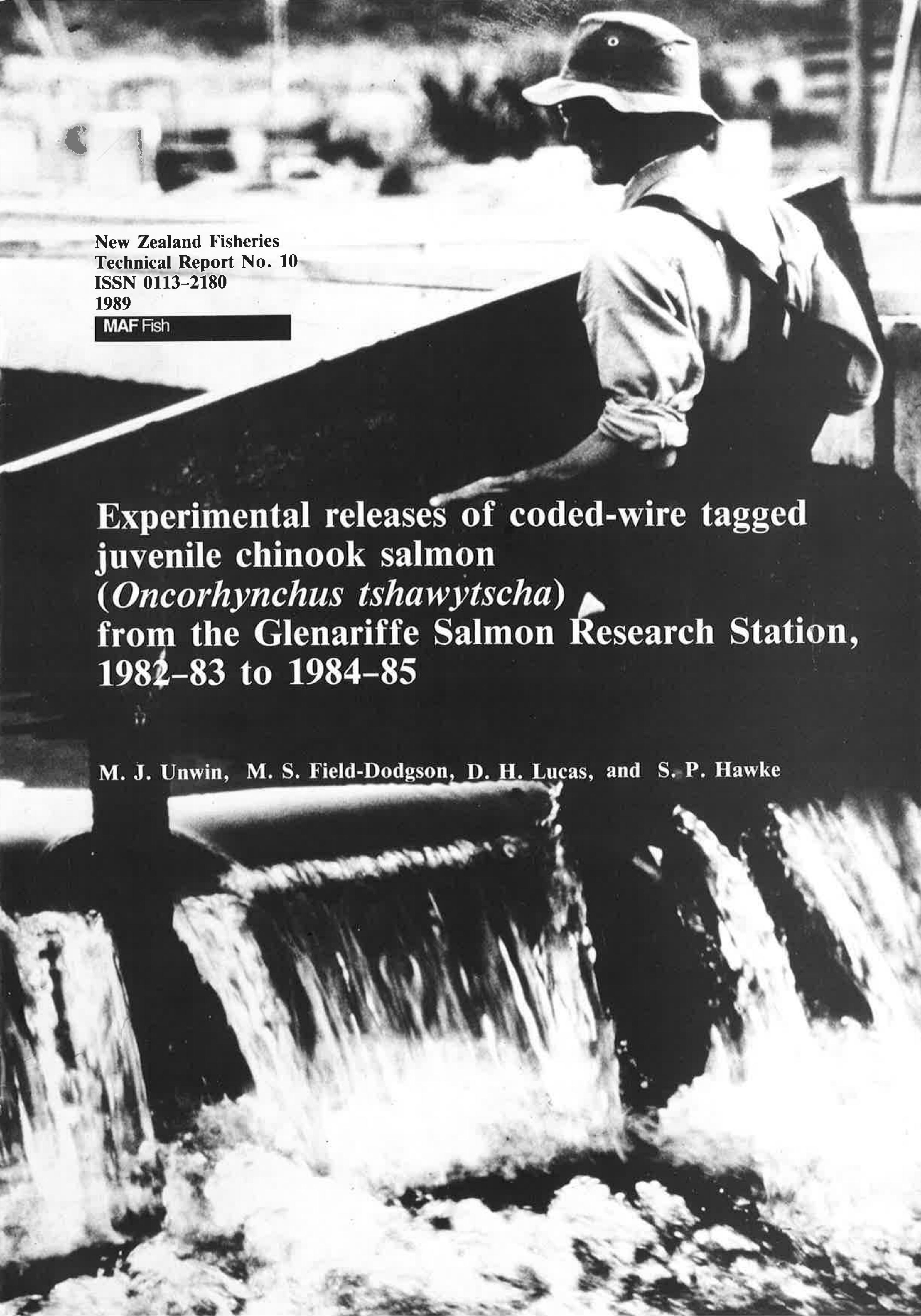

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MAF Fish

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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.)**

Contents

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).

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

Hatchery operations

The hatchery is on the headwaters of the Rakaia River about 100 km from the sea at an altitude of 486 m (Figure 1). It is supplied with water from the eastern branch of the spring-fed Glenariffe Stream.

When the 1982–85 programme began, the primary facilities at Glenariffe were the upstream and downstream traps on the Glenariffe Stream, a pen for holding and stripping adult fish, and seven concrete raceways for incubating and rearing juveniles. Additions during the programme included a building for the coded-wire tagging of juveniles, eight circular ponds for holding small batches of fish, and a food store (Figure 2). The hatchery has since undergone a major expansion, involving the construction of six new raceways, a hatchery-incubation building, and more small circular ponds for experimental work. The husbandry methods described here are those used during the 1982–85 programme.

Table 1: Water quality analysis for the eastern branch of the Glenariffe Stream, 2 March 1985 (units are g^3, except for pH or where otherwise stated)

Temperature (°C)	12.8
pH	7.6
Acidity to pH 8.3 (as CO_3)	2
Total alkalinity (as HCO_3)	39
Alkalinity to pH 8.3 (as CO_3)	0
Turbidity (NTU*)	0.47
Absorbance (270 nm, 1 cm cell)	0.005%
Dissolved Oxygen	8.7
Biochemical Oxygen Demand (5 days)	0.3
Ammoniacal Nitrogen	0.085
Nitrate Nitrogen	0.023
Phosphate (as P)	< 0.05
Sulphate	6.1
Bromide	< 0.05
Chloride	0.5
Fluoride	0.05

* Nephelometric Turbidity Units (arbitrary units used to calibrate turbidimeters.

Weather and stream conditions

The climate is characterised by hot dry summers and cold dry winters. Mean daily maximum and minimum air temperatures in January are 26 °C and 6 °C; those for July are 10 °C and -3 °C. Temperatures are low in winter until at least midday, and they rise substantially in the afternoon only if the sun is shining. Annual rainfall is 915 mm (N.Z. Meteorological Service 1981). Snow covers the surrounding mountains from May until September and settles briefly on the hatchery three or four times a year.

The eastern branch of the Glenariffe Stream has a stable flow regime, with a mean discharge of 0.91 $m^3.s^{-1}$. It is not affected much by climatic conditions: after localised heavy rain, flow increases by, at most, 0.1 $m^3.s^{-1}$, and the water becomes light brown. Suspended sediment levels are usually low (about 2.3 ppm), and they increase only during floods, or when the bed is disturbed by cattle grazing the stream margins. Mean daily maximum and minimum water temperatures are 13–15 °C in December, January, and February and 6–8 °C in July and August (Unwin 1986). Temperatures below 7 °C are usually recorded only when periods of heavy rain and snow from the south-west are immediately followed by severe frosts. Water quality is high (Table 1), with a neutral pH and close to 100% oxygen saturation regardless of season. The outflow from the hatchery discharges into the Glenariffe Stream through a settling pond.

Husbandry

The adult holding and stripping facility consists of a long concrete raceway, subdivided into pens by galvanised iron gates, leading up to a small shed used as a stripping area. Ripe and near-ripe fish collected at the upstream trap are transferred to the holding race, where they are held until there are sufficient ripe females (nominally 60–70) for stripping. When stripping begins, females considered to be ripe are killed by two sharp blows to the head. The caudal artery is then cut, and the body is put on a rack to bleed. Six fish are stripped in each batch: the eggs from each female are put into an individual stainless steel bowl, milt from six males is added to each bowl, and the contents are stirred with a goose feather to ensure thorough mixing.

