

New Zealand Fisheries  
Technical Report No. 10  
ISSN 0113-2180  
1989

MAF Fish

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M. J. Unwin, M. S. Field-Dodgson, D. H. Lucas, and S. P. Hawke

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**Published by MAFFish  
Wellington  
1989**

**ISBN 0-477-08079-0**

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MAFFish is the fisheries business group of the New Zealand Ministry of Agriculture and Fisheries. It was established on 1 April 1987 and combines the functions of the old Fisheries Research Division and Fisheries Management Division and the fisheries functions of the old Economics Division.

The *New Zealand Fisheries Technical Report* series in part continues the *Fisheries Research Division Occasional Publication* series. Conference proceedings and bibliographies will now be published in the *New Zealand Fisheries Occasional Publication* series.

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New Zealand.

Set in 10 on 11 English Times

Typesetting by Industrial Art and Communication Ltd.

Printed by Thames Publishing Co. Ltd.

**Cover:** A salmon release from the Glenariffe Salmon Research Station, May 1983. After removing a screen from the lower end of the raceway, the retaining boards are lifted out one by one, enabling the young fish to move down into Glenariffe Stream and the Rakaia River. (Photograph by Warren Jones.)

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# Abstract

Unwin, M. J., Field-Dodgson, M. S., Lucas, D. H., and Hawke, S. P. 1989: Experimental releases of coded-wire tagged juvenile chinook salmon (*Oncorhynchus tshawytscha*) from the Glenariffe Salmon Research Station, 1982-83 to 1984-85. *N.Z. Fisheries Technical Report No. 10*. 22 p.

A major experimental programme, involving the release of over 1 million tagged juvenile chinook salmon, was carried out at the Glenariffe Salmon Research Station between 1982 and 1985. The aim was to investigate the relationships between juvenile release weight and date and survival to adulthood. The releases consisted of 133 groups of tagged fish with a wide range of weights and release dates and from three consecutive brood years.

Samples were taken on the day of release, and the mean release weight, sex ratio, and rate of tag loss were determined for each group of tagged fish. Most groups were released between 6 March and 2 October, and release weights averaged 10-70 g, though one group averaged over 150 g. The mean weight at release was similar for males and females, but males were significantly larger than females in groups raised for more than 12 months. Sex ratios were generally nearly 50 : 50, though males tended to predominate in the heavier groups. Tag loss over the 3 years averaged 5.0%.

There was little success in attempts to monitor the fish on their downriver journey after their release from Glenariffe. The limited data suggest that most fish passed through the lower Rakaia River within 1 or 2 days of release.

## Introduction

Since 1965 Fisheries Research Division (FRD)\* of the Ministry of Agriculture and Fisheries (MAF) has been conducting research into the biology of chinook salmon (*Oncorhynchus tshawytscha*). Most of this has been at the Glenariffe Salmon Research Station, in the foothills of the Southern Alps. Before 1977, work at Glenariffe was on wild populations of salmon, and data were gathered from traps on Glenariffe Stream (Flain 1982, Unwin 1986).

Since 1977 research at Glenariffe has increasingly concentrated on ocean ranching chinook salmon, and the station has evolved into an experimental hatchery (Field-Dodgson and Galloway 1985). The hatchery releases about 0.5 million fish annually, and facilities are being expanded to provide rearing space for up to 1 million fish. Coded-wire tagging (see Jefferts, Bergman, and Fiscus 1963) has been used routinely to monitor all releases from the hatchery (Unwin, Lucas, and Gough 1987).

Release and return data for the 1977-81 brood years were summarised by Unwin, Lucas, and Gough (1988). By 1982 it had become apparent that releases of fish weighing less than about 10 g, at any time before January-February, seldom produced returns over 0.5%. A release of 35 g fish in August 1979 produced returns of 2.5%, which suggested that size and age, or both, at release had a significant influence on survival (Unwin 1985).

A major experimental release programme was carried out at Glenariffe between 1983 and 1985, and it used all the progeny from the 1982, 1983, and 1984 brood years. The programme was designed to monitor returns at maturity of chinook salmon in relation to age and weight at release, and it was modelled on similar Canadian studies on coho salmon (see Bilton, Alderdice, and Schnute 1982) and chinook salmon (see Bilton, Coburn, and Morley 1983). Data recorded for each group of tagged salmon at the time of release included length, weight, sex, and tag loss. These data are presented here with a description of hatchery practices at Glenariffe and the overall 1982-85 release programme.

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\*Freshwater Fisheries Centre, MAFFish, as from 1 April 1987.

Rearing facilities consist of seven concrete raceways and the eight circular ponds built in 1984. Four of these raceways were built in 1978 and measure 25 × 2 × 1.25 m deep. The others were built in 1981 and are 30 × 3.3 × 1.5 m deep. All raceway floors have a slope of 1 : 200. The raceways are gravity-fed from a header race, the inflow being adjusted by movable boards. The raceways are scrubbed and cleaned every 14–21 days. All experimental groups of fish released during 1982–85 were raised in these raceways; however, during the 1984–85 season the circular ponds were frequently used as a temporary holding area.

Loading densities are decided by eye until the fish weigh about 2 g. At this time they are weighed and counted out to the raceways available, loading densities being established by use of the relationship given by Wedemeyer, Saunders, and Clarke (1980). The inflow to the raceways is adjusted to maintain 1–2 exchanges per hour for fish up to 5 g, and it rises to 3–4 exchanges per hour for fish up to 60 g.

Growth is most rapid during October–March (Figure 3), when it averages 2.6% of body weight per day and ranges from 3.5% in October to 1.7% in March. Growth is usually impaired for a few days after grading or tagging, and it is very slow during winter. Since 1985 a Neilson fish grader has been used to grade all fish in the raceways during January–February, after which they are reallocated to the raceways according to size. This greatly reduces cannibalism and promotes uniform growth within each raceway.

For the 1984–85 season additional incubation and early rearing of fry was carried out at the MAF Silverstream hatchery on a tributary of the Waimakariri River (Hardy in press). About 250 000 fertilised eggs were taken from Glenariffe to Silverstream, incubated in jars, and the fry were reared until they were about 2 g, when they were transferred back to Glenariffe. Water temperatures at Silverstream are typically

10–13 °C during winter (Hardy in press), which is about 3–5 °C warmer than at Glenariffe, so these fish were much further developed than Glenariffe fish of the same age.

