MAF Fisheries Research

Experimental rearing of chinook salmon fingerlings in unfed ponds at Glenariffe

Fisheries Environmental Report No. 67

Fisheries Research Division
N.Z. Ministry of Agriculture and Fisheries
ISSN 0111-4794

Fisheries Environmental Report No. 67

Experimental rearing of chinook salmon fingerlings in unfed ponds at Glenariffe

by

C.L. Hopkins

Fisheries Research Division

N.Z. Ministry of Agriculture and Fisheries

Christchurch

May

1986

FISHERIES ENVIRONMENTAL REPORTS

This report is one of a series of reports issued by Fisheries Research Division on important issues related to environmental matters. They are issued under the following criteria:

(1) They are informal and should not be cited without the author's permission.

(2) They are for limited circulation, so that persons and organisations normally receiving Fisheries Research Division publications should <u>not</u> expect to receive copies automatically.

(3) Copies will be issued initially to organisations to which the report is directly relevant.

(4) Copies will be issued to other appropriate organisations on request to Fisheries Research Division, Ministry of Agriculture and Fisheries, P.O. Box 8324, Riccarton, Christchurch.

(5) These reports will be issued where a substantial report is required with a time constraint, e.g., a submission for a tribunal hearing.

(6) They will also be issued as interim reports of on-going environmental studies for which year by year or intermittent reporting is advantageous. These interim reports will not preclude formal scientific publication.

MAF Libraries cataloguing-in-publication data.

HOPKINS, C.L. (Ceri)
Experimental rearing of chinook salmon fingerlings in unfed ponds at Glenariffe. - Christchurch : Fisheries Research Division, Ministry of Agriculture and Fisheries, 1986.

28 p. -(Fisheries environmental report, ISSN 0111-4794 ; no. 67)

1. Fish-culture - New Zealand - Glenariffe
2. Fish breeding - New Zealand - Glenariffe
3. Chinook salmon - Growth I. Title II. Series

ISBN 0477 032265

CONTENTS

TABLES

FIGURES

SUMMARY

Between 1975 and 1982 juvenile chinook salmon were reared in two small (1.5 ha) impoundments in the upper parts of the Glenariffe Stream in the Rakaia River catchment. After a period of growth, a minimum of 4 months, they were released to the Glenariffe Stream to migrate to sea. Fingerlings leaving the lakes were marked so that they would be recognisable on return as adults to the stream. The project was intended to test the feasibility of rearing chinook salmon fry in low-cost, unfed ponds as a means of salmon enhancement.

For the first 3 years of the project only one lake was available. A second lake was excavated and stocked in 1978. From 1975 to 1977, inclusive, 50 000 chinook fry were stocked annually in the first lake. The first release of fingerlings was made in January 1976; the lake was opened at intervals thereafter until September for further releases. In the next 2 years the lake was open almost continuously from a February starting date until late winter or early spring. In 1976 and 1977 all outmigrants were counted and marked by removal of the adipose fin. In subsequent years marking was confined to one batch annually, obtained when the lakes were first opened; these batches were coded-wire tagged.

From 1978 the two lakes were stocked with varying numbers of fry in each spring; the highest number stocked was 50 000 and the lowest 10 000. Tagged fingerlings were released in various months in each year, between February and September. In all years survival to release date was low, but it was relatively higher with decreased stocking. Growth rate increased as stocking rate was reduced.

Adult returns from the 1977 release of fingerlings were estimated at 1.49%, but doubt attaches to such a high result. Returns of coded-wire

tagged salmon originating from lake releases (0.11-1.55%) were generally similar to returns to the Glenariffe hatchery in the same years. Retention of salmon to yearling status before release increased adult return rate, but low survival of fingerlings over such a long retention period resulted in inadequate numbers available for liberation.

It was concluded that intitial rearing in unfed impoundments is not an effective means of salmon enhancement. In discussion it is suggested that considerable improvement to results could be achieved by supplementary feeding of juveniles in the lakes or by lake fertilisation which should lead to increased rearing capacity, growth, and survival.

1. INTRODUCTION

A large part of the Ministry of Agriculture and Fisheries (MAF) salmon research programme is concerned with enhancement of chinook salmon stocks (Hopkins 1981). Increasingly the programme has come to centre on hatchery production of young salmon for river release (Hardy 1980, Field-Dodgson 1982), though experimental schemes have also been examined for salmon rearing in semi-natural environments. Part of this work was a project, carried out between 1975 and 1982, to test the feasibility of rearing chinook salmon fry in low-cost, unfed ponds as a means of salmon enhancement. This report presents the results of the project which was done in two small impoundments in the upper reaches of the Glenariffe Stream, an upland tributary of the Rakaia River.

The Glenariffe Stream is an important spawning area for fall chinook salmon which have been the subject of research at the Glenariffe Salmon Research Station since 1965 (Galloway 1976). Studies on the outmigration of juvenile salmon from the stream were begun in 1966 when a horizontal screen, downstream fry trap was constructed near the mouth of the stream, which is about 100 km from the sea. In the first few years of operation of the trap it became apparent that a very high proportion of the juvenile outmigrants were newly emerged fry. At the time, it was believed that few of these fry could survive in the main stem of the Rakaia (Little 1972), a braided river with an unstable bed criss-crossed by shifting channels and subject to frequent spring and summer floods. These features are common to most of the major salmon rivers of the eastern side of the South Island. It was therefore suggested that a means be found of holding fry within the Glenariffe system, to grow on for several months before release to the main river, in this way increasing the proportion of outmigrants surviving to reach the ocean.