Fertilised eggs are incubated in Washington pond trays (*see* Senn, Pattie, and Clayton 1973) arranged in banks in one of the main raceways. Each bank contains eight trays, and the trays are divided into four sections, each capable of holding the eggs from a single female (average 4500). There are usually four banks per raceway, and they are submerged and covered with a double layer of black polythene to exclude light. The flow in the raceways is reduced to about 5 $l.s^{-1}$, the water passing initially through a dacron foam filter and then through an aluminium baffle positioned vertically in the raceway immediately up stream of the incubators. Water temperatures average 9.5 °C (range 6.5–11.0 °C) during incubation. The eggs become eyed within 5–6 weeks and hatch in about 12 weeks. Total mortality from fertilisation to the eyed stage has varied between 2.8 and 8.4%, but it is usually 4–6%.

Fungal infection during incubation is minimised by treating the raceway with malachite green three times a week. The only time the trays are disturbed during this period is about 5 weeks after fertilisation, when the eggs are shocked and any dead eggs are floated off in a magnesium sulphate solution. While the eggs are temporarily out of the raceway, the trays are thoroughly cleaned and disinfected, and the raceways are scrubbed down. When hatching is complete, the empty trays are removed from the raceway and the water flow is increased to the appropriate level.

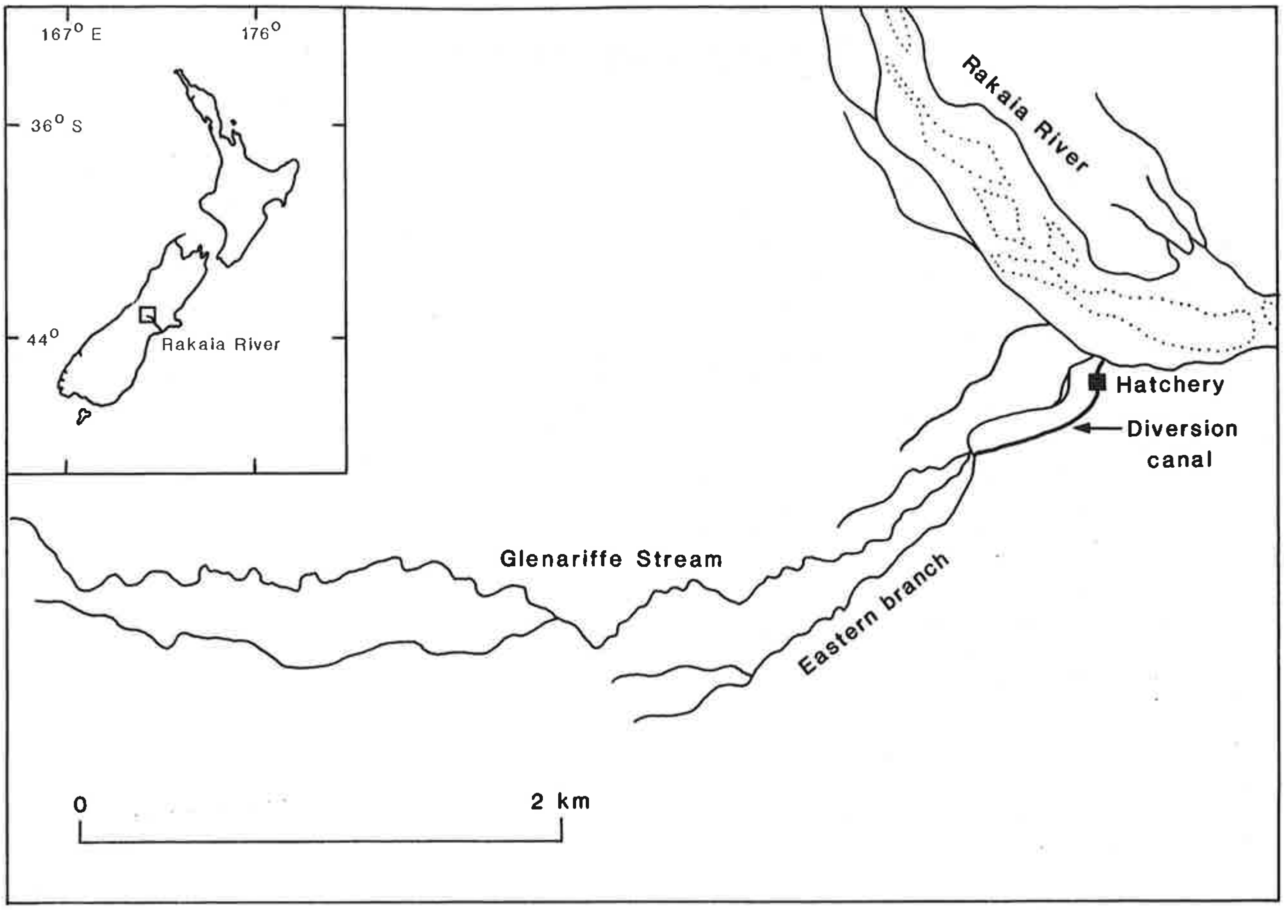

Figure 1: Part of the upper Rakaia River catchment, showing Glenariffe Stream, the eastern branch and the diversion canal, and the hatchery.

