AGE AND LENGTH COMPOSITION OF COLUMBIA BASIN SPRING CHINOOK SALMON SAMPLED AT BONNEVILLE DAM IN 1990

Technical Report 91-1

Jeffrey K. Fryer
Matthew Schwartzberg

March 15, 1991

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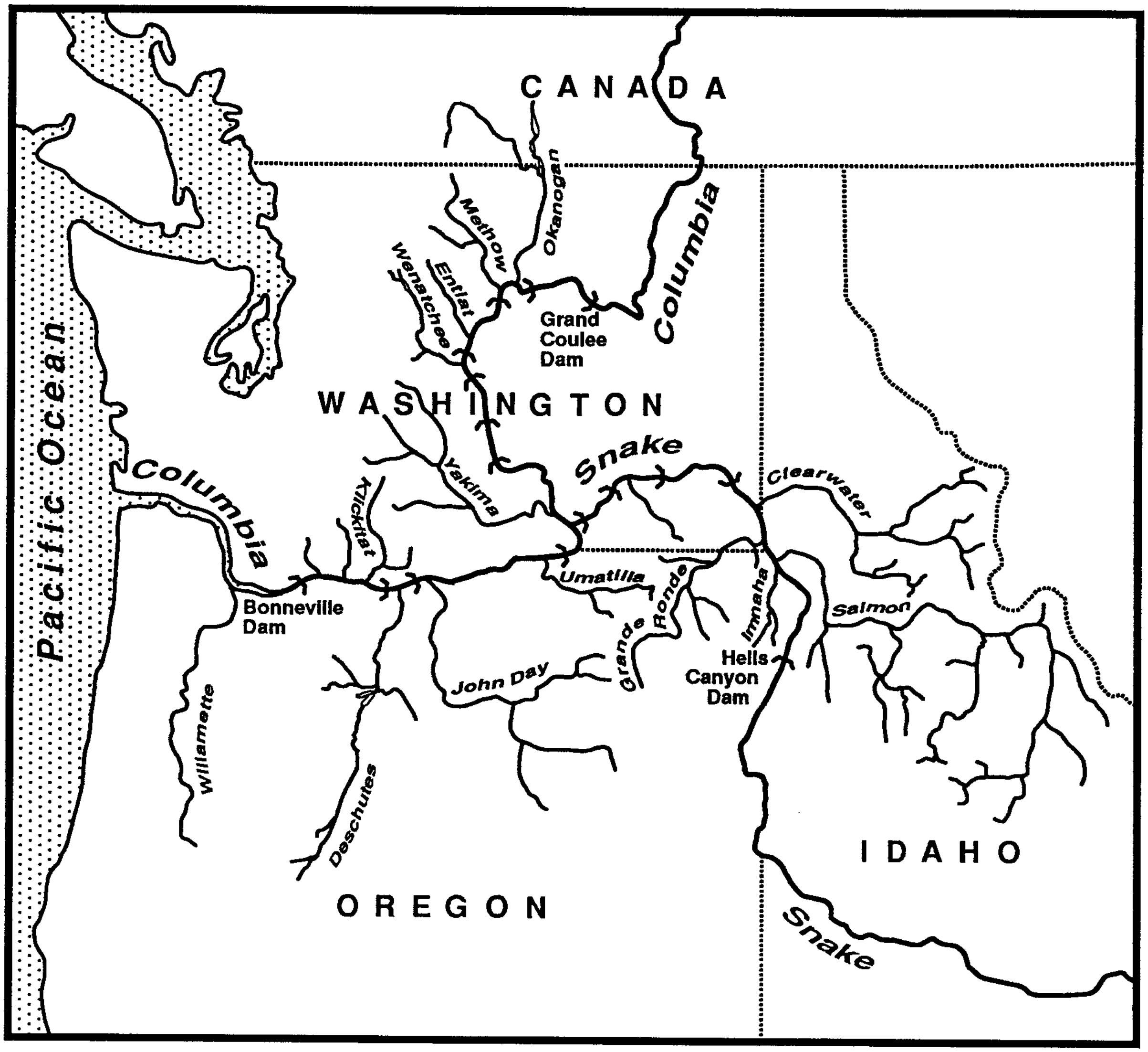
INTRODUCTION

The Stock Assessment Project of the Columbia River Inter-Tribal Fish Commission is a part of the U.S.-Canada Pacific Salmon Treaty spawning escapement monitoring program (Pacific Salmon Treaty 1985). A principal aim of the project is the design and development of salmon stock identification techniques. Experiments will also be made in the application of these techniques to individual stocks or groups of stocks of Columbia Basin salmon originating above Bonneville Dam[1], located on the Columbia River at river kilometer 235 (Figure 1).

This report summarizes age and length-at-age composition estimates for spring chinook salmon *Oncorhynchus tshawytscha* (Walbaum) sampled at Bonneville Dam in 1990. Columbia Basin spring chinook salmon are defined as those chinook salmon migrating past Bonneville Dam before June 1. Later migrating Columbia Basin chinook salmon are known as summer chinook (June 1 through July 31) and fall chinook salmon (after July 31). At Bonneville Dam, the spring chinook salmon population is composed of a mixture of both hatchery and natural origin stocks. This research was begun in 1987, and reports of previous results are available (Schwartzberg 1988, 1989; Schwartzberg and Fryer 1990a). Scale pattern analysis was and continues to be the primary study method used.

1. Those stocks originating upstream of Bonneville Dam are regionally referred to as *upriver* stocks.

Figure 1. Map of the Columbia Basin showing principal (upriver) spring chinook salmon spawning and rearing tributaries and Bonneville, Grand Coulee, and Hells Canyon dams.



METHODS

Sampling Methods

To collect a representative sample of the Columbia River (upriver) spring chinook salmon population, fish were trapped at the Fisheries Engineering and Research Laboratory located beside the Second Powerhouse of Bonneville Dam. The U.S. Army Corps of Engineers, the National Marine Fisheries Service, and the Oregon Department of Fish and Wildlife assisted in sampling operations.

