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by

G.D. James

K.R. Deverall

Freshwater Fisheries Centre

MAFFish

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SUMMARY

This report presents information on quinnat salmon spawning runs in the lower Waitaki and Hakataramea Rivers (lower Waitaki system) from 1959 to 1986. Data on age, size, and sex of both angler-caught salmon and carcasses, together with counts of redd numbers, were used to estimate the number of spawners and emergent juveniles.

Fewer than 1% of spawners were 5 years old. The majority (65%) were 3 years old, followed by 27% at 4 years, and 8% at 2 years old. The proportion in each age group varied significantly from year to year. Although males tended to be longer and heavier than females, mean length and weight varied between years, and the salmon were particularly large in 1978. The sex ratio of angler-caught salmon was usually 50:50, but ratios for carcass recoveries were biased in favour of males.

The estimated number of spawning salmon in the lower Waitaki system from 1975 to 1986 ranged approximately from 4200 to 16 200 per year (mean 10 000), with corresponding numbers of emergent fry ranging from about 8 million to 32 million (mean 20 million). The most realistic estimate on which to base recommendations for a residual river is thought to be 16 000 spawners, which would produce 32 million emergent fry. However, on average, about 12.3% of spawning in the lower Waitaki system took place in the Hakataramea River. Thus, if a residual river is to be incorporated in a lower Waitaki River hydro-electric power scheme, it would need to be able to accommodate up to 14 000 spawners and 29 million fry.

1. INTRODUCTION

A major hydro-electric power scheme has been proposed for the lower Waitaki River. It has been suggested that, should development proceed, the existing salmonid stocks might be maintained within a residual river carrying a fraction of the present flow (Graynoth *et al.* 1981). However, more information was needed on the number and size of quinnat salmon returning to spawn, in order to estimate the salmon spawning and rearing areas required within the residual river.

In this study, we investigated several aspects of the spawning run of quinnat salmon into the lower Waitaki River and its major tributary, the Hakataramea River, including size, age, and sex of angler-caught salmon and spawned-out carcasses, and the number of redds constructed by spawning fish.

Historically, the Hakataramea River (Fig. 1) is the most important spawning tributary of the lower Waitaki River and it was the site of the first quinnat salmon hatchery in New Zealand. Redds in the Hakataramea have been surveyed annually since 1959, usually by taking a single count late in May. Because the timing of spawning and the visibility of redds has changed, year-to-year comparisons of redd counts were only approximate, and the total annual run into the river had not been estimated because it was not known what proportion the single counts were of the yearly total. Hence a series of foot counts was carried out over the 1983 and 1985 spawning seasons to gather information on redd visibility, superimposition of redds, and timing and distribution of spawning, as a basis for estimating the total run.

This report presents the results of spawning surveys in the Hakataramea and lower Waitaki Rivers from 1959 to 1986. These data are used to estimate the number of spawning salmon and the resulting number of emergent fry that a residual river could be expected to support.

2. METHODS

2.1 Biological Data Collection

Scale samples were taken from salmon caught by anglers in the lower Waitaki River between 1976 and 1983, and details of the length, weight, and sex of these fish were recorded. Age was determined from the scales, and the early life history in fresh water was derived from the scale nuclei, which were classified as:

(a) Ocean-type nuclei - showing no period of freshwater residence.

(b) Intermediate-type nuclei - showing a period of freshwater residence, thought to be a few months, before entering the sea.

(c) Stream-type nuclei - showing a period of freshwater residence, including the first winter check, before entering the sea.