### Diet and feeding

The food used at Glenariffe is a dry (10% moisture) pellet based on the Abernathy dry pellet diet (see Fowler and Burrows 1971), adapted to compensate for ingredients (such as cottonseed meal) not available in New Zealand. A dry diet rather than a moist diet was chosen because of several practical considerations. Dry pellets can be transported and stored more easily than moist pellets, which must either be fed shortly after manufacture, or frozen until required. The hatchery is 135 km (a 2 hour drive, the last 50 km being on rough gravel roads) from the food mill in Christchurch, so ease of transport is an important consideration. A dry diet produces less wastage than a moist diet, and it has a lower biological oxygen demand (BOD).

As soon as about 50% of the fry have absorbed their yolk sac and begun to swim freely, a finely ground high protein (55%) starter diet is sparingly distributed over the water surface every 10–15 min, to encourage the young fry to accept food as soon as possible. This continues for up to 10 days, and then a fine crumble is gradually introduced. Food size is increased as the fish grow (Table 2).

Until 1982 compressed-air driven automatic feeders were used throughout the rearing period. However, since 1983 automatic feeders have been used only until the fish reach about 3 g. Larger fish are now fed by demand feeders, which consist of a food hopper fitted with a dispensing plate, and are mounted above the raceway. The fish activate the feeder by butting or mouthing a small knob a few centimetres below water level and attached to the lower end of a brass rod fixed rigidly to the dispensing plate. The agitation moves the plate, thereby dislodging food from the hopper. Thus, the amount of feeding activity by the fish determines the quantity of food released. The demand feeders seem much more efficient than the automatic feeders, because they produce less wastage and promote more rapid growth.

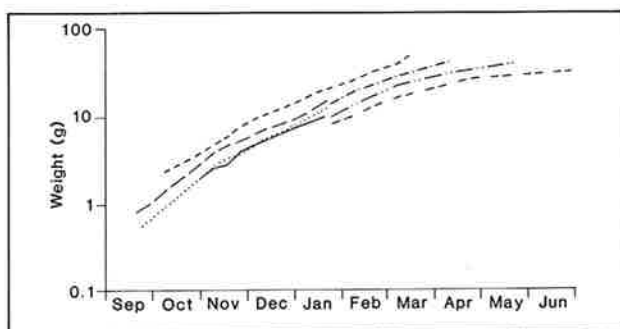


Figure 3: Representative growth curves for 1984 brood year juvenile chinook salmon reared at the Glenariffe hatchery, September 1984 to June 1985. (The discontinuities in mid January are associated with grading, the fish being reallocated into groups according to size).

Table 2: Food grades used for each size range of fish

| Food grade     | No. of fish per kilogram | Weight (g) |
|----------------|--------------------------|------------|
| Starter        | > 1800                   | < 0.55     |
| 0.4 mm crumble | 1800–1100                | 0.55–0.91  |
| 0.8 mm crumble | 1100–440                 | 0.91–2.3   |
| 1.6 mm crumble | 440–220                  | 42.3–4.5   |
| 2.4 mm crumble | 220–170                  | 4.5–5.9    |
| 2.4 mm pellet  | 170–110                  | 5.7–9.1    |
| 3.9 mm pellet  | < 110                    | > 9.1      |

# The 1982–85 experimental programme

## Experimental design

The original experimental design was for three groups of tagged fish of different sizes to be released on five dates at 30 day intervals from 5 April to 3 August. Each group of 10 000 fish was to be replicated three times, which meant 45 separate tag groups. The releases were to continue for 3 years to assess the extent of interseasonal variability in returns. It was intended that the technique of response surface analysis developed by Schnute and McKinnell (1984) be used to aid interpretation of the return data and to identify release strategies which maximised returns and cost-benefit ratios.

In practice, the essential feature of this design (the release of different size classes of fish on a range of equally spaced dates) was adhered to, but details (such as the number of size classes released on each date and the number of replicates) were altered as the programme developed. Several considerations led to these modifications. The most important was to have as wide a range of release dates and weights as possible, while keeping costs and labour requirements associated with the tagging to a minimum. For this reason, some of the 1983 and 1984 brood releases included only two replicates. On other occasions, groups of fish set aside for tagging were found to have not enough fish, which reduced the number of possible replicates. The amount of raceway space at Glenariffe was also a constraint, because in March and April each year at least one raceway was needed for the incubation of the next year's brood stock. In 1984–85 the number of tagged fish per group was reduced to 5000, partly in response to an increase in the price of tags.

To provide a comparison between the Glenariffe and Silverstream incubated fish, the April 1985 release included eight groups of tagged fish, four of which had been incubated at Silverstream and four at Glenariffe.

## Sorting and tagging

Details of the tagging procedures used at Glenariffe were given by Unwin, Lucas, and Gough (1987). The only modification to those procedures was to grade the fish into different size classes before they were tagged. All grading was done manually by using a measuring board. To calibrate the boards before tagging each group of fish, a subsample of about 300 fish was measured to the nearest millimetre, and the data were tabulated as a length frequency distribution. Fish in the upper and lower 2.5% of the length range defined by the subsample were rejected as being oversized or undersized respectively, and the rest

were divided into two or three equal classes. Thus, the mean weight of the fish in each class was predetermined by the overall weight distribution of the population. The classes were "small", "medium" (when there were three classes), and "large". Fish rejected as undersized or oversized were accumulated over the season and used to make up additional size classes, sometimes after further grading.

All coded-wire tags were applied by use of the standard equipment available from Northwest Marine Technology (NMT) in Washington, United States. The fish were anaesthetised and graded, and their adipose fin was removed. During the 1982–83 season this was done in a specially constructed caravan (see Unwin, Lucas, and Gough 1987), which provided working space for only one tagging machine. Large fish were tagged immediately, whereas medium and small fish were returned to the raceways and held until grading was finished. A second tagging unit was then set up in one of the hatchery buildings, and the rest of the tagging was done by use of both machines. To improve the efficiency of this process, and to allow two tagging machines to operate in tandem, a permanent tagging shed was built before the 1983–84 season. It was then possible to tag both large and medium fish at the time of grading, so only the small fish needed to be handled twice.