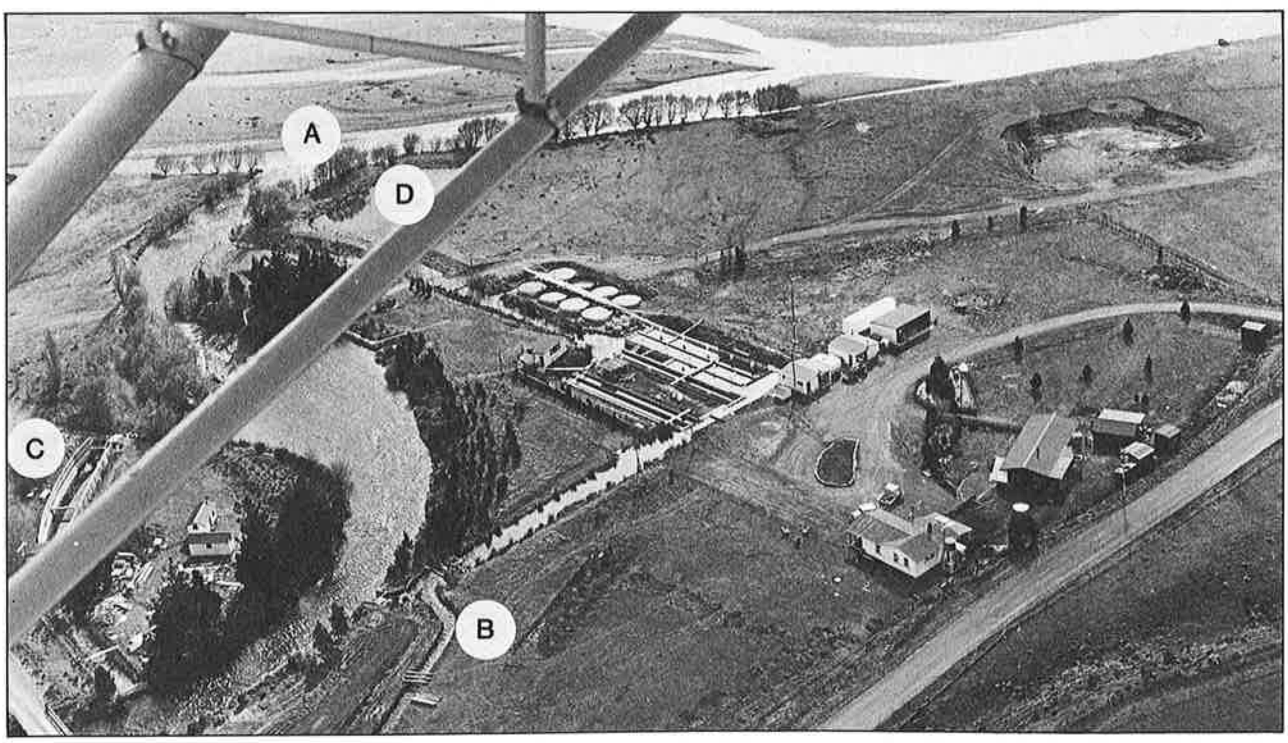

Figure 2: An aerial view looking north-east over the Glenariffe Salmon Research Station, January 1986. The Glenariffe Stream flows from the lower left towards its confluence with the Rakaia River (A). The hatchery raceways, circular ponds, and the associated buildings are in the centre of the photograph, with the staff quarters in the lower right. Also shown are part of the diversion canal (B) which feeds the hatchery, the raceway (C) used to hold ripe adults before stripping, and the settling pond (D) below the hatchery outfall. The upstream trap on the Glenariffe Stream is obscured by part of the aircraft.

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.

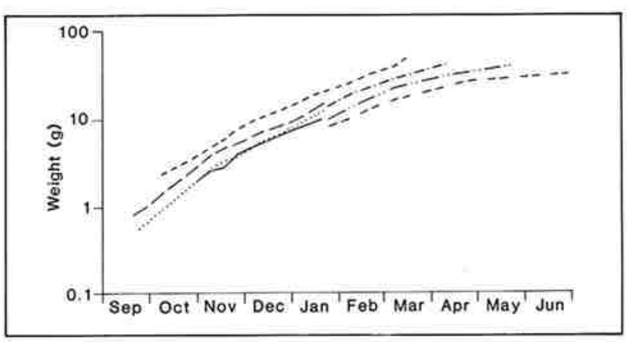

Figure 3: Representative growth curves for 1984 brood year juvenile chinook salmon reared at the Glenariffe hatchery, September 1984 to June 1985. (The discontinuities in mid January are associated with grading, the fish being reallocated into groups according to size).

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.

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.

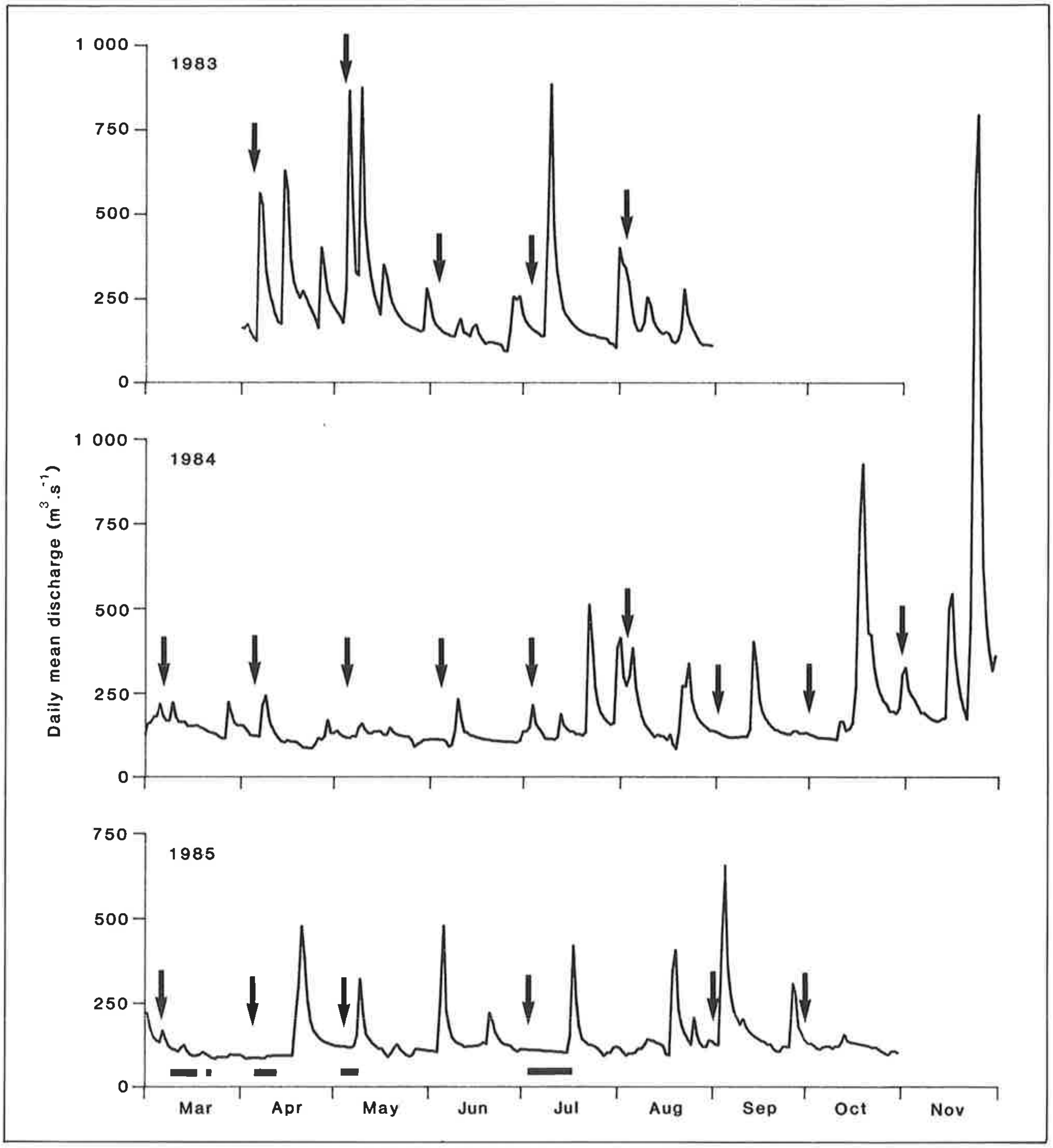

Figure 4: Rakaia River mean daily discharge ($m^3.s^{-1}$) during the releases of juvenile salmon from the Glenariffe hatchery, 1983–85. Release dates are marked by arrows, and the solid horizontal bars below the 1985 flow record show days on which sampling was conducted in the lower Rakaia River. (Discharge 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