Fish were trapped, anesthetized, sampled for scales and biological data, allowed to revive, and then returned to a fishway leading to one of the fish ladders. Six scales per fish were collected to minimize the sample rejection rate (Knudsen 1990). Length measurements were recorded, as were observed mark and/or tag information. Fish were not sacrificed in the study. Therefore, the sex of collected specimens, all in the earliest stages of sexual maturation, could not be determined.

Sample Design

Desired sample sizes were estimated using a method based on Bonneville Dam fish ladder counts (CRITFC 1990). Fish ladder counts are made from visual observations of all upstream migrating salmon (except for an unknown and presumably small number that use the navigation locks for upstream passage or that migrate during certain nighttime hours). The derivation of weekly sample sizes was based on an estimate of the average weekly proportion of the total annual run during the previous ten years. This estimate was weighted post season using a stratified sampling method to account for deviations between estimated and actual 1990 migration (Fryer 1991). To improve the accuracy of weekly age and length-at-age composition estimates, a minimum weekly sample size of 50 was collected, when possible. The desired composite sample size, chosen to achieve a minimum overall desired level of precision and accuracy (d=0.05, 90% c.i.) as well as improved weekly estimates, was 812 fish (Table 1). A sample of 703 fish was actually used for age and length-at-age composition estimates made in this study. Differences in desired and collected sample sizes reflected over- or under-sampling in certain weeks and the rejection of unusable scale samples.

Table 1. Sample sizes for Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1990.

Date	Statistical Week[a]	Desired Number[b]	Actual Number
4/04/90, 4/06/90	14	72	47
4/11/90	15	102	89
4/18/90, 4/20/90	16	143	77
4/25/90	17	137	148
5/03/90	18	122	145
5/09/90	19	80	93
5/16/90	20	56	66
5/23/90, 5/25/90	21	50[c]	12
5/31/90	22	50[c]	26
Total		**812[d]**	**703[e]**

a. Statistical weeks are sequentially numbered calendar-year weeks. Except for the first and last week of most years, weeks are seven days long, beginning on Sunday and ending on Saturday. In 1990, for example, Statistical Week 14 began on April 1 and Statistical Week 22 began on May 27.

b. Desired weekly sample proportions and numbers were based on the proportional weekly migration rate for previous years' spring chinook salmon fish ladder counts at Bonneville Dam (ten year average, 1980-1989).

c. A minimum sample size of 50 per week was set to allow for more accurate weekly age composition estimates.

d. The composite sample size was based on the number of samples necessary to obtain a population composition estimate (d=0.05, 90% c.i.). Simulation techniques were used to calculate the composite sample size taking into account errors in run timing prediction (Fryer 1991). A 15% rate of unusable samples was assumed.

e. Differences between the number of samples desired and the number of samples collected and analyzed reflect over- or under-sampling during certain weeks and the rejection of unusable scale samples.

Age Determination

Scales were prepared and mounted according to methods described in Clutter and Whitesel (1956) and the International North Pacific Fisheries Commission (1963). Individual samples were visually examined and categorized using well established scale age-estimation methods (Johnston 1905, Gilbert 1913, Van Oosten 1929). Age estimates were corroborated by personnel at the Harvest Management Division of the Washington Department of Fisheries. Validation of ages (Beamish and McFarlane 1983) was not extensive because very few fish of known age fish were present in the sample.

The method used for fish age description was that recommended by Koo (1955), which is sometimes referred to as the *European* method. The number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The number following the period indicates the number of winters a fish spent in saltwater. Total age, therefore, is equal to one plus the sum of both numerals.

Comparison of Age Composition Estimates

Inter-Annual Age Composition Estimates

Inter-annual age composition estimates for 1987-1990, derived from this and past years using similar techniques, were compiled and reported.

Intra-Annual Age Composition Estimates

Intra-annual age composition estimates obtained from Bonneville Dam scale samples were compared to estimates from two different and independent sources. The first comparison was made to visual Bonneville Dam fish ladder counts. As a regular part of this monitoring program (USACE 1989), spring chinook salmon estimated to be less than approximately 61 cm (24 in) in overall length are separately identified as *jacks*, typically of ages 1.1 and 0.2. An estimate of the proportion of these fish in the Bonneville Dam fish ladder counts was made by dividing the number jacks by the total number of adult and jack salmon counted.

The second comparison was made with estimates obtained from scales collected from the Corbett test fishery, located approximately 32 km downstream from Bonneville Dam. The Corbett test fishery is conducted annually by the Washington Department of Fisheries to collect age-specific population abundance data for spring chinook salmon (Dammers 1990). The data are then used in linear forecasting run-size prediction models based on sibling age-class returns. The sampling period is limited to April 1 through April 30, and 18.42 cm (7.25 in)-mesh gillnets are used.

Length Measurements

Fork lengths were measured to the nearest 0.5 cm. Mean lengths and measurements of variability were calculated for each age class and brood year, by weekly sampling period, and for the composite sample.

RESULTS

Run Timing and Sampling Accuracy

Post-season analysis of the 1990 sample design disclosed a time-related bias because the weekly proportions of the composite sample differed from actual 1990 migratory timing. According to post-season analysis of Bonneville Dam fish ladder counts, that portion of the population migrating in Statistical weeks 15 and 16 was under-sampled while the later migration period, Statistical weeks 18-20, was over-sampled (Figure 2). This resulted in a bias in unadjusted composite sample age and length-at-age composition estimates. The effect of this bias was determined, and results were subsequently adjusted to remove it. Although the difference between adjusted and unadjusted estimates was small, adjusted estimates of total age and length-at-age composition are herein reported.

