Age composition**

The estimated age composition data from the sampled rainbow and brown trout are shown in Table III. In the summer/autumn 2002 samples, nearly all of the rainbow trout were aged 1+ winters, whereas the samples collected in spring 2003 comprised roughly equal numbers aged 2+ and 1+. Some of these older fish were thin and may have over-wintered at liberty. However, others had large amounts of visceral fat, suggesting recent escapement. The abbreviated age distribution indicated that most of the rainbow trout that escape into the River Earn System are short-lived in the wild.

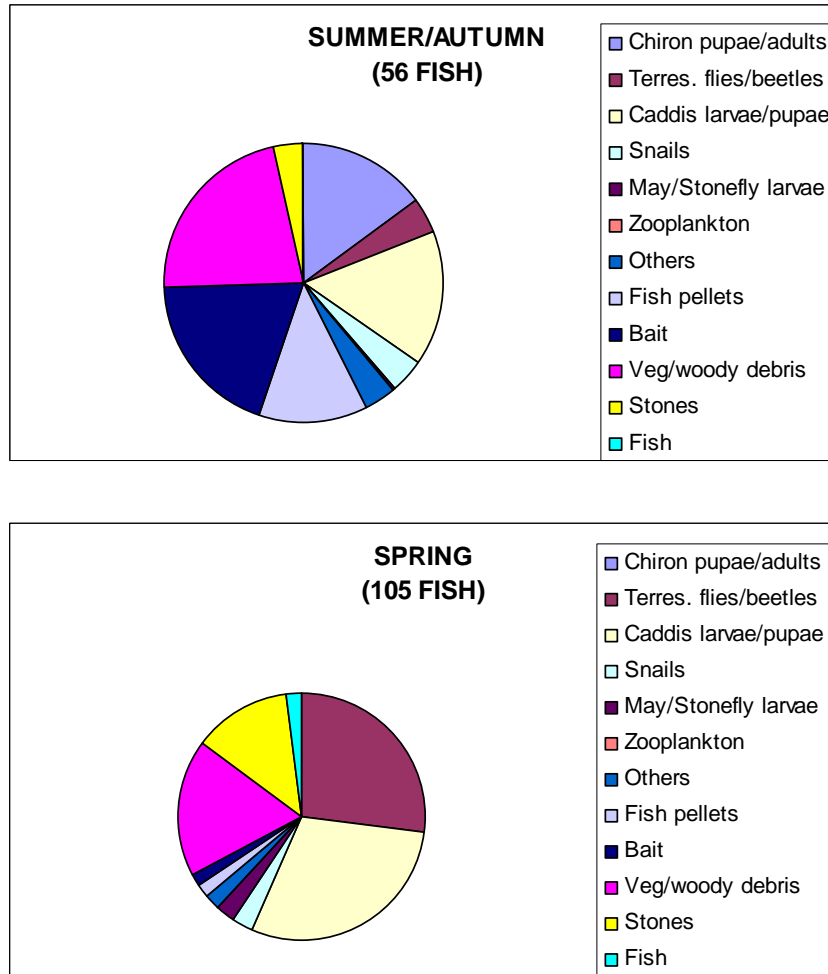
### **3.4 Sex and maturity status**

The overall sample of rainbow trout available for sexing comprised 16 males and 188 females (1.0:11.75). The heavy predominance of females is explained by the current use of mainly “all-female” fish for fish farming and for stocking. Eleven fish (11%) in the June/December sample were maturing to spawn (two males and nine females). One female obtained in the river in December was close to ovulation. During May, 2002, two female fish (288 mm and 336 mm), also from the river, were fully spent and another female (336 mm) was partly-spent. A male fish (305 mm) sampled later (19 June) in the same area was recently spent. The scales from these four fish showed edge erosion (“spawning marks”).

Thus, there was indirect evidence of some spawning. However, no rainbow trout sampled during the survey appeared to be of natural origin; all showed fin shortening typical of a fish farming provenance. Had “wild” fish been common, there would have been a higher proportion of males, as natural spawning would be expected to lead to equal numbers of male and female fry.

### 3.5 Stomach contents

The stomach contents of the samples of rainbow trout obtained from the River Earn during summer/autumn 2002 and spring 2003 are shown in Figures 4 and 5.