A site was chosen in the upper part of the Glenariffe Stream, about 8 km from the stream's confluence with the Rakaia River. At the site a small dam had been built to provide electric power, but had fallen into disuse. With the agreement of the runholder the Glenariffe Stream was diverted around the lake, except for a small supply draw-off left to enter the lake. The lake's overflow control structure was screened and a trap was built at the main outlet. In 1978 a second impoundment was excavated and supplied with water from the screened overflow from the first (upper) lake.

North American studies, summarised by Wallis (1968), showed that hatchery-raised fall chinook salmon should be grown to at least 70-80 mm (4-5 g) before release, a size reached by fingerlings in the Glenariffe Stream between January and March. Wallis further suggested that longer rearing produced greater survival to adult return. Based on this it was planned to make annual introductions of chinook fry, obtained from the Glenariffe trap in September and held for varying periods (with a minimum of 4 months), that would utilise the natural resources of the lake, and then be released from the lake into the Glenariffe Stream. All outmigrants would be counted and marked so that subsequent adult returns could be verified. The first fry were stocked in 1975. The last input was made in 1981 and released in 1982, with adult returns expected up to 1985.

2. DESCRIPTION OF THE LAKES

Both lakes (Fig. 1) were of about the same surface area, 1.5 ha, with a water depth of 0.5-1.0 m increasing to 2 m around each outlet. Small islets served to break the churning effect of prevailing north-westerly winds. Further shelter was introduced by planting trees on the islets and along the lake banks, though the trees only began to provide a windbreak towards the end of the 7-year project.

Until 1981 the outlet from the upper lake to the Glenariffe Stream was in the south-east corner of the lake. It was controlled by a sluice gate and led via a timber sluice to a fish-holding pen. With the gate open, capture of outmigrants relied on fish finding their own way out into the sluice because the lake could not be drawn right down. In 1981 a new outlet was made near the original one by driving a 30-cm-diameter pipe through the lake wall so that complete drainage could be obtained when required. Fish leaving through the new outlet were channelled to a new holding pen.

The lower lake was designed with the capability of being completely drained to a holding pen through a 23-cm-diameter pipe in the south-east bank near the screened overflow.