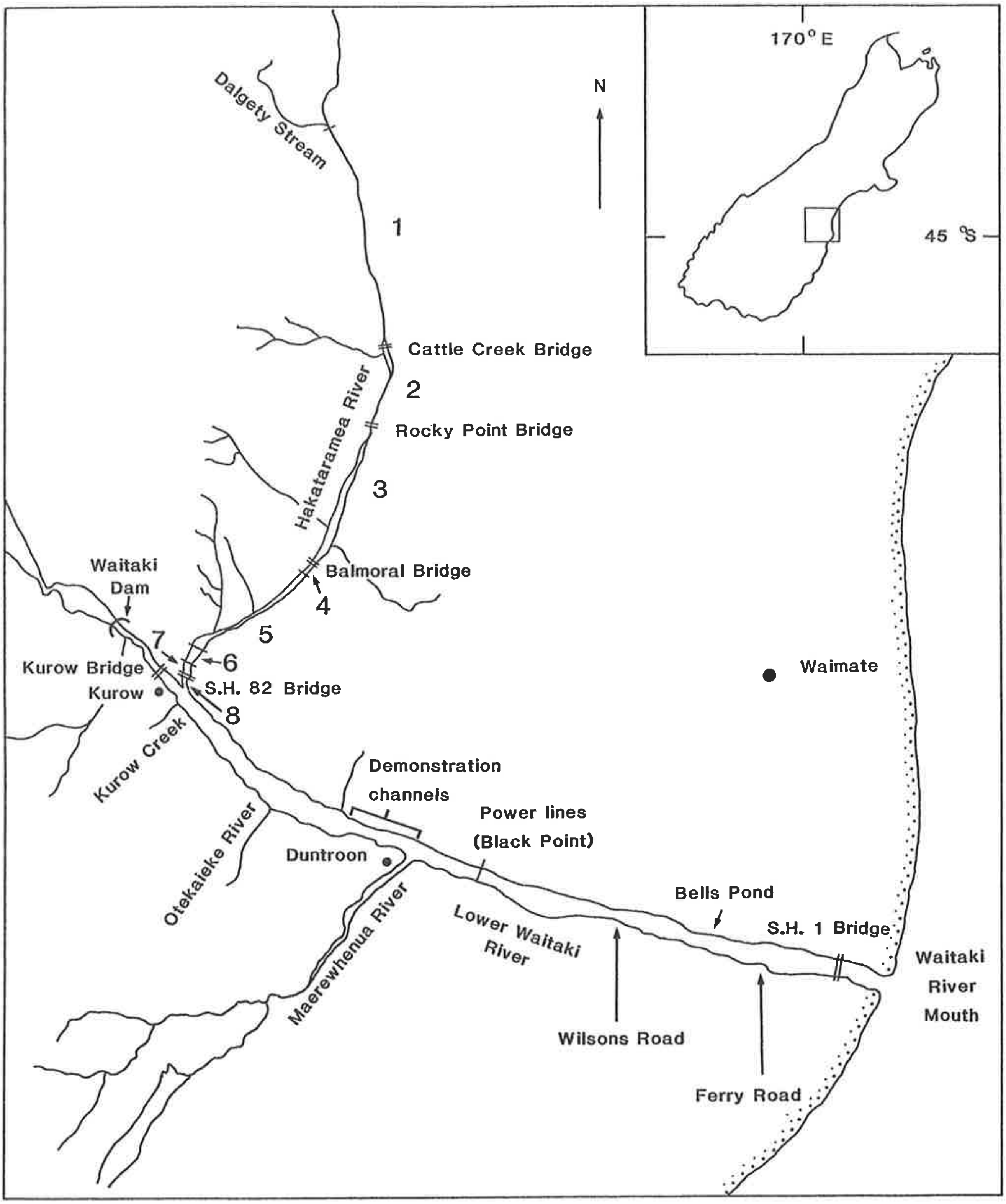

FIGURE 1. Map of the lower Waitaki River and tributaries, showing the survey reaches.

Carcasses were recovered in 1981-83 from the Hakataramea riverbed and from a wire mesh fence spanning the river about 200 m downstream from the State Highway (S.H.) 82 bridge in Reach 8 (Fig. 1). This fence was part of a trap designed to catch adult trout moving upstream. Dead and moribund salmon drifted downstream and collected on the fence, except when the trap was washed out by flood flows. Carcasses were recovered regularly while debris was removed from the fence.

On 31 May and 1 June 1983, carcasses were recovered from the Hakataramea River, between its confluence with Cattle Creek and the adult trout trap. In addition, carcasses were collected during weekly redd surveys in Reaches 4, 6, and 8.