Figs 5 and 6. Stomach Contents of Escaped Rainbow Trout in the Upper River Earn (St Fillans to Crieff) during May to December 2002 and April to June 2003

The numbers of fish from both loch and river that had eaten the different items are shown in Table IV. The rainbow trout contained mainly small terrestrial flies and beetles, cased caddis larvae and indigestible material (woody/vegetable/stony debris and two cigarette butts). Some contained fish food pellets and various items of bait (worms, maggots and sweetcorn). One had eaten a fairly large minnow (75 mm). The brown trout contained a similar range of invertebrates, but the low sample numbers and the fact that this species comprised fish of both stocked and wild origin precluded further comparison.

### 3.6 Electro-fishing

Qualitative, single-search electro-fishing was carried out in the Beich Burn, near the fish farm in Loch Earn, on 28 August, 2002. On the same date, a second site was visited in the River Earn, about 4 km below the loch, and another main river site was visited on 19 June, 2003. One of the two river sites was beside and the other about 1 km below the Kindrochet Trout Farm.

Moderate to good numbers of trout and salmon (0+ and 1+) were captured at all three sites. Other species found were stone loaches (*Neomacheilus barbatulus* (L.)), minnows (*Phoxinus phoxinus* (L.)), sticklebacks (*Gasterosteus aculeatus* L.), eels (*Anguilla anguilla* (L.) and lampreys (*Lampetra planeri* (Bloch)). A single rainbow trout (1+; 122 mm) found in the Beich Burn was of fish farm origin. No other juvenile rainbow trout were captured.

## 4.0 DISCUSSION

The questionnaire survey confirmed that there has been substantial growth in the numbers of Scottish waters stocked with rainbow trout and in the intensity of stocking with this species since the last survey (Frost, 1974). Although there was some concern about the potential for replacement of native species, no rainbow trout of wild origin were found in the River Earn case study. Despite the current use locally of “all-females” for fish farming and restocking, a few males were found in the river and some escaped fish probably do spawn there, although no evidence has been found so far that this is successful. From time to time, small numbers of naturally-produced juveniles have occurred in various Scottish stillwaters (Phillipps *et al*, 1984, 1985 and Walker, 2003a, b), but no reports have been authenticated from our rivers.

Thirty years ago, Frost (1974) found self-sustaining populations at only five localities in Britain and Ireland. Maitland and Campbell (1992) and Walker (2003a) refer to a sixth one, in a hill lochan in Inverness-shire (Ardochy Loch), the present status of which is unknown. It is unclear to what extent these long-standing populations of wild rainbow trout have been affected by stocking, or farmed escapes. For example, spawning of fin-perfect and apparently wild rainbow trout still occurs on the River Wye (pers comm. W. Slaney), but there is now a local fish farm and the possibility of genetic introgression with the original population. Also, at Lough Shure, replacement of the original population with fish of farmed origin took place after the original population was thought to have died out.

No obvious environmental explanation can be given for the poor spawning success of rainbow trout in the wild in Britain. Our temperate climate seems to be highly suitable and the species is easily raised in hatcheries. Furthermore, during spring 2003, we buried under gravel in three streams in Perthshire, a series of mesh boxes, each containing 40 fertilised ova from a local fish farm strain, achieving 54 – 88% levels of survival, in spite of low water flows (McMullan, 2003). The species was still common at the end of July, two months after 10,000 unfed fry were released in one of the streams. By that time they measured  $51 \pm 6$  mm [*None were found there the following year, but survivors could have migrated downstream to a stocked loch*]. The initial stocking density in this trial was approximately  $2/m^2$ . The monitored density of rainbow trout fry

was 0.5/m<sup>2</sup>, while naturally-spawned brown trout fry (54±2 mm) and parr (99±9 mm) were present at much lower densities (both 0.04/m<sup>2</sup>).

Previously, various British authors (Frost, 1974; Lever, 1977; Maitland & Campbell, 1992) concluded that established brown trout fry might prevent late-emerging rainbow trout fry from gaining feeding territories. Although rainbow trout may spawn here in any of the colder months of the year, most do so in spring, prompting the suggestion that a shift to autumn-spawning could lead to greater success (Phillipps *et al* 1984). Conversely, Scott (2000) reports competitive exclusion of brown trout by later-spawning rainbow trout through overcutting of their redds in tributaries of two lakes in New Zealand.

Perhaps more significantly, the domesticated rainbow trout that are used for stocking in the UK are likely to be maladapted to life at liberty (Berejikian *et al.*, 1996), and exhibit poor reproductive performance (Fleming & Gross, 1992; Fleming *et al.*, 1996; Youngson & Verspoor, 1998). Scott (pers comm) believes that the comparative lack of domestication of rainbow trout in New Zealand may help to explain why the species reproduces so effectively there. In their World review, Fausch *et al.* (2001) found that colonising success of rainbow trout was best explained by a match between fry emergence and months of low flood probability. They added that the low invasion success of rainbow trout in Europe could be due to hampering of reproduction by low water temperatures and mortality due to Whirling Disease (*Myxobolus cerebralis*). These seem implausible explanations for Scotland, considering our equable climate and the fact that rainbow trout often spawn here in stillwater, where incubation conditions are more stable. Whirling Disease is uncommon in the UK (pers. comm. D. Bruno) and so can be discounted.