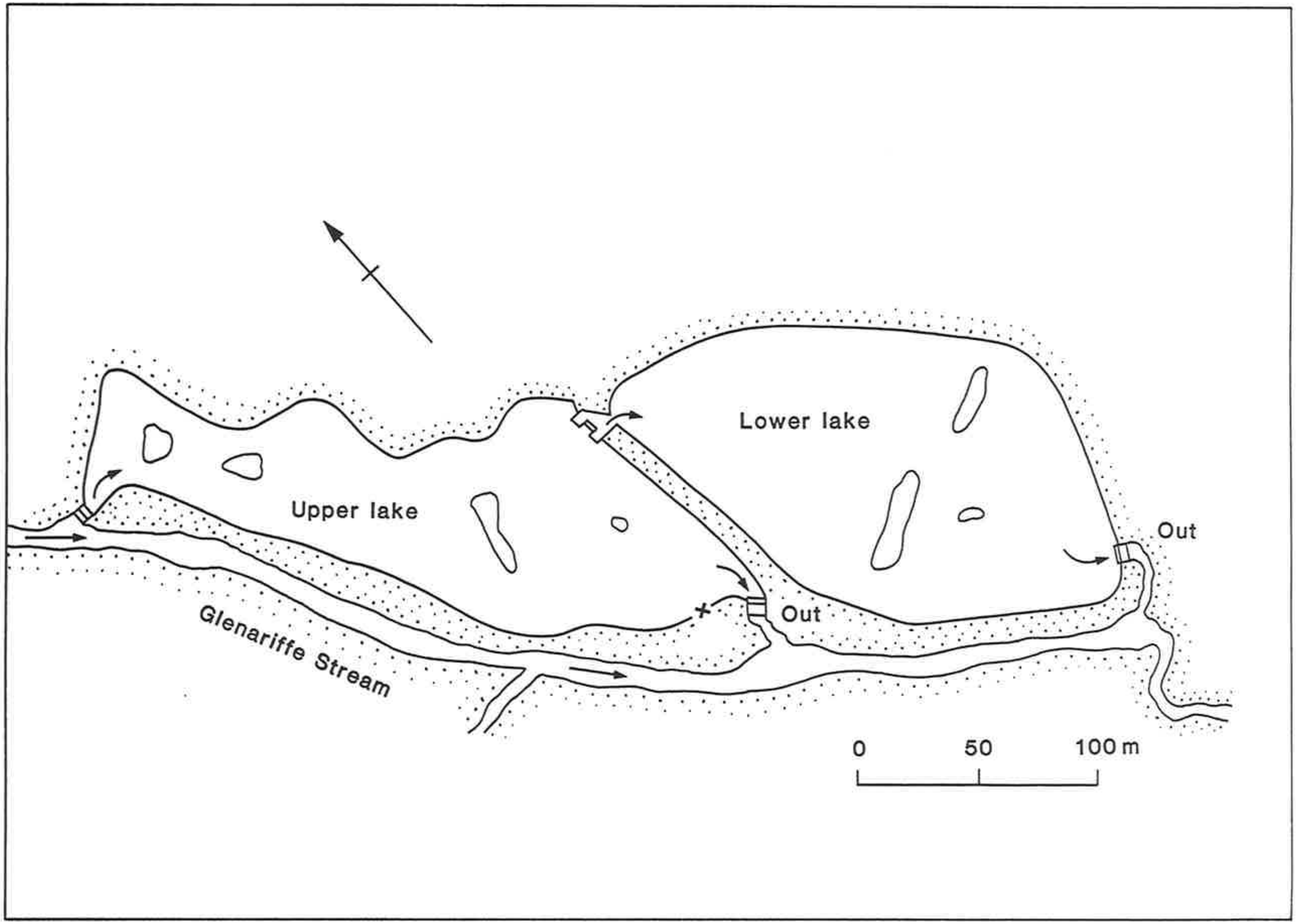

FIGURE 1. The two Glenariffe impoundments used for rearing juvenile chinook salmon. Arrows indicate direction of water flow. Cross near the outlet to the stream from the upper lake marks position of new outlet made in 1981.

A small, controlled flow of water was maintained through both lakes by a diversion channel out of the Glenariffe Stream entering the north-west corner of the upper lake and delivering 0.15 m^3/s. A rotary screen in the channel prevented movement of fish into or out of the upper lake. The lower lake was fed from a spillway carrying the overflow from the upper lake. Screens prevented fish escaping from the upper to the lower lake.

In the upper lake an extensive macrophytic flora developed, consisting of beds of milfoil (*Myriophyllum elatinoides*) and pondweed (*Potamogeton cheesemanii*). Between these beds the lake bottom was carpeted with filamentous algae in spring and summer. In the more recently created lower lake there was much less growth of macrophytes up to the time when the project was completed.

Sampling of the benthic invertebrate fauna in the upper lake, done in 1973 and in 1976-77, showed a community dominated numerically by oligochaetes, molluscs (*Potamopyrgus antipodarum*, *Physastra variabilis*), chironomids, and trichopterans, the latter (*Pycnocentria evecta*, *Pycnocentrodes* spp, *Beraeoptera roria*) consisting of species normally associated with lotic environments. Corixid hemipterans (*Sigara* sp) were present in the weed beds and algal mat. The benthic fauna of the lower lake was not sampled, but was likely to have developed a similar community to that in the upper lake, the major source of colonisation.

Before the start of the stocking programme the upper lake contained brown trout (*Salmo trutta*), long-finned eel (*Anguilla dieffenbachii*) and upland bully (*Gobiomorphus breviceps*). It was intended that trout be excluded from the lower lake after its formation, but a flood in 1979 broke the screens between the two lakes and allowed fish ingress to the lower lake.

3. METHODS

Chinook salmon fry, captured at the Glenariffe salmon trap, were stocked into the lakes in September of each year. Mean fork length of the fry was 35 mm with a size range of 30-40 mm. So far as possible, brown trout were removed from the upper lake before the first salmon fry were introduced.

3.1 Upper Lake

From 1975 to 1977, inclusive, 50 000 salmon fry were stocked annually in the upper lake. In subsequent years stocking numbers were reduced to 25 000 in 1978 and 1979, and to 10 000 in 1980 and 1981.

The first release of fingerlings was made in January 1976 when the lake was opened for 16 days. In subsequent months the lake was opened at intervals until mid September; it remained open for periods varying from 1 to 16 days. In the next 2 years the lake was open almost continuously from a February starting date until 20 October in 1977 and 15 August in 1978. The earlier closing date in 1978 was necessitated while alterations were being made to improve the outlet. At the end of each season the lake was netted to remove any remaining salmon that had not migrated.

During the first 2 years of fingerling releases all migrants were counted and marked by removal of the adipose fin. Samples, generally of 30 fish when this number was available, were measured to the nearest 1 mm fork length. Starting in 1978, outmigrants were tagged with an internal, coded-wire nose tag, the procedure being essentially the same as that which has been described by Jenkinson and Bilton (1981) in

Canada. With the advent of coded-wire tagging, marked releases were confined to one batch annually, obtained over 1-2 weeks when the lake was first opened. However, in 1978 the outmigration from the upper lake continued to be monitored until the end of winter, though no further fish were marked.

All fish were released to the Glenariffe Stream from whence they entered the Rakaia river.

3.2 Lower Lake

First stocking of the lower lake occurred in 1978 when 50 000 fry were introduced. The lake was afterwards stocked in each year at the same rate as the upper lake. By draining the lake right down, all fingerlings could be removed from the lower lake over a short, predetermined period for counting and tagging. Apart from this difference, procedures were the same as in the upper lake and releases from each lake were done at the same time.

3.3 Adult Returns

Returning adult survivors of the lake releases were identifiable by lack of an adipose fin. These were expected to home back to the Glenariffe Stream where they could be captured at the main fish trap. In the case of tagged fish, returns could also be recognised by anglers fishing in the main river (and in other rivers) or as carcasses recovered in other spawning streams.

