AN INVESTIGATION OF ESCAPED RAINBOW TROUT IN THE UPPER RIVER EARN AND LOCH EARN DURING 2002/03

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Executive Summary

- Escaped rainbow trout were common in the upper River Earn and Loch Earn in summer/autumn of 2002 and Spring 2003. Two hundred and fifteen specimens were sampled, 180 from the river and 35 from the loch. Escaped fish were less common in the river below Crieff. The high prevalence of escaped fish in the upper parts of the river and the loch during 2002-03 was not believed to be an unusual occurrence.

- Rainbow trout escape from cages at Loch Earn and may also have come from land-based fish farms. Also, some fish originated from at least one stocked stillwater fishery in the catchment when an outflow screen was overwhelmed during a severe spate.

- The sampled rainbow trout covered a wide size range (fork length range 122-456 mm), suggesting more than one escape incident, or source population.

- Seventy-two percent of the escaped fish were aged 1+ winters, 27% were aged 2+ and only 1% were aged 3+, indicating short-term survival in the wild.

- The diet of the sampled fish was mainly invertebrates, but there was also a lot of indigestible material, including sticks and stones. There was no evidence of predation on salmon or trout fry and parr. One fish contained a large minnow (75 mm).

- The densities of salmon and trout fry and parr appeared to be normal at sites close to the trout farms, also suggesting that predation by escaped rainbow trout is insignificant.

- There was some evidence of food resource partitioning with brown trout that were collected at the same sites, but too few brown trout (25) were available to make a detailed comparison. The brown trout were of both wild and stocked origin. Some brown trout that had been stocked in Loch Earn were found in the river.

- Among the rainbow trout that could be sexed, females were much more common than males (188:16). During the summer/autumn sampling, nine females and two males were found to be maturing (11%). In the spring sample, three females were spent or part-spent and there was a single male kelt (4% matured fish). No rainbow trout fry were found. All of the sampled fish had fin damage consistent with farmed fish. Thus, there was no evidence of successful natural spawning.

- In a farmed fish study carried out near Pitlochry in spring 2003, at three running water sites and one stillwater site, most (75%) rainbow trout eggs buried under gravel in mesh boxes hatched and developed normally to the point of fry emergence, when they were removed. In a subsequent stocking trial in a hill burn, 10,000 unfed fry were released in early June. They were still present when monitoring was carried out in late July, nearly two months after release, although the stream was reduced due to a drought. These results suggest that natural ova incubation and early survival of rainbow trout in Perthshire is not prevented by unfavourable environmental conditions. Other explanations for the lack of sustained breeding success of the species in Scotland are discussed.

- Sampling of escaped and wild fish also was carried out for disease examination. The results were negative for important disease viruses (infectious pancreatic necrosis (IPN), sleeping disease).

- The continuing high prevalence of escaped rainbow trout in the upper Earn system shows that more needs to be done to prevent their loss into the wild. Adverse impacts upon the wild fish stocks are likely to occur, although these are difficult to detect and quantify. Also, increased angling pressure resulting from news of the availability of escaped fish may depress wild fish stocks. Recommendations are made for better containment at fish farms.
1. Introduction

This report describes the biological details and the stomach contents of rainbow trout (*Oncorhynchus mykiss* (Walbaum)) sampled in the upper parts of the River Earn and Loch Eam, in eastern Scotland, during summer and autumn 2002 and spring 2003. Some brown trout (*Salmo trutta* L.) were included in the survey for comparison. The Earn System was chosen for a case study after a questionnaire survey was distributed throughout Scotland in 2001/02 by the FRS Freshwater Laboratory (Walker, 2003). The survey revealed continuing concerns about the ecological impacts of rainbow trout upon native fish species when they are present in areas where they were not deliberately stocked. Most of these fish, termed escapes, are presumed to come from fish farms but some may come from inadequately screened angling fisheries. However, some respondents to the questionnaire alleged that rainbow trout numbers in the wild were augmented by natural spawning.

The last similar investigation of the status of rainbow trout (Frost, 1974) was undertaken throughout the UK and Ireland nearly 30 years ago. Since then there has been a large increase in the scale of use of rainbow trout for fish farming and restocking (Walker, 2003). The FRS questionnaire inquired about the numbers and locations of stocked rainbow trout fisheries in Scotland, any occurrences of the species in the wild where they were not stocked and sought information on sites of successful natural spawning. Based on more than 350 replies received, the survey revealed that rainbow trout are currently stocked in more than 300 waters. This figure may be a substantial under-estimate, as private fisheries were less likely to be disclosed. In addition to these stocked waters, escaped fish had been found in recent years in 54 rivers or streams, seven freshwater lochs and three sea lochs or estuaries, where they were not deliberately stocked.

The River Earn System was cited by several respondents as an area where escaped rainbow trout were common. Therefore, it was chosen for a case study of:

- the current extent and sources of rainbow trout escapes;
- the size, age, sex composition and maturity status of the escaped fish;
- their seasonal diet and;
- evidence for or against their successful natural reproduction.
2. **The Study Area**

The River Earn (Figure 1) is the lowest major tributary of the River Tay, whose estuary it enters near Bridge of Earn, south of Perth. The main river flows due east from Loch Earn, a large mesotrophic loch, situated in rugged mountainous country to the west of Comrie and St Fillans. Loch Earn lies at an elevation of about 100 metres above mean sea level. It is about 10 km in length, over one km in mean breadth and has a greatest depth of 87.5 metres. The main tributaries enter the loch near the western end. The River Earn flowing from the loch is at first a small river running through dense deciduous woodland, but it more than doubles in volume at Comrie. There, it meets the spatey Water of Ruchill, which flows in a north—easterly direction from mountainous Glen Artney. Further downstream, it is joined by a series of large tributaries, including the rivers Lednock, Turret, Machany, Ruthven, May and Farg, plus many smaller streams. The main river meanders through rich, mixed arable and pastoral land to the tidal waters near Bridge of Earn, a river distance of about 70 km. It flows past several towns and villages, the largest communities being Crieff and Auchterarder.