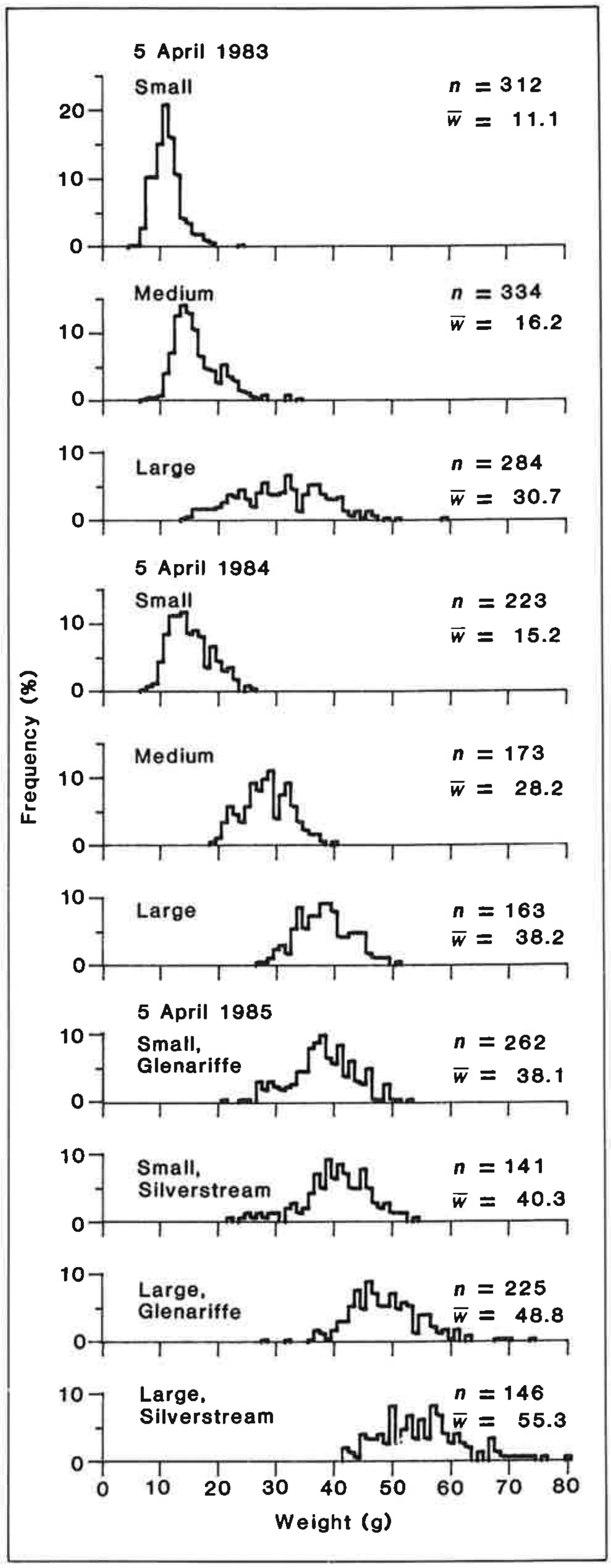

Figure 5: Weight frequency distribution by size class for release of juvenile chinook salmon from the Glenariffe and Silverstream hatcheries on 5 April 1983, 1984, and 1985.

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

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

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

	1983			1984			1985			Total		
Date	*n*	*np*	%	*n*	*np*	%	*n*	*np*	%	*n*	*np*	%
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.

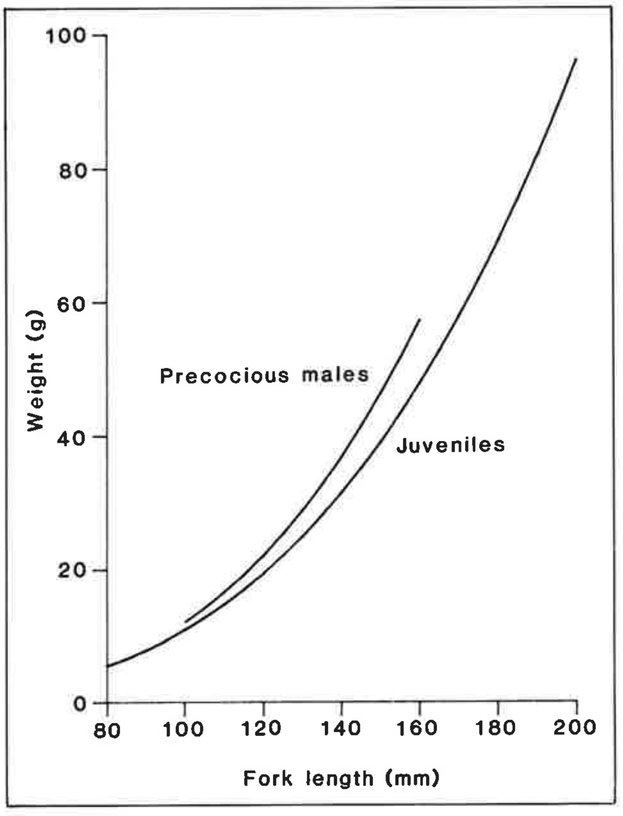

Figure 6: Length-weight relationship for juvenile chinook salmon at the Glenariffe hatchery (lower curve) (log *W* = 3.132log *FL* − 5.224, *see* Table 7) and for a subsample of 137 precocious males (upper curve) (log *W* = 3.307log *FL* − 5.531).

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

	n	*r*	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*.

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 (± 2s.e.) by month of release for juvenile chinook salmon from the Glenariffe hatchery, April 1983 to October 1985

	n	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
	n	Weight (g)	s.e.	*n*	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)
				Hatchery		
			Wild	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	

Acknowledgments

The release programme described in this report was a direct result of a visit to FRD's Christchurch laboratory by Dr Tom Bilton, from the Pacific Biological Station in Nanaimo, British Columbia, during 1982. The experimental design is essentially that proposed by Tom, and he provided help and advice throughout the programme.

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Appendix 1

Releases from the 1982–84 brood years

Release date	Tag code	Size class	Replicate No.	Weight (g)	No. released: Tagged	Untagged	Total
					1982 brood year		
5 Apr 1983	63/36/07	small	1	11.4	9 069	0	9 069
5 Apr 1983	63/36/08	small	2	10.9	8 321	0	8 321
5 Apr 1983	63/36/09	small	3	11.2	9 708	0	9 708
5 Apr 1983	63/36/10	medium	1	17.1	9 801	0	9 801
5 Apr 1983	63/36/11	medium	2	15.4	8 969	0	8 969
5 Apr 1983	63/36/12	medium	3	16.0	9 888	0	9 888
5 Apr 1983	63/36/04	large	1	30.9	9 801	0	9 801
5 Apr 1983	63/36/05	large	2	30.9	9 246	0	9 246
5 Apr 1983	63/36/06	large	3	30.3	9 801	0	9 801
Total (9 groups)					82 299	0	82 299
5 May 1983	63/36/19	small	1	11.1	9 468	0	9 468
5 May 1983	63/36/20	small	2	11.6	9 760	0	9 760
5 May 1983	63/36/21	small	3	11.9	9 499	0	9 499
5 May 1983	63/36/16	medium	1	19.4	9 469	0	9 469
5 May 1983	63/36/17	medium	2	18.2	9 469	0	9 469
5 May 1983	63/36/18	medium	3	18.9	9 568	0	9 568
5 May 1983	63/36/13	large	1	35.5	9 635	0	9 635
5 May 1983	63/36/14	large	2	32.7	8 543	0	8 543
5 May 1983	63/36/15	large	3	34.3	9 967	0	9 967
Total (9 groups)					85 378	0	85 378
4 Jun 1983	63/36/28	small	1	10.4	9 453	0	9 453
4 Jun 1983	63/36/29	small	2	10.7	9 648	0	9 648
4 Jun 1983	63/36/30	small	3	10.2	9 569	0	9 569
4 Jun 1983	63/36/25	medium	1	15.0	9 470	0	9 470
4 Jun 1983	63/36/26	medium	2	14.5	9 670	0	9 670
4 Jun 1983	63/36/27	medium	3	14.9	9 204	0	9 204
4 Jun 1983	63/36/22	large	1	30.1	9 486	0	9 486
4 Jun 1983	63/36/23	large	2	30.5	9 541	0	9 541
4 Jun 1983	63/36/24	large	3	26.1	9 521	0	9 521
Total (9 groups)					85 562	0	85 562
4 Jul 1983	63/36/43	under	1	12.1	4 106	0	4 106
4 Jul 1983	63/36/40	over	1	66.4	10 001	0	10 001
4 Jul 1983	63/36/41	over	2	66.9	9 245	0	9 245
4 Jul 1983	63/36/42	over	3	64.1	10 153	0	10 153
Total (4 groups)					33 505	0	33 505
3 Aug 1983	63/36/37	small	1	12.8	9 243	0	9 243
3 Aug 1983	63/36/38	small	2	13.4	9 290	0	9 290
3 Aug 1983	63/36/39	small	3	13.0	9 364	0	9 364
3 Aug 1983	63/36/34	medium	1	19.9	8 990	0	8 990
3 Aug 1983	63/36/35	medium	2	19.1	9 216	0	9 216
3 Aug 1983	63/36/36	medium	3	19.4	9 222	0	9 222
3 Aug 1983	63/36/31	large	1	35.5	9 445	0	9 445
3 Aug 1983	63/36/32	large	2	35.3	9 764	0	9 764
3 Aug 1983	63/36/33	large	3	39.2	8 606	0	8 606
Total (9 groups)					83 140	0	83 140
Total, 1982 (5 release dates, 40 groups)					369 884	0	369 884