4. RESULTS

4.1 Outmigrant Numbers

In the first 3 years of fingerling releases from the upper lake, outmigrants numbers were monitored for several months (Table 1). As a proportion of total outmigrants in each year, 63-77% of fingerlings vacated the lake during the first 2 weeks of opening. The movements recorded in 1976 are not strictly comparable with those of the other 2 years because the lake was not open continuously. However, in this year the first opening period was long enough to provide the same initial flush of outmigrants as occurred in 1977 and 1978. Through autumn and winter volitional outmigrants numbers were low, even when the lake was open continuously. Some salmon always remained in the lake to the end of winter when netting was done to remove these before introducing the next batch of fry.

It is clear from Table 1 that few of each initial stock of fry survived to migrate in these first 3 years, or remained in the lake at the end of each winter. Outmigrants numbers were particularly small in 1977. The reason for this is unknown, though in January of that year the screens on the overflow were, on one occasion, found to be broken and it is possible that fish escaped to the Glenariffe Stream during the short period between breakage and repair.

After 1978 the only outmigrants counted out of the upper lake were those trapped at the initial opening of the lake each year. In the lower lake all salmon fingerlings were forced out at this time. Total fingerlings trapped annually from each lake are shown in Table 2. The 1979 year class was affected by a massive flood (December 1979) caused

TABLE 1. Number of chinook salmon fingerlings obtained from the upper lake, 1976-78, as outmigrants (M) and netted from the lake (R) at end of winter or spring. Also shown, final, live marked releases

	1976			1977			1978		
	Date	M	R	Date	M	R	Date	M	R
Jan	8-23	4 554	-	-	-	-	-	-	-
Feb	29	222	-	2-28	1 713	-	13-28	3 115	-
Mar	1-8, 25	291	-	1-31	13	-	1-31	1 090	-
Apr	10-13	39	-	1-30	29	-	1-30	355	-
May	18-28	233	-	1-31	101	-	1-31	41	-
Jun	-	0	-	1-30	3	-	1-3, 7-30	7	-
Jul	14-19	2	-	1-31	0	-	1-31	3	-
Aug	27-31	6	423	1-31	7	-	1-15	2	-
Sep	1-14	25	21	1-30	73	16	27-28	-	5
Oct	-	-	-	1-21	13	7	10	-	150
Total		5 372	444		1 952	23		4 613	155
Live released		5 494			1 943			4 751	

TABLE 2. Total number of chinook salmon fingerlings obtained from each lake annually, for the year classes 1975-81

Year class	Stocked Upper	Stocked Lower	Out Upper	Out Lower	% survival Upper	% survival Lower	Release period
1975	50 000	-	5 816	-	11.6	-	Jan-Sep 1976
1976	50 000	-	1 975	-	4.0	-	Feb-Oct 1977
1977	50 000	-	4 768	-	9.5	-	Feb-Oct 1978
1978	25 000	50 000	3 406	13 380	13.6	26.8	Mar 1979
1979	25 000	25 000	267	11 008	1.1	44.0	Mar 1980
1980	10 000	10 000	2 001	5 561	20.0	55.6	Apr 1981
1981	10 000	10 000	678	829	6.8	8.3	Sep 1982

by water from the Rakaia River entering the upper Glenariffe Stream and inundating both lakes. The flood broke down the screens between the two lakes, swept salmon from upper to lower lake, and probably took some out of the lower lake to the Glenariffe. The 1981 class was held through to September 1982 in both lakes for a late release of yearlings. In this year the upper lake, like the lower, could be drained right down to obtain all salmon still present. The very low survival evident in this year was aggravated by an unusually hard winter, ice up to 30 cm thick was present on both lakes for a period of 7 weeks (interrupted once by a brief melt) during June and July. Many dead fish were seen and it is surmised that high mortality occurred owing to anoxia.

Since the lower lake could be completely drawn down and all fingerlings obtained as one batch, the capture figures for this lake represent total survival up to lake opening. It is supposed that survival rates were likely to be similar in both lakes for equivalent stocking numbers. If this is so then, without emigration, about a quarter of an initial 50 000 fry might survive to early autumn, and the data indicate an increasing relative survival with decreasing stocking rate. Because of flood damage in 1979 it is impossible to measure survival of the 1979 year class, but over half of the 10 000 fry stocked in the lower lake in 1980 survived to April 1981.

4.2 Growth

During the first 3 years of operation of the upper lake, fingerlings leaving at first lake opening were 72-75 mm mean length. Subsequent growth in the lake, as reflected by the increasing size of outmigrants, varied markedly between years (Fig. 2), possibly in response to population density. Least growth occurred during 1976 when the lake

