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

Technical Report 91-4

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June 15, 1991

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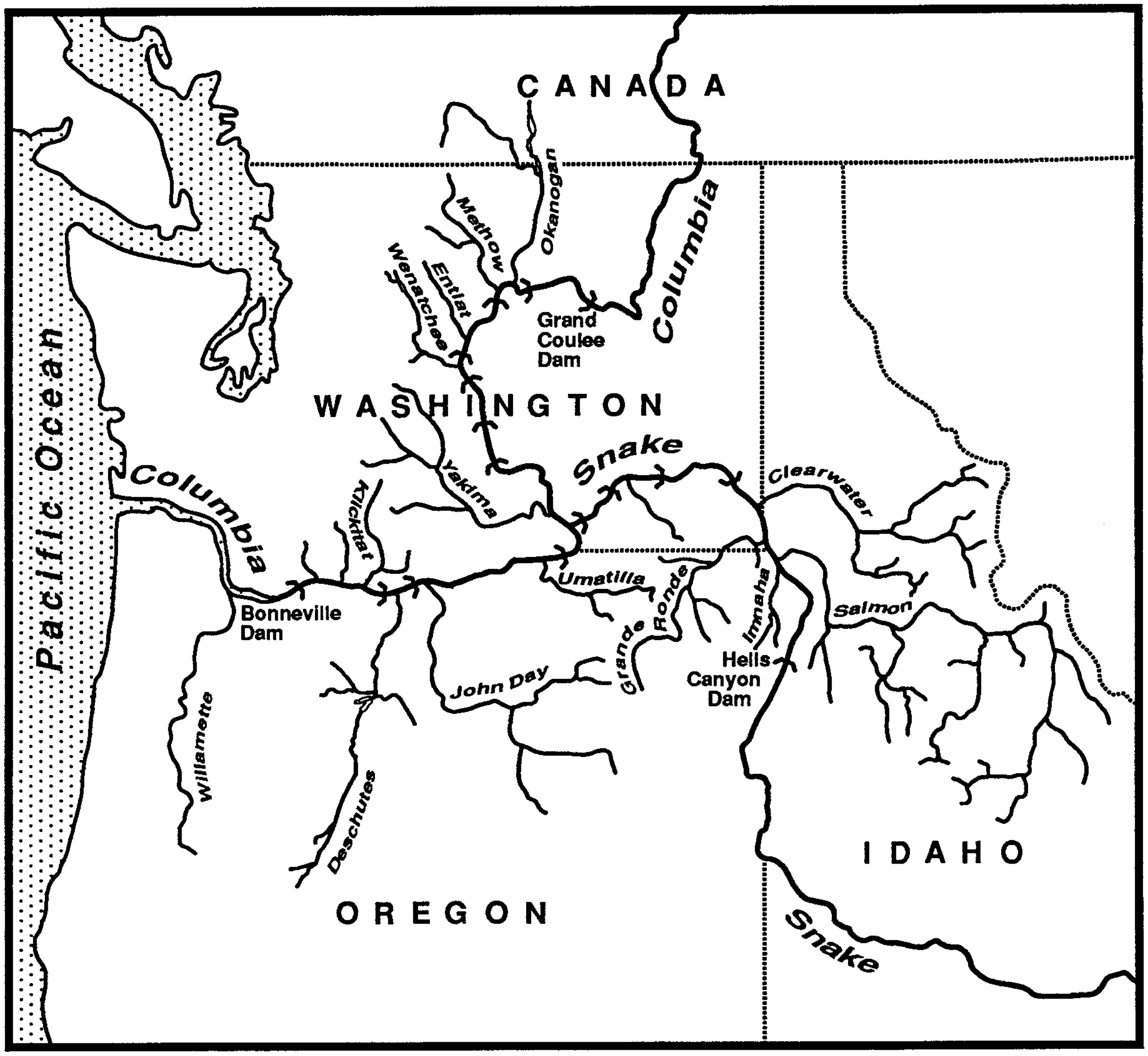
INTRODUCTION

The Stock Assessment Project of the Columbia River Inter-Tribal Fish Commission (CRITFC) is a part of the U.S.-Canada Pacific Salmon Treaty spawning escapement monitoring program (PST 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, located on the Columbia River at river kilometer 235 (Figure 1).

