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A test of the reliability of otolith and scale readings of chinook salmon (*Oncorhynchus tshawytscha*)

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Abstract The reliability of otolith and scale readings of Rakaia River chinook salmon, *Oncorhynchus tshawytscha*, were tested. One experienced reader aged samples of 405 and 508 adult fish of known age, from otoliths and scales, virtually 100% correctly. Ages estimated from scales from 402 adult fish of unknown age, read in triplicate, were in complete agreement 92.5% of the time. The freshwater life history type was consistently identified for 90.6% of the fish on the basis of pattern of scale circuli in the first year's growth. A comparison of these results with those in the literature indicates that fish aging by one experienced reader was more precise and more accurate than by combined efforts of several readers.

Keywords aging; Rakaia River; coded-wire tags; chinook salmon; *Oncorhynchus tshawytscha*; otoliths; scales; accuracy; precision

INTRODUCTION

In their broad survey of the scientific literature on the age of fish in the Northern Hemisphere, Beamish & McFarlane (1983) were highly critical of the fact that relatively few authors had adequately validated the method of age determination used in their analysis. They emphasised that accurate ages are essential to management and understanding of fish populations, a stipulation which we completely endorse.

The criticism by Beamish & McFarlane (1983) could rightly have been directed at most of the published New Zealand works containing information on the age of fishes, of both freshwater and marine stocks. For example, earlier salmonid studies by Godby (1919), Finlay (1931), Parrott (1934), and Stokell (1962) did not validate the method of age determination. Somewhat later, modest attempts were made by various workers (Burnet 1969; Parrott 1971; Flain 1972) to ascertain the accuracy of age determinations of salmonids by examining small samples of known-age fish in a population. A more complete attempt to validate scale ages by Bilton et al. (1983) provided some evidence of age validation, though the accuracy of this study was weakened by the inclusion of scales from several populations in the sample.

In the present study, scales from a single stock of adult chinook salmon, *Oncorhynchus tshawytscha*, of known and unknown ages were read by one of us (MF) to test the precision and accuracy of age determination and the precision of classification of freshwater life history types. Age estimates determined from otoliths were compared to ages estimated from scales.

METHODS

The otolith and scale samples were taken exclusively from chinook salmon from the Rakaia River, a large braided river system situated on the east coast of the South Island, New Zealand.

A total of 405 fish of known age was aged using otoliths and 508 fish of known age were aged from scales, with no knowledge of the fishes' length. Samples were collected from 1980 to 1985 (Table 1). All fish were part of the large numbers of fish which were coded-wire tagged as smolts, primarily at the Glenariffe Salmon Research Station, to determine the rate of adult returns in relation to time and size at release of smolts (Unwin 1985). Both otoliths and scales were read without any prior knowledge of the actual age.

The precision of age estimates and of life history determinations was determined for 402 angler-caught

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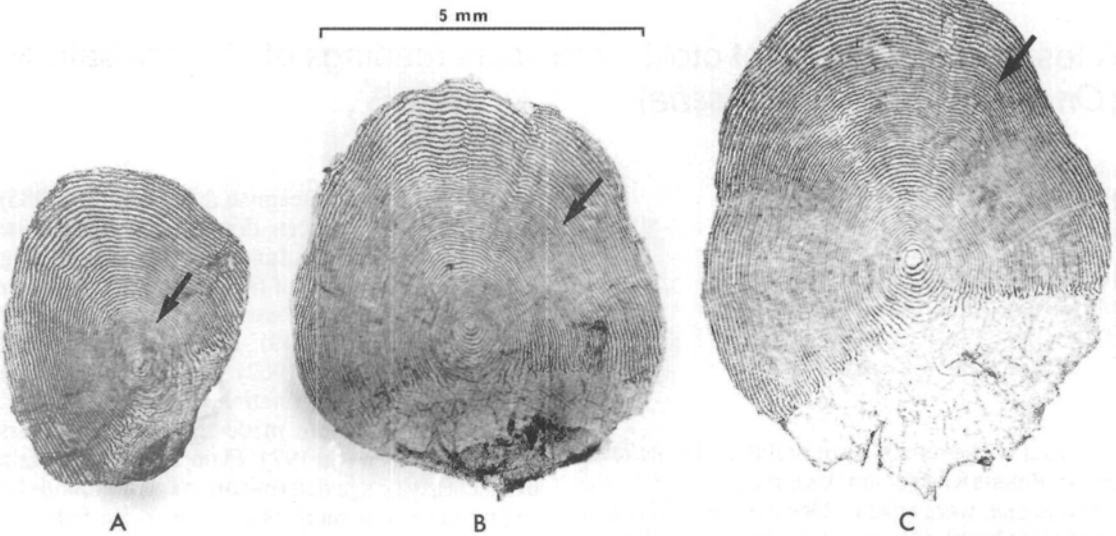