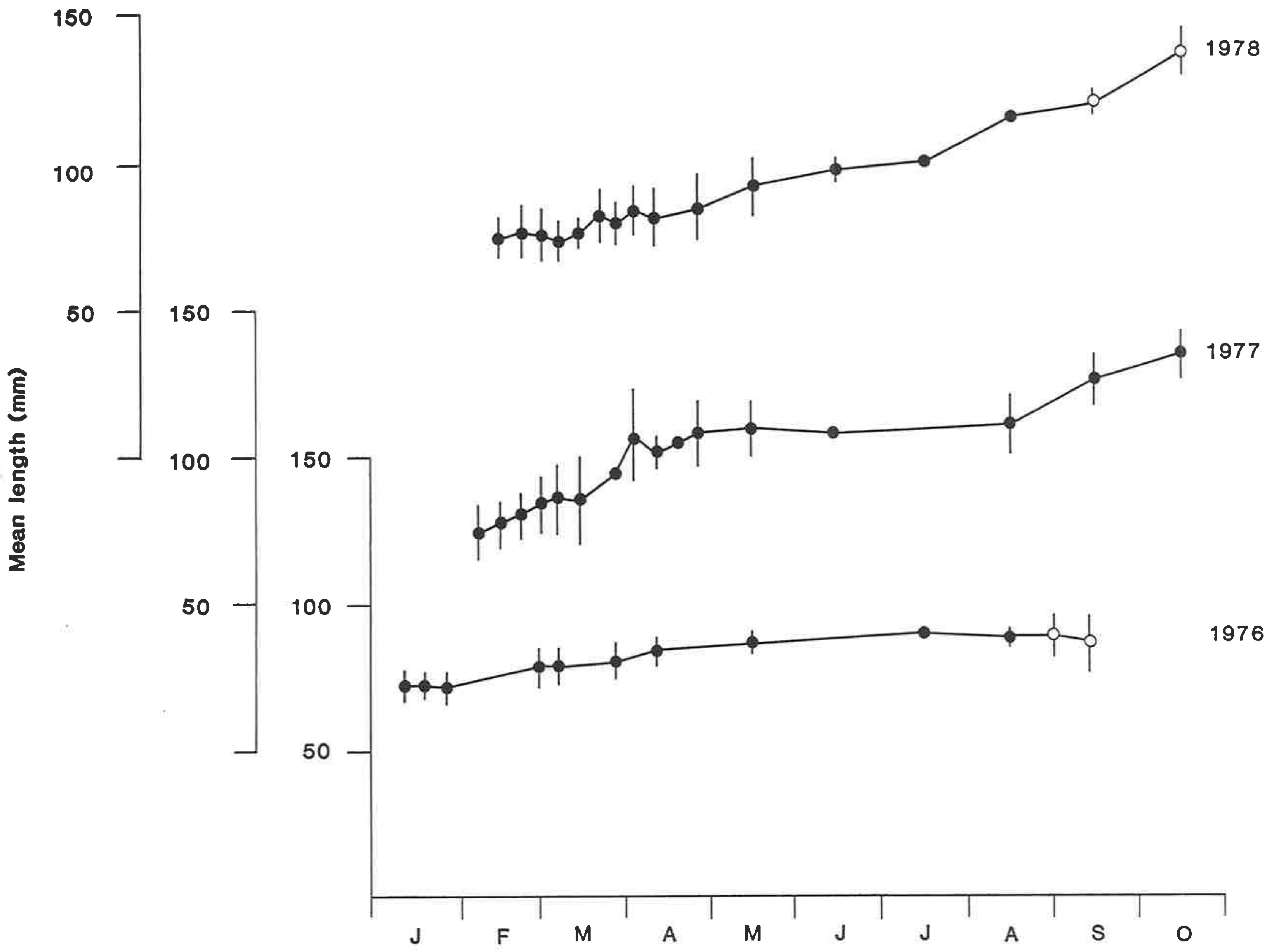

FIGURE 2. Mean length, with ±1 standard deviation, of chinook salmon fingerlings leaving the upper lake in various months, 1976-78. Open circles = fish taken out by netting. Standard deviation not shown where $n<5$.

was only open intermittently and the opportunity for volitional migration discontinous. Fish in the remnant population removed by netting in September 1976 were 89 mm mean length, contrasting with 128 mm and 122 mm, respectively, in September 1977 and 1978. The fastest growth was observed in 1977, the year in which outmigrant numbers and, presumably, surviving residents, were lowest. In this year growth was much greater between February and May than over the same period in the other 2 years; mean length of migrants reached 111 mm by May (87 mm in 1976 and 93 mm in 1978). The eventual mean size reached in 1977, after further spring growth, was 137 mm in October. A similar size was achieved by the same month in 1978.

The size of fish released from both lakes after 1978 is shown in Table 3. Sample mean lengths in the upper lake in March 1979 were similar to those of 1976 and 1978, but in the April release of 1981, after reduction in stocking rate to 10 000 fry, they were closer to 1977 measurements. The data imply improved growth in the lower lake as initial stocking rate was reduced from 50 000 fry in 1978 to 10 000 in 1980. The final size achieved in September 1982 was less than that of 1977 and 1978, despite low stocking rate, but in this year no salmon were allowed to leave the lake beforehand.

TABLE 3. Size of tagged chinook salmon fingerlings released from each lake, 1979-82 (the 1979 year class, released 1980, was not measured). N = sample size; $\overline{L}$ = mean length (mm); S.D. = standard deviation

Year class	Lake	Date	N	$\overline{L}$	SD	Range
1978	Upper	Mar 1979	373	78.9	10.02	56-103
	Lower		313	70.2	6.05	57-105
1980	Upper	Apr 1981	99	94.6	9.62	80-117
	Lower		101	105.1	8.94	85-126
1981	Upper	Sep 1982	137	99.8	8.68	84-134
	Lower		137	117.3	11.54	95-142

4.3 Adult Returns

The numbers of adults returning from the 7 years of lake releases are best considered in two categories:

1. The 1975 and 1976 year classes which were liberated over an extended period and identifiable only by the removal of the adipose fin.