During all three tagging seasons it was not possible to fully use the NMT quality control device (QCD) to gather up any fish which had not been tagged. The QCD relies on a jet of water to deflect tagged fish into an appropriate outlet (Unwin, Lucas, and Gough 1987), and it operates most efficiently on fish weighing about 5 g. Because all tagging was done during February–April, by which time fish weighing up to at least 30 g were common, the QCD tended to reject most fish, whether tagged or not. In practice, both outlets of the QCD were piped directly into the hatchery raceway, so to maintain quality control the operator relied on the audible alarm generated whenever an untagged fish was identified. Consequently, it was not possible to re-tag any of the untagged fish. (The Mark IV QCD, now available from NMT, does not suffer from this problem.)

After tagging, the fish being released on a particular day were returned to one raceway, where they were allowed to mingle. This ensured that, as far as possible, fish released at the same time had been reared under identical conditions. However, when oversized or undersized fish formed part of a release they were kept apart because the difference in weight was often sufficient for these fish to need food of a different particle size to those in the small, medium, and large groups. The time between tagging and release ranged from 6 weeks for earlier (March and April) releases to over 6 months for the later releases.



## Release sampling

A sample of fish (nominally 100 for every tag code used) was taken on the day of release. A total of 13 690 salmon was sampled over the three release seasons. Individual monthly samples averaged 685 fish, and they ranged from 93 (November 1984) to 1022 (April 1983).

Fish were given a lethal dose of anaesthetic and were measured and weighed while still fresh (fork length (*FL*) to the nearest millimetre and weight (*W*) to the nearest 0.1 g). They were then put in a numbered self-sealing plastic bag, frozen, and returned to the laboratory. The tag was later extracted and decoded, or recorded as lost if absent. Fish from all 1982 brood samples were sexed (by dissection and examination of the gonads), as were those from all but three of the oversize groups from the 1983 brood. For the 1984 brood only the March and April releases were sexed. In some instances the combined effects of freezing and thawing were such that the sex could not be determined; these fish were recorded as unsexable.

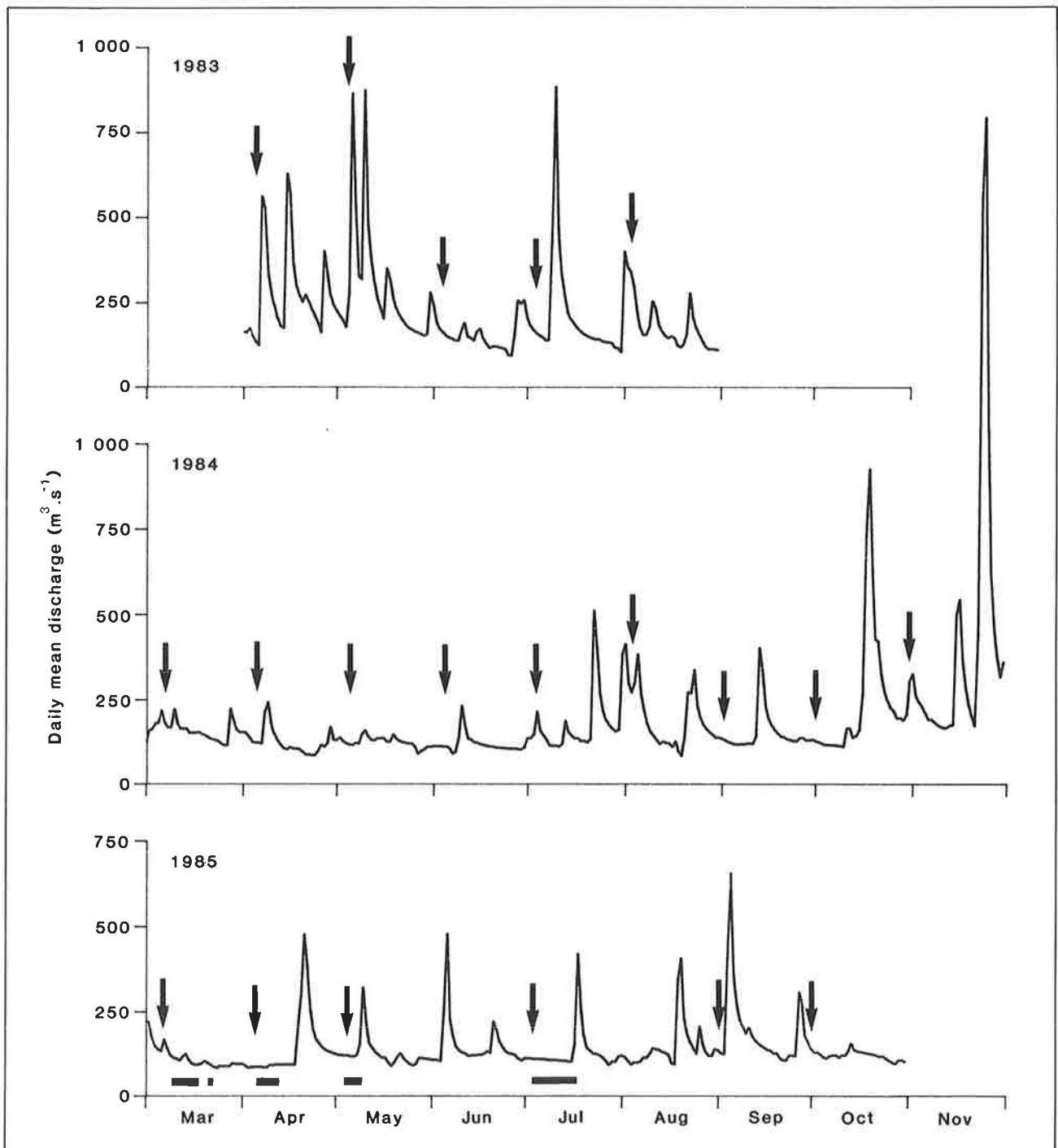
Releases were made in the evening, beginning about 30 min before sunset, in accordance with the natural behaviour of wild salmon (Unwin 1986). Discharges in the Rakaia River at the time of each release are shown in Figure 4. In 1985 an attempt was made to monitor the downstream movement of fish by seine and fyke netting in the lower Rakaia River. Two fyke nets were used, each attached to lead-in wings 20 m long, set so as to intercept a reach of river channel up to 10 m wide. Use of the nets was limited to minor braids, in depths of 0.3–0.7 m. On two occasions (21 March and 11 April) seine nets were used to sample deeper pools. The 21 March samples were taken over about 20 km of the river, but the 11 April sample was collected from a series of small pools in an otherwise dry channel.