Fig. 1 Scales of 2-year-old Rakaia River chinook salmon showing the different freshwater life history types: A, stream; B, intermediate; C, ocean. Arrows indicate location of first annulus.

Table 1 Percentage by age per year of Rakaia River chinook salmon determined from coded-wire tag returns (unbracketed) and from otoliths and scales (both bracketed).

Year	Age of fish (Years) 2	3	4	Total
Otoliths				
1981	15.1 (15.1)	82.5 (82.5)	2.4 (2.4)	126
1982	13.5 (13.5)	62.2 (62.2)	24.3 (24.3)	148
1984	40.5 (39.7)†	56.5 (56.5)	3.0 (2.3)†	131
				405
Scales				
1980	83.8 (83.8)	16.2 (16.2)	–	111
1983	72.8 (72.5)†	22.7 (22.7)	4.5 (4.5)	334
1985	15.9 (15.9)	77.8 (76.2)†	6.3 (4.8)†	63
				508

† Indicates a single aging discrepancy

fish. Three determinations were made for each fish, separated by four years between replicates (1974, 1978, and 1982).

Scale patterns were classified as one of three types (Fig. 1):

(A) stream type consisting of closely spaced circuli to the first annual check ring, which was considered to be indicative of relatively slow freshwater growth;

(B) intermediate type where only a portion of the circuli were closely spaced, the remainder to the first annual check ring being more widely spaced, indicative of faster growth in the sea;

(C) ocean type in which most of the circuli to the first annual check ring were widely spaced, indicating a very early move to sea.

All otoliths were read without magnification using transmitted light, with the end of each summer's growth identified as the outer edge of the dark zones (Fig. 2). Annuli in otoliths of New Zealand chinook salmon are easily distinguished, in contrast to the opaque otoliths frequently found in North American stocks (Chilton & Bilton 1986). All scale samples were read with a Maruzen scale projector at a magnification of ×38.

The low variability in both the otolith and scale data did not warrant application of statistical tests.

RESULTS

Accuracy of aging

Accuracy in aging Rakaia River chinook salmon was high for both the otolith and scale readings. Of the several hundred fish aged by either method, only two fish were aged incorrectly from otoliths and three fish were incorrectly read from scales (Table 1). Errors in aging from otoliths included a 3-year-old fish read as a 2, and a 4-year-old fish read as a 3. In the first instance the otoliths were inadequately cleaned before reading, and were confirmed as those of a 3-year-old fish after cleaning.

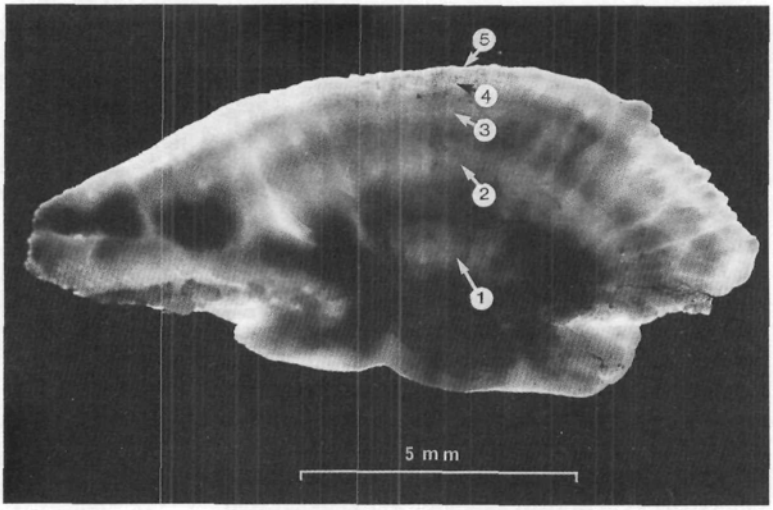

Fig. 2 Otolith of a 5-year-old Rakaia River chinook salmon.