*Figure 1: The River Earn system in eastern Scotland, showing sites of rainbow trout culture in 2002.*

Within the Earn System, there are several commercial fish farm and hatchery sites that produce rainbow trout. There is a cage farm near the top end of Loch Earn and between St Fillans and Comrie there are two land-based farms fed by lades from the river. The lower of these fish farms is a very popular visitor venue that also contains ponds catering for angling. Two hatchery sites in the catchment of the Water of Ruthven specialise in sales of eyed-ova and early fry to other fish farms. Three other farm sites were not operational during the study.

Loch Earn is a popular multi-watersports venue and angling fishery. It is accessible to salmon (*Salmo salar* L.), sea trout (*S. trutta* L.) and eel (*Anguilla anguilla* (L.)), but is fished more frequently for stocked and natural brown trout (*S. trutta* L.) and escaped rainbow trout. It also contains Arctic charr (*Salvelinus alpinus* (L.)) that are occasionally caught by anglers. Several small lochs and ponds in the Earn catchment are stocked with rainbow trout. Two larger lochs, Lednock and Turret, dammed for hydro-power generation, contain natural brown trout. The River Earn supports sizeable angling fisheries for salmon, sea trout, brown trout and grayling (*Thymallus thymallus* (L.)). A limited amount of commercial netting for salmon and sea trout is still carried out in the lower estuary.
3. Sampling

a) River Earn
Samples of rainbow trout, to be supplied frozen, with details of place and date of capture, were requested from angling beats. The sampling was co-ordinated by the River Earn Angling Improvement Association. Further samples, including some taken from brown trout, were obtained by the author and friends. All of the fish obtained from the river were caught between Loch Earn and Crieff and mainly above Comrie. Four rainbow trout were obtained by electrofishing in the area of the outflow from the Dalchonzie Power Station during salmon brood stock collection in November and December, 2002. All of the fish were later defrosted and examined at the FRS Freshwater Laboratory, where they were measured by fork length (mm) and weighed (g). Sex and maturity status were recorded and scales were taken for age determination. Stomachs were removed and preserved in glyceralcohol (70% alcohol + 2% glycerol). These were later cut open longitudinally and the contents assessed first by overall displacement volume, and then by proportion of the various food items, following standard methodology established by Hynes (1950) and others. Food items were identified only to broad groups.

b) Loch Earn
Gill-nets of a wide range of mesh sizes (15 –120 mm stretched mesh) were used to obtain fish samples from Loch Earn on a single visit (29 August). The nets were set in daylight near to the fish farm in Ardveich Bay and lifted later on the same day. Most were set to fish along the bed of the loch, perpendicularly from the shore. One was set to float over deeper water (ca 15 metres depth). It was impractical to set any of the nets closer than 50-200 metres from the cages, because of boat angling activity and the presence of mooring buoys. According to reports from the anglers and the fish farming staff, many large fish (rainbow trout, brown trout and char) lie below the groups of cages, where they feed on fish food pellets that pass through the meshes. It was planned to set nets in at least one other area, well away from the cages, but the prevailing stormy weather conditions at the time of the visit meant that the netting had to be confined to the relatively sheltered waters of Ardveich Bay. However, on two previous days (23 May, 21 Aug), small samples were collected by angling near the south-west end of the loch and within two km of the outflow at St. Fillans. Rainbow trout and brown trout were obtained from the loch at all three sites.

Most of the freshly-caught, gill-netted fish were used initially for disease monitoring. Blood and pathology samples were taken by the FRS Marine Laboratory Epidemiology Group for examination in Aberdeen. The results from these tests are shown in Appendix 1 (pers. comm. S. Wallace). The carcases of these fish and the others were then frozen for later examination. Later, some fish were not able to be sexed and were found to have incomplete stomach contents due to the pathology sampling. However, other data from these fish were included in the overall survey.

As a further part of the sampling of fish for disease examination, during summer 2002, qualitative, single-search, electro-fishing was carried out at two stream sites (28 August, 2002). These were:

1) The Bheich Burn – a section of total length of about 60 metres, above and below the roadbridge, close to the onshore facilities of the fish farm on Loch Earn (NN616242).

2) The main River Earn, about 3 km downstream from the loch (NN731230). Only part of the width of the river was fished over a linear distance of about 30 metres.
3) A third site on the upper main River Earn (NN723233) was electro-fished qualitatively on 19 June, 2003. This site was near the outfall from the trout farm at Kindrochet, near St Fillans. On this occasion, the main purpose was to supplement the samples of rainbow trout for dietary investigation and look for evidence of their fry. About 50 metres of river length was searched from a bridge to slightly above the farm outfall. Part of the river width was omitted because of deeper water (>1m).