## Release schedules

Releases for the 1982, 1983, and 1984 brood years are summarised in Appendix 1. A total of 1.07 million fish was tagged and released over the three seasons, in 133 groups. In 1982–83 and 1983–84 the entire output was tagged, whereas in 1984–85 only 24% of the fish were tagged, and about 500 000 additional fish were released untagged. The number of untagged fish released each month is an estimate, based on the ratio total fish weight to mean fish weight when the fish were graded. It was assumed that the tagged fish represented a random subsample of the population in each raceway, so the untagged fish could be evenly apportioned between the various codes.

There was a shortage of fish in the 1982–83 release, and it was necessary to use all available undersized and oversized fish for the July 1983 release. For the 1983 brood the main series of releases was between 6 March and 2 October 1984, with each release containing at least two replicates of small, medium, and large fish. Oversized and undersized fish, or both, were used to supplement the releases in May, August, September, and October, and a single group of undersized fish was held until 1 November. The 1984 brood release was mainly of large (> 40 g) fish, particularly in March and April, to fill some of the gaps left by the 1982 and 1983 brood schedules in the time and size pattern.

The 133 tag groups were released mainly between 6 March and 2 October, generally at weights of 10–70 g. Some releases were at weights of up to 150 g, though coverage of weights over 70 g was uneven and poorly replicated. Similarly, the single November release was unique. Data for some of these outlying groups may be discarded when the results are analysed.



**Figure 4: Rakaia River mean daily discharge (m<sup>3</sup>.s<sup>-1</sup>) during the releases of juvenile salmon from the Glenariffe hatchery, 1983–85. Release dates are marked by arrows, and the solid horizontal bars below the 1985 flow record show days on which sampling was conducted in the lower Rakaia River. (Discharge data (for the Fighting Hill gauging site about 35 km down stream from Glenariffe) were provided by the Water and Soil Division of the Ministry of Works and Development).**

# Characteristics at release

## Weight

Mean release weights for all tagged fish sampled, and mean weight and coefficient of variation (c.v.) for all fish, are given in Appendix 2.

Mean weight always differed significantly between the small, medium, and large size classes released on any given date, though there was often substantial overlap between adjacent classes (Figure 5). This applied particularly in 1983, when the small groups typically averaged 10–12 g, and the medium groups were 15–20 g, whereas the corresponding large size groups were usually 30–35 g. Thus, each release was mainly of fish less than 20 g in weight, which was contrary to the aim of the tagging programme to cover as wide a range of release weights as possible.

The 1984 releases were much more distinctly separated into size classes; however, when undersized fish made up part of a release there was usually little difference between them and the small sized group. The improvement over the previous season was due to the improvement in husbandry techniques, which tended to produce a more even weight distribution in each raceway population. Further improvement occurred in 1984–85, when machine grading early in the season, followed by hand grading at the time of tagging, tended to produce size classes with a very narrow weight distribution. This was most apparent in the March, April, and May 1985 samples, for which the c.v.s were generally much lower than in previous years.

For samples where weight data were available for both males and females, Student's *t*-test was used to test the significance of the difference between the mean release weights of males and females (Appendix 2). Of 112 groups tested, there was no significant difference in 69, males were significantly larger than females in 39, and females significantly larger in 4. On average, males were heavier than females by 4.4%, the difference tending to increase for the later releases (Table 3). The largest and most consistent differences were recorded in August, September, and October 1984, when males were larger than females by as much as 17% (code 63/37/36, 2 October).

## Sex ratio

Of the 10 849 fish examined, 50.9% were males. Percentages of males in individual groups ranged from 24 to 65%. The deviation from a 50 : 50 sex ratio was statistically significant in 13 of the 112 groups (Table 4). The difference was significant at the 95% level in 8 groups and at the 99% level another 5. However, in 5 of these 13 groups there were many unsexable fish, not necessarily equally male and female. In a random sample of 112 groups drawn from a population with a 50 : 50 sex ratio, deviations significant at the 95% level would appear