The fork length and sex of each carcass was recorded and the otoliths were removed. Weight was not recorded. Age was determined later from the otoliths. Timing of the appearance of the carcasses was assessed for males and females separately, by graphing cumulative percentages of the number of male and female carcasses recovered from the Hakataramea riverbed during weekly surveys.

2.2 Redd Surveys

From 1959 to 1974, redds were counted on foot 1, 2, or 3 times each year in the part of the Hakataramea River formerly known as the Technical Field Service (TFS) section (Reach 6, Fig.1) (Moore *et al.* 1962, Moore *et al.* 1963, Boud *et al.* 1965, Galloway and Cudby 1965, Wing and Johnson 1966, Dougherty *et al.* 1970, Galloway *et al.* 1970, Dougherty *et al.* 1971, Wing 1972, Boud 1975). Surveys were not conducted in 1969 and 1972. From 1975 to 1986, the entire river was surveyed from a helicopter late in May (Wing and Gledhill 1977, Wing and Gledhill 1978, Wing 1979, Gledhill 1984, James 1985, James 1986, FFC unpublished data), and for this, it was divided into 8 reaches (Fig. 1). To test for year-to-year differences in the distribution of spawning from 1977 to 1986 (excluding 1984), redd counts for the different reaches were compared using a 4 x 9 contingency table analysis (Sokal and Rohlf 1981).

In 1976, 1977, 1978, 1984, 1985, and 1986, a survey of redds in the lower Waitaki River was made from a helicopter (Wing and Gledhill 1977, Wing and Gledhill 1978, Gledhill 1984, James 1985, James 1986). Counting was prevented between 1979 and 1983 by poor water clarity, probably resulting from the upper Waitaki hydro-electric development.

In June 1980, a flood caused the lower Waitaki River to intrude into a portion of the Hakataramea River (the "Hakataramea extension"), some distance above the old river mouth, and this shortened Reach 8 (Fig. 1) from 0.85 km (referred to here as Reach 8a) to 0.70 km (Reach 8b). Since 1984, the Hakataramea extension has been regarded as a side-braid of the lower Waitaki River for the purposes of redd counts.

Two studies were carried out to examine patterns of redd formation and distribution in the Hakataramea. For the first, in 1983, 3 reaches (Reaches 4, 6, and 8; Fig. 1), 1-3 km in length, were surveyed on foot about once weekly. The numbers of new salmon redds, live salmon, and spawned-out carcasses were recorded. So that these redds would not be recounted in subsequent surveys, a 1-m iron rod was driven into the riverbed at the upstream end of each redd. The number of redds in the river, from its confluence with Dalgety Stream to the mouth, was counted from a helicopter on 11 May 1983. This included separate counts of the number of redds in the 3 reaches previously surveyed on foot. Redds were also counted from a fixed-wing aircraft on 31 March and 20 April, and from an inflatable boat on 31 May and 1 June.

The cumulative percentage of new redds in each reach was calculated for each survey date to estimate the peak period of salmon spawning, and to identify differences in spawning time between reaches. In addition, redd counts made from a helicopter in 5 reaches of the Hakataramea River from Cattle Creek to the S.H.82 bridge were compared with those made 3 weeks later from an inflatable boat.

The second study, in 1985, involved counting redds on foot about every 2 weeks, and marking them with iron rods. This provided a total foot count to be compared with the annual helicopter count, as well as yielding information on superimposition.

3. RESULTS AND DISCUSSION

3.1 Biological Data

3.1.1 Limitations of the Information Obtained from Carcasses

Samples of carcasses taken from the Hakataramea River between 1981 and 1983 were found to contain consistently many more males than females, rather than displaying the expected sex ratio of approximately 50:50. More than 60% of the carcasses collected from the riverbed were male, and about 87% of those drifting onto the trap fence were male. It is apparent that, for some reason, male carcasses drift downstream more readily than female carcasses. Also, it seems that not all female carcasses were recovered during sampling in the riverbed, because the number of female carcasses recovered differed from the number of redds counted for any given reach of the Hakataramea River.

Consequently, the carcass samples were thought to be biased, and thus the biological data derived from them have been treated with caution. Where possible, carcass information has been compared with other data to check its validity.