2. Subsequent annual releases of which the identifiable fish were those that were coded-wire tagged and released as a batch at one time in each year - February 1978, March 1979 and 1980, April 1981, and September 1982. All returns being externally recognisable by lack of adipose fin are referred to below as AR (adipose removed) fish.

Returns from category 1 appeared from 1977 (2-year-olds of the 1975 year class) to 1980 (4-year-olds of the 1976 class). Chinook salmon older than 4 years are rare in New Zealand waters (Flain 1982) and were assumed to be absent in the return data. Difficulties attend a precise analysis of AR returns in 1978 and 1979 because most of those caught in the Glenariffe trap were released, after measuring, to spawn upstream, on the assumption that their carcasses would be recovered later for age assessment. In the event, less than half of these fish were recovered. In 1980 all AR fish, which by then included returns from hatchery releases, were held at the trap for tag recovery and/or age assessment, though the records show that seven AR salmon were not aged.

Adult AR returns to the Glenariffe trap from 1977 to 1980 are listed in Table 4. Some apparent AR fish exhibited regrowth of the adipose fin and these have been omitted in case they were misidentified. The possiblity could not be discounted of a few AR salmon returns from a small release made in the Glenariffe Stream in 1974, associated with

TABLE 4. Returns of AR chinook salmon to Glenariffe trap, 1977-1980. Lengths in mm. Ages quoted where known. Only 4-year-olds and unaged salmon listed for 1980

1977		1978		1979		1980	
Length	Age	Length	Age	Length	Age	Length	Age
470	2	595		540	2	693	
488	2	650		552	2	740	
657		661		553	2	742	
806		672		625	2	748	
		673		638	3	750	4
		682	3	662	3	752	
		705	3	683		777	
		740		700	3	795	4
		745		732		808	
		754		737		820	4
		764		737		820	4
		770	3	743		825	4
		785		760		832	4
		805		764		858	4
		812		782		858	4
		813	3	793		870	4
		818		795			
		824	3	806			
		835		830			
		845	3	890			
		863		928			
		865	3				
		865					
		900	3				
		914	3				
(N = 4)		(N = 25)		(N = 21)		(N = 16)	

marking experiments. To assign AR returns to the 1975 and 1976 year classes, age-length keys (Kimura 1977) were derived from large samples of fish of known age in the wild runs to the Glenariffe Stream in each of the years 1977-80. The keys were then used to estimate age distribution amongst the unaged AR salmon that had entered the stream in each of the 4 years. From these data, estimated returns of lake-reared fish of the 1975 and 1976 year classes can be presented (Table 5). Total returns from the 2 year classes show 25 (0.46%) for the 1975 class and 29 (1.49%) for the 1976 class.

TABLE 5. Estimated returns of lake-reared chinook salmon, 1975 and 1976 year classes

Age	1975 (N)	1976 (N)
2	2	3
3	22	16
4	1	10
Total	25	29

These difficulties do not attend analysis of returns from coded-wire tagged salmon. Estimated percentage returns to Glenariffe Stream from all tagged releases from the two lakes are shown in Table 6. With the exception of returns from the September 1982 (1981 year class) releases, the percentage returns are all smaller than those estimated for the 1975 and 1976 classes. Greater reliance can be put on the coded-wire tag returns than on those which rest only on an adipose fin clip, and the returns recorded for the tagged salmon probably present a truer picture of the size of returns that should be expected from the two lakes. Returns to the Glenariffe Stream for fingerlings released between February and April range from 0.04% to 0.39%. The release of yearlings in September 1982 provided a larger percent return, 1.08% from the upper lake and 0.74% from the lower.

The use of coded-wire tags allows identification of salmon taken outside the natal stream, either by anglers fishing the Rakaia and other rivers (and at sea) or by the recovery of carcasses on other spawning streams. Hence the total returns (Table 6) are usually higher than returns recorded for the Glenariffe Stream. Over the 5 year classes that were tagged, four salmon were caught in rivers other than the Rakaia and two that had entered the Rakaia were found to have spawned in streams other than the Glenariffe.

TABLE 6. Returns of tagged, lake-reared chinook salmon up to winter 1985. Year classes 1977-81

Upper lake					
Year class	1977	1978	1979	1980	1981
Fingerlings released	2 625	3 345	257	1 851	647
Release month	Feb 1978	Mar 1979	Mar 1980	Apr 1981	Sep 1982
Glenariffe returns	7 (0.27%)	13 (0.39%)	1 (0.39%)	2 (0.11%)	7 (1.08%)
Total returns	10 (0.38%)	15 (0.45%)	1 (0.39%)	2 (0.11%)	10 (1.55%)
Lower lake					
Year class	1977	1978	1979	1980	1981
Fingerlings released	-	11 206	8 431	5 261	816
Release month	-	Mar 1979	Mar 1980	Apr 1981	Sep 1982
Glenariffe returns	-	24 (0.21%)	10 (0.12%)	2 (0.04%)	6 (0.74%)
Total returns	-	27 (0.24%)	15 (0.18%)	3 (0.06%)	8 (0.98%)