Appendix 1—*continued*

Release date	Tag code	Size class	Replicate No.	Weight (g)	No. released: Tagged	Untagged	Total
			1983 brood year				
6 Mar 1984	63/37/13	small	1	12.9	9 485	0	9 485
6 Mar 1984	63/37/14	small	2	13.2	9 191	0	9 191
6 Mar 1984	63/37/15	small	3	12.2	9 088	0	9 088
6 Mar 1984	63/37/08	medium	1	23.6	12 987	0	12 987
6 Mar 1984	63/37/09	medium	2	24.6	9 119	0	9 119
6 Mar 1984	63/37/07	large	1	31.7	9 331	0	9 331
6 Mar 1984	63/37/10	large	2	30.4	12 317	0	12 317
Total (7 groups)					71 518	0	71 518
5 Apr 1984	63/37/20	small	1	15.4	8 478	0	8 478
5 Apr 1984	63/37/21	small	2	14.9	9 178	0	9 178
5 Apr 1984	63/37/16	medium	1	28.5	9 506	0	9 506
5 Apr 1984	63/37/19	medium	2	28.0	9 732	0	9 732
5 Apr 1984	63/37/17	large	1	38.6	9 156	0	9 156
5 Apr 1984	63/37/18	large	2	37.9	9 375	0	9 375
Total (6 groups)					55 425	0	55 425
5 May 1984	63/37/34	small	1	11.4	9 479	0	9 479
5 May 1984	63/37/35	small	2	11.4	9 686	0	9 686
5 May 1984	63/37/32	medium	1	19.5	9 319	0	9 319
5 May 1984	63/37/33	medium	2	19.4	9 275	0	9 275
5 May 1984	63/37/30	large	1	37.1	9 503	0	9 503
5 May 1984	63/37/31	large	2	37.1	8 970	0	8 970
5 May 1984	63/37/28	over	1	58.5	7 874	0	7 874
5 May 1984	63/37/29	over	2	59.7	7 825	0	7 825
Total (8 groups)					71 931	0	71 931
4 Jun 1984	63/37/26	small	1	15.1	9 263	0	9 263
4 Jun 1984	63/37/27	small	2	14.9	9 121	0	9 121
4 Jun 1984	63/37/24	medium	1	26.3	9 242	0	9 242
4 Jun 1984	63/37/25	medium	2	24.9	9 309	0	9 309
4 Jun 1984	63/37/22	large	1	48.7	9 268	0	9 268
4 Jun 1984	63/37/23	large	2	44.0	8 874	0	8 874
Total (6 groups)					55 077	0	55 077
4 Jul 1984	63/37/55	small	1	15.4	9 169	0	9 169
4 Jul 1984	63/37/56	small	2	14.6	9 462	0	9 462
4 Jul 1984	63/38/04	small	3	13.1	9 314	0	9 314
4 Jul 1984	63/38/06	small	4	14.0	9 751	0	9 751
4 Jul 1984	63/38/05	medium	1	33.8	10 430	0	10 430
4 Jul 1984	63/38/07	medium	2	35.1	10 373	0	10 373
4 Jul 1984	63/37/57	large	1	44.3	9 991	0	9 991
4 Jul 1984	63/37/58	large	2	40.1	8 606	0	8 606
Total (8 groups)					77 096	0	77 096
3 Aug 1984	63/38/15	under	1	17.0	8 653	0	8 653
3 Aug 1984	63/37/46	small	1	16.7	7 676	0	7 676
3 Aug 1984	63/37/47	small	2	17.2	7 717	0	7 717
3 Aug 1984	63/37/44	medium	1	30.1	9 666	0	9 666
3 Aug 1984	63/37/45	medium	2	27.0	6 060	0	6 060
3 Aug 1984	63/37/42	large	1	56.6	9 727	0	9 727
3 Aug 1984	63/37/43	large	2	57.6	7 358	0	7 358
3 Aug 1984	63/38/10	over	1	87.1	4 727	0	4 727
Total (8 groups)					61 584	0	61 584
2 Sep 1984	63/38/12	under	1	19.2	8 815	0	8 815
2 Sep 1984	63/38/13	under	2	16.7	8 140	0	8 140
2 Sep 1984	63/37/53	small	1	20.1	8 376	0	8 376
2 Sep 1984	63/37/54	small	2	20.1	9 220	0	9 220
2 Sep 1984	63/37/51	medium	1	35.5	9 223	0	9 223
2 Sep 1984	63/37/52	medium	2	32.7	8 688	0	8 688
2 Sep 1984	63/37/49	large	1	69.2	9 859	0	9 859
2 Sep 1984	63/37/50	large	2	67.9	10 316	0	10 316
2 Sep 1984	63/38/09	over	1	105.2	5 218	0	5 218
Total (9 groups)					77 855	0	77 855
2 Oct 1984	63/38/16	under	1	30.3	9 395	0	9 395
2 Oct 1984	63/38/17	under	2	34.4	4 024	0	4 024
2 Oct 1984	63/37/40	small	1	29.1	8 794	0	8 794
2 Oct 1984	63/37/41	small	2	27.8	9 322	0	9 322
2 Oct 1984	63/37/37	medium	1	47.2	8 765	0	8 765
2 Oct 1984	63/37/38	medium	2	44.6	8 265	0	8 265
2 Oct 1984	63/37/36	large	1	86.5	9 017	0	9 017
2 Oct 1984	63/37/39	large	2	88.2	8 180	0	8 180
2 Oct 1984	63/38/08	over	1	152.2	5 679	0	5 679
Total (9 groups)					71 441	0	71 441
1 Nov 1984	63/38/11	under	1	31.8	10 948	0	10 948
Total (1 group)					10 948	0	10 948
Total, 1983 (9 release dates, 62 groups)					552 875	0	552 875