3.1.2 Length and Weight

Appendix I shows grouped length-frequency data by age and sex, together with mean lengths and weights, for salmon caught by anglers in the lower Waitaki River for each year between 1976 and 1983. Mean length was compared between years using Duncan's multiple range test (Larkin 1979), to determine variability in size at age of return. Values were found to vary from year to year, sometimes significantly (Fig. 2). In 1978, both 3- and 4-year-old salmon were much longer than average. However, in 1976 and 1981, they were shorter than average. The mean length of carcasses from the Hakataramea riverbed also varied between years (Table 1).

The mean lengths of salmon from the lower Waitaki and Hakataramea Rivers (Table 1) were compared for 1981-83. Only 1 of 13 tests (3-year-old males in 1983, $t = 3.38$, $p = 0.05$) indicated a significant difference, suggesting that salmon in the lower Waitaki and Hakataramea Rivers are very similar in length-at-age.

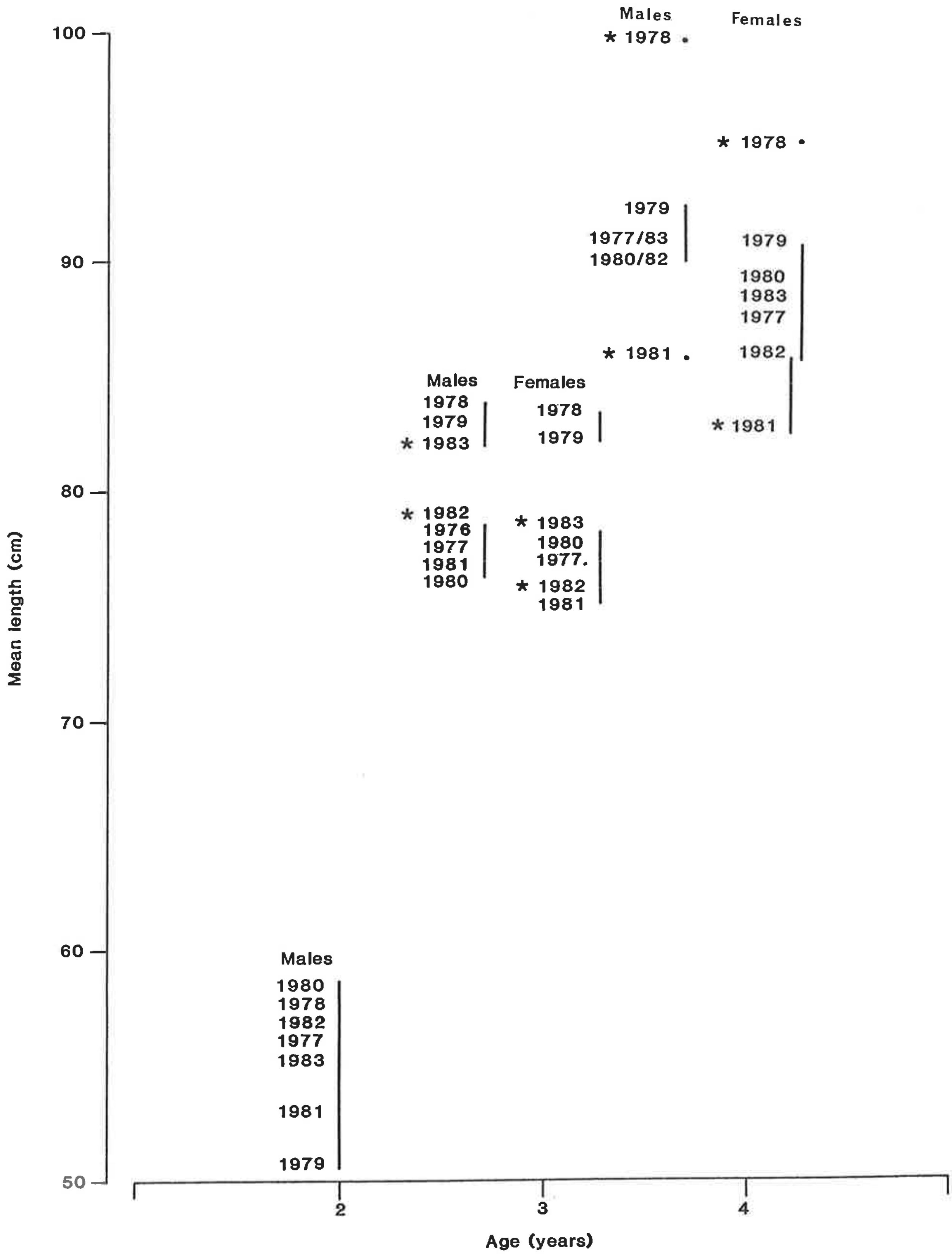

FIGURE 2. Mean lengths in each age class of angler-caught salmon from the lower Waitaki River, 1976-83. Lines join years when mean lengths were not significantly different using Duncan's multiple range test. Asterisks indicate years when males were significantly longer than females at the 95% confidence level.

TABLE 1. Mean length of salmon carcasses from the Hakataramea riverbed and angler-caught fish from the lower Waitaki River, 1981-83

River	1981 Mean length ± 1 S.D.(mm)	1981 Sample size	1982 Mean length ± 1 S.D. (mm)	1982 Sample size	1983 Mean length ± 1 S.D. (mm)	1983 Sample size
2-yr-old males						
Hakataramea	504 ± 60	60	608 ± 98	13	578 ± 82	6
Lower Waitaki	529 ± 82	18	569 ± 112	14	555 ± 136	7
2-yr-old females						
Hakataramea River	438	3	-	-	630	2
Lower Waitaki River	598 ± 66	6	-	-	520	3
3-yr-old males						
Hakataramea River	709 ± 56	13	799 ± 76	55	875 ± 58	51
Lower Waitaki River	767 ± 122	14	784 ± 83	86	820 ± 103	61
3-yr-old females						
Hakataramea River	692 ± 57	7	749 ± 67	39	792 ± 62	34