Age Composition Estimates

From Statistical weeks 20 through 22, many fish of less than 35 cm in length were observed. Some of these relatively small fish, known locally as *minijacks*, were sampled. Examination of minijack scale patterns indicated that most spent their entire lives in freshwater. Therefore, fish of less than 35 cm in length were excluded in the preparation of the reported results.

The estimated[2] proportion of four-year-old fish (the 1986 brood-year group including age 0.3 and 1.2 fish) in the composite sample was 0.83 (Figure 3). This age group was predominant in all of the nine weekly 1990 samples (Table 2, Figure 4). The proportion of four-year-old fish in the weekly samples ranged from 0.68 (Statistical weeks 15 and 21) to 0.92 (Statistical Week 16).

The estimated proportion of five-year-old fish (the 1985 brood-year group including age 1.3 fish) was 0.14. The proportion of five-year-old fish in the weekly samples ranged from 0.07 (Statistical Week 17) to 0.32 (Statistical Week 15).

2. Known-age fish composed only a portion of the sample. Therefore, all scale age and length-at-age composition results reported could not be validated and must be considered estimates.

Figure 2. Actual 1990 migratory timing of Columbia Basin spring chinook salmon compared with sample timing and that predicted by a ten year average of Bonneville Dam fish ladder counts.

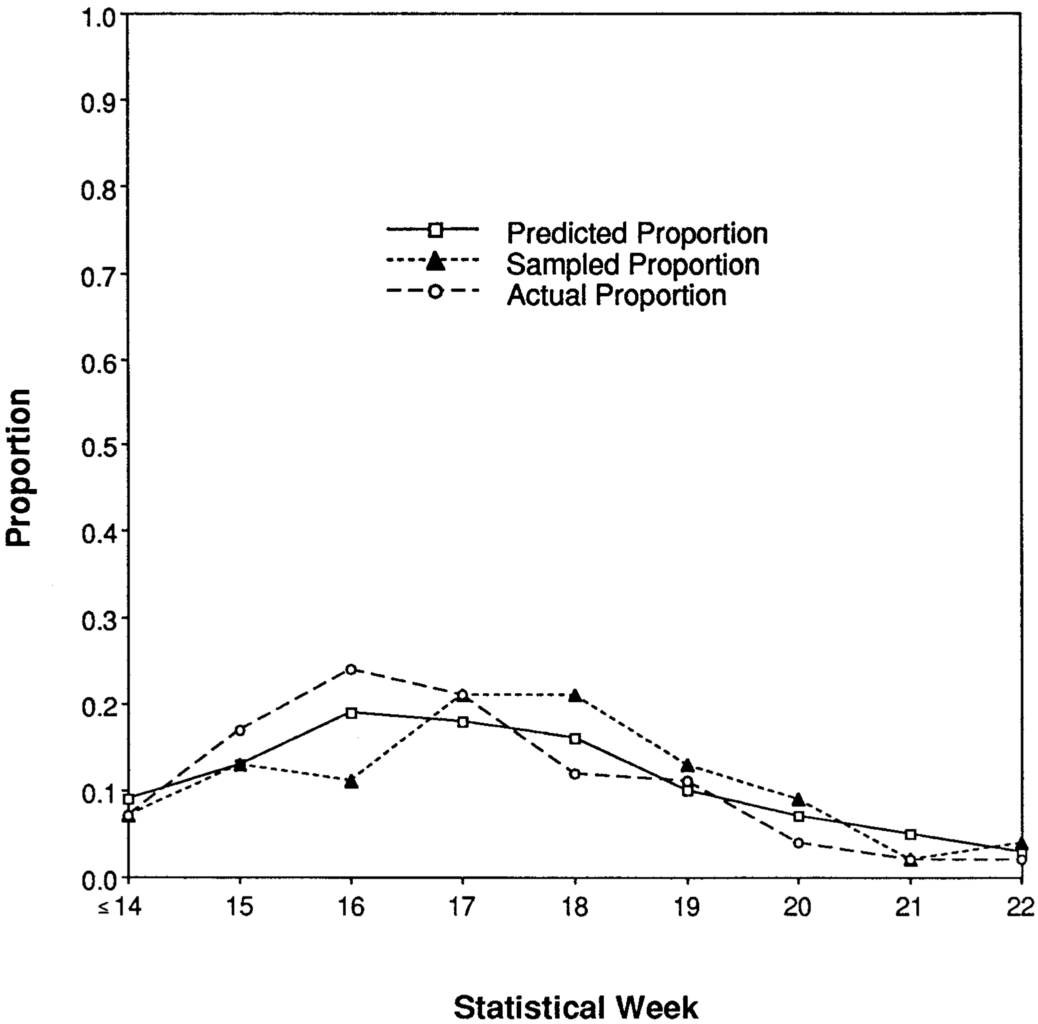


Figure 3. Age composition estimates of Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1990.