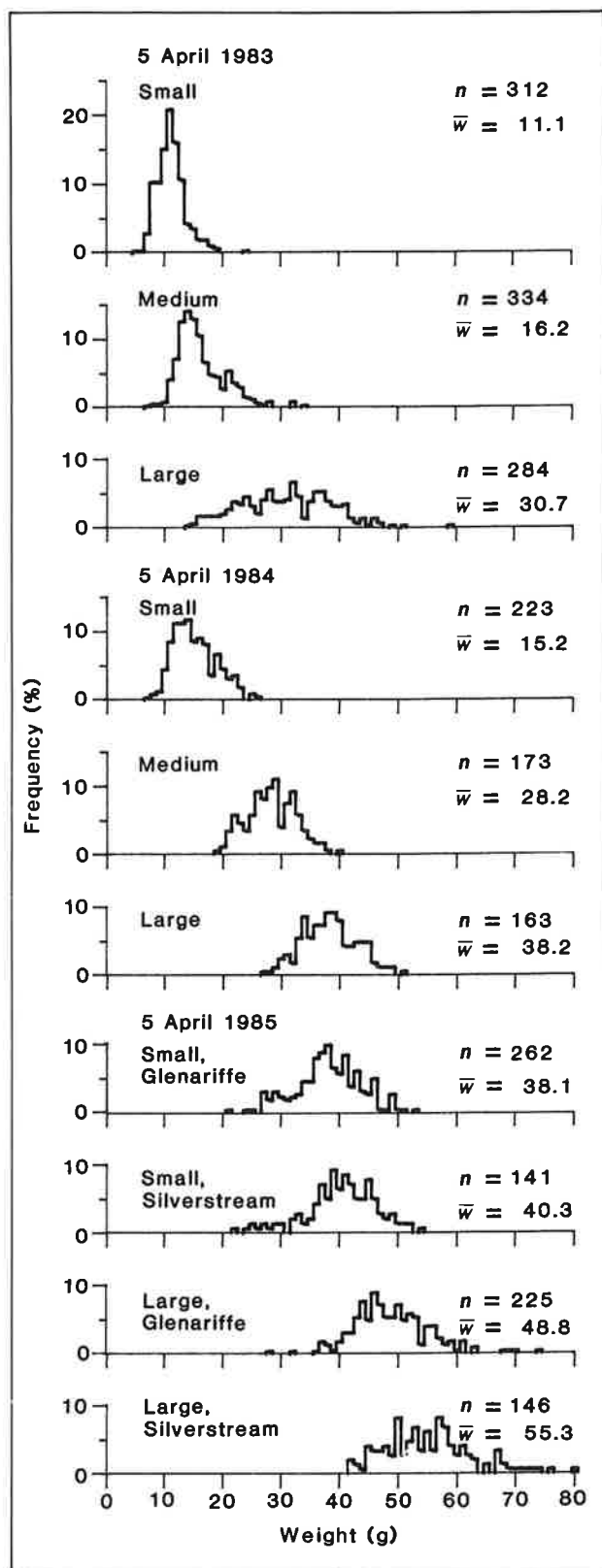


Figure 5: Weight frequency distribution by size class for release of juvenile chinook salmon from the Glenariffe and Silverstream hatcheries on 5 April 1983, 1984, and 1985.

**Table 3: The percentage by which the mean release weight of male juvenile salmon exceeded that of females, for 1982-84 brood year releases from the Glenariffe hatchery\***

| Release date | 1983     | 1984     | 1985    |
|--------------|----------|----------|---------|
| 6 Mar        |          | -0.9 (7) | 3.6 (5) |
| 5 Apr        | 1.3 (9)  | 2.0 (6)  | 0.6 (8) |
| 5 May        | 2.7 (9)  | 3.6 (8)  |         |
| 4 Jun        | 6.1 (9)  | 6.1 (6)  |         |
| 4 Jul        | -1.6 (4) | 4.2 (8)  |         |
| 3 Aug        | 4.8 (9)  | 6.9 (7)  |         |
| 2 Sep        |          | 9.2 (8)  |         |
| 2 Oct        |          | 13.7 (8) |         |
| 1 Nov        |          | 3.4 (1)  |         |

\* Each percentage is an average over all release groups for which mean weight data were available; the number of groups is in parentheses.

(on average) in 5 or 6 samples, so little if any error would be incurred in assuming a 50 : 50 sex ratio for all tag groups.

Sex ratio data by size class show the selectivity caused by grading (Table 5). Except for the oversized class (for which only the July 1983 data were available), all classes showed significant deviations from a 50 : 50 ratio, the proportion of males increasing directly with size. (The 1984 brood year data were excluded from this analysis because in 1985 both the March and April releases were fish which were machine graded (as large) before being hand graded and tagged.) These results are consistent with the observed differences in the mean weights of males and females (see Appendix 2), and they show that grading by size had a small but significant tendency to select for females in the smaller size classes.

Sexually mature, or precocious, males (see Flain 1970) were common during tagging, and were found in all except one of the samples for which sex data were obtained (Table 6). Their precocity was obvious when they were internally examined, but they were usually readily identifiable by their external appearance, being deeper-bellied than normal fish and brown-green rather than the usual silver. They readily produced milt when squeezed gently about the abdomen, sometimes shedding it spontaneously as soon as they were handled. They were most abundant in March, April, and May, when they accounted for 2.1-7.8% of the fish examined. Overall, 137 were recorded, 2.4% of the 5708 males sampled.

### Length-weight relationship and condition factor

Linear regression of log *W* on log *FL* produced almost identical results for males and females (Table 7). The length-weight relationship for both sexes combined is shown in Figure 6. Precocious males were considered separately because they tended to be substantially heavier than normal males of equivalent length. Weights of 30, 40, and 50 g correspond roughly to fork lengths of 140, 150, and 160 mm respectively. Mean condition factor

$$c.f. = 10^6 \left( \frac{W}{FL^3} \right)$$

was calculated for each monthly release (Table 8). Values ranged from 10.8 to 12.9; however, because the coefficient of log *FL* in the length-weight regression exceeds 3, *c.f.* tends to increase with increasing *FL* irrespective of the actual condition of the fish.

**Table 4: Release data for the 13 groups of tagged salmon sampled at the Glenariffe hatchery for which an  $X^2$  test showed a sex ratio significantly different from 50 : 50**

| Release date | Tag code | Size class | Release weight (g) | Sample size* | % female | $X^2$ | Significance level (%) |
|--------------|----------|------------|--------------------|--------------|----------|-------|------------------------|
| 6 Mar 1984   | 63/37/10 | large      | 30.4               | 109 (22)     | 34.5     | 8.4   | 99                     |
| 6 Mar 1985   | 63/38/57 | large†     | 57.4               | 105 (4)      | 35.6     | 8.3   | 99                     |
| 5 May 1984   | 63/37/31 | large      | 37.1               | 95 (25)      | 35.7     | 5.7   | 95                     |
| 5 Apr 1984   | 63/37/16 | medium     | 28.5               | 77 (11)      | 36.4     | 4.9   | 95                     |
| 5 Apr 1984   | 63/37/18 | large      | 37.9               | 88 (2)       | 37.2     | 5.6   | 95                     |
| 4 Jul 1984   | 63/37/57 | large      | 44.3               | 88 (0)       | 37.5     | 5.5   | 95                     |
| 6 Mar 1985   | 63/38/55 | large†     | 57.4               | 100 (1)      | 39.4     | 4.5   | 95                     |
| 5 Apr 1983   | 63/36/10 | medium     | 17.1               | 111 (0)      | 40.5     | 4.0   | 95                     |
| 3 Aug 1984   | 63/37/46 | small      | 16.7               | 109 (1)      | 60.2     | 4.5   | 95                     |
| 4 Jul 1984   | 63/38/06 | small      | 14.0               | 115 (0)      | 62.6     | 7.3   | 99                     |
| 5 Apr 1984   | 63/37/20 | small      | 15.4               | 97 (18)      | 64.6     | 6.7   | 99                     |
| 5 May 1984   | 63/37/34 | small      | 11.4               | 98 (34)      | 65.6     | 6.3   | 95                     |
| 2 Sep 1984   | 63/38/13 | under      | 16.7               | 67 (1)       | 75.8     | 17.5  | 99                     |

\* The number of unsexed fish in each sample is in parentheses.