A fixed generator, supplying power (ca 300 volts) through a hand-held anode and static cathode was used on each date. Stunned fish were captured by hand-net and stored in a keepnet, before being anaesthetised, measured (fork length in mm) and released, or used for disease testing (only on 28 August, 2002).
4. Results

4.1 Fish samples for stomach analysis
Details of the monthly distribution of the fish that were sampled for stomach analysis are given below in Table I. Some details of the sampling dates of specimens that were received from angling beats on the river were missing, but the general areas and approximate dates of capture were known. During 2002, total samples of 110 rainbow trout and 20 brown trout were collected between May and December. No charr were captured. During late April to June 2003, the samples comprised 105 rainbow trout and five brown trout. In this latter period, no sampling was carried out in Loch Earn. However, 30 rainbow trout and one brown trout that were obtained from immediately above the weir at St. Fillans in a narrow stretch of loch outflow are included in the river sample for convenience.

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainbow Trout</th>
<th>Brown Trout</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loch</td>
<td>River</td>
</tr>
<tr>
<td>May, 2002</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>June</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>July</td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td>Aug</td>
<td>—</td>
<td>22</td>
</tr>
<tr>
<td>Sept</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Oct</td>
<td>—</td>
<td>22</td>
</tr>
<tr>
<td>Nov</td>
<td>—</td>
<td>2</td>
</tr>
<tr>
<td>Dec</td>
<td>—</td>
<td>2</td>
</tr>
<tr>
<td>Jan 2003</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Feb</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Mar</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Apr</td>
<td>—</td>
<td>19</td>
</tr>
<tr>
<td>May</td>
<td>—</td>
<td>47</td>
</tr>
<tr>
<td>June</td>
<td>—</td>
<td>39</td>
</tr>
<tr>
<td>Other*</td>
<td>—</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>180</td>
</tr>
</tbody>
</table>

* Unspecified dates in June to September, 2002
4.2 Size composition

Details of the length composition of the samples of both species are provided below in Table II. The samples obtained during each calendar year, are shown separately. The size ranges of rainbow trout from the loch and the river were broadly similar, although the fish taken from the river were larger on average. The overall length range was 122 – 456 mm. The heaviest rainbow trout overall weighed 1,227g. A much larger specimen, estimated to weigh between eight and ten kilos, was netted near the cage farm but it escaped from the meshes as it was being lifted from the water. Rainbows weighing more than 10 kg are reported caught by anglers fishing near the cages.

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

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

The brown trout samples from the loch and from the river also were broadly comparable with each other, although the numbers were small. Most fish measuring upwards of about 350 mm appeared to be of stocked origin (based on fin erosion and supported by subsequent scale examination). In order to enhance the sport fishery, Loch Earn is stocked annually with more than 10,000 large brown trout (>600g), obtained from commercial sources. These augment a numerous natural population of mainly smaller trout (<300mm) and occasional larger, piscivorous trout (ferox). The overall size range of brown trout sampled from loch and river during the present survey was 121-685 mm. The largest fish came from the loch and weighed 4880 g. This fish was caught near to the cages, like the big rainbow trout that escaped from the gill-net. Based on the worn appearance of some of its fins, it was believed to be of stocked origin, but it had grown on well after stocking. The largest brown trout sampled in the river measured 640 mm and weighed 2250 g. This specimen appeared to be of wild origin (see 4.3). In addition, a single male sea trout, measuring 520 mm and aged 2.1+sm+ (overall age of 4+), was netted in Ardveich Bay. It was excluded from the brown trout data.
4.3 Age composition

The estimated age composition data from the sampled rainbow and brown trout are shown together in Table III. In the summer/autumn samples collected in 2002, the rainbow trout were primarily aged 1+ winters (93%). Seven fish (6%) were aged 2+ and one taken from the river may have been aged 3+ winters. The rainbow trout held in the cages at the time of sampling were hatched in August/September 2001 (pers. comm. A. Murray), so were approximately one year old. This means that nearly all of the sampled fish were consistent with this age. All but three (4%) of the rainbow trout obtained from the river also were consistent with the 1+ modal age of the trout grown at the local farms (pers. comm. A. Murray/S. Barnes). The samples collected in spring 2003, however, contained roughly equal numbers of rainbow trout aged 2+ and 1+. Another fish obtained during the spring sampling was aged 3+. It is possible that some of the specimens older than one year were over-wintered survivors from escapes during 2002, as they were relatively thin, but others had large amounts of visceral fat deposits, suggesting that they were recent escapees. [Normally, in Scottish put-and-take fisheries, recently-stocked rainbow trout contain large amounts of visceral fat, having been fed to appetite in captivity. With time, as the fish adjust to the new, often limited, natural feeding regime in the wild, these fat reserves are depleted. In these heavily stocked populations, it may be possible to estimate the length of time at liberty of individual trout from the extent of their visceral fat.]

The overall age frequency distribution of the rainbow trout samples obtained in the whole survey comprised 152 aged 1+ (72%), 57 (27%) aged 2+ and only 2 fish aged 3+ (1%). These results indicate that most of the rainbow trout that escape into the River Earn System are short-lived in the wild.