Appendix 1—*continued*

Release date	Tag code	Size class	Replicate No.	Weight (g)	No. released Tagged	Untagged	Total
					1984 brood year		
6 Mar 1985	63/38/39	-*†	-	50.3	4 814	0	4 814
6 Mar 1985	63/38/56	small†	1	44.3	4 828	42 048	46 876
6 Mar 1985	63/38/58	small†	2	45.1	4 755	42 048	46 083
6 Mar 1985	63/38/55	large†	1	57.4	4 848	42 048	46 896
6 Mar 1985	63/38/57	large†	2	57.4	4 746	42 048	46 794
Total (5 groups)					23 991	168 192	192 183
5 Apr 1985	63/38/40	-†	-	45.7	5 074	0	5 074
5 Apr 1985	63/38/60	small	1	38.6	4 978	15 172	20 150
5 Apr 1985	63/38/62	small	2	37.0	4 073	15 172	19 245
5 Apr 1985	63/39/05	small†	1	42.6	4 788	0	4 788
5 Apr 1985	63/39/07	small†	2	38.8	3 882	0	3 882
5 Apr 1985	63/38/59	large	1	50.0	4 756	15 172	19 928
5 Apr 1985	63/38/61	large	2	47.2	5 080	15 172	20 252
5 Apr 1985	63/39/04	large†	1	58.4	4 947	0	4 947
5 Apr 1985	63/39/06	large†	2	53.9	4 810	0	4 810
Total (9 groups)					42 388	60 688	103 076
5 May 1985	63/39/09	small	1	41.4	4 667	24 036	28 703
5 May 1985	63/39/11	small	2	40.6	4 889	24 036	28 925
5 May 1985	63/39/08	large	1	59.0	5 018	24 036	29 054
5 May 1985	63/39/10	large	2	58.9	5 014	24 036	29 050
Total (4 groups)					19 588	96 144	115 732
4 Jul 1985	63/39/13	small	1	41.0	4 881	14 617	19 498
4 Jul 1985	63/39/15	small	2	39.5	4 991	14 617	19 608
4 Jul 1985	63/39/12	large	1	65.9	4 775	14 617	19 392
4 Jul 1985	63/39/16	large	2	64.4	5 107	14 617	19 724
Total (4 groups)					19 754	58 468	78 222
2 Sep 1985	63/39/22	small	1	25.3	4 548	14 141	18 689
2 Sep 1985	63/39/24	small	2	25.2	3 607	14 141	17 748
2 Sep 1985	63/39/21	large	1	70.1	4 841	14 141	18 982
2 Sep 1985	63/39/23	large	2	66.1	4 856	14 141	18 997
Total (4 groups)					17 852	56 564	74 416
2 Oct 1985	63/39/30	-	-	63.7	9 051	0	9 051
2 Oct 1985	63/39/18	small	1	25.1	4 783	13 109	17 892
2 Oct 1985	63/39/20	small	2	23.2	4 694	13 109	17 803
2 Oct 1985	63/39/17	large	1	59.0	4 775	13 109	17 884
2 Oct 1985	63/39/19	large	2	57.7	4 747	13 109	17 856
Total (5 groups)					28 050	52 436	80 486
Total, 1984 (6 release dates, 31 groups)					151 623	492 492	644 115

* Groups which were not graded or replicated and were secondary to the experimental programme.
† Fish incubated at Silverstream hatchery.