† Fish incubated at Silverstream hatchery.

**Table 5: Sex ratio data by size class for the 1982 and 1983 brood years of Glenariffe juvenile chinook salmon**

| Size class | Males | Females | Unsexed | % males* | $X^2$ † | Significance level (%) |
|------------|-------|---------|---------|----------|---------|------------------------|
| Under      | 147   | 215     | 4       | 40.61    | 12.40   | > 99.95                |
| Small      | 1400  | 1540    | 221     | 47.62    | 6.57    | 99.0                   |
| Medium     | 1388  | 1286    | 125     | 51.91    | 3.81    | 95.0                   |
| Over       | 262   | 237     | 2       | 52.51    | 1.15    |                        |
| Large      | 1333  | 1133    | 90      | 54.06    | 16.06   | > 99.99                |

\* Percentage of the total number of fish sexed.

† Values were derived by assuming that the sample for each size class was drawn from a population with a 50 : 50 sex ratio.

**Table 6: Incidence of precocious males\* among juvenile chinook salmon from the Glenariffe hatchery, April 1983 to April 1985**

| Date  | 1983     |           |     | 1984     |           |     | 1985     |           |     | Total    |           |     |
|-------|----------|-----------|-----|----------|-----------|-----|----------|-----------|-----|----------|-----------|-----|
|       | <i>n</i> | <i>np</i> | %   | <i>n</i> | <i>np</i> | %   | <i>n</i> | <i>np</i> | %   | <i>n</i> | <i>np</i> | %   |
| 6 Mar |          |           |     | 288      | 9         | 3.1 | 281      | 22        | 7.8 | 569      | 31        | 5.4 |
| 5 Apr | 572      | 26        | 4.5 | 285      | 10        | 3.5 | 397      | 16        | 4.0 | 1254     | 52        | 4.1 |
| 5 May | 517      | 11        | 2.1 | 325      | 8         | 2.5 |          |           |     | 842      | 19        | 2.3 |
| 4 Jun | 507      | 3         | 0.6 | 292      | 4         | 1.4 |          |           |     | 799      | 7         | 0.9 |
| 4 Jul | 195      | 4         | 2.0 | 430      | 7         | 1.6 |          |           |     | 625      | 11        | 1.8 |
| 3 Aug | 451      | 2         | 0.4 | 338      | 9         | 2.7 |          |           |     | 789      | 11        | 1.4 |
| 2 Sep |          |           |     | 335      | 3         | 0.9 |          |           |     | 335      | 3         | 0.9 |
| 2 Oct |          |           |     | 353      | 3         | 0.9 |          |           |     | 353      | 3         | 0.9 |
| 1 Nov |          |           |     | 36       | 0         | 0.0 |          |           |     | 36       | 0         | 0.0 |

\* For each sample the number of precocious males (*np*) is shown as a percentage of the total number of males recorded (*n*).

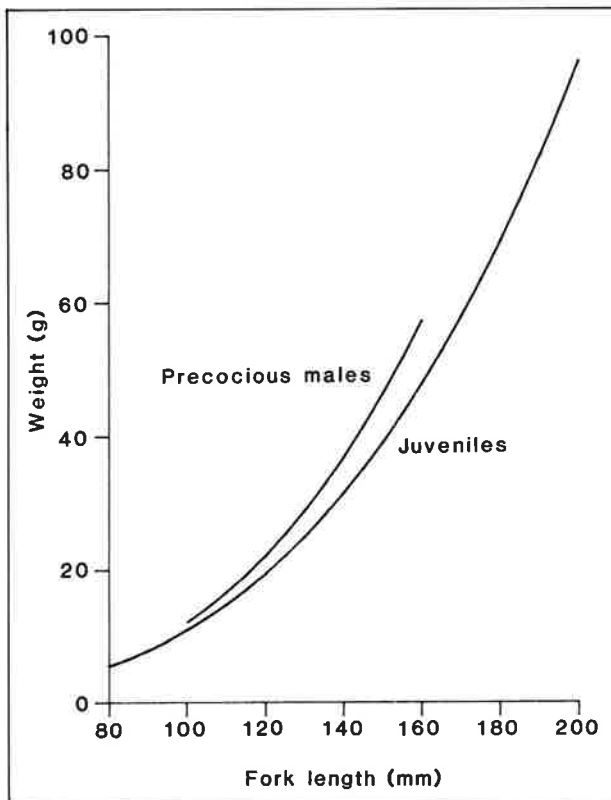
For example, the relatively high *c.f.* for the fish released in July 1983 (which were mostly oversize) is more indicative of their size than their condition. To provide a measure of condition independent of size, the average "relative condition factor" (defined as  $W_{actual}/W_{calc}$ , where  $W_{calc}$  is derived from  $FL$  by the regression equation in Table 7) is also given in Table 8. Relative condition varied little between most of the releases, though three samples differed from the population mean by more than 5%. One of these was the March 1985 release (made up exclusively of fish incubated at Silverstream hatchery), which had a relative *c.f.* 10% higher than average. The other two (November 1984 and October 1985) had *c.f.s*

5-6% lower than average. Other samples with below average *c.f.s* included the September and October 1984 groups. There was some fin rot in both of these groups, and in the October 1985 sample, and this may have caused some loss of condition.

**Table 7: Length-weight relationships\* for juvenile chinook salmon sampled at the Glenariffe hatchery, 1983-85**

|                  | <i>n</i> | <i>r</i> | Slope | Intercept |
|------------------|----------|----------|-------|-----------|
| Females          | 5 384    | 0.995    | 3.135 | -5.229    |
| Males            | 5 465    | 0.996    | 3.146 | -5.253    |
| Unsexed          | 2 704    | 0.996    | 3.117 | -5.193    |
| Total            | 13 553   | 0.996    | 3.132 | -5.224    |
| Precocious males | 137      | 0.985    | 3.307 | -5.531    |

\* Correlation coefficient (*r*), slope, and intercept determined by linear regression of  $\log W$  on  $\log FL$ .