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

<table>
<thead>
<tr>
<th>Age (winters)</th>
<th>Loch Rainbow</th>
<th>Loch Brown</th>
<th>River Rainbow</th>
<th>River Brown</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1+</td>
<td>30</td>
<td>0</td>
<td>70 (52)</td>
<td>1</td>
</tr>
<tr>
<td>2+</td>
<td>5</td>
<td>5</td>
<td>2 (50)</td>
<td>3 (3)</td>
</tr>
<tr>
<td>3+</td>
<td>0</td>
<td>4</td>
<td>1 (1)</td>
<td>3</td>
</tr>
<tr>
<td>4+</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5+</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6+</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7+</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8+</td>
<td>0</td>
<td>0</td>
<td>(1)</td>
<td></td>
</tr>
</tbody>
</table>

Sex and maturity status

During June to December, 2002, of 99 rainbow trout whose gonads were intact after disease examination, 11 were male and 88 were female. In the sample collected during April to June, 2003, there were five males and 100 females. Therefore the sex ratio in the overall Earn System sample was 16 males : 188 females (1.0 :11.75). The highly skewed sex ratio may be explained by the current predominant use locally (and nationally) of all-gender fish for fish farming and for stocking. (pers. comm A. Murray, S. Barnes and A. Fox).
Eleven fish in the June/December sample (11%), two males and nine females, were maturing to spawn. One female that was obtained in December from the Machany, a tributary of the River Earn by Kinkell Bridge, below Crieff, was in an advanced state of maturity, close to ovulation. During May, 2002, two female fish (288 mm and 336 mm) were found to be fully spent and another female (336 mm) was partly spent. A male fish (305 mm) sampled later (19 June) was recently spent. The scales from these four fish showed appreciable edge erosion (‘spawning marks’). Each of these fish came from an area of the river, about 100 metres downstream of the Drummond Trout Farm and Fishery above Comrie. Thus, there was indirect evidence of spawning, albeit that the numbers of potential spawners, and the mature males in particular, may have been low.

The overall brown trout sample that could be sexed comprised eight males and 16 females. Three of the males (38 %) and ten of the females (62%) were maturing. Most of the maturing fish appeared to be of stocked origin. It should be noted that many of the young trout from the Earn System migrate to sea as smolts while still immature and become sea trout. Those fish that begin to mature early are more likely to remain as brown trout. On 19 June, 2003, I caught an exceptional female brown trout on a small nymph, once again below the outfall from the fish farm above Comrie. It measured 640 mm, but weighed only 2,250g. It appeared to be spent and not to have recovered after spawning. Internal examination showed that it was heavily parasitised with encysted tapeworms. Scale reading indicated an age of at least eight years and a probable wild origin. The stomach was empty.
4.4 Stomach contents

In the dietary analysis of the rainbow trout, comparison between dates was not attempted because of the small numbers of fish that were available. Only broad comparisons can be made between sites, sampling dates and between the rainbows and brown trout. A wide variety of food items and indigestible material was identified. The stomach contents data are shown grouped by percentage volume as a series of pie charts (Figures 2 - 7). The numbers of fish that had eaten the different items are shown in Table IV.

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

<table>
<thead>
<tr>
<th>Food Item</th>
<th>SUMMER/AUTUMN</th>
<th>SPRING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>RL</td>
</tr>
<tr>
<td>Chironomid pupae/adults</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Terrest. flies/beetles</td>
<td>32</td>
<td>5</td>
</tr>
<tr>
<td>Caddis larvae/pupae</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Aquatic snails</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Mayfly/stonefly larvae</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Fish</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Zooplankton</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Fish pellets</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bait</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Vegetable/woody debris</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>Stones</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

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.
Figure 2 (a–f): Stomach contents of sampled rainbow and brown trout in the upper River Earn system (2002 – 2003)
a) Autumn samples
The rainbow trout sampled in the loch (14 fish) had been feeding mainly on very small emerging chironomid pupae, terrestrial flies and beetles picked off the water surface. There was also some zooplankton (*Daphnia* spp.), and smaller amounts of caddis larvae/pupae and snails. Stones and woody/vegetable debris were found in significant quantities and one fish had eaten artificial pellets. However, pellets ought to have figured more heavily in the results, as five rainbow trout that contained the paste had to be excluded from the quantitative sample because the contents of their stomachs were partially lost through incision damage during disease examination. Therefore, six rainbows from 19 (32%) had eaten fish pellets.

In contrast, the rainbow trout from the river (56 trout) contained mainly vegetable/woody debris, bait (maggots, chrysalids, earthworms and sweetcorn) and a lesser amount of stones. Under ‘Others’, are included occasional hairworms (*Gordius* spp.) and water mites. The main true food items were chironomid pupae/adults and caddis larvae/pupae. Terrestrial flies and beetles were of minor significance. Once again, some fish pellets were present. Some were still intact, showing very recent ingestion. Perhaps these pellets, and the sweetcorn and maggots, had been loose fed into the river by anglers to induce feeding activity. Alternatively, the fish concerned may have been feeding in the discharge stream from a fish farm.

The brown trout sampled in the loch (8 fish) also contained a lot of vegetable/woody debris, stones and some bait, but lacked fish pellets. However, this also is misleading in that two further fish (i.e. 20% of the total number) had eaten pellets. These fish again could not be included because of stomach damage during examination. One of these fish was a large brown trout (4,880 g) that was netted close to the cages and found to be full of fish pellet paste. Unfortunately, the distended stomach was ruptured and part of the contents were lost. Overall, with this proviso, the major natural food items of the brown trout sampled in Loch Earn were caddis larvae/pupae and terrestrial flies and beetles.