This report summarizes age and length-at-age composition estimates for summer chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), sampled at Bonneville Dam in 1990. At this sampling location, the summer chinook salmon population is composed of a mixture of both hatchery and natural origin stocks. Scale pattern analysis was the primary study method.

Columbia Basin summer chinook salmon are defined as those chinook salmon passing Bonneville Dam between June 1 and July 31. Earlier migrating chinook salmon are known as spring chinook salmon. Later migrating chinook salmon are known as fall chinook salmon. One goal of this project is to specify other criteria for categorizing and identifying the three groups of chinook salmon. This is the first year such research was conducted for summer chinook salmon but reports of similar spring chinook salmon studies were conducted from 1987 through 1990 (Schwartzberg 1988, 1989; Schwartzberg and Fryer 1990; Fryer and Schwartzberg 1991).

Figure 1. Map of the Columbia Basin including principal summer chinook salmon spawning and rearing tributaries and Bonneville, Grand Coulee, and Hells Canyon dams.



METHODS

Sampling Methods

In order to collect a representative sample of the Columbia River summer chinook salmon population, fish were sampled at the Fisheries Engineering and Research Laboratory (FERL) located adjacent to 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 the sampling operations.

Fish were trapped, anesthetized, quickly sampled for scales and biological data, allowed to revive, and then returned to the exit fishway leading to one of the Bonneville Dam fish ladders. Six scales per fish were collected to minimize the sample rejection rate (Knudsen 1990). Length measurements were recorded along with observed mark and/or tag information. No fish were sacrificed in the study. Therefore, gender of collected specimens, all in early stages of sexual maturation, could not be determined.

Fish less than 30 cm in fork length (locally known as *minijacks*) were not included in the sample because examination of their scale patterns indicated that they spent little time in saltwater.

Sample Design

Before this study began, it was impossible to predict the number of summer chinook salmon that could be trapped in a day of sampling. Because of the relatively small population sizes of adult summer chinook salmon (ODFW and WDF 1991), it was unclear whether sufficient samples could be collected at Bonneville Dam to meet the minimum overall desired level of precision and accuracy (d=0.05, 90% c.i.). Therefore, neither composite nor weekly sample size goals were set in this first year of study. Generally, sampling was conducted two days per week for approximately six hours per day. This effort produced a sample of 611 fish. Samples from forty two fish (0.07 of the sample) were unreadable and consequently rejected. The remaining sample of 569 fish was used for the age and length-at-age composition estimates made in this study (Table 1).

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

Date	Statistical Week[a]	Sample Size	Sample Size Proportion
6/04/90	23	35	0.06
6/12/90, 6/14/90	24	93	0.16
6/18/90, 6/21/90	25	139	0.24
6/25/90, 6/28/90	26	93	0.16
7/03/90, 7/05/90	27	56	0.10
7/09/90, 7/12/90	28	33	0.06
7/16/90, 7/18/90	29	33	0.06
7/23/90, 7/25/90	30	52	0.09
7/30/90	31	35	0.06
Composite Sample		569	

a. Statistical weeks are sequentially numbered calendar-year weeks. Excepting 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 23 began on June 3 and Statistical Week 31 began July 29.

Actual 1990 migratory timing was determined from post-season analysis of 1990 Bonneville Dam fish ladder counts (CRITFC 1991). Weekly Bonneville Dam fish ladder counts were compared to the number of weekly samples collected for this study. A stratified sampling method (Fryer in preparation) was used to adjust for biased sample sizes if the number of weekly samples proportionally differed from fish ladder counts. The composite age and length-at-age composition estimates reported in this study were based on adjusted sample sizes.

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 possible because no known-age fish were present in the sample.

The method used for fish age description was that recommended by Koo (1955), which is also 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.

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

Migratory Timing and Sampling Accuracy

Post-season analysis of the 1990 sample design disclosed a time-related bias because the number of samples collected each week differed proportionally from actual 1990 summer chinook salmon migratory timing (Figure 2). Composite sample age and length-at-age composition estimates were corrected based on adjusted sample sizes.

Age Composition Estimates

The proportion of five-year-old fish (from the 1985 brood-year group, including age 1.3 and 0.4 fish) was estimated as 0.49 of the composite sample (Figure 3). This age class was the largest single age group in all but the first two of the nine weekly 1990 samples (Table 2, Figure 4). Proportions of this age group in the weekly samples ranged from 0.32 (Statistical Week 23) to 0.58 (Statistical Week 30).

