ISSN 0117-2001

NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORT NO. 38

SALMON LIFE HISTORIES
BASED ON ANALYSIS OF SCALES

by

M.J. Unwin

D.H. Lucas

Report to: Department of Conservation

Final report: Investigation No. S7050/572

Freshwater Fisheries Centre

MAF Fisheries

PO Box 8324

CHRISTCHURCH

Servicing freshwater fisheries and aquaculture

JUNE
1990

NEW ZEALAND FRESHWATER FISHERIES MISCELLANEOUS REPORTS

This report is one of a series initiated in January 1989, and issued by the Freshwater Fisheries Centre, MAF Fisheries. The series was established to ensure that reports prepared for clients, tribunal hearings, internal use, etc., are collected together and available to future users. They are for limited circulation, and some may be confidential.

ISBN 0-477-08186-X

MAF Fisheries is the fisheries business group of the New Zealand Ministry of Agriculture and Fisheries. The name MAF Fisheries was formalised on 1 November 1989 and replaces MAFFish, which was established on 1 April 1987. It combines the functions of the former Fisheries Research and Fisheries Management Divisions, and the fisheries functions of the former Economics Division of MAF.

Enquiries to: The Librarian
Freshwater Fisheries Centre
PO Box 8324
Riccarton, Christchurch

CONTENTS

TABLE

1. INTRODUCTION

For many years, analysis of the growth patterns displayed in salmon scales has been a valuable tool in understanding the biology of salmon. By carefully studying variations in the spacing between adjacent growth rings (or circuli) in the central portion (or nucleus) of the scale, a skilled observer can determine the duration of freshwater residence during the first year of life. For a particular group or population of salmon, such data reveal the age structure, and identify how survival to maturity is related to juvenile life history.

These studies show that scale nucleus patterns found in adult salmon generally fall into one of two distinct classes corresponding to juveniles which spent 3-6 months in fresh water, and those which remained in fresh water for 12 months or longer. These two classes are known as "intermediate nuclei" and "stream nuclei", respectively. To date, all studies of this type have been qualitative rather than quantitative, based on a visual impression of the pattern exhibited in the nucleus. Since growth in fresh water is slower than growth at sea, circuli laid down in fresh water are more closely spaced than those laid down at sea, and the transition from fresh to salt water is usually clearly visible. The size of the freshwater nucleus is the main factor in distinguishing stream from intermediate nuclei.

Over the last decade, a third category of scale patterns has become increasingly common, and has been identified as corresponding to juvenile salmon which were raised in a hatchery. Because this pattern often has characteristics which overlap both with intermediate and with stream nuclei, it has been necessary to re-examine the criteria by which scale nuclei have been classified in the past, and to search for measurable criteria which can be used to distinguish the various types. The need to put scale analysis on a more quantitative basis has been highlighted by recent work showing that hatchery fish now make up 80%-90% of the salmon returning to some rivers, leading to serious concerns about the status of wild (or naturally spawned) stocks (see Investigation No. S7050/343).

This report describes work on scale nucleus classification which has been conducted over the last 12 months.

2. OBJECTIVES

- To identify parameters which can be identified and measured in salmon scale nuclei.
- To identify how these parameters vary amongst scales taken from salmon of known fresh water life history.
- To develop quantitative criteria by which to distinguish between intermediate, stream, and hatchery nuclei.

3. METHODS

From the extensive collection of salmon scales held at the Freshwater Fisheries Centre, two sub-samples were selected for detailed examination. One group, comprising 1083 scale sets collected from anglers fishing the Rakaia River from 1973 to 1975, was chosen because it pre-dated the first hatchery releases (which began in 1977) by several years and thus represented a "clean" sample known to be free of hatchery nuclei. To represent hatchery nuclei, 742 scale sets were examined from adult salmon which were coded-wire tagged (Unwin *et al* 1987), and therefore known to be of hatchery origin. These comprised 274 fish from the New Zealand Salmon Company's Coleridge hatchery in 1984, and 468 fish from MAF Fisheries' Glenariffe Salmon Research Station in the same year.

Scales were examined using a Nikon Profile Projector, which displays an image at a magnification of 50x. The 1973-75 scales were mounted on glass microscope slides, while the 1984 scales were pressed onto acetate plates. Most samples yielded at least one "readable" scale, although a few samples consisted of replacement scales, laid down as a result of scale loss at some undetermined point during the life cycle, and were classified as unreadable.

Readable scales were those in which two key features could be identified. These were the transition from fresh water to salt water (marked by an increase in the spacing between adjacent circuli), and the end of the first year of life (marked by two circuli laid down more or less on top of each other in a single annulus, as growth reduced to a minimum over the winter). For all such scales, measurements were made of the radius and number of circuli to the freshwater check (R_f and N_f), and the radius and number of circuli to the annulus representing the first year's growth (R_1 and N_1). The radius to the 15^{th} circuli (R_{15}) also was measured. All radii were measured in units of 100^{th} of a mm (10^{-5} m).

All scales measured also were classified according to nucleus type, using the original (visual) criteria. For each nucleus type, the values for each of the five measured parameters were tabulated according to mean, range etc., from which the general characteristics of each type were identified.

4. RESULTS

4.1 Overall Characteristics

Based on the measured parameters, there are clear differences between the three nucleus types studied (Table 1). The main differences are in the size of the freshwater portion of the nucleus, and the size of the nucleus up to the end of the first year of life.