The brown trout from the river (7 fish) contained mainly terrestrial flies/beetles and caddis larvae/pupae. Again, stones again were prominent, presumably having been collected while the fish were grazing the river bed. In contrast to the rainbow trout, there was no evidence of bait.

b) Spring samples
The stomachs of the 105 rainbow trout sampled in the river contained mainly terrestrial flies and beetles and cased caddis larvae. Again, there was a large element of vegetable/woody debris and stones and two fish had consumed single cigarette butts. One trout, measuring 342 mm and weighing 590 g, had eaten a moderately large minnow (75 mm), the only evidence of piscivory found in the entire, year-round, Earn System sample.
4.5 Electro-fishing results

Electro-fishing carried out on 28 August, 2002, in the Beich Burn, near the fish farm at Loch Earn, captured 92 trout (0+ and 1+; length range 50-150 mm), 12 salmon (0+ and 1+; length range 55 - 120 mm), one rainbow trout (1+; 122 mm), 10 stone loaches (Neomacheilus barbatulus (L.)) and a minnow (Phoxinus phoxinus (L.)). Although the main object of the qualitative sampling, which was carried out by a single search of an area of approximately 200 m$^2$, was to obtain fish for disease testing, the densities of trout and salmon appeared to be as high as could be expected for the habitat concerned. Similarly, the partial width stretch (about 300 m$^2$) of the River Earn by the Sawmill, near St. Fillans, sampled on the same date, contained moderate numbers of wild fish. Here, 31 salmon and four trout fry and parr, plus an eel were obtained. The capture efficiency of the electro-fishing is likely to have been lower than at the Beich site, due to the greater width and depth of the river by the Sawmill and the fact that the section was heavily shaded by riparian trees. No juvenile rainbow trout were found, although this was an area of the river where the Comrie Angling Club suspected that they had spawned successfully (pers.comm. L. Fraser). Larger rainbow trout were sampled by angling in nearby pools.

In the spring, single-search electro-fishing carried out near the outfall from the Kindrochet Trout farm, resulted in the capture of 59 juvenile salmon (length range 30-100 mm) and 21 trout (45-120 mm), plus several eels, sticklebacks (Gasterosteus aculeatus L.), minnows and stone loach. Almost all of the salmon and trout fry were found in a riffle beside the outfall, in an area of about 150 m$^2$. Few fish were caught in the pool below the riffle, but occasional parr and larger fish were seen to move into deeper parts that could not be reached safely and fished effectively. A few rainbow trout had been removed from there by fly-fishing on an earlier visit. However, the numbers that were present seemed low.

These results indicate that salmon and trout are continuing to spawn successfully in close proximity to the rainbow trout farms and indicative sampling suggested that the densities of juveniles were moderate to good for the habitat concerned.
During the sampling required for this survey of the current status of rainbow trout, escaped fish were sampled in the upper part of the River Earn down to Crieff. They were common above Comrie, but progressively fewer were obtained with distance downriver from there. According to reports from fishing beats affiliated to the River Earn Improvement Association, large numbers of escaped fish have occurred sporadically throughout the river over several years. During the period of this study, occasional rainbow trout were reported from the main river near Gask (Dunning area), but none from the syndicate members fishing the Dupplin Estate waters, some 5-10 km by river above Bridge of Earn. Rainbow trout that were common at the Kinkell Beat in the early months of 2002 were believed to have escaped from a privately stocked loch when a barrier was overwhelmed during a severe flood. In the upper river, most of the escaped fish probably came from local fish farms, based on the consistently large numbers involved. A persistent loss of a large number of rainbow trout from the cages on Loch Earn was notified to Scottish Executive Environment and Rural Affairs Department (SEERAD) during 2002. This was blamed on net mesh damage caused by predatory bird strikes. However, rainbow trout may have been lost from land-based sites as well.

Under the terms of the Registration of Fish Farming and Shellfish Farming Businesses (Amendment) Order (Scotland) 2002, there is now a mandatory requirement upon fish farmers to notify escape incidents to the SEERAD. Early notification should also be provided to:

- the relevant District Salmon Fishery Board;
- the local police, if vandalism or other criminal activity is suspected; and
- the Scottish Environment Protection Agency (SEPA) (for freshwater farms only).

The fish farming industry continues to implement improvements in stock containment and recovery arrangements. However, some escapement is almost inevitable, for instance through extreme climatic events or vandalism. SEERAD has been notified of various escape incidents at Scottish marine and freshwater fish farms since May, 2002, when the legal requirement to report these was introduced. In a recent escape (January, 2003), 70-80,000 rainbow trout weighing about 250 g were lost into the River Whiteadder, a tributary of the River Tweed. According to press reports, larger farm escapes of rainbow trout have occurred elsewhere in Scotland within the last two decades. However, the level of losses from poorly screened stocked fisheries also may be substantial and these are not normally reported.

The broad size structure of the samples of rainbow trout from the upper Earn System suggests that the losses were not confined to single escape events, but may be indicative of a chronic seepage of fish into the wild. On the other hand, the narrow age range of the escaped fish (99% aged 1+ or 2+) suggests that they do not survive for long in the loch and river, or it may be argued that they migrate to the sea and do not return. Undoubtedly, some do visit the sea. Small numbers of sea-run rainbow trout have occurred in various rivers in Scotland for many years (Shearer, 1975). There have been reports of occasional ones caught in the River Earn. More likely, however, most of the escaped rainbow trout are quickly removed by anglers, or predators and others may not find enough food to sustain them.