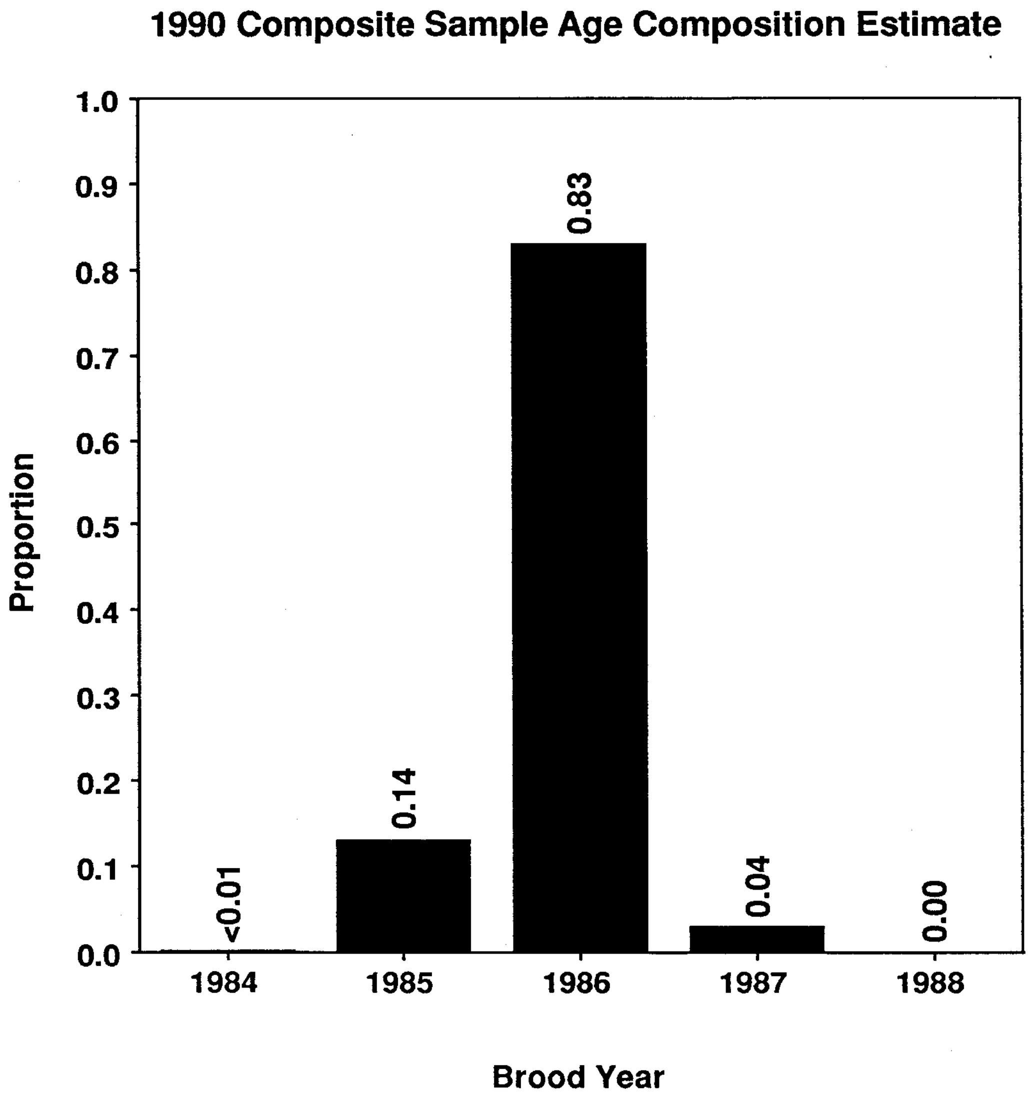


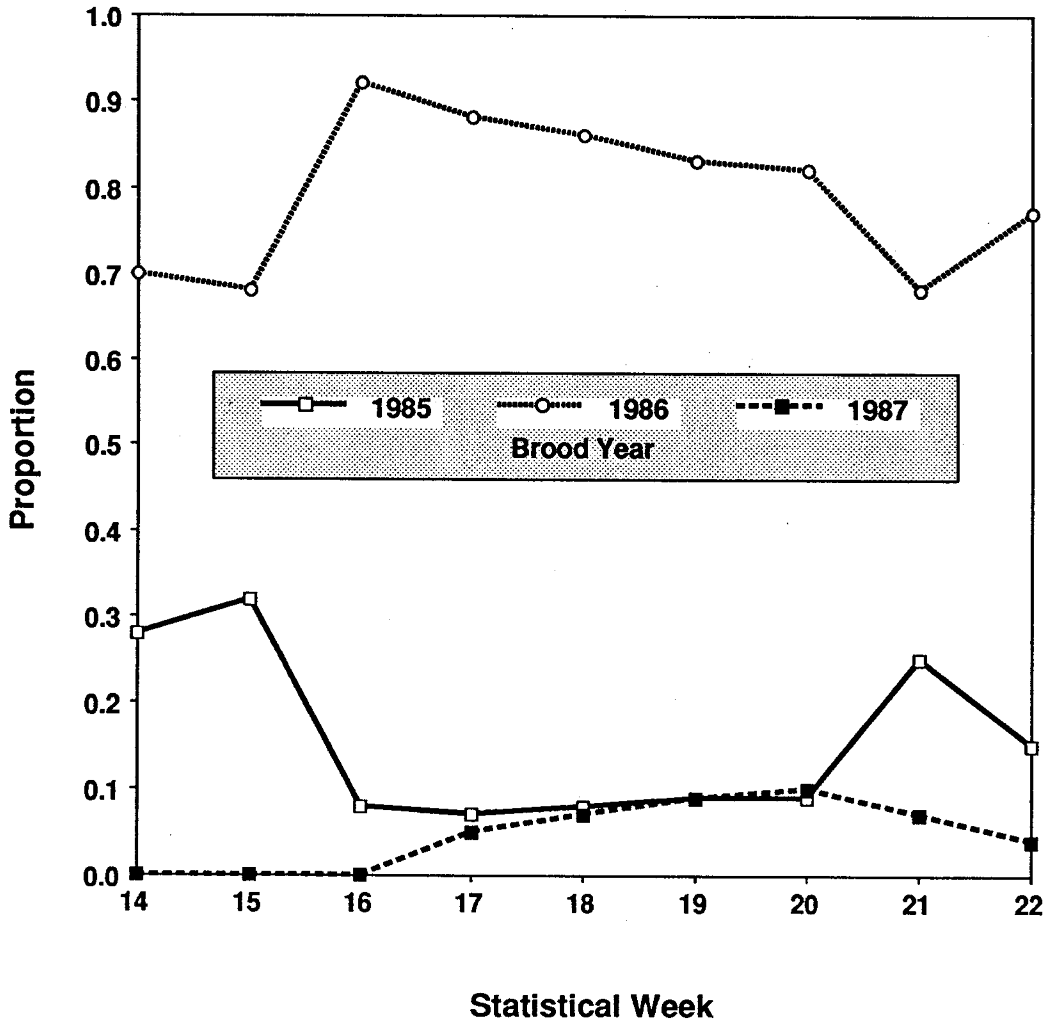
Table 2. **Weekly age composition estimates of Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1990.**