Four-year-old fish (from the 1986 brood-year group, including age 0.3 and 1.2 fish) were next highest in abundance, comprising a proportion of 0.36 of the composite sample. Four-year-old fish were the largest single age group in the first two weekly 1990 samples. Proportions of this age group in the weekly samples ranged from 0.25 (Statistical Week 30) to 0.63 (Statistical Week 23).

The proportion of six-year-old fish (from the 1984 brood-year group, including age 0.5 and 1.4 fish) was 0.08 of the composite sample. Proportions of this age group in the weekly samples ranged from 0.03 (Statistical Week 23) to 0.12 (Statistical Week 28).

The proportion of three-year-old fish (from the 1987 brood-year group, including age 0.2 and 1.1 fish) was 0.05 of the composite sample. Proportions of this age group over the sample period ranged from 0.03 (Statistical weeks 23 and 31) to 0.12 (Statistical weeks 28 and 29).

Figure 2. Actual 1990 migratory timing of Columbia Basin summer chinook salmon compared with sample timing.

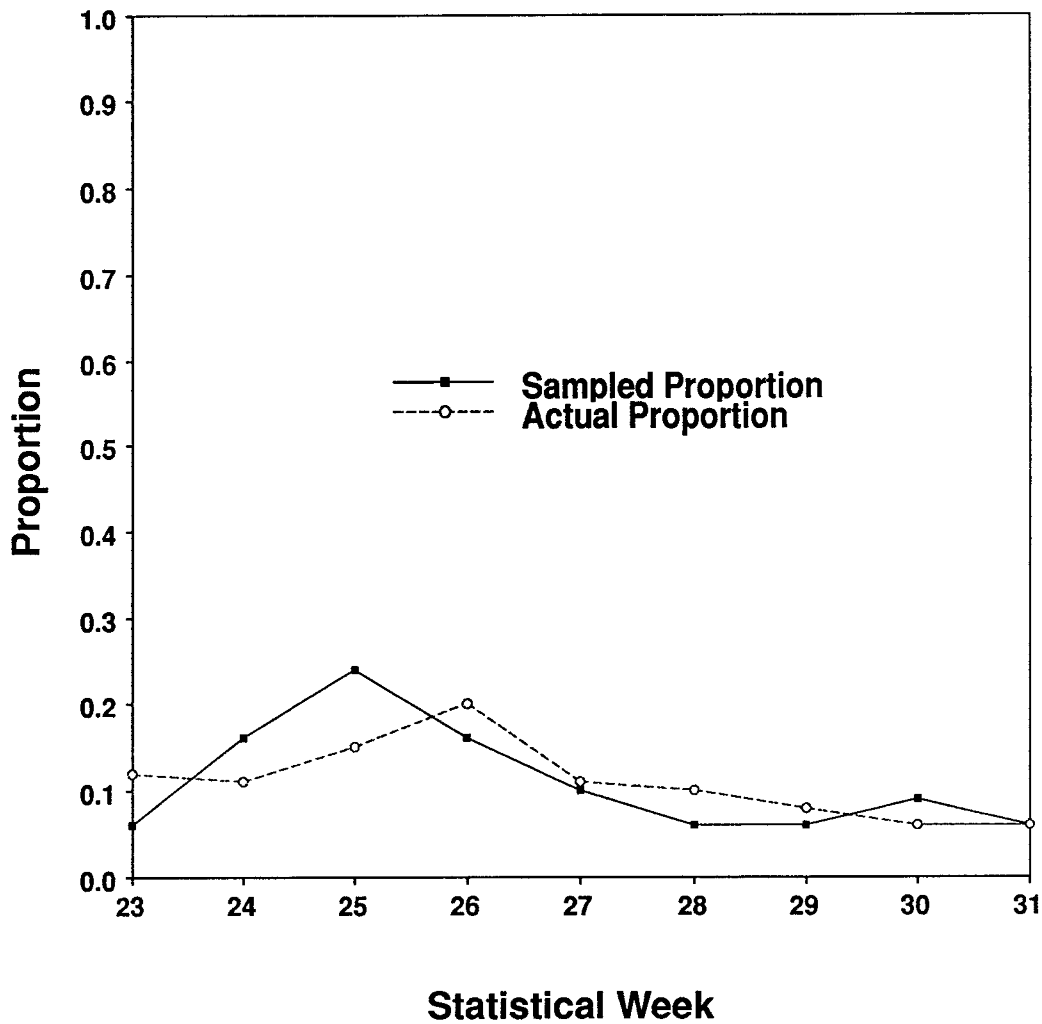


Figure 3. **Age composition estimates of Columbia Basin summer chinook salmon sampled at Bonneville Dam in 1990.**