Intermediate nuclei are distinguished by a small freshwater nucleus and a large first year annulus. The freshwater nucleus usually consists of between 5 and 14 circuli, with a radius of between 17 and 47 units. The first annulus generally lies between the 24^{th} and 42^{th} circuli, with a radius between 65 and 150 units. This reflects the growth pattern during the first year of life, which consists of a relatively short period of slow growth in fresh water followed by a somewhat longer period of more rapid growth once the young fish enters the sea.

Stream nuclei have a relatively large freshwater nucleus, which includes the first annulus, indicating that the fish spent all of its first year of life within fresh water. The first annulus falls between the 9th and 23rd circuli, at a radius of between 21 and 64 units. Since there is virtually no overlap between these measurements and the corresponding figures for intermediate nuclei, the location of the first annulus provides a clear-cut measurement for distinguishing between intermediate and stream nuclei.

TABLE 1. Values of five scale nucleus parameters for three different nucleus types. Values shown are the mean ± 1 S.D., and the range enclosing the central 99% of the measurements.

		Nucleus type	
Parameter	Intermediate (n=636)	Stream (n=424)	Hatchery (n=746)
N_f	9.4 ±1.8 (5 - 14)	16.8 ±3.2 (9 - 23)	22.5 ±3.7 (13 - 32)
N_1	33.2 ±3.7 (24 - 42)	15.7 ±2.0 (11 - 21)	22.6 ±3.6 (14 - 32)
R_f	31.6 ±6.0 (17 - 47)	42.2 ±8.6 (21 - 64)	66.8 ±13.8 (32 - 101)
R_1	109.8 ±18.3 (65 - 156)	39.5 ±6.3 (24 - 55)	67.2 ±13.7 (33 - 101)
R_{15}	50.0 ±6.5 (35 - 66)	38.2 ±4.0 (28 - 48)	45.8 ±4.9 (34 - 58)

Scales from hatchery fish show an extended freshwater nucleus containing up to 32 circuli, with a radius of up to 100 units, significantly larger than in stream and intermediate nuclei. The first annulus is generally found on, or close to, the edge of the freshwater nucleus, and the two points may be indistinguishable. This pattern is consistent with rearing and release practices at most hatcheries, which involve holding fish for 8-12 months and releasing them in late autumn or early winter, by which time growth has slowed to a minimum. By the end of their first year, hatchery fish have grown larger than wild fish which remained in fresh water, but not as large as wild fish which went to sea at an earlier stage and were able to benefit from an extra six months of growth at sea.

4.2 Cluster Analysis

A preliminary analysis of the 1973-75 data was conducted using a cluster analysis routine implemented in the statistical package SYSTAT. Given a set of measurements, this routine looks for natural groupings which occur in the data by searching for subsets of the data which fall into two (or more) essentially disjoint groups.

Applied to the 1973-75 data, this analysis identified two natural groupings in the data, corresponding almost perfectly to the two scale types (intermediate and stream). Out of 929 scales, 921 (99.1%) were classified correctly.

5. DISCUSSION

The differences between the three scale nucleus types summarised in Table 1 suggest that the five parameters measured in this study capture a good proportion of the essential characteristics which contribute to the visual appearance of each nucleus type. Although recognising the edge of the freshwater nucleus and the location of the first annulus requires a degree of subjective judgement, the results of this study show that these judgements can be put on a sound quantitative footing.

The next stage of the study is to develop the cluster analysis approach further, so that it can be applied to populations containing a mixture of wild and hatchery fish in which all three nucleus types are present. Because the characteristics of hatchery nuclei overlap those of both intermediate and stream nuclei, a more formal approach will be required. Cluster analysis provides a means for detecting groupings within existing data, but does not lead to a predictive model which can be applied to other data sets. By employing more powerful analytical methods (based on linear discriminant analysis), it should be possible to derive a set of purely arithmetic criteria for distinguishing the three scale types.

The ability to distinguish between wild and hatchery salmon is crucial to managing the salmon resource. This study aims to develop a powerful tool for identifying wild and hatchery fish with a high degree of confidence, in a much more objective way than has been possible to date. Given the high incidence of hatchery fish shown by preliminary readings of scale samples from salmon returning to fresh water in 1989 and 1990, and the level of concern about the state of the wild stock, there is a clear need for independent confirmation and validation of the scale-reading techniques used.

6 CONCLUSIONS

- Analysis of scale nuclei provides a means of classifying adult salmon according to their freshwater life history. Three main categories of nucleus can be identified, and are known as "intermediate", "stream", and "hatchery" nuclei.

- Recent increases in the incidence of hatchery-origin salmon, and concern about low numbers of wild salmon returning to fresh water, have highlighted the need to develop a more quantitative approach to scale reading.

- Measurements of scale nuclei collected from wild salmon caught between 1973 and 1975, and coded-wire tagged salmon known to be of hatchery origin, demonstrate how such an approach could be developed. The key features to identify and measure in the nucleus are the transition from fresh water to salt water, and the end of the first year of life.

- Further research is needed to develop analytical techniques for separating mixed populations of wild and hatchery fish.

7 ACKNOWLEDGEMENTS

Thanks are extended to Malcolm Flain for undertaking the painstaking task of reading and measuring scales.

REFERENCE

Unwin, M.J., Lucas, D.H., and Gough, T. 1987. Coded-wire tagging of juvenile chinook salmon (*Oncorhynchus tshawytscha*) in New Zealand, 1977-86. *N.Z. Fisheries Technical Report No. 2.* 24 p.