Brood Year and Age Class

Statistical[a] Week	1987 0.2	1987 1.1	1986 0.3	1986 1.2	1985 0.4	1985 1.3	1984 1.4
14				0.70		0.28	0.02
15				0.68		0.32	
16				0.92		0.08	
17	0.02	0.03		0.88		0.07	
18	0.01	0.06		0.86		0.08	
19	0.01	0.08		0.83		0.09	
20	0.02	0.08	0.03	0.79		0.09	
21		0.07		0.68		0.25	
22		0.04		0.77		0.15	0.04
Total Sample	0.01	0.03	<0.01	0.83	0.00	0.14	<0.01

a. Statistical weeks are sequentially numbered calendar-year weeks. Except for the first and last week of most years, weeks are seven days long, beginning on Sunday and ending on Saturday. In 1990, for example, Statistical Week 14 began on April 1 and Statistical Week 22 began on May 27.

Figure 4. Weekly age composition estimates for the three major Columbia Basin spring chinook salmon brood year age classes sampled at Bonneville Dam in 1990.



The estimated proportion of three-year-old fish (the 1987 brood-year group including age 0.2 and 1.1 fish) in the composite sample was 0.04. The proportion of three-year-old fish in the weekly samples ranged from 0.00 (Statistical weeks 14-16) to 0.10 (Statistical Week 20). Two six-year-old fish (the 1984 brood-year group including age 1.4 fish) were sampled in Statistical weeks 14 and 22.

Eight fish, or 0.01 of the composite sample, were judged to be age 0-plus (including six of age 0.2 and two of age 0.3). These fish were believed to have originated at any of several hatcheries presently conducting accelerated rearing programs. Age 0-plus fish were combined with their respective brood-year cohorts in the above summaries. Twelve percent of the total sample was rejected and not classified by age because of unreadable scales.

Comparison of Age Composition Estimates

Inter-Annual Age Composition Estimates

Inter-annual age composition estimates for 1987-1990 are provided in Figure 5. Data for years 1987 and 1988 are slightly different from those previously reported (Schwartzberg 1988, 1989) because of adjustments made to account for differences in actual and predicted migratory timing upon which weekly sample sizes were based.

Intra-Annual Age Composition Estimates

The proportion of three-year-old fish in the composite 1990 sample was estimated to be 0.03. This compares to an estimate of 0.02 based on visual fish ladder counts made at Bonneville Dam. In 1987, 1988, and 1989, adjusted results from our studies estimated that three-year-old fish proportional abundance was 0.04, 0.06, and 0.11, respectively. Visual fish counts estimated proportional abundances of 0.03, 0.04, and 0.07 during those years, respectively.

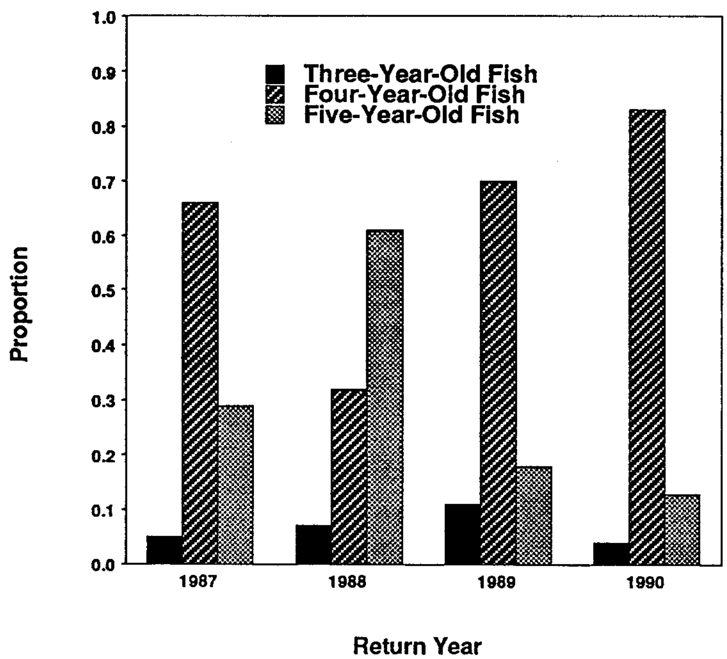
The 1990 Corbett test fishery age composition estimates agreed closely with those of this study after correcting for both the timing of the fishery and for the fact that Corbett gear does not effectively catch smaller fish (Dammers 1990). During the period when the fishery was in operation (Statistical weeks 14-17), and after removal of three-

Figure 5. Age composition estimates of Columbia Basin spring chinook salmon sampled at Bonneville Dam from 1987–1990[a].

Age Class

Year	0.1	0.2	1.1	0.3	1.2	0.4	1.3	1.4
1987	0.00	0.01	0.04	<0.01	0.66	0.00	0.29	<0.01
1988	<0.01	0.01	0.06	0.01	0.31	<0.01	0.61	0.00
1989	0.00	<0.01	0.11	0.01	0.69	<0.01	0.18	<0.01
1990	0.00	0.01	0.03	<0.01	0.83	0.00	0.14	<0.01

Age Composition



a. Estimates for 1987 and 1988 differed slightly from previously reported data (Schwartzberg 1988, 1989) because of adjustments made to account for differences between actual and predicted run timing.

year-old fish from the Bonneville Dam estimate, the proportional age-composition profile was 0.84 four-year-old and 0.16 five-year-old fish compared to the Corbett fishery estimate of 0.80 four-year-old and 0.20 five-year-old fish. The estimated proportion of six-year-old fish for both sample groups was less than 0.01.