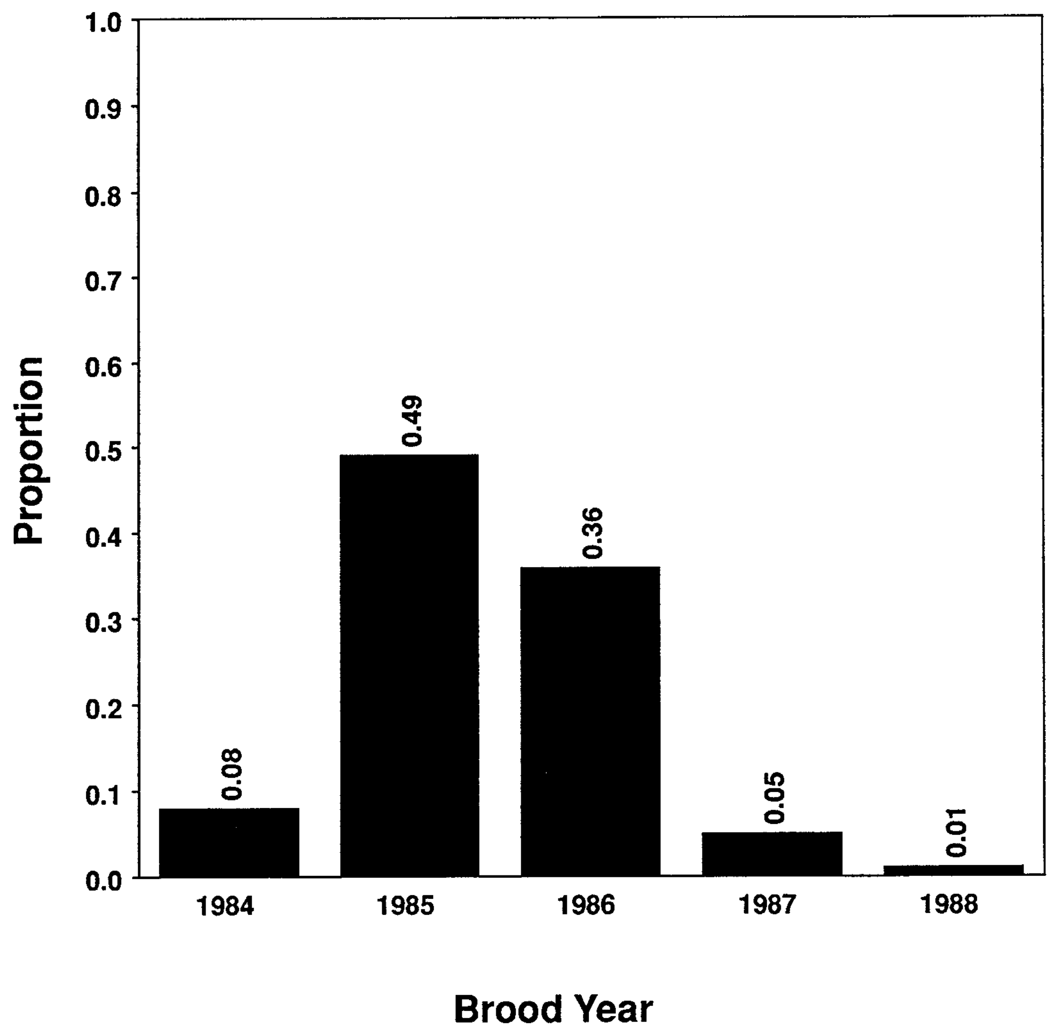


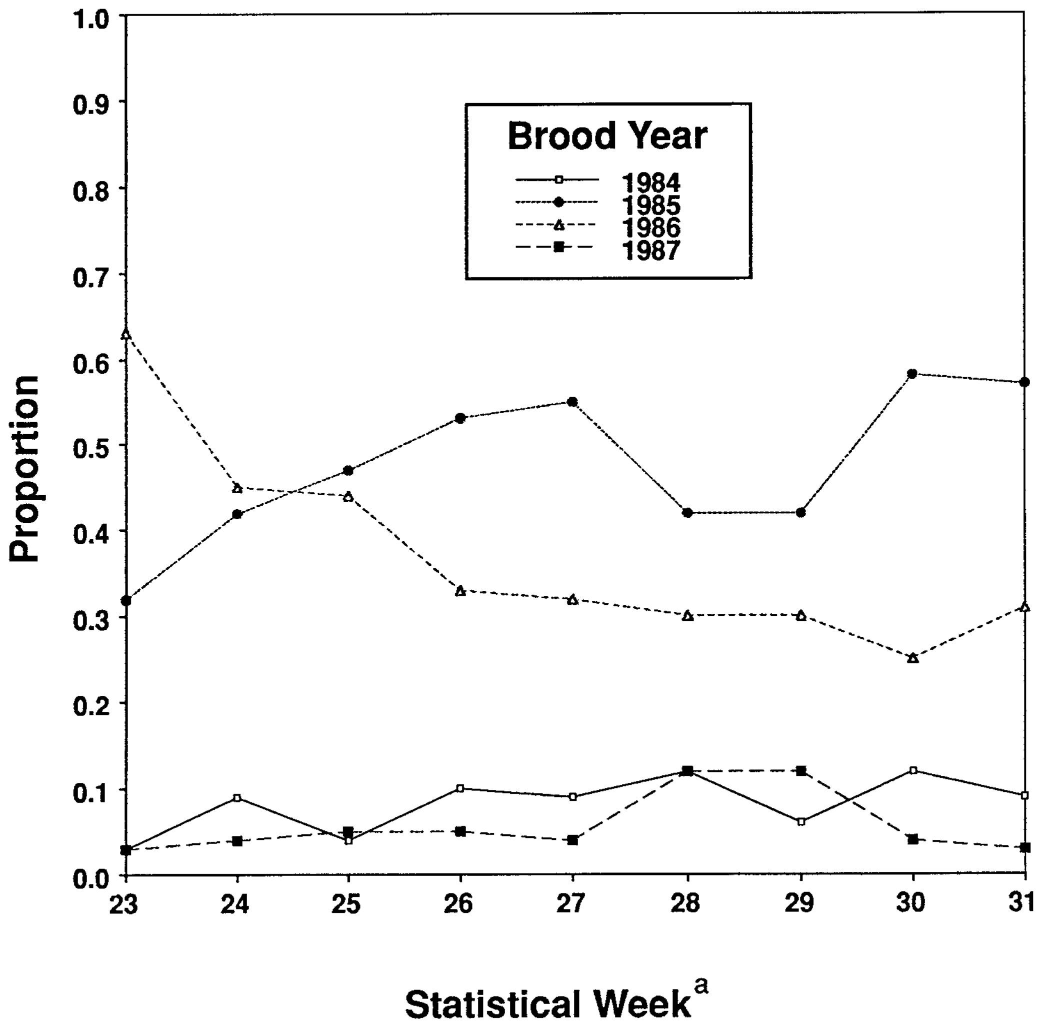
Table 2. Age composition estimates of Columbia Basin summer chinook salmon sampled at Bonneville Dam in 1990.

Brood Year and Age Class

Statistical	1988	1987		1986		1985		1984	
Week[a]	0.1	0.2	1.1	0.3	1.2	0.4	1.3	0.5	1.4
23		0.03		0.03	0.60	0.09	0.23	0.03	
24		0.02	0.02	0.05	0.40	0.09	0.33		0.09
25		0.01	0.04	0.06	0.38	0.20	0.27		0.04
26		0.01	0.04	0.08	0.25	0.29	0.24		0.10
27			0.04	0.18	0.14	0.30	0.25	0.04	0.05
28	0.03		0.12	0.18	0.12	0.15	0.27		0.12
29	0.09	0.03	0.09	0.15	0.15	0.18	0.24		0.06
30	0.02		0.04	0.15	0.10	0.33	0.25	0.04	0.08
31		0.03		0.26	0.06	0.37	0.20	0.03	0.06
Composite Sample	0.01	0.01	0.04	0.12	0.24	0.23	0.26	0.01	0.07

a. Statistical weeks are sequentially numbered calendar-year weeks. Excepting 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 23 began on June 3 and Statistical Week 31 began on July 29.

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



a. Statistical weeks are sequentially numbered calendar-year weeks. Excepting 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 23 began on June 3 and Statistical Week 31 began on July 29.