Lower Waitaki River	752 ± 93	19	756 ± 60	74	781 ± 68	65
4-yr-old males						
Hakataramea River	822 ± 40	24	930	1	941 ± 54	9
Lower Waitaki River	858 ± 55	35	904 ± 86	11	905 ± 78	21
4-yr-old females						
Hakataramea River	784 ± 52	14	930	2	863 ± 46	12
Lower Waitaki River	825 ± 39	20	857 ± 60	7	883 ± 36	25

In both rivers, male salmon tended to be longer than females at a given age (Fig. 2). When mean length-at-age data for 1981-83 (Table 1) were compared, males were found to be significantly longer than females in 7 out of 12 cases (t-test, $p = 0.05$).

Length-weight relationships were developed for angler-caught salmon from the lower Waitaki River (Appendix I) using the GM regression technique of Ricker (1975):

Males	$\log W = 2.56 \log L - 3.59$	($N = 547$, $r = 0.92$)
Females	$\log W = 2.79 \log L - 4.28$	($N = 477$, $r = 0.85$)

Males were generally slightly heavier than females at a given length.

3.1.3 Age Composition

Salmon from the lower Waitaki River were mostly aged 3 years (65.0%), with fewer fish aged 4 years (26.9%) or 2 years (7.7%) (Table 2). The 2-year-olds were mostly males, and the 5-year-olds, which were rare, were exclusively so (Fig. 3). The relative proportion of 3- and 4-year-old salmon in the lower Waitaki River varied greatly between years; the proportion of 3-year-olds ranged from 30% to 88% and that of 4-year-olds from 7% to 63%. However, the proportion of both combined was remarkably constant, varying from 92% to 97% in 9 out of 11 years, with a mean of 92% for the 11 years (Table 2). The exceptions were 1972 (81%) and 1981 (79%), when many 2-year-old fish were present.

Because carcass samples collected from the Hakataramea River during this study were considered to be biased (Section 3.1.1), the resulting age composition data are not included here. The age composition of Hakataramea River salmon runs in 1969-76 was described briefly by Flain (1971), and the proportions of the different age groups were generally similar to those described above for angler-caught salmon from the lower Waitaki River.