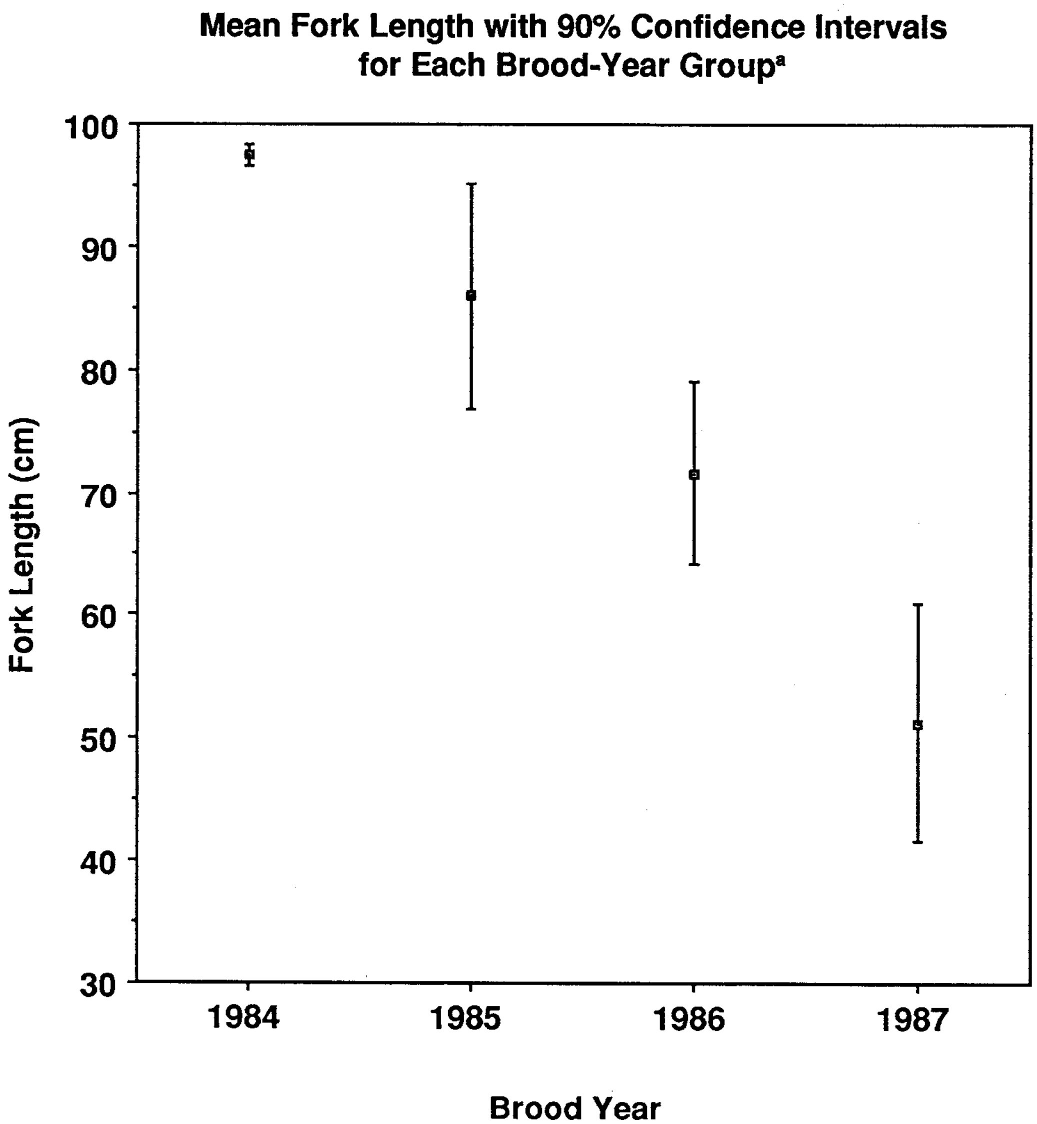
Length-at-Age Composition

The average length of three-year-old fish (1987 brood) in the total sample was 51.3 cm (Table 3, Figure 6). The 90% confidence interval was 41.6 to 60.9 cm (n = 32). The average length of four-year-old fish (1986 brood) was 71.6 cm, with a 90% confidence interval of 64.2 to 79.0 cm (n = 580). The average length of five-year-old fish (1985 brood) was 86.0 cm with a 90% confidence interval of 76.8 to 95.2 cm (n = 89).

Table 3. Weekly and total length-at-age composition estimates of Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1990.