Nevertheless, the sampled specimens had been feeding and, by implication, finding living space, however temporary that may have been. In so doing, they surely had some impact on the wild fish present in the same areas, albeit that the extent of this impact cannot yet be quantified. The diet of the rainbow trout was varied and apparently fairly haphazard. Their stomachs contained a wide variety of invertebrates, terrestrial
flies and beetles, but also fish pellets, anglers’ baits and pieces of plant material, seeds, wood and stones. Some of this extraneous indigestible material is likely to have come from the breakdown of caddis larval cases. Caddis larvae were one of the most important true food items in the spring. However, clearly some of it, such as cigarette butts, was consumed directly.

Dietary comparison between the rainbow trout and the brown trout was limited by the small numbers of brown trout that were obtained. The situation was further complicated by the fact that they were of both stocked and wild origin. Although the samples of brown trout were combined for simplicity, they should ideally have been treated as separate wild and stocked groups, and only combined if the results were similar. Overall, however, the brown trout had fed on a similar wide range of invertebrates to the rainbow trout. These results are comparable with Loch Leven, Kinross-shire, where stocked rainbow trout and brown trout ate a similar range of food items and the rainbows had consumed a large quantity of vegetation, twigs, stones and other debris (Duncan, 1994).

Importantly, fish comprised a negligible component of the diet of the escaped rainbow trout. The potential for their predation on native salmon and trout was a major concern of several respondents to the questionnaire survey (Walker 2003). Also, over the years, FRS Freshwater Laboratory has received a number of anecdotal accounts from the Rivers Earn, Tay and Aray (Argyllshire) of rainbow trout eating salmon fry and parr. Predation by introduced fish that are larger than most of the residents is hardly surprising. However, no evidence that such predation was found in the Earn samples, even though those were obtained throughout a full year. Also, there was no shortage of young salmon and trout close to the trout farms, where escaped rainbow trout would be expected to be most common.

Other effects of the feeding of escaped rainbow trout were more difficult to ascertain. At the outset of the Earn study, it was decided for conservation reasons not to ask for samples of brown trout because the larger river-resident trout were believed to be relatively scarce, and the smaller trout (ca 100-180 mm) were potential sea trout. Likewise, salmon parr were not included. No char or grayling were included, simply because none were obtained. However, in view of the diverse feeding of the escaped rainbow trout, some overlap with the diet of each of these other fish species can be expected. To prove this it would be necessary to carry out a quantitative assessment of the impact of escaped rainbow trout on the feeding ecology of the wild fish, which would require an intensive study to be carried out, ideally in situ. Each species would need to be assessed in the presence and the absence of the others. Behavioural adjustments of the wild fish and habitat partitioning are likely to occur to accommodate the intruding species (see Phillipps et al., 1985; Duncan, 1994). However, a field study of this scope and 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. However, it is likely that the introduction of large numbers of escaped rainbow trout will cause a loss in productivity of the individual wild fish species, unless more food is added to the system (Phillipps et al., 1985). It may be argued that fish farming supplies just such an increase through waste pellets, some of which are intercepted by fish living outwith the farms, and by raising the overall biological productivity through faeces and nutrient discharges. In the loch, chemical enrichment may improve the trout fishery potential for a time, but may result in an increased tendency for damaging algal blooms. Varying ecological consequences also may occur in the outflowing River Earn.
chemical and biological condition of the water in both habitats is regularly monitored by SEPA. Also, it is encouraging that good numbers of young salmon and trout were found at sampled sites, two of which were immediately adjacent to trout farms. Furthermore, kingfishers (*Alcedo atthis*) were regularly seen fishing in the Upper River Earn and there was ample evidence of the presence of otter (*Lutra lutra* L.).

The unplanned release into Loch Earn of large numbers of alien rainbow trout undoubtedly adds to the economic value of the sport fishery by attracting anglers. Large numbers of visiting boat and shore anglers catch many escaped rainbow trout and large, stocked brown trout. Smaller, wild brown trout and some charr also are caught. Most of the boat anglers seem to concentrate their efforts near the fish farm cages, whereas the shore anglers can be found all round the loch. Fishing for migratory fish is of minor consequence. In the river, by contrast, salmon and sea trout provide the main sport fishery, although brown trout and grayling are important too. There, the intrusion of large numbers of rainbow trout is seen as a distinct nuisance by some fishery owners and their managers, but just something else to fish for by others. Occasional large brown trout that are stocked in Loch Earn also find their way into the river, but these fish appear to cause less concern, perhaps because they are regarded as native fish, even though they are not of local origin.

In an interesting parallel situation in England, a court case concerning escapes of rainbow trout on the River Kennet was heard at Swindon County Court in 1993. The case was taken by the Savernake Flyfishing Club against a fish farmer (Gale and Ainslie Ltd) for damage caused by negligent escapes of rainbow trout into their brown trout fishery. 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 escapes were unwanted and 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.

It is possible to envisage a similar court action being taken in Scotland, although the outcome would depend on local circumstances. It will be interesting to see how escapes will be dealt with under the terms of the Water Framework Directive (WFD), which will increasingly impact upon the management of river catchments and ecosystems. The level of escapement of rainbow trout from fish farms and fisheries should be controllable, even if the arrangements for retention of the fish may need greater care and resourcing. Specifically, it was apparent during the survey on the River Earn that rainbow trout were present in the outflow channels of both land-based fish farms and, in one case also the inflow channel, albeit enclosed by screens. Any damage to these screens, or overtopping during spates, was likely very quickly to result in lost fish. These problems are being addressed locally.
Recommendation

It would be better that no fish be present 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 are likely to help prevent the more mundane incidents. Improvements in containment within cage farms may have to be addressed by better management practices, such as the more regular replacement and inspection/repair of nets, and the use of double-walls. Security may need to be tightened to restrict damage and losses through the ingress of 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. Unfortunately, all of these actions will add costs to fish farming operations.