Appendix 2

Release weight data for the 1982–84 brood years

Release date	Tag code	Size class	Males n	Males Weight (g)	Males 2s.e.	Females n	Females Weight (g)	Females 2s.e.	Unsexed n	Unsexed Weight (g)	Unsexed 2s.e.	Total n	Total Weight (g)	Total 2s.e.	Total c.v.	Significance level (%)*
5 Apr 1983	63/36/07	small	57	11.8	0.6	42	10.9	0.5	0	0.0	0.0	99	11.4	0.4	18.6	99
	63/36/08	small	62	11.5	0.8	52	10.1	0.7	0	0.0	0.0	114	10.9	0.5	26.2	99
	63/36/09	small	50	11.2	0.7	49	11.3	0.6	0	0.0	0.0	99	11.2	0.5	20.1	
	63/36/10	medium	66	17.1	1.1	45	17.2	1.4	0	0.0	0.0	111	17.1	0.8	26.1	
	63/36/11	medium	52	15.0	0.9	46	15.8	1.2	0	0.0	0.0	98	15.4	0.7	23.3	
	63/36/12	medium	68	16.3	0.9	57	15.7	1.3	0	0.0	0.0	125	16.0	0.8	26.6	
	63/36/04	large	64	31.0	2.1	52	30.7	2.1	0	0.0	0.0	116	30.9	1.5	25.8	
	63/36/05	large	59	30.0	2.1	45	32.0	2.2	0	0.0	0.0	104	30.9	1.5	25.2	
	63/36/06	large	38	30.2	2.7	26	30.4	2.9	0	0.0	0.0	64	30.3	2.0	26.0	
5 May 1983	63/36/19	small	38	11.6	0.6	41	10.6	0.4	0	0.0	0.0	79	11.1	0.4	14.7	99
	63/36/20	small	55	11.5	0.5	66	11.6	0.5	0	0.0	0.0	121	11.6	0.4	17.6	
	63/36/21	small	50	12.3	0.9	46	11.4	0.6	0	0.0	0.0	96	11.9	0.5	22.0	99
	63/36/16	medium	64	19.8	1.2	58	18.9	1.5	0	0.0	0.0	122	19.4	0.9	26.2	
	63/36/17	medium	56	17.9	1.4	44	18.6	1.5	0	0.0	0.0	100	18.2	1.0	28.2	
	63/36/18	medium	56	19.7	1.3	39	17.9	1.5	0	0.0	0.0	95	18.9	1.0	25.5	99
	63/36/13	large	45	35.7	2.1	54	36.0	1.7	0	0.0	0.0	99	35.9	1.3	18.2	
	63/36/14	large	48	33.0	2.0	38	32.4	2.0	0	0.0	0.0	86	32.7	1.4	19.8	
	63/36/15	large	51	33.9	1.7	43	34.9	1.9	0	0.0	0.0	94	34.3	1.2	17.5	
4 Jun 1983	63/36/28	small	60	10.6	0.4	54	10.3	0.5	0	0.0	0.0	114	10.4	0.3	16.5	
	63/36/29	small	35	11.4	0.7	37	10.0	0.6	0	0.0	0.0	72	10.7	0.5	18.9	99
	63/36/30	small	40	10.7	0.6	55	9.9	0.5	0	0.0	0.0	95	10.2	0.4	18.9	99
	63/36/25	medium	67	15.4	0.8	64	14.6	0.6	0	0.0	0.0	131	15.0	0.5	18.2	95
	63/36/26	medium	52	15.3	1.0	54	13.8	0.5	0	0.0	0.0	106	14.5	0.6	19.8	99
	63/36/27	medium	46	15.0	0.8	53	14.7	0.7	0	0.0	0.0	99	14.9	0.5	16.9	
	63/36/22	large	66	30.5	2.3	70	29.7	2.2	0	0.0	0.0	136	30.1	1.6	30.5	
	63/36/23	large	58	31.0	2.5	63	30.2	2.6	0	0.0	0.0	121	30.5	1.8	32.4	
	63/36/24	large	59	27.0	2.3	42	24.9	2.1	0	0.0	0.0	101	26.1	1.6	30.9	
4 Jul 1983	63/36/43	under	20	12.5	1.9	26	11.9	1.8	0	0.0	0.0	46	12.1	1.3	36.5	
	63/36/40	over	56	62.9	4.1	55	69.9	4.5	0	0.0	0.0	111	66.4	3.1	24.6	99
	63/36/41	over	42	65.7	5.9	45	68.1	6.4	0	0.0	0.0	87	66.9	4.3	30.1	
	63/36/42	over	60	64.8	4.2	47	63.1	4.6	0	0.0	0.0	107	64.1	3.1	24.8	
3 Aug 1983	63/36/37	small	43	13.2	0.8	57	12.5	0.7	0	0.0	0.0	100	12.8	0.5	20.6	
	63/36/38	small	39	14.0	0.9	55	12.9	0.7	0	0.0	0.0	94	13.4	0.5	19.8	99
	63/36/39	small	39	13.5	0.9	49	12.7	0.7	0	0.0	0.0	88	13.0	0.6	20.0	95
	63/36/34	medium	54	19.9	1.1	62	19.8	1.0	0	0.0	0.0	116	19.9	0.8	20.5	
	63/36/35	medium	44	19.7	1.5	45	18.6	1.1	0	0.0	0.0	89	19.1	0.9	23.1	
	63/36/36	medium	49	19.4	1.1	45	19.3	1.3	0	0.0	0.0	94	19.4	0.9	21.8	
	63/36/31	large	57	36.7	3.0	45	34.1	3.2	0	0.0	0.0	102	35.5	2.2	31.0	
	63/36/32	large	53	36.7	3.4	49	33.8	2.6	0	0.0	0.0	102	35.3	2.2	31.2	
	63/36/33	large	40	39.4	3.6	39	38.9	3.8	0	0.0	0.0	79	39.2	2.6	29.5	
6 Mar 1984	63/37/13	small	26	12.4	1.2	21	13.9	1.5	32	12.7	1.3	79	12.9	0.7	25.7	95
	63/37/14	small	29	13.4	1.2	29	14.2	1.2	32	12.1	1.2	90	13.2	0.7	25.2	
	63/37/15	small	31	12.4	1.3	29	12.2	1.1	37	12.1	1.3	97	12.2	0.7	28.7	
	63/37/08	medium	49	24.4	1.0	51	22.7	1.0	31	23.8	1.3	131	23.6	0.6	15.3	99
	63/37/09	medium	31	24.4	1.0	23	24.1	0.9	16	25.5	1.3	70	24.6	0.6	10.3	
	63/37/07	large	40	32.0	1.2	38	31.7	1.1	19	31.0	1.8	97	31.7	0.7	11.4	
	63/37/10	large	57	30.3	0.8	30	30.2	1.0	22	30.7	1.5	109	30.4	0.6	9.8	
5 Apr 1984	63/37/20	small	28	16.7	1.5	51	15.1	1.1	18	14.3	1.8	97	15.4	0.8	25.7	95
	63/37/21	small	58	15.4	1.0	45	14.8	0.9	23	14.0	1.3	126	14.9	0.6	23.0	
	63/37/16	medium	42	27.9	1.2	24	29.5	1.6	11	28.2	3.2	77	28.5	0.9	14.3	95
	63/37/19	medium	42	27.2	1.3	47	28.7	1.2	7	28.8	3.4	96	28.0	0.9	15.1	95
	63/37/17	large	40	39.6	1.2	32	37.6	1.6	3	35.2	8.7	75	38.6	1.0	11.4	99
	63/37/18	large	54	38.4	1.3	32	37.1	1.7	2	37.1	1.0	88	37.9	1.0	12.9	
5 May 1984	63/37/34	small	22	12.0	0.7	42	10.8	0.6	34	11.7	1.0	98	11.4	0.4	19.4	99
	63/37/35	small	34	11.2	0.5	36	11.3	0.6	32	11.6	0.6	102	11.4	0.3	14.5	
	63/37/32	medium	28	20.1	1.7	29	18.4	2.1	24	20.1	2.3	81	19.5	1.2	27.1	
	63/37/33	medium	44	19.7	1.3	30	19.3	1.9	24	18.8	1.9	98	19.4	0.9	23.8	
	63/37/30	large	41	37.0	2.5	45	37.8	2.2	17	35.6	3.8	103	37.1	1.5	20.5	
	63/37/31	large	45	38.2	2.2	25	35.7	2.8	25	36.5	3.5	95	37.1	1.6	20.4	95
	63/37/28	over	58	58.5	2.5	55	58.7	2.3	1	50.6	0.0	114	58.5	1.7	15.6	
	63/37/29	over	46	61.0	2.5	35	58.3	3.1	1	51.5	0.0	82	59.7	1.9	14.7	
4 Jun 1984	63/37/26	small	62	16.1	1.1	67	14.1	0.6	4	14.8	3.8	133	15.1	0.6	23.8	99
	63/37/27	small	55	15.9	1.2	63	14.1	0.6	1	12.3	0.0	119	14.9	0.7	24.2	99
	63/37/24	medium	47	27.3	2.7	49	25.2	2.8	1	35.3	0.0	97	26.3	1.9	36.0	
	63/37/25	medium	43	24.2	2.0	40	25.7	2.6	0	0.0	0.0	83	24.9	1.6	30.0	
	63/37/22	large	43	49.4	2.9	31	47.7	3.7	0	0.0	0.0	74	48.7	2.3	20.0	
	63/37/23	large	26	45.3	4.3	27	42.7	4.0	0	0.0	0.0	53	44.0	2.9	24.0	