Although the age composition of lower Waitaki salmon appears, on average, to be similar to that for the Rakaia (Flain 1982) and Rangitata Rivers (Davis *et al.* 1986), Figure 3 shows that there can be a considerable difference in age composition in any 1 year between different east coast salmon rivers (in this case, the lower Waitaki and

Rangitata Rivers). This is not surprising, but it does emphasise the discreteness of salmon stocks in individual rivers.

TABLE 2. Age composition of angler-caught salmon from the lower Waitaki River, 1970-72 and 1976-83. The 1970-72 data are from Flain (1982)

Year	Age composition (%) 2	3	4	5	Sample size
1970	7.8	82.7	9.1	0.4	231
1971	5.4	60.8	33.5	0.4	278
1972	19.1	56.0	25.0	0.0	84
1976	5.5	87.8	6.7	0.0	90
1977	7.8	29.7	62.5	0.0	64
1978	4.8	46.1	48.1	1.0	104
1979	2.0	77.7	18.8	1.5	197
1980	7.1	50.0	42.9	0.0	182
1981	21.2	30.1	48.7	0.0	113
1982	8.1	82.8	9.1	0.0	198
1983	6.5	68.3	24.7	0.5	186
Mean	7.7	65.0	26.9	0.4	

3.1.4 Freshwater Residence Period from Adult Scales

On average, about half of the adult salmon which returned to spawn in the Waitaki River had scales indicative of a stream-type life history, and around half had scales indicative of an intermediate-type life history. Those with scales indicative of an ocean-type life history were rare. There was a considerable variation between years (Table 3), possibly because of differences in the survival of year classes. The proportions of each life history type differed significantly (χ^2 = 581.8) from those recorded from angler catches on the Rakaia River from 1967 to 1976 (Flain 1982). Intermediate-type salmon were significantly fewer (t = 5.09) and stream-type significantly greater (t = 4.80) in the Waitaki River than in the Rakaia. There was no significant difference in the proportion of ocean-type salmon (t = 0.9).

Waitaki River salmon with stream-type life histories were significantly older (χ^2 = 130) than those with intermediate-type life histories (Table 4). A greater proportion of stream-type salmon returned at 4 years of age, compared to intermediate-type salmon, although the majority of both types returned as 3-year-olds.