	Brood Year and Age Class						
	1987		1986		1985		1984
	0.2	1.1	0.3	1.2	0.4	1.3	1.4
Stat. Wk. 14							
Mean Fork Length (cm)				72.4		84.2	98.0
Minimum				63.0		81.0	98.0
Maximum				78.5		87.5	98.0
Standard Deviation				3.2		2.4	—
n in Group				33		13	1
Stat. Wk. 15							
Mean Fork Length (cm)				71.5		87.5	
Minimum				62.0		72.5	
Maximum				78.5		97.0	
Standard Deviation				4.1		6.0	
n in Group				61		28	
Stat. Wk. 16							
Mean Fork Length (cm)				71.3		85.5	
Minimum				55.0		75.0	
Maximum				81.0		96.0	
Standard Deviation				4.9		8.5	
n in Group				71		6	
Stat. Wk. 17							
Mean Fork Length (cm)	54.8	53.4		70.6		86.8	
Minimum	53.0	44.0		51.0		78.0	
Maximum	58.0	58.0		80.5		93.0	
Standard Deviation	2.2	5.5		5.1		6.2	
n in Group	3	4		131		10	
Stat. Wk. 18							
Mean Fork Length (cm)	58.0	49.8		72.5		85.9	
Minimum	58.0	42.0		57.0		76.5	
Maximum	58.0	60.0		82.5		90.0	
Standard Deviation	—	5.7		4.5		4.1	
n in Group	1	8		125		11	
Stat. Wk. 19							
Mean Fork Length (cm)	53.5	49.6		72.3		82.7	
Minimum	53.5	40.0		60.0		67.5	
Maximum	53.5	67.0		83.0		90.5	
Standard Deviation	—	8.3		4.6		7.2	
n in Group	1	7		77		8	
Stat. Wk. 20							
Mean Fork Length (cm)	59.5	50.5	79.0	71.2		84.0	
Minimum	59.5	46.0	73.5	56.0		76.5	
Maximum	59.5	55.5	84.5	80.5		90.5	
Standard Deviation	—	3.4	5.5	5.6		5.1	
n in Group	1	5	2	52		6	
Stat. Wk. 21							
Mean Fork Length (cm)		45.0		70.9		83.0	
Minimum		45.0		67.0		75.5	
Maximum		45.0		76.5		88.0	
Standard Deviation		—		3.5		5.4	
n in Group		1		8		3	
Stat. Wk. 22							
Mean Fork Length (cm)		48.0		72.5		87.4	97.0
Minimum		48.0		60.0		76.0	97.0
Maximum		48.0		83.5		92.0	97.0
Standard Deviation		—		5.6		6.6	—
n in Group		1		20		4	1
1990 COMPOSITE							
Mean Fork Length (cm)	55.7	50.1	79.0	71.6		86.0	97.5
Minimum	53.0	40.0	73.5	51.0		76.8	97.0
Maximum	59.5	67.0	84.5	83.5		95.2	98.0
Standard Deviation	2.6	6.1	5.5	4.5		5.6	0.5
N in Group	6	26	2	578		89	2

Figure 6. Length-at-age composition estimates of Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1990.



a. Age 0-plus fish were included with their respective brood year cohorts.

DISCUSSION

Comparison of the above results to those obtained in the 1987-1989 study years shows variability with no trends yet discernible in composite sample age compositions. In the four study years, 1990 was the one with the largest estimated proportion of age 1.2 fish (0.83). Conversely, 1990 also appeared to be the year with the lowest proportion of age 1.3 and 1.1 fish at 0.13 and 0.03 of the run, respectively.

Predominance of age 1.2 fish in 1990 was also noted in a 1990 Columbia Basin sockeye salmon stock identification study (Fryer and Schwartzberg 1991). However, in that study a large proportion of age 1.1 sockeye was also noted, a finding not parallel to the low proportion of age 1.1 spring chinook salmon estimated herein. The tendency for different stocks and species of Columbia Basin salmon to show parallel age changes was noted in 1988 and 1989 (Schwartzberg 1989, Schwartzberg and Fryer 1990a, 1990b, Fryer and Schwartzberg 1990).

The estimated composite sample spring chinook salmon age composition was observed to change over the course of the 1990 sampling period. Five-year-old fish tended to appear in higher proportions earlier in the migratory season while the proportion of three-year-old fish increased in the later migratory period. This observation was similar to that noted for Columbia Basin sockeye salmon migratory characteristics (Schwartzberg and Fryer 1990b; Fryer and Schwartzberg 1991). Such a trend has been apparent in spring chinook salmon research made over the previous three years (Schwartzberg 1988, 1989; Schwartzberg and Fryer 1990a). However, in all four years of spring chinook salmon sampling, the tendency has been toward increasing numbers of five-year-old and decreasing numbers of four-year-old fish at the end of the migratory period. No such trend has been observed with sockeye salmon stocks. If summer chinook salmon are similar to spring chinook and sockeye salmon in that older fish appear earlier in the migration, this may suggest that the five-year-old fish observed at the end of the spring chinook salmon migration may actually be early migrant summer chinook salmon.

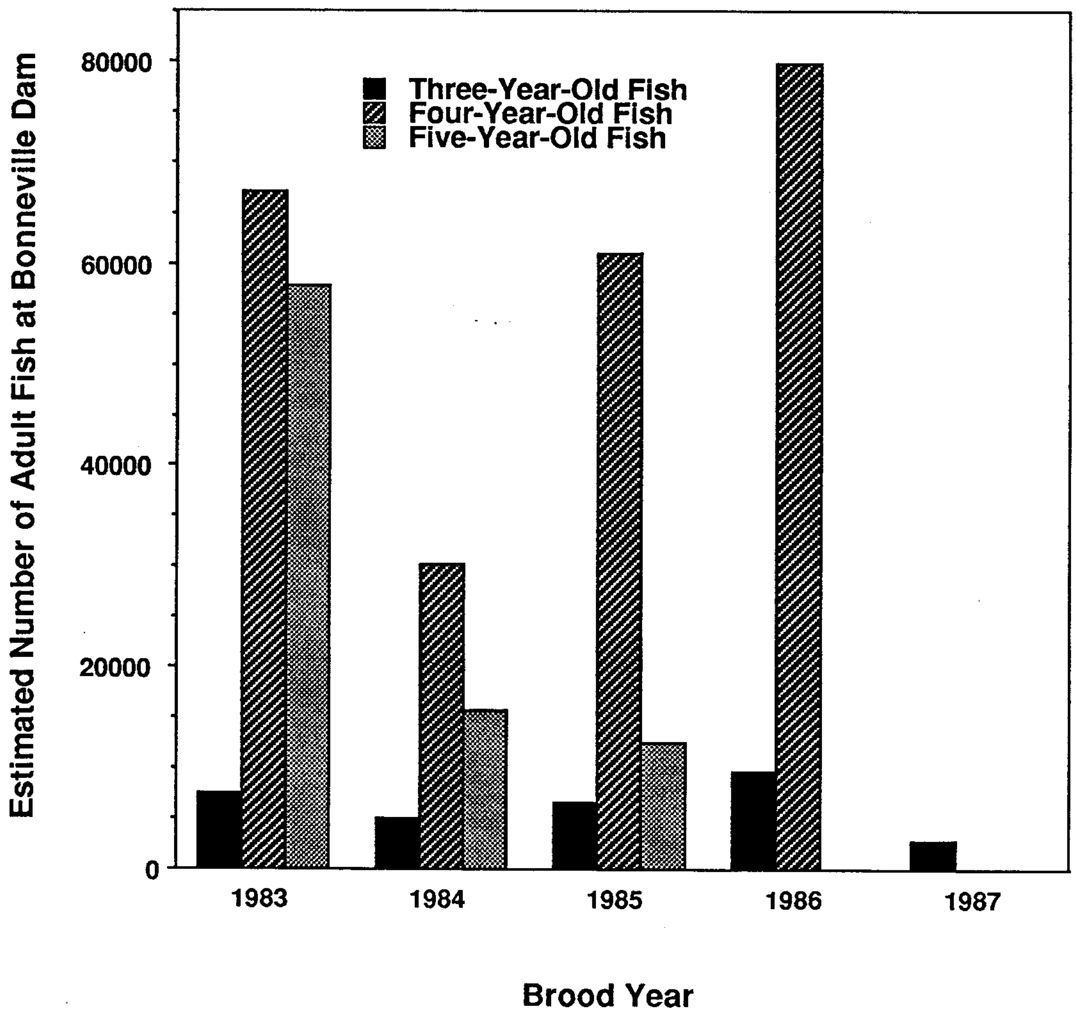
The progeny of a salmon population spawning in a given year will themselves return to freshwater as future adult spawners in several different years. All progeny of a given year's spawning population are known as a *brood*. Many salmon population size