The proportion of two-year old fish (from the 1988 brood-year group, including age 0.1 fish) was 0.01 of the composite sample. Proportions of this age group in the weekly samples ranged from 0.00 (in seven different statistical weeks) to 0.09 (Statistical Week 29).

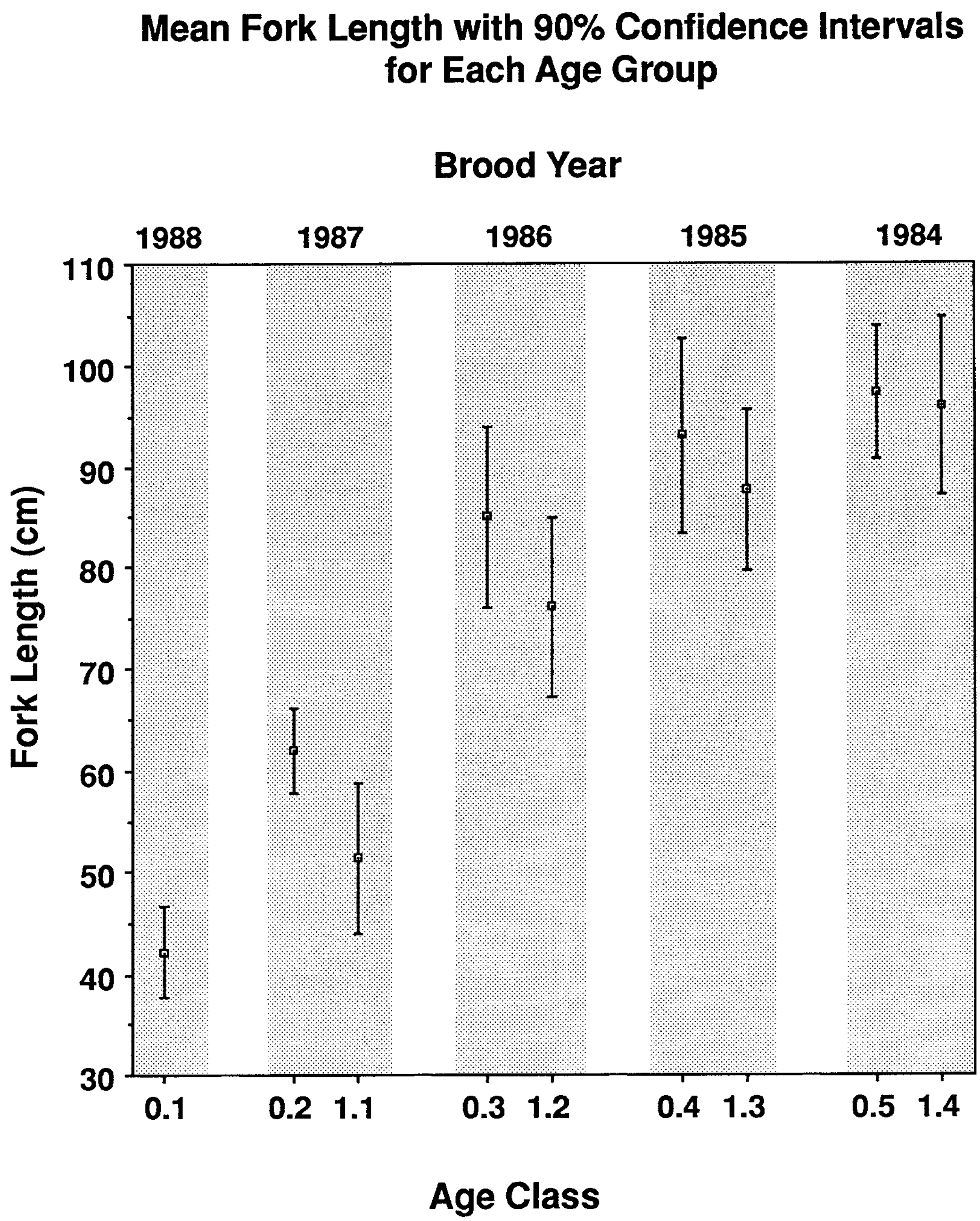
Length-at-Age Composition

Mean fork lengths of summer chinook salmon sampled at Bonneville Dam ranged from 42.2 cm for age 0.1 fish to 97.3 cm for age 0.5 fish (Table 3, Figure 5). The largest fish was an 113.0 cm age 0.4 fish sampled in Statistical Week 26 while the smallest (excluding minijacks) was a 40.0 cm age 0.1 fish sampled in Statistical Week 29.