5. DISCUSSION

From an annual stocking of 50 000 fry over 3 years, the output of fingerlings achieved as volitional migrants in the upper lake varied between 5816 and 1975. These fish left the lake over a period of 7-9 months. By comparison, from the same sized stock of fry, enforced evacuation of the total population from the lower lake in March 1979 provided 13 380 fingerlings. Even the small number of 10 000 fry stocked in the lower lake in spring 1980 produced 5561 fingerlings when the lake was drained in April 1981, a figure close to the highest output from the upper lake. If survival rate is assumed to be about the same in the two lakes, then at the highest stocking rate the majority of fingerlings surviving to summer failed to leave the upper lake thereafter as volitional migrants, and most died through autumn and winter. This failure to migrate may have been due to the inability of fingerlings to find the lake exit, there being little or no guiding current through the impoundment. Clearly, a far higher yield of fingerlings for release to the Glenariffe was obtained by enforced evacuation than by allowing fish to leave at will over several months.

At least until autumn, there appeared to be a trend of increasing relative survival with reduced stocking rate. In the upper lake, from an initial stock of 50 000 fry, 4.0-11.6% appeared as outmigrant fingerlings and end of winter in-lake survivors. If the flood-affected 1979 year class is omitted, 13.4% of an initial 25 000 fry were obtained as fingerlings from the upper lake in March 1979, and 20% from a stock of 10 000 fry in April 1981; in both these years some fingerlings must have remained in the lake to migrate later, but were not monitored. In the lower lake, total percent survival up to lake opening in 1981 (from a stock of 10 000 fry) was more than double that of 1979 (from a stock of 50 000 fry), thus showing the same trend as in the upper lake. However, in both lakes, retention of all salmon of the 1981 class until the end of winter resulted in a very low survival. Mortality during the hard winter of 1982 was undoubtedly increased because of a long period of ice cover, but end of winter populations in the upper lake in 1977-79 were also small, despite a low migration rate in preceding months.

As with survival rate, growth rate in the lakes appeared to be density dependent, increasing with reduced population size. In most instances, even at the highest stocking rates, growth in the lakes was better than that occurring amongst wild populations in the Glenariffe Stream. Sample mean lengths of stream migrants caught at the Glenariffe trap in January and February ranged from 65 to 76 mm (unpublished data for 1974-76), generally smaller than fingerlings leaving the upper lake at an equivalent time of year. The mean size reached by lake yearlings of the 1976 and 1977 year classes was appreciably greater than that of the residual salmon population overwintering in the Glenariffe Stream in which sample mean lengths taken at various times between August and October did not exceed 110 mm. Lake yearlings of the 1975 year class, which were not allowed continuous volitional escape from the lake, did not reach this size.

Except for the yearlings released in 1981 the highest adult returns to the Glenariffe Stream came from the 1975 and 1976 year classes whose marked (untagged) fingerlings were released over a long period, though with most leaving in the summer. The returns of the 1976 class were so high as to be viewed with suspicion, though no reasons can be found to indicate that the figure of 1.49% should be much revised. Nevertheless, the returns of coded-wire tagged fish must be regarded as providing the most reliable information. As a proportion of fingerlings released, these returns were, in most cases, not greatly different from those obtained on releases from the Glenariffe hatchery in the same years (Table 7). The highest returns of tagged lake fish came from yearlings liberated in early spring.

Throughout the project, chinook salmon stocked into the lakes relied on the natural food resources of the lakes. Under such feeding conditions the numbers of +70 mm fingerlings surviving to be liberated into the Glenariffe Stream were small. The largest number recovered from either lake was 13 380, of which 11 206 were liberated with tags. This compares with an annual range of 98 000-149 000 salmon released from the Glenariffe hatchery during 1979-82 when four 2 m x 30 m rearing races were used. Known adult returns from the lake liberations numbered 1-30 in any single year, which would have made little difference to the adult population entering the Glenariffe Stream.

TABLE 7. Percentage returns of tagged chinook salmon released from Glenariffe hatchery. Year classes 1977-81. 1981 year class not complete until 1985

Year class	Release month	Fingerlings released	Glenariffe returns (%)	Total returns (%)
1977	Jan 1978	11 317	0.06	0.08
	Jan 1978	13 853	0.09	0.14
1978	Jan 1979	52 041	0.24	0.39
	Feb 1979	25 657	0.24	0.36
	Feb 1979	27 618	0.45	0.69
	Mar 1979	10 494	0.37	0.46
	Aug 1979	7 333	1.98	2.59
1979	Dec 1979	19 970	0.03	0.06
	Jan 1980	19 784	0.02	0.05
	Jan 1980	19 986	0.06	0.11
	Feb 1980	20 312	0.09	0.24
	Mar 1980	20 803	0.14	0.26
	Apr 1980	20 161	0.23	0.35
1980	Jan 1981	21 107	0.02	0.07
	Jan 1981	21 290	0.03	0.06
	Feb 1981	21 171	0.03	0.06
	Mar 1981	21 004	0.01	0.23
	Apr 1981	21 336	0.13	0.33
1981	Jan 1982	20 355	0.14	0.29
	Jan 1982	20 105	0.18	0.30
	Feb 1982	19 169	0.24	0.52
	Mar 1982	19 828	0.60	1.10
	Aug 1982	18 714	2.99	5.09

Overall, the project indicated that rearing juvenile chinook salmon in small, unfed impoundments for later release is not an effective means of enhancement, though it is undoubtedly cheaper than hatchery production. However, most of the fish released from the Glenariffe lakes left in summer or autumn. Returns of hatchery-reared fall chinook salmon have been found to improve with increasing size of fingerlings released (Wallis 1968) and are markedly higher from releases of yearlings than from summer fingerling releases (Sholes and Hallock 1979). Current work at the Glenariffe hatchery also supports these findings. There was good evidence that retention of fingerlings in the lakes until early spring could provide a better relative return as compared with releases made in summer or early autumn. The major drawback to a long retention time appears to be low survival, such that release numbers are inadequate.