prediction techniques are based on a study of systematic patterns notable in population age compositions from successive broods. Predictions of future spring chinook salmon population sizes are made, in part, by such analysis of the Corbett test fishery (Dammers 1990). By combining age composition estimates from previous studies (Schwartzberg 1988; Schwartzberg and Fryer 1989, 1990a) with visual count data (CRITFC 1990), estimates of age distribution of progeny of each brood year can be obtained (Figure 7). Because our studies were begun in 1987, data for three year-old fish from the 1983 brood year were estimated by multiplying the number of jacks from Bonneville Dam fish ladder counts by 1.5. This was based on the observation that, over the past four years, our study has estimated approximately 50% more three-year-old spring chinook salmon than are counted by visual fish ladder counting programs. The number of three-year-old fish for a given brood year appears, based on the limited data presented, to be a relatively good predictor of the number of subsequently returning four-year-old fish of the same brood year. In the 1984 brood year, the ratio of four-year-old fish to three-year-olds was 6.0:1 while, in 1983, 1985, and 1986, that ratio varied from 8.3:1 to 9.1:1. Based on these ratios and the estimated 2,900 three-year-old fish returning in 1990, the number of four-year-old fish returning in 1991 would be expected to be within the range of 17,300 to 26,500. If this prediction is accurate, it would represent the lowest number of the predominant age class within the previous four years. It does not appear that four-year-old fish are a good predictor of the five-year-old group. The ratio of four-year-old to five-year-old fish has been inconsistent, ranging from 1.2:1 for the 1983 brood year to 5.0:1 for the 1985 brood year.

The age composition estimate obtained from Corbett test fishery scale samples, as read by Washington Department of Fisheries personnel, was similar to that estimated from Bonneville Dam samples collected during the period in which the fishery operated. Since the age of only a very small number of spring chinook salmon sampled in this study could be determined by freeze brands applied for other research purposes, the Corbett test fishery provided a measure of corroboration of the age composition estimates presented in this report.

Length-at-age composition has remained relatively stable over the four study years for both four- and five-year-old fish. Among these age groups, mean fork-lengths have differed over time by less than 2.0 cm. However, there has been a notable variation in the length of three-year-old fish in different study years. Within this age group, a steady decrease in size from 52.4 cm in 1987 to 48.6 cm in 1989 has been observed. In 1990, age 1.1 fish were estimated to have increased in mean length to 50.1 cm.

Figure 7. Estimates of Columbia Basin spring chinook salmon population sizes based on cohort analysis[a,b].



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a. The estimated number of three-year-old fish for the 1983 brood year was derived by multiplying the number of age 1.1 spring chinook salmon visually counted at Bonneville Dam fish ladders by 1.5 to account for the tendency of scale pattern work to estimate approximately 50% more age 1.1 fish than visual fish ladder counts. All other estimates were obtained by multiplying the total annual population size (based on Bonneville Dam visual fish ladder counts) by age composition estimates from this study.

b. In some years, six-year-old fish were sampled. However, because in each year this age class represented less than 0.01 of the run, they were not included in this analysis.

For each of the past four study years, the estimated proportion of age 1.1 fish in the composite sample was higher in comparison to estimates based upon Bonneville Dam visual fish ladder counts. Only in 1989, however, was this difference statistically significant ($p<0.01$). The proportion of age 1.1 fish visually observed at other mainstem Columbia River dams agrees with the Bonneville Dam estimate suggesting the possibility that either this study overestimates abundance of this age group or that their abundance is systematically underestimated in mainstem Columbia River dam fish ladder counting programs. We intend to conduct a closer examination of the sampling methods used in this study in 1991 to determine if the number of three-year-old fish sampled is representative of the entire population.

In 1990, 0.12 of the scale samples collected proved to be unreadable and were rejected. The scale rejection rate has increased over the past three years of this study, being 0.05 in 1988 and 0.08 in 1989. An explanation for this is not apparent.

This program will be continued in future years to develop an accurate age- and length-at-age composition database for the Columbia Basin upriver spring chinook salmon population. This information will aid fisheries managers in detecting and possibly explaining changes in the composition of stocks. Patterns detectable in age and length-at-age composition of successive brood groups may allow managers to more accurately monitor the effects of ocean harvest restrictions imposed by the Pacific Salmon Treaty. As this study progresses, the database being created may also provide a basis for more accurate future population size prediction models.

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