**Figure 6: Length-weight relationship for juvenile chinook salmon at the Glenariffe hatchery (lower curve) ( $\log W = 3.132 \log FL - 5.224$ , see Table 7) and for a subsample of 137 precocious males (upper curve) ( $\log W = 3.307 \log FL - 5.531$ ).**

### Tag loss

The proportion of fish recorded as adipose fin-clipped but having no tag is summarised for each release sample in Table 9. These fish were all regarded as "lost tag", the tag having been dislodged immediately after insertion or after the fish was returned to the hatchery raceway. On two occasions (May 1983 and November 1984), the estimated tag loss was inflated by the presence of fish which had been graded and fin-clipped, but which accidentally escaped into the hatchery raceways before they could be tagged. Excluding these two samples, the average tag loss over the three seasons was 5.0%. The major variable affecting tag loss seems to have been the ability of the tagging crew (in 1983 and 1984 temporary employees were used, whereas in 1985 all tagging was done by FRD staff). Tag loss in 1985 averaged 2.8%, compared with 6.6% in 1983 and 6.8% in 1984. These figures are acceptable, but would have been lower had the QCD been fully used.

All tagged fish scheduled for release on a particular date were from a common raceway, so it was not possible to determine the tag loss for individual codes. Instead, mean weights were calculated for tagged and untagged fish from each release sample, and a Student's *t*-test was used to assess whether the means differed significantly. If they did not, the average tag loss for that release was assumed to apply

**Table 8: Mean absolute and relative condition factors ( $\pm$  2s.e.) by month of release for juvenile chinook salmon from the Glenariffe hatchery, April 1983 to October 1985**

|            | <i>n</i> | Absolute condition factor | Relative condition factor |
|------------|----------|---------------------------|---------------------------|
| 5 Apr 1983 | 1022     | 11.24 (0.05)              | 100.2 (0.4)               |
| 5 May      | 1008     | 11.04 (0.04)              | 98.2 (0.3)                |
| 4 Jun      | 1021     | 11.25 (0.04)              | 100.5 (0.4)               |
| 4 Jul      | 380      | 11.91 (0.08)              | 101.9 (0.6)               |
| 3 Aug      | 934      | 11.19 (0.04)              | 99.2 (0.3)                |
| 6 Mar 1984 | 738      | 11.30 (0.04)              | 100.3 (0.3)               |
| 5 Apr      | 609      | 11.40 (0.05)              | 100.4 (0.4)               |
| 5 May      | 806      | 11.37 (0.04)              | 99.9 (0.3)                |
| 4 Jun      | 599      | 11.56 (0.04)              | 102.3 (0.3)               |
| 4 Jul      | 850      | 11.41 (0.05)              | 100.9 (0.3)               |
| 3 Aug      | 833      | 11.37 (0.04)              | 98.9 (0.3)                |
| 2 Sep      | 812      | 11.31 (0.04)              | 97.8 (0.3)                |
| 2 Oct      | 841      | 11.38 (0.05)              | 97.1 (0.4)                |
| 1 Nov      | 93       | 10.79 (0.09)              | 93.7 (0.9)                |
| 6 Mar 1985 | 515      | 12.89 (0.07)              | 110.3 (0.5)               |
| 5 Apr      | 795      | 11.86 (0.05)              | 101.7 (0.4)               |
| 5 May      | 434      | 11.70 (0.07)              | 99.8 (0.7)                |
| 4 Jul      | 497      | 11.88 (0.05)              | 101.6 (0.4)               |
| 2 Sep      | 482      | 11.56 (0.05)              | 100.2 (0.5)               |
| 2 Oct      | 424      | 10.97 (0.07)              | 94.3 (0.6)                |

equally to all size classes. Otherwise, the average tag loss was computed for each size class by comparing the weight frequency distribution for that class with the weight frequency distribution for the fish which had lost tags. (This process is the same as using an age-length key (Kimura 1977).) Tag losses calculated in this way ranged from 13.6% (small, 5 April 1984) to 0.3% (large, 5 May 1984). Release numbers listed

in Appendix 1 have been adjusted to reflect these losses.

In all instances where there was a significant difference between the mean weights of tagged and untagged fish, untagged fish were smaller. Similar findings were reported by Bilton, Coburn, and Morley (1983). Tag loss rates were increased because the QCD could not be fully used; however, the 1985 results show that with due care tag loss could be held to an acceptable level.

### Down-river movement after release

Catches from the seine and fyke netting in the lower Rakaia are summarised in Table 10. Catches have been listed as of wild or hatchery origin on the basis of size; hatchery fish weighing 30–60 g (140–170 mm FL) were readily distinguishable from wild fingerlings of 90–110 mm FL (Hopkins and Unwin 1987).

The netting programme provided little useful data because few tagged fish (41) were recovered. Adverse river conditions in March prevented fyke nets from being set until 3 days after the release (on 6 March), and only one tagged fish was recovered. Tagged fish from the March release were recorded in both seine samples, but none were taken after that. Fyke net catches in April, May, and July suggest that most fish released from Glenariffe passed through the lower river 24–48 h after release. Tagged fish from more than one release date were not recovered in the same sample.