Most likely, the problem for rainbow trout reproduction in the wild in the UK is a complex interaction of more than one factor. Viewed in the context of conserving our native stocks of fish, colonisation by rainbow trout through natural reproduction is not a high priority issue at present. However, with gradually changing climatic conditions, it is conceivable that the species could become naturalised more successfully in the future. Further, in a more recent paper, Fausch (2007) points out that “primary factors to consider in any risk analysis of rainbow trout invasion in the U.K. include the decline of native salmonid populations due to degradation or overexploitation, the evolutionary history of newly introduced rainbow trout stocks, local or global influences that change aquatic environments and reduce biotic resistance by native parasites or diseases, and rapid evolution of local adaptations by new or marginally established populations of rainbow trout that make them more invasive.”

In addition to the comments in the questionnaire survey about possible spawning in the River Earn System was the concern about continuing large levels of escapes. The case study confirmed that escaped fish were common in the upper river but were scarcer with distance downstream from Crieff. A persistent loss of a large number of rainbows from the cages on Loch Earn that was notified to SEERAD during 2002 was blamed on net mesh damage caused by predatory bird strikes. However, rainbow trout may have escaped into the river from land-based sites as well.

The broad size structure of the samples of rainbow trout from the upper System appears to indicate a chronic seepage of fish into the wild. On the other hand, they do not survive for long, or they migrate to the sea and mostly fail to return. Small numbers of “steelhead” have occurred in various rivers in Scotland (Shearer, 1975). Many of the escaped rainbow trout are quickly removed by anglers, or predators, and the remainder may not find enough food to sustain them.

Nevertheless, the case study showed that the escaped rainbow trout had been feeding and, by implication, finding living space, albeit that the extent of any impact on the wild fish could not be quantified. There was no evidence of predation on salmon or trout fry or parr, but the rainbow trout diet was varied and their food selection apparently fairly haphazard. Dietary comparison with brown trout was limited by the small numbers obtained and also because they were of both stocked and wild origin. Overall, however, the two species had fed on a similar wide range of invertebrates, results that are comparable with studies on Loch Leven, Kinross-shire (Duncan, 1994).

In order to demonstrate any ecological impact of escaped rainbow trout, it would be necessary to assess each fish species in both the presence and the absence of the other. Behavioural adjustments and habitat partitioning are likely to occur when they live together (see Phillipps *et al*, 1985; Duncan, 1994). However, a manipulative field study of this magnitude would be impractical to undertake on a moderately large river like the Earn. Nilsson (1967) suggested that the mixing of fishes of closely similar feeding habits may improve the overall productivity of fish within a water body. Nonetheless, the intrusion of large numbers of escaped rainbow trout is likely to cause a loss in productivity of the other individual wild fish species, unless more food is added to the system (Phillipps *et al*, 1985). While fish farming supplies waste pellets, and raises biological productivity through faecal decomposition and nutrient discharges, these effluents may cause damaging algal blooms and other ecological consequences. However, in that respect it is encouraging that good numbers of young salmon and trout were found at sites adjacent to the trout farms. Also, kingfishers (*Alcedo atthis* L.) and ospreys (*Pandion haliaetus* (L)) were regularly seen and there was ample evidence of otter activity (*Lutra lutra* L.).

The unplanned release into Loch Earn of large numbers of rainbow trout adds to the economic value of the sport fishery by attracting additional anglers. In the river, by contrast, the free supply of rainbow trout is viewed as an asset on some beats, but as a distinct problem on others. Some of the large brown trout that are stocked in Loch Earn also find their way into the river, but they appear to cause less concern. In an interesting parallel situation concerning rainbow trout in England, a court case was heard at Swindon County Court in 1993. The case was taken by the Savernake Flyfishing Club against a fish farmer for damage caused by negligent escapes of rainbow trout into their brown trout fishery on the River Kennet. No attempt was made to quantify the effect of the escaped fish on the existing brown trout and grayling population. The main point at issue was that the rainbow trout reduced the enjoyment of the fishing club. Nuisance damage was proven for inconvenience, loss of amenity and enjoyment and the sum awarded was £10,500. Damages were based on a proportion of the total annual value of annual fishing membership charges (@£500 per rod) in the most affected year, plus an amenity factor of 50% representing loss of enjoyment. The case established a precedent for legal action in England by affected parties when escapes occur.