Fortunately, there is no evidence that the escaped rainbow trout are breeding successfully in the River Earn. The lack of such evidence agrees with the general findings elsewhere. Frost (1974) identified only five long-term spawning sites in the British isles, all of which are now compromised by restocking, or by their proximity to fish farms. A small amount of spawning success was identified in small stillwaters in the recent Scottish questionnaire survey (Walker, 2003). This evidence was based on accounts spread over a number of years. However, no self-maintaining populations were found. We already knew of a small hill loch in Inverness-shire that contained a self-supporting population for many years (Lever, 1977), but this stock appears to have died out. Since the 1970s, small numbers of naturally-produced juveniles have appeared in various Scottish stillwaters (for example Phillipps et al., 1984; Walker, 2003), yet no authenticated instances have occurred in our rivers.

Now that the aquaculture industry uses mainly all-female and to a lesser extent, sterile triploids, the chances of successful spawning should be greatly reduced, although the technology involved in triploidising trout is never 100% effective. However, the level of farmed production has increased substantially since the early days of the industry, reaching 5,466 tonnes in 2001 (Scottish Fish Farms Annual Production Survey, 2002), so there are many more rainbow trout available to escape. Even if only a small percentage of these escaped fish become sexually mature, there will be a large number of potential pairings. Although predominantly female, small numbers of maturing fish of both sexes were found in the River Earn during the autumn and there were indications in the spring that one male and two females had spawned. However, no rainbow trout fry were obtained by electro-fishing. A single rainbow trout parr (aged 1+) that was sampled in the Bheich Burn, near the cage farm on Loch Earn was likely to have escaped from the cages. Crucially, none of the sample of 215 rainbow trout appeared to be of wild origin. All of the fish showed fin erosion typical of a fish farming provenance. Had fish from natural spawning been an important element of the population, there would have been a greater number of male fish, as natural spawning would lead to equal numbers of male and female fry. In practice, males were uncommon. The results of this survey suggest either that successful natural reproduction of rainbow trout in the River Earn does not occur, or it is too insignificant in scale to be readily detected.
The history of 'very poor' to 'absent' breeding success of rainbow trout in this country is surprising, since the wide-ranging environmental conditions to which the species is exposed here are broadly similar to parts of their extensive native range within western North America. In contrast, we have ample experience of holding and stripping brood fish at ambient water temperatures and, in most cases, the ova hatch normally and the fry outperform brown trout or salmon grown in parallel. In a trial carried out in a gravel raceway at the FRS Freshwater Laboratory in 1975, rainbow trout produced some feeding fry, even though there had been two temporary losses of the water supply (pers. obs). We undertook a follow-up trial near Pitlochry during Spring 2003 in which fertilised rainbow trout eggs were planted under gravel in 26 small egg incubators lined with 2 mm plastic (netlon) mesh (stocking density = 40 eggs per incubator). The incubators were planted in three streams and at one stillwater site and the surface stream water and sub-gravel environmental conditions were monitored and survival levels ascertained (McMullan, 2003). At the sites in the three streams, most of the eggs survived to the eyed stage (54 - 88%). Alevin survival to point of emergence of first-feeding fry, when the incubators were removed, was lower (36 - 88%) and depended on the pertaining hyporheic conditions (especially dissolved oxygen levels). All of the sites were affected to a varying extent by declining water levels, as the study took place during a dry spell of weather. None of the rainbow trout eggs survived for long at the stillwater site. In an on-going trial, 10,000 unfed rainbow trout fry from the same source batches were stocked in one of the burns that supplies a loch which is operated as a put-and-take rainbow trout fishery and has a natural population of small brown trout. Many of the rainbow trout fry were still present in the burn two months after release, although the water level was by then extremely low due to continuing drought conditions. Further monitoring will be carried out to determine whether any of the rainbow trout survive to maturity and return to spawn in the burn.

Possible reasons for the lack of sustained natural breeding success of the species in Scotland and the wider UK have been discussed by Frost (1974), Lever (1977) and Phillipps (1984). Under natural conditions, rainbow trout tend to spawn in Spring, some months later than brown trout. Consequently, their fry emerge from the gravel when all of the suitable feeding and hiding territories are already occupied. However, earlier spawning strains are available to fish farmers and a shift to earlier spawning in the wild could conceivably lead to greater spawning success (Phillipps et al, 1985). Also, examination of the world distribution of naturally-spawning rainbows (MacCrimmon, 1971; Fausch et al, 2002) suggests that the species competes more successfully with brown trout at the warmer end of the temperate climate range, for example, in North Island, New Zealand. Interestingly, there has been little domestication of rainbow trout in New Zealand and this may be one of the reasons why the species is able to reproduce so effectively there (pers. comm. D. Scott). Rainbow trout may have more success in spawning in Scotland in the future through climatic warming. On the other hand, it is likely that the continuing use of long-term domesticated strains for fish farming and for stocking for angling in the UK may always restrict their chances of sustained reproduction in the wild.
6. References


Acknowledgements

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APPENDIX
FISH HEALTH REPORTS

Case No. 2002—1050
Date of Sampling 28—August—2002
River System Earn
Location Beich Burn

The Beich burn survey was undertaken by Andy Walker from the Fisheries Laboratory, Pitlochry and Stuart Wallace from the Marine Laboratory, Aberdeen. Andy was monitoring the distribution of rainbow trout within the Earn Catchment and describing the diet of these fish. He has reported on this separately. Stuart was testing wild fish for the presence of the Infectious Pancreatic Necrosis Virus (IPNV). This work is part of a project set up to determine the prevalence of IPNV in wild marine and freshwater fish and to investigate possible interactions between farmed and wild fish in terms of the spread of this disease.