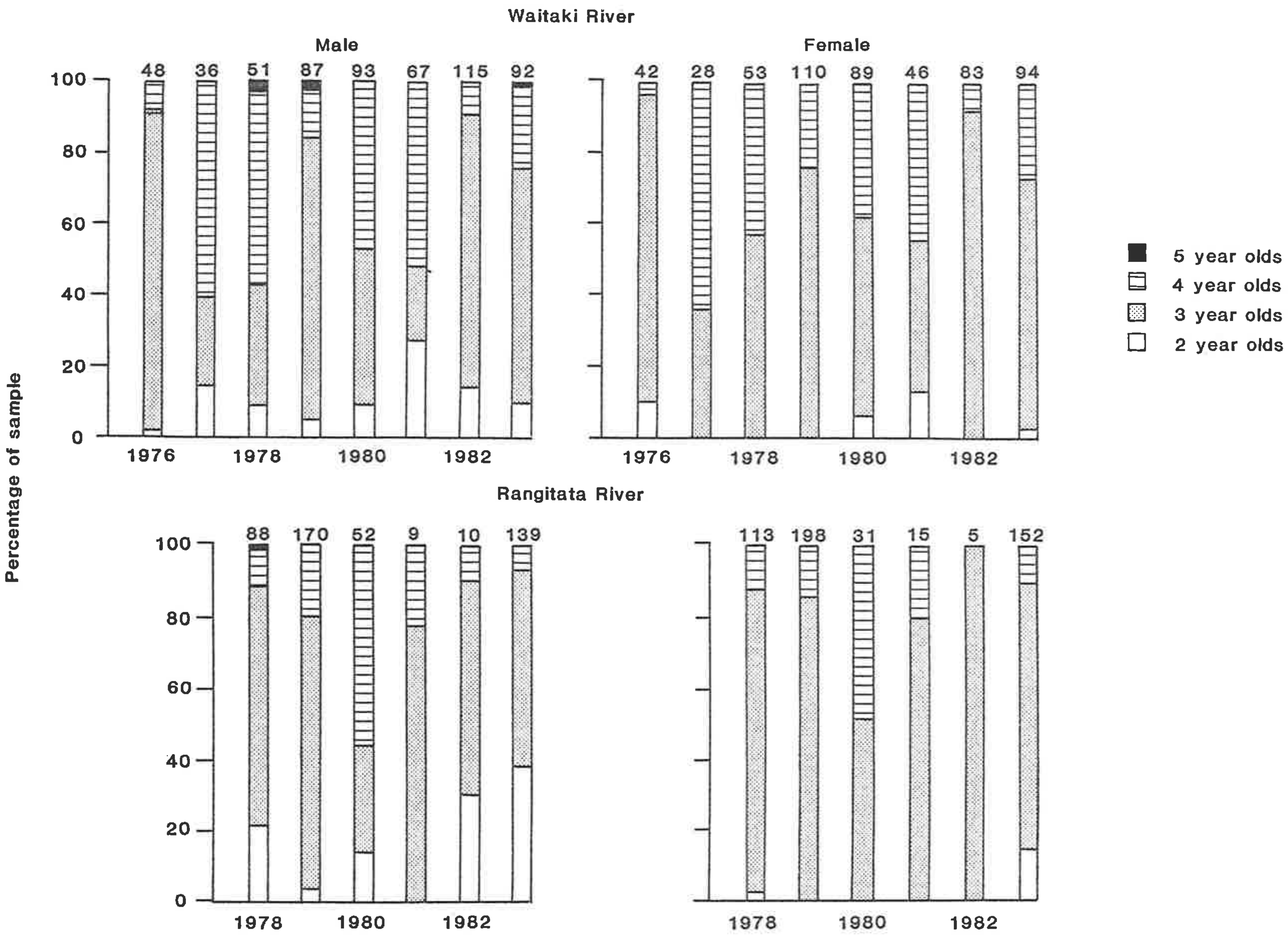

FIGURE 3. Age composition (%) of samples of angler-caught salmon from the lower Waitaki River, 1976-83, compared with samples from the Rangitata River. (Data from Davis *et al*. 1986.)

TABLE 3. Scale nucleus types of angler-caught salmon from the lower Waitaki River

Date	Stream	Nucleus type (%) Intermediate	Ocean	Sample size
1976	26.3	72.6	1.1	95
1977	67.7	30.8	1.5	65
1978	40.6	59.4	0.0	106
1979	39.3	52.9	7.8	206
1980	57.4	41.5	1.1	183
1981	49.6	50.4	0.0	119
1982	65.9	33.5	0.6	182
1983	66.4	33.6	0.0	134
Mean	51.9	46.2	1.9	

TABLE 4. Age frequency (%) of stream-type and intermediate-type salmon in angler catches from the lower Waitaki River, 1976-83

Age (years)	Stream-type salmon	Intermediate-type salmon	Sample size
2	37.8	62.2	82
3	47.6	52.4	645
4	68.8	31.2	327
5	60.0	40.0	5

The mean length of salmon appeared to be positively related to their residence time in the ocean. Those with intermediate-type life histories tended to be larger than stream-type salmon of the same age (Table 5). For instance, 4-four-year-old stream-type salmon which had spent about 3 years in the ocean, tended to be smaller than 4-year-old intermediate-type salmon, which had spent between 3 and 4 years in the ocean.

TABLE 5. Mean lengths (± 1 S.D.) of stream-type and intermediate-type salmon in angler catches from the lower Waitaki River

Age (years)	Mean length stream-type salmon (mm)	Sample size	Mean length intermediate-type salmon (mm)	Sample size
2	486 (± 73)	25	610 (± 60)	48
3	756 (± 81)	287	817 (± 68)	231
4	888 (± 71)	206	920 (± 87)	93

3.1.5 Sex Ratio

The mean sex ratio (% males:% females) of angler-caught salmon from the lower Waitaki River in 1976-83 was 52:48 (range 44:56 to 59:41, N = 1134) (Table 6). The annual ratios for all age groups combined did not differ significantly from 50:50 in any of the 8 years using the χ^2 test. As noted earlier, most 2-year-olds and all 5-year-olds were male. The mean sex ratios for each age group were 79:21 (2 years), 48:52 (3 years), 53:47 (4 years), and 100:0 (5 years) (Table 6).