**Table 9: Mean weight at release for tagged and untagged fish, and percentage tag loss, for releases of chinook salmon from the Glenariffe hatchery, April 1983 to October 1985**

| Release date | Tagged   |            |      | Untagged |            |      | Significance level (%)* | % tag loss |
|--------------|----------|------------|------|----------|------------|------|-------------------------|------------|
|              | <i>n</i> | Weight (g) | s.e. | <i>n</i> | Weight (g) | s.e. |                         |            |
| 5 Apr 1983   | 945      | 19.0       | 0.3  | 77       | 20.0       | 1.1  |                         | 7.5        |
| 5 May 1983†  | 894      | 21.3       | 0.4  | 114      | 15.7       | 0.8  | 99                      | 11.3       |
| 4 Jun 1983   | 976      | 18.8       | 0.3  | 45       | 19.3       | 1.6  |                         | 4.4        |
| 4 Jul 1983   | 352      | 58.7       | 1.3  | 28       | 24.3       | 4.5  | 99                      | 7.4        |
| 3 Aug 1983   | 870      | 23.0       | 0.4  | 64       | 21.6       | 1.5  |                         | 6.9        |
| 6 Mar 1984   | 677      | 21.7       | 0.3  | 61       | 21.3       | 1.1  |                         | 8.3        |
| 5 Apr 1984   | 561      | 25.9       | 0.4  | 48       | 22.1       | 1.7  | 95                      | 7.9        |
| 5 May 1984   | 775      | 31.9       | 0.7  | 31       | 15.3       | 1.6  | 99                      | 3.8        |
| 4 Jun 1984   | 559      | 25.6       | 0.6  | 40       | 22.1       | 2.1  |                         | 6.7        |
| 4 Jul 1984   | 804      | 25.7       | 0.5  | 46       | 16.4       | 1.3  | 99                      | 5.4        |
| 3 Aug 1984   | 800      | 40.9       | 1.0  | 33       | 35.0       | 3.5  |                         | 4.0        |
| 2 Sep 1984   | 755      | 46.9       | 1.2  | 57       | 31.1       | 2.9  | 99                      | 7.0        |
| 2 Oct 1984   | 749      | 58.5       | 1.6  | 92       | 66.1       | 3.1  |                         | 10.9       |
| 1 Nov 1984†  | 48       | 31.9       | 0.7  | 45       | 31.7       | 0.8  |                         | 48.4       |
| 6 Mar 1985   | 500      | 51.0       | 0.4  | 15       | 48.9       | 2.0  |                         | 2.9        |
| 5 Apr 1985   | 783      | 44.8       | 0.3  | 12       | 40.8       | 3.4  |                         | 1.5        |
| 5 May 1985   | 428      | 49.2       | 0.6  | 6        | 37.6       | 2.6  | 95                      | 1.4        |
| 4 Jul 1985   | 490      | 51.0       | 0.7  | 7        | 61.4       | 3.7  |                         | 1.4        |
| 2 Sep 1985   | 457      | 41.1       | 1.1  | 24       | 30.6       | 3.8  | 95                      | 5.0        |
| 2 Oct 1985   | 402      | 45.3       | 1.2  | 20       | 36.3       | 4.1  |                         | 4.7        |

\* Releases for which tagged fish were significantly heavier than untagged fish.

† Tag loss was artificially high because of the escape of fish before they could be tagged.

Table 10: Results of lower Rakaia River netting, March-July 1985

| Date   | Distance below Glenariffe (km)* | Fishing method | No. of fish caught |          |          | Release date (tagged fish) |
|--------|---------------------------------|----------------|--------------------|----------|----------|----------------------------|
|        |                                 |                | Wild               | Hatchery |          |                            |
|        |                                 |                |                    | Tagged   | Untagged |                            |
| 9 Mar  | 80                              | fyke           | 0                  | 0        | 2        |                            |
| 10 Mar | 80                              | fyke           | 1                  | 1        | 0        | 6 Mar                      |
| 11 Mar | 80                              | fyke           | 0                  | 0        | 0        |                            |
| 12 Mar | 80                              | fyke           | 0                  | 0        | 0        |                            |
| 13 Mar | 80                              | fyke           | 0                  | 0        | 0        |                            |
| 14 Mar | 80                              | fyke           | 0                  | 0        | 0        |                            |
| 15 Mar | 80                              | fyke           | 0                  | 0        | 0        |                            |
| 16 Mar | 80                              | fyke           | 1                  | 0        | 0        |                            |
| 17 Mar | 80                              | fyke           | 1                  | 0        | 0        |                            |
| 21 Mar | 65-85                           | seine          | 58                 | 7        | 17       | 6 Mar                      |
| 5 Apr  | 80                              | fyke           | 14                 | 0        | 0        |                            |
| 6 Apr  | 80                              | fyke           | 2                  | 0        | 0        |                            |
| 7 Apr  | 80                              | fyke           | 7                  | 10       | 10       | 5 Apr                      |
| 8 Apr  | 80                              | fyke           | 13                 | 0        | 1        |                            |
| 9 Apr  | 80                              | fyke           | 2                  | 1        | 1        | 5 Apr                      |
| 10 Apr | 80                              | fyke           | 2                  | 0        | 2        |                            |
| 11 Apr | 90                              | seine          | 72                 | 15       | 43       | 6 Mar                      |
| 4 May  | 80                              | fyke           | 0                  | 0        | 0        |                            |
| 5 May  | 80                              | fyke           | 1                  | 0        | 0        |                            |
| 6 May  | 80                              | fyke           | 2                  | 2        | 29       | 5 May                      |
| 7 May  | 80                              | fyke           | 0                  | 0        | 4        |                            |
| 8 May  | 80                              | fyke           | 1                  | 1        | 1        | 5 May                      |
| 4 Jul  | 80                              | fyke           | 0                  | 0        | 0        |                            |
| 5 Jul  | 80                              | fyke           | 0                  | 1        | 0        | 4 Jul                      |
| 6 Jul  | 80                              | fyke           | 14                 | 0        | 4        |                            |
| 7 Jul  | 80                              | fyke           | 28                 | 2        | 0        | 4 Jul                      |
| 8 Jul  | 80                              | fyke           | 11                 | 0        | 1        |                            |
| 9 Jul  | 80                              | fyke           | 14                 | 1        | 0        | 4 Jul                      |
| 10 Jul | 80                              | fyke           | 17                 | 0        | 0        |                            |
| 11 Jul | 80                              | fyke           | 6                  | 0        | 1        |                            |
| 12 Jul | 80                              | fyke           | 10                 | 0        | 0        |                            |
| 13 Jul | 80                              | fyke           | 12                 | 0        | 0        |                            |
| 14 Jul | 80                              | fyke           | 13                 | 0        | 0        |                            |
| 15 Jul | 80                              | fyke           | 9                  | 0        | 0        |                            |
| 16 Jul | 80                              | fyke           | 0                  | 0        | 1        |                            |
| 17 Jul | 80                              | fyke           | 23                 | 0        | 0        |                            |