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

	Brood Year and Age Class								
	1988	1987		1986		1985		1984	
	0.1	0.2	1.1	0.3	1.2	0.4	1.3	0.5	1.4
Statistical Week 23									
Mean Fork Length (cm)		56.0		78.0	74.4	90.5	79.2	89.0	
Minimum		56.0		78.0	67.5	86.5	70.0	89.0	
Maximum		56.0		78.0	82.0	93.0	91.0	89.0	
Standard Deviation		—		—	4.4	2.9	6.5	—	
Sample Size		1		1	21	3	8	1	
Statistical Week 24									
Mean Fork Length (cm)		64.0	46.5	83.4	75.2	93.2	89.3		95.9
Minimum		61.5	43.5	78.5	65.0	89.0	78.5		84.0
Maximum		66.5	49.5	89.5	88.5	98.0	97.0		104.5
Standard Deviation		2.5	3.0	3.7	5.2	3.3	4.2		6.4
Sample Size		2	2	5	37	8	31		8
Statistical Week 25									
Mean Fork Length (cm)		67.2	53.8	82.2	78.5	93.1	89.3		96.1
Minimum		64.5	51.0	71.5	64.0	83.0	80.0		87.0
Maximum		70.0	59.5	90.0	95.0	104.5	98.5		106.0
Standard Deviation		2.8	3.3	5.6	6.0	4.9	4.1		5.9
Sample Size		2	5	8	52	28	38		6
Statistical Week 26									
Mean Fork Length (cm)		57.0	54.0	86.4	77.2	91.0	86.2		98.6
Minimum		57.0	47.0	77.0	61.5	70.0	78.0		87.0
Maximum		57.0	61.5	98.5	89.0	99.0	99.5		111.0
Standard Deviation		—	5.2	6.8	6.5	6.6	5.8		6.1
Sample Size		1	4	7	23	27	22		9
Statistical Week 27									
Mean Fork Length (cm)			53.0	83.8	74.9	92.1	88.1	101.8	92.2
Minimum			52.0	78.0	63.0	76.0	76.0	97.0	85.0
Maximum			54.0	99.0	80.0	102.0	95.0	106.5	96.5
Standard Deviation			1.0	5.9	5.4	6.8	6.3	4.8	5.1
Sample Size			2	10	8	17	14	2	3
Statistical Week 28									
Mean Fork Length (cm)	42.5		47.2	87.3	72.4	93.4	90.4		95.6
Minimum	42.5		41.0	83.5	68.0	86.5	82.5		92.0
Maximum	42.5		53.0	91.0	74.0	102.0	99.5		98.5
Standard Deviation	—		2.2	2.8	2.5	6.1	4.2		2.4
Sample Size	1		4	6	4	5	9		4
Statistical Week 29									
Mean Fork Length (cm)	42.0	64.0	53.5	86.6	75.3	96.2	89.7		95.8
Minimum	40.0	64.0	46.0	79.0	68.5	89.0	82.0		92.5
Maximum	44.0	64.0	59.5	98.0	84.5	108.5	93.0		99.0
Standard Deviation	2.7	—	5.6	6.7	5.6	7.5	3.6		3.2
Sample Size	3	1	3	5	5	6	8		2
Statistical Week 30									
Mean Fork Length (cm)	42.5		51.8	87.3	77.6	97.2	87.5	100.5	95.5
Minimum	42.5		45.5	76.5	70.5	88.0	79.5	98.0	90.0
Maximum	42.5		58.0	95.0	84.0	112.0	94.0	103.0	101.0
Standard Deviation	—		6.2	5.8	5.1	5.7	4.1	2.5	4.4
Sample Size	1		2	8	5	17	13	2	4
Statistical Week 31									
Mean Fork Length (cm)		65.0		85.9	89.8	98.8	89.9	98.5	95.8
Minimum		65.0		80.0	87.5	88.0	87.0	98.5	93.0
Maximum		65.0		95.0	92.0	113.0	94.0	98.5	98.5
Standard Deviation		—		5.2	2.2	7.5	2.7	—	2.8
Sample Size		1		9	2	13	7	1	2
1990 COMPOSITE									
Mean Fork Length (cm)	42.2	62.0	51.4	85.0	76.1	93.1	87.7	97.3	96.0
Minimum	42.5	56.0	41.0	71.5	61.5	70.0	70.0	89.0	84.0
Maximum	44.0	70.0	61.5	99.0	95.0	113.0	99.5	106.5	111.0
Standard Deviation	2.7	2.6	4.5	5.5	5.4	5.9	4.9	4.0	5.3
Sample Size	5	8	22	59	157	124	150	6	38

Figure 5. Length-at-age composition estimates of Columbia Basin summer chinook salmon sampled at Bonneville Dam in 1990.



DISCUSSION

Validation of summer chinook salmon age estimates was not possible because known-age specimens were not present in the sample. The age estimation methods used in this study and a large proportion of the resultant age estimates were reviewed and supported by experienced scale analysts from a different agency. Nevertheless, freshwater annulus position (or its very existence) in summer chinook salmon scales was often difficult to determine because this scale feature was typically located close to the scale check associated with saltwater entry. It was sometimes difficult to differentiate these two scale features from each other. Sub-yearling migrants may be subjected to an extended migration period with individuals entering saltwater late in the growing season (Hayes and Peven 1991). Summer chinook salmon age composition estimates and the identification of sub-yearling and yearling outmigrant classes should be subjected to further examination.

The age composition estimates of summer chinook salmon sampled at Bonneville Dam in 1990 appeared to change over the sampling period. When the total age of samples (based on brood year group) was considered, it was observed that the proportion of four-year-old fish was greatest early in the migratory period and declined as the migration progressed. The proportion of five-year-old fish was lowest early in the migratory period and generally increased as the migration progressed (Figure 4). In contrast, similar studies of Columbia Basin spring chinook and sockeye salmon have noted the tendency for older fish to migrate earlier in the migratory periods of their respective stocks (Fryer and Schwartzberg 1991a, 1991b).

Grouping summer chinook salmon sampled by different age categories suggested a different interpretation of migratory trends for this stock. The four major age groups (ages 0.3, 0.4, 1.2, and 1.3) were grouped according to their freshwater life histories. The proportion of the sub-yearling outmigrant group (ages 0.3 and 0.4) was lowest early in the migratory period and generally increased as the migration progressed (Table 2). The proportion of one of the yearling outmigrant groups (age 1.2) was highest early in the migratory period and generally decreased as the migration progressed. The proportion of the other yearling outmigrant group (age 1.3) remained relatively constant throughout the migratory period.

Although data so far collected in this study are relatively insubstantial, many possible preliminary interpretations of these observations may be made. One possible explanation of the observed migratory timing of different age-class fish is that the two different freshwater age groups represent two distinct stocks with different life histories. Earlier reports of the age composition of Snake River Basin summer chinook salmon has indicated that virtually all fish are yearling outmigrants while mid-Columbia stock fish are, except for some experimental hatchery groups, typically sub-yearling outmigrants (U.S. vs. Oregon Technical Advisory Committee 1991). Partially confirming this theory were age estimates we made of known-stock Snake River Basin fish from the South Fork of the Salmon River. All fish in this sample (n=56) were estimated to have been yearling outmigrants (unpublished data). However, samples of mid-Columbia stock fish obtained from the Wenatchee, Methow, and Similkameen rivers and from Wells Fish Hatchery were estimated to contain both yearling and sub-yearling type specimens. If these age estimates are accurate, the hypothesis may be incorrect that Snake and mid-Columbia summer chinook salmon stocks are distinct and differentiable by freshwater life histories alone.

Another possible explanation for time-based trends in the observed summer chinook salmon age estimates is the hypothesis that summer chinook salmon (combined Snake and mid-Columbia stocks) may not accurately be recognized, as they are today, by their migratory timing alone (Gibson et al. 1979). Those fish classified as summer chinook salmon may instead be representatives of late and early migrating spring and fall chinook groups, respectively (Thompson 1951). It has been reported that spring chinook salmon are typically yearling outmigrants while fall chinook salmon are typically sub-yearling type (U.S. vs. Oregon Technical Advisory Committee 1991). Our weekly age and length-at-age composition estimates of spring (Fryer and Schwartzberg 1991a) and fall chinook (unpublished data) salmon sampled at Bonneville Dam in 1990 agree with this theory. The proportion of spring chinook salmon estimated to have been yearling outmigrants was 0.99 compared with 0.09 of fall chinook salmon (Table 4).