The level of escapement of rainbow trout from Scottish fish farms and fisheries should be controllable, although the arrangements for their retention need more care. Rainbow trout were present in the outflow channels of both land-based fish farms on the River Earn and, in one case also the inflow channel, although these were separated from the river by screens. Any damage to these screens, or overtopping during spates, would result in lost fish. Problems with damage to net enclosures and losses of rainbow trout in Scottish lochs also require greater attention.

### ***Recommendation***

*In land-based rainbow trout farms, no fish should be allowed between the production ponds and the top and bottom fish farm screens, so that this area would act as a buffer zone and an indicator of escapes. Buffer zones might not prevent escapes during exceptional spates, but they would help prevent the more mundane incidents. Improvements in containment within cage farms may have to be addressed by better management, such as more regular replacement and inspection/repair of nets and use of double-walls. Security may need to be tightened to restrict damage and losses through predators and vandals. The cages should only be stocked with fish that are clearly larger than the meshes used to contain them. Probably this means an increase in the mean size of fish at the time of stocking the cages, because problems of mesh clogging will restrict the use of very small mesh nets.*

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**Table I: Monthly Distribution of Samples of Trout from the River Earn System 2002/03**

Month	Rainbow Trout		Brown Trout	
	Loch	River	Loch	River
May, 2002	4	4	4	-
June	-	-	-	-
July	31	15	-	3
Aug	-	22	9	3
Sept	-	-	-	-
Oct	-	22	-	-
Nov	-	2	-	-
Dec	-	2	-	-
Jan 2003	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	19	-	-
May	-	47	-	3
June	-	39	-	2
Other*	-	8	-	1
Total	35	180	13	12

\* Unspecified dates in June to September, 2002

**Table II The length composition of rainbow and brown trout sampled in Loch Earn and the River Earn during 2002 and 2003 (in brackets)**

Length (mm)	Loch		River	
	Rainbow	Brown	Rainbow	Brown
101-150	14	0	3 (1)	2 (0)
151-200	12	2	15 (22)	4 (0)
201-250	1	1	22 (25)	0 (0)
251-300	4	2	18 (20)	0 (0)
301-350	2	1	13 (24)	1 (3)
351-400	2	2	3 (10)	0 (0)
401-450	0	1	1 (2)	0 (1)
451-500	0	3	0 (1)	0 (0)
501-550	0	0	0 (0)	0 (0)
551-600	0	0	0 (0)	0 (0)
601-650	0	0	0 (0)	0 (1)
651-700	0	1	0 (0)	0 (0)

**Table III : The age composition of rainbow and brown trout sampled in Loch Earn and the River Earn during 2002 and 2003 (in brackets)**

Age (winters)	Loch		River	
	Rainbow	Brown	Rainbow	Brown
0+	0	0	0	0
1+	30	0	70 (52)	1
2+	5	5	2 (50)	3 (3)
3+	0	4	1 (1)	3
4+	0	2	0	0
5+	0	1	0	0
6+	0	1	0	0
7+	0	0	0	1
8+	0	0	0	(1)

**Table IV: Trout Samples from the Upper Earn System, 2002/03  
Numbers of Fish with Food Items**

Food Item	SUMMER/AUTUMN				SPRING	
	RR	RL	BR	BL	RR	BR
Chironomid pupae/adults	6	1	1	1	4	0
Terrest. Flies/beetles	32	5	3	2	46	3
Caddis larvae/pupae	13	1	1	5	38	2
Aquatic snails	4	3	1	2	1	0
Mayfly/stonefly larvae	3	1	1	0	8	0
Fish	0	0	0	0	1	0
Zooplankton	0	2	0	1	0	0
Others	4	1	1	1	4	0
Fish pellets	1	1	0	2	0	0
Bait	9	0	0	2	2	0
Vegetable/woody debris	13	2	0	3	35	1
Stones	4	1	1	3	24	0

RL = loch rainbows; RR = river rainbows; BL = river brown trout; BR = loch browns  
 Five rainbow trout and two brown trout netted from the loch are included that had eaten pellets but were not included in the volume data because they had been part-dissected during disease sampling.  
 Others includes two shrimps (*Gammarus* spp.), water mites, caterpillars and occasional *Gordius* sp. parasites. Bait includes worms, maggots and chrysalids and sweetcorn.