Appendix 2—*continued*

Release date	Tag code	Size class	Males *n*	Males Weight (g)	Males 2s.e.	Females *n*	Females Weight (g)	Females 2s.e.	Unsexed *n*	Unsexed Weight (g)	Unsexed 2s.e.	Total *n*	Total Weight (g)	Total 2s.e.	Total c.v.	Significance level (%)*
4 Jul 1984	63/37/55	small	49	16.0	1.0	37	14.8	1.1	0	0.0	0.0	86	15.4	0.8	22.7	95
	63/37/56	small	39	15.1	0.8	51	14.2	1.0	0	0.0	0.0	90	14.6	0.7	22.0	
	63/38/04	small	53	13.7	0.6	67	12.7	0.6	0	0.0	0.0	120	13.1	0.5	19.4	99
	63/38/06	small	43	14.4	1.1	72	13.7	0.7	0	0.0	0.0	115	14.0	0.6	23.6	
	63/38/05	medium	74	34.5	3.5	57	32.8	3.6	0	0.0	0.0	131	33.8	2.5	42.3	
	63/38/07	medium	41	33.7	4.2	48	36.3	4.2	0	0.0	0.0	89	35.1	3.0	39.7	
	63/37/57	large	55	45.6	3.3	33	42.1	3.8	0	0.0	0.0	88	44.3	2.5	26.8	95
	63/37/58	large	49	40.4	3.7	34	39.8	4.4	0	0.0	0.0	83	40.1	2.8	31.6	
3 Aug 1984	63/38/15	under	43	16.9	1.2	43	17.0	1.5	1	23.4	0.0	87	17.0	0.9	25.9	
	63/37/46	small	43	16.5	0.8	65	16.9	0.8	1	14.1	0.0	109	16.7	0.6	17.8	
	63/37/47	small	48	18.4	1.3	49	16.0	0.8	1	20.7	0.0	98	17.2	0.8	22.2	99
	63/37/44	medium	61	31.7	3.2	47	28.0	2.7	3	32.6	1.7	111	30.1	2.1	36.9	95
	63/37/45	medium	38	29.2	3.3	39	25.1	3.0	1	19.7	0.0	78	27.0	2.2	36.4	99
	63/37/42	large	49	58.3	3.7	50	54.8	3.4	1	67.6	0.0	100	56.6	2.5	21.8	95
	63/37/43	large	39	58.5	4.1	30	56.5	4.3	1	52.8	0.0	70	57.6	2.9	21.2	
	63/38/10	over	0	0.0	0.0	0	0.0	0.0	42	87.1	3.3	142	87.1	3.3	22.7	
2 Sep 1984	63/38/12	under	29	20.2	1.9	37	18.4	1.4	0	0.0	0.0	66	19.2	1.2	24.5	95
	63/38/13	under	16	18.2	1.6	50	16.3	0.7	1	13.2	0.0	67	16.7	0.7	16.7	99
	63/37/53	small	38	20.3	1.2	29	20.0	1.4	1	17.8	0.0	68	20.1	0.9	18.1	
	63/37/54	small	38	19.9	1.1	36	20.1	1.0	1	26.3	0.0	75	20.1	0.7	15.4	
	63/37/51	medium	38	38.6	3.7	46	33.4	3.3	2	27.4	1.5	86	35.5	2.5	32.0	99
	63/37/52	medium	43	34.5	2.9	47	31.2	2.6	3	25.7	2.9	93	32.6	1.9	28.5	95
	63/37/49	large	58	74.2	4.0	54	63.9	4.0	0	0.0	0.0	112	69.2	3.0	22.7	99
	63/37/50	large	43	72.1	4.3	40	63.4	4.2	0	0.0	0.0	83	67.9	3.1	20.9	99
	63/38/09	over	0	0.0	0.0	0	0.0	0.0	99	05.2	3.1	99	05.2	3.1	14.6	
2 Oct 1984	63/38/16	under	39	33.5	3.8	53	28.2	3.0	1	19.0	0.0	93	30.3	2.4	37.7	99
	63/38/17	under	25	36.3	6.0	19	33.0	6.8	2	24.4	1.6	46	34.4	4.3	42.5	
	63/37/40	small	49	29.6	1.8	50	28.6	1.5	1	27.4	0.0	100	29.1	1.1	19.6	
	63/37/41	small	44	29.8	1.9	55	26.3	1.3	2	26.4	0.5	101	27.8	1.1	20.5	99
	63/37/37	medium	46	53.2	6.7	50	41.8	3.9	1	36.7	0.0	97	47.2	3.9	40.6	99
	63/37/38	medium	47	47.8	4.8	47	41.6	3.8	1	30.0	0.0	95	44.6	3.1	33.7	99
	63/37/36	large	32	94.1	8.7	40	80.4	5.3	0	0.0	0.0	72	86.5	5.0	24.7	99
	63/37/39	large	24	94.0	2.0	26	82.8	5.7	0	0.0	0.0	50	88.2	6.5	26.2	95
	63/38/08	over	1	40.3	0.0	0	0.0	0.0	92	52.4	6.1	93	52.2	6.0	19.1	
1 Nov 1984	63/38/11	under	18	32.6	2.9	30	31.5	1.7	0	0.0	0.0	48	31.9	1.5	16.3	
6 Mar 1985	63/38/39	–†‡	51	52.0	2.7	34	48.2	3.2	6	48.5	7.3	91	50.3	2.0	18.9	99
	63/38/56	small‡	53	45.2	1.3	49	43.6	1.6	4	41.0	3.5	106	44.3	1.0	12.0	95
	63/38/58	small‡	44	45.7	1.5	49	44.4	1.5	3	48.1	5.9	96	45.1	1.0	11.3	
	63/38/55	large‡	60	57.5	2.2	39	56.6	2.2	1	87.3	0.0	100	57.4	1.7	14.4	
	63/38/57	large‡	65	58.0	1.9	36	56.7	2.6	4	54.3	2.3	105	57.4	1.5	13.1	
5 Apr 1985	63/38/40	–‡	0	0.0	0.0	4	44.0	6.1	1	52.6	0.0	5	45.7	5.2	12.7	
	63/38/60	small‡	87	38.8	1.4	78	38.3	1.1	12	39.3	4.0	177	38.6	0.9	15.2	
	63/38/62	small‡	46	36.4	1.3	33	37.3	1.7	6	40.0	2.1	85	37.0	1.0	12.6	
	63/39/05	small	29	42.4	2.1	25	42.8	2.7	1	41.1	0.0	55	42.6	1.6	14.0	
	63/39/07	small	45	39.5	1.7	38	38.1	2.0	3	37.1	4.6	86	38.8	1.3	15.0	
	63/38/59	large‡	68	49.6	1.7	57	50.5	1.6	4	50.6	2.0	129	50.0	1.1	13.0	
	63/38/61	large‡	53	47.5	1.6	39	47.1	2.1	4	43.7	5.9	96	47.2	1.2	12.9	
	63/39/04	large	18	59.4	3.8	24	57.7	3.4	0	0.0	0.0	42	58.4	2.5	13.7	
	63/39/06	large	44	54.5	2.1	58	53.6	1.8	2	56.8	1.0	104	54.0	1.3	12.4	
5 May 1985	63/39/09	small	0	0.0	0.0	0	0.0	0.0	22	41.4	1.3	122	41.4	1.3	17.8	
	63/39/11	small	0	0.0	0.0	0.0	0.0	10	40.6	1.6	110	40.6	1.6	20.2		
	63/39/08	large	0	0.0	0.0	0	0.0	0.0	96	59.0	1.7	96	59.0	1.7	14.0	
	63/39/10	large	0	0.0	0.0	0	0.0	0.0	00	58.9	1.8	100	58.9	1.8	15.6	
4 Jul 1985	63/39/13	small	0	0.0	0.0	0	0.0	0.0	81	41.0	1.8	181	41.0	1.8	29.4	
	63/39/15	small	0	0.0	0.0	0	0.0	0.0	03	39.5	2.4	103	39.5	2.4	30.9	
	63/39/12	large	0	0.0	0.0	0	0.0	0.0	56	65.9	1.6	156	65.9	1.6	14.7	
	63/39/16	large	0	0.0	0.0	0	0.0	0.0	50	64.4	2.1	50	64.4	2.1	11.7	
2 Sep 1985	63/39/22	small	0	0.0	0.0	0	0.0	0.0	88	25.3	1.1	188	25.3	1.1	29.0	
	63/39/24	small	0	0.0	0.0	0	0.0	0.0	98	25.2	1.6	98	25.2	1.6	30.7	
	63/39/21	large	0	0.0	0.0	0	0.0	0.0	83	70.1	4.4	83	70.1	4.4	28.4	
	63/39/23	large	0	0.0	0.0	0	0.0	0.0	86	66.1	3.7	86	66.1	3.7	26.0	
2 Oct 1985	63/39/30	–	0	0.0	0.0	0	0.0	0.0	97	63.7	5.1	97	63.7	5.1	39.1	
	63/39/18	small	0	0.0	0.0	0	0.0	0.0	92	25.1	1.3	92	25.1	1.3	24.5	
	63/39/20	small	0	0.0	0.0	0	0.0	0.0	77	23.2	1.3	77	23.2	1.3	24.6	
	63/39/17	large	0	0.0	0.0	0	0.0	0.0	71	59.0	4.4	71	59.0	4.4	31.1	
	63/39/19	large	0	0.0	0.0	0	0.0	0.0	64	57.7	4.7	64	57.7	4.7	32.6	

* Difference between the release weight of males and females.
† Groups which were not graded or replicated and were secondary to the experimental programme.
‡ Fish incubated at Silverstream hatchery.

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