Inaccuracies in aging chinook salmon from scales consisted of a 2-year-old read as 3, and two 3-year-olds read as 4. The error in aging one of the latter two resulted from the difficulty in distinguishing the scale circuli pattern of a 3-year intermediate from that of a 4-year stream type fish.

More than 90% of the fish were 2 and 3 years old in all but the 1982 returns (Table 1). The relatively young age composition of these samples may have helped to minimise errors in aging. However, even with the 4-year-old fish in the samples, accuracy in aging was virtually 100%.

Precision of readings

Good precision was achieved between replicates in aging and identifying freshwater life history of Rakaia River chinook salmon from scales. When the results are expressed as a percentage for each of the age classes of the 402 scale samples read, the inconsistencies between replicates are not greater than 1% for age determinations and 3% for identification of life history type (Table 2). Complete agreement between all three replicates was obtained for 92.5% of the total sample by age and 90.6% by life history type. The inconsistencies resulted from samples being misread, difficulty in distinguishing between intermediate and stream life history types, and erosion of scale edges.

DISCUSSION

The present study clearly demonstrates that an experienced reader can achieve high accuracy in aging, and can maintain good precision in aging and assigning life history type for large numbers of chinook salmon from a single population. Such confirmation will be important in future studies requiring determination of age composition and freshwater life history type of chinook salmon populations for which known-age fish are not available.

We believe that accuracy in aging sea-run chinook salmon from other New Zealand rivers (e.g., Waimakariri, Rangitata, Waitaki) by an experienced scale reader would be similar to that obtained in this study, because of the similar age composition and freshwater life history of these runs (Flain 1972; Davis et al. 1986). An exception to this may be sea-run populations with an extended freshwater residence (M. Flain unpubl. data), as occur in the lower Clutha, Moeraki, and Paringa Rivers in the South Island. Fish from these populations possess greater complexity and variability in scale pattern. Scales from one of these populations were included in a sample of 34 fish of known age analysed by Bilton et al. (1983), for which 5 readers scored an average aging accuracy of 88% and a precision in assigned ages between readers of 77%.

Table 2 Precision in aging and in assigning freshwater life history type for scales from 402 Rakaia River adult chinook salmon. Values are percentage of total sample in each age class.

	Age of fish (Years)				Type of scale		
Year	2	3	4	5	Stream	Intermediate	Ocean
1974	11.7	61.7	26.4	0.2	34.1	65.9	0.0
1978	12.5	61.9	25.4	0.2	33.6	66.4	0.0
1982	11.9	61.0	26.1	1.0	31.1	68.9	0.0

The accuracy that one might obtain in aging wholly freshwater resident chinook salmon, as occur in Lakes Coleridge and Wakatipu in the South Island, is uncertain. As yet, the aging of these populations has not been validated. However, an examination of scales and otoliths from fish of these lakes by one of us (MF), suggests that they can be read by an experienced reader with an accuracy and a precision similar to that reported here for sea-run fish.

Accuracy in aging North American chinook salmon was less than that obtained in this study. Godfrey et al. (1968) reported an average accuracy of 75% in aging fish of known age from scales, although their approach suffered from the variable experience of several scale readers. Chilton & Bilton (1986) reported an average accuracy of 91% for age determinations from dorsal fin rays of several chinook salmon stocks in British Columbia. They emphasised that accuracy in aging North American salmon stocks from scales would be less, particularly for older fish, because of scale resorption. The incidence of 4-year-old chinook salmon in New Zealand has been found to be underestimated by c. 5% from scale readings owing to scale resorption (unpubl. data D. H. Lucas, Ministry of Agriculture & Fisheries, Freshwater Fisheries Centre, Christchurch). Accuracy in aging in this study was not significantly affected by scale resorption. It is interesting that for Rakaia River chinook salmon of unknown age, the level of agreement in assigning ages to scales by several scale readers (Bilton et al. 1983) was similar (range 70-79%) to that reported by Godfrey et al. for North American stocks. Their scores are appreciably less than the 92.5% agreement obtained between replicate readings by one reader from scales in this study. These differences lead us to suggest that accuracy and precision of fish otolith and scale readings by one experienced reader will invariably be better than those from several readers, of varying experience, combined.

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