Sample Description:
14 Atlantic salmon, 84 brown trout, 1 rainbow trout, 1 suspected salmon/trout hybrid, 7 stone loach and 1 minnow were caught by electrofishing from the Beich Burn, (NGR NH 616 242). A length of approximately 200 metres consisting of pools and riffles was fished. The rainbow trout had a swollen pale red kidney and several worms in the body cavity. Externally this fish appeared healthy with well formed fins. All other fish appeared healthy externally and internally.

Samples Taken:
Tissue samples were taken from all fish to test for IPN. In addition, tissue samples were obtained from the rainbow trout and two brown trout for Sleeping Disease. Histology samples were also taken from these three fish.

Results: (IPN)
Virology: Samples of kidney from all the fish were tested for IPN using tissue culture methods. The results of these tests were negative.

Results: (Sleeping disease)
Virology: Samples of kidney from three fish were tested for sleeping disease using tissue culture methods. The results of these tests were negative.

Molecular Genetics: Samples of kidney were tested for sleeping disease using the reverse transcriptase polymerase chain reaction method (RT-PCR). The results of these tests were negative.

Results: (Histology)
Histology: Gill pathology was observed in all three fish. The cestode Eubothrium sp. was found in the spleen of the rainbow trout. These tapeworms are considered to be fairly common parasites of wild fish and should not greatly affect fish health unless present in high numbers.

Appraisal: The following pathogens were not identified from the samples examined:
Infectious pancreatic necrosis virus (IPNV)
Sleeping disease virus

The following pathogen was identified from the samples examined:
Eubothrium sp.

End
The river Earn survey was undertaken by Andy Walker from the Fisheries Laboratory, Pitlochry and Stuart Wallace from the Marine Laboratory, Aberdeen. Andy was monitoring the distribution of rainbow trout within the Earn Catchment and describing the diet of these fish. He has reported on this separately. Stuart was testing wild fish for the presence of the Infectious Pancreatic Necrosis Virus (IPNV). This work is part of a project set up to determine the prevalence of IPNV in wild marine and freshwater fish and to investigate possible interactions between farmed and wild fish in terms of the spread of this disease.

Sample Description
29 Atlantic salmon, 4 brown trout and 1 eel were caught by electrofishing from the River Earn, (NGR NH 731 230). An area of approximately 50 metres was fished consisting of two pools and a riffle. Most of the fish were caught from the riffle. In addition, 1 brown and 1 rainbow trout were caught on rod and line from a deep pool at the bottom of the section. The rainbow trout displayed stunted fins and was thin but otherwise appeared healthy and was not of wild origin. One of the salmon had a swollen kidney with greyish—white nodules present. A large white granular lump was observed at the neck of the swim bladder. All other fish appeared healthy externally and internally.

Samples Taken
Tissue samples were taken from all fish to test for IPN. In addition, tissue samples were obtained from the two rod caught fish for Sleeping Disease. Diagnostic samples were taken from the one salmon exhibiting internal clinical signs of disease. A histology sample was taken from the rainbow trout. Stomach samples were taken from the rod caught fish.

Results: (IPN)
Virology: Samples of kidney from all the fish were tested for IPN using tissue culture methods. The results of these tests were negative.

Results: (Sleeping disease)
Virology: Samples of kidney from two fish were tested for sleeping disease using tissue culture methods. The results of these tests were negative.

Molecular Genetics: Samples of kidney from two fish were tested for sleeping disease using the reverse transcriptase polymerase chain reaction method (RT—PCR). The results of these tests were negative.

Results: (Diagnostic sampling)
Histology: Gill pathology was noted in the rainbow trout. Kidney pathology was observed in the one salmon but no cause could be determined.

Bacteriology: Kidney material from the one salmon was inoculated onto Tryptone Soya Agar (TSA), Tryptone Soya Agar plus salt (TSA + NaCl), Anacker and Ordal’s media (A&O) and Mueller-Hinton Cysteine Agar (MHCA)
Slight, moderate fairly pure growth was observed on the TSA plate. The identity of the main colony type was unknown but a motile Aeromonas bacteria was suspected.

The TSA+NaCl and A&O plates illustrated very slight growth of similar colony type.

No growth was observed on the MHCA plates.

**Molecular Genetics:** A sample of kidney from the one salmon was tested for the presence of the Infectious salmon anaemia virus (ISAV) using the reverse transcriptase polymerase chain reaction method (RT-PCR). The result of this test was negative.

**Results: (Stomach samples)**
This has been reported separately by Andy Walker.

**Appraisal:** The following pathogens were not identified from the samples examined:
- Infectious pancreatic necrosis virus (IPNV)
- Sleeping disease virus
- Infectious salmon anaemia virus (ISAV)
- *Renibacterium salmoninarum* the causative agent of Bacterial kidney disease (BKD)

The following pathogen was identified from the samples examined:
- Motile *Aeromonas sp.* of unknown identity

**End**