There are alternative ways of managing such impoundments to provide an increase in rearing capacity per unit volume, better growth, and higher survival. Supplementary feeding with prepared diets has been found to increase production of juvenile chinook salmon in previously unfed impoundments (Anon. 1968) and is used by the Oregon Department of Fish and Wildlife in their pond-rearing chinook salmon enhancement programme in the Willamette River basin (Smith, Williams, and Zakel 1983). Experimental application of inorganic fertilisers to increase lake productivity has also provided increased growth and survival of salmonids (Weatherly and Nicholls 1955, Le Brasseur, McAllister, Barraclough, Kennedy, Manzer, Robinson, and Stephens 1978, Stockner, Shortreed, and Stephens 1980), though in one such study, of relevance to high country ponds in New Zealand, fertilisation of a small (1.7 ha) lake resulted in winter-kill of trout under ice cover (Ball 1948). Since mortality rate is usually at its highest amongst young fry, and decreases as the fish grow, stocking with small fingerlings could be advantageous. Management procedures along these lines may provide a practicable extension to more expensive means of salmon enhancement.

6. ACKNOWLEDGMENTS

The Glenariffe lakes project was begun by J.R. Galloway who supervised it until he left the Ministry in 1979. Other members of FRD staff managed the two lakes thereafter, under the supervision of S.P. Hawke. The tagging team, under D.H. Lucas, carried out all coded-wire tagging. I thank all these staff who provided the labour and the data for this report.

7. LITERATURE CITED

Anon. 1968. Hatchery evaluation programmes. Ringold rearing pond, fall chinook. *Washington State Department of Fisheries 78th Annual Report 1968*: 116-118.

Ball, R.C. 1948. Fertilization of natural lakes in Michigan. *Transactions of the American Fisheries Society 78*: 145-155.

Field-Dodgson, M.S. 1982. Glenariffe surprise. *Freshwater Catch 16*: 13.

Flain, M. 1982. Quinnat salmon runs, 1965-1978, in the Glenariffe Stream, Rakaia River, New Zealand. *Fisheries Research Division Occasional Publication, N.Z. Ministry of Agriculture and Fisheries, No. 28*. 22 p.

Galloway, J.R. 1976. Salmon research at Glenariffe. *Fisheries Research Division Information Leaflet, N.Z. Ministry of Agriculture and Fisheries, No. 8*. 17 p.

Hardy, C.J. 1980. Silverstream induced run. *Freshwater Catch 8*: 12.

Hopkins, C.L. 1981. Salmon research update. *Freshwater Catch 12*: 14.

Jenkinson, D.W., and Bilton, H.T. 1981. Additional guidelines to marking and coded-wire tagging of juvenile salmon. *Canadian Technical Report of Fisheries and Aquatic Sciences 1051*. 24 p.

Kimura, D.K. 1977. Statistical assessment of the age-length key. *Journal of the Fisheries Research Board of Canada 34*: 317-324.

Le Brasseur, R.J., McAllister, C.D., Barraclough, W.E., Kennedy, O.D., Manzer, J., Robinson, D., and Stephens, K. 1978. Enhancement of sockeye salmon (*Oncorhynchus nerka*) by lake fertilization in Great Central Lake: summary report. *Journal of the Fisheries Research Board of Canada 35*: 1580-1596.

Little, R.W. 1972. Juvenile quinnat salmon production, with reference to the Glenariffe downstream trapping. *In*: Hardy, C.J. (Ed.). South Island Council of Acclimatisation Societies Proceedings of the Quinnat Salmon Fishery Symposium, Ashburton, October 1971: 119-125.

Sholes, W.H. and Hallock, R.J. 1979. An evaluation of rearing fall-run chinook salmon, *Oncorhynchus tshawytscha*, to yearlings at Feather River Hatchery, with a comparison of returns from hatchery and downstream releases. *California Fish and Game 65*: 239-255.

Smith, E.M., Williams, R.H., and Zakel, J.C. 1983. Fall chinook and coho studies. *Oregon Department of Fisheries and Wildlife, Fisheries Division Progress Reports 1983*: 12-15.

Stockner, J.G., Shortreed, K.S., and Stephens, K. 1980. The British Columbia lake fertilization program: limnological results from the first two years of nutrient enrichment. *Canadian Technical Report of Fisheries and Aquatic Science 924*. 91 p.

Wallis, J. 1968. Recommended time, size and age for release of hatchery reared salmon and steelhead trout. *Oregon Fish Commission, Clackamas, Processed Report.* 62 p.

Weatherley, A., and Nicholls, A.G. 1955. The chemical enrichment of a lake. *Australian Journal of Marine and Freshwater Research 6*: 443-468.