Good estimates of the sex ratio of spawning salmon are necessary if redd counts representing female fish are to be extrapolated to estimates of the total number of spawners, both male and female. Overseas information for chinook or quinnat salmon indicates that the sex ratio over several years is close to 50:50, despite yearly variation (Cramer and McPherson 1981). Within New Zealand, data from the Glenariffe trap on the Rakaia River, collected over the period from 1965 to 1978 (Flain 1982), gave an overall ratio of 50:50 (25 884 fish), although the ratio

TABLE 6. Sex ratio of angler-caught salmon by age group from the lower Waitaki River, 1976-83

Year	Sex ratio (% males:% females) Age 2		Age 3		Age 4		Age 5		Total	
1976	20:80	(5)	54:46	(79)	67:33	(6)		(0)	53:47	(90)
1977	100:0	(5)	47:53	(19)	55:45	(40)		(0)	56:44	(64)
1978	100:0	(5)	37:63	(48)	54:46	(50)	100:0	(1)	49:51	(104)
1979	100:0	(4)	45:55	(153)	32:68	(37)	100:0	(3)	44:56	(197)
1980	62:38	(13)	45:55	(91)	56:44	(78)		(0)	51:49	(182)
1981	75:25	(24)	41:59	(34)	64:36	(55)		(0)	59:41	(113)
1982	100:0	(16)	54:46	(164)	61:39	(18)		(0)	58:42	(198)
1983	75:25	(12)	48:52	(127)	46:54	(46)	100:0	(1)	50:50	(186)
Total	79:21*	(84)	48:52	(715)	53:47	(330)	100:0	(5)	52:48	(1134)

* χ^2 test indicates that this ratio is significantly different from 50:50 at 95% confidence level.

in individual years varied from 62:38 to 40:60. Data from runs in the Rangitata River over 12 seasons (Davis *et al.* 1986) also showed a mean ratio approaching 50:50 (mean 48:52, range 67:33 to 35:65, N = 2031).

Most of the information available on salmon in the lower Waitaki system indicates a sex ratio of about 50:50. As noted above, the sex ratio of angler-caught salmon from the lower Waitaki River for 1976-83 was 52:48,and a trap on the lower Hakataramea River in 1983 gave a ratio for 78 salmon of 54:46 (FFC unpublished data). Another trap was installed in a similar position over the later part of the run in 1985, and this gave a ratio of 50:50 for 451 salmon (Waitaki Valley Acclimatisation Society 1985, G. Hughes pers. comm.). Flain (1971) reported a sex ratio of 53:47 for 712 salmon sampled from Hakataramea River runs in 1969, 1970, and 1971. As noted in Section 3.1.1, considerably more male than female carcasses were recovered from the Hakataramea River during this study, but because the sex ratios estimated from carcass recoveries vary from the live fish estimates discussed above, they are considered to be anomalous.

In conclusion, the best information available indicates that the average sex ratio in the Hakataramea and lower Waitaki Rivers is about 50:50, but this can vary greatly from year to year.

3.2 Redd Surveys

3.2.1 Hakataramea River Surveys

The number of redds counted from a helicopter in the Hakataramea River from 1975 to 1986 ranged from 77 to 470 (Table 7). Earlier counts, made in Reach 6 from 1959 to 1971, (Fig. 1), ranged from 29 to 460 (Table 7).

In 1983, the helicopter count agreed closely with the number of redds counted in foot survey reaches (Table 8), although only 42.4% of redds had been deposited by this date. When spawning was complete, the counts were 16 for Reach 4, 56 for Reach 6, and 265 for Reach 8 (Table 8). Combining these numbers, and dividing by the proportion seen in the reaches on 11 May 1983 (0.424), gave a total estimated redd count of 795 for the Hakataramea River in 1983. In 1985, about 80% of the run had occurred by the helicopter survey date, and there was a considerable difference between the helicopter and foot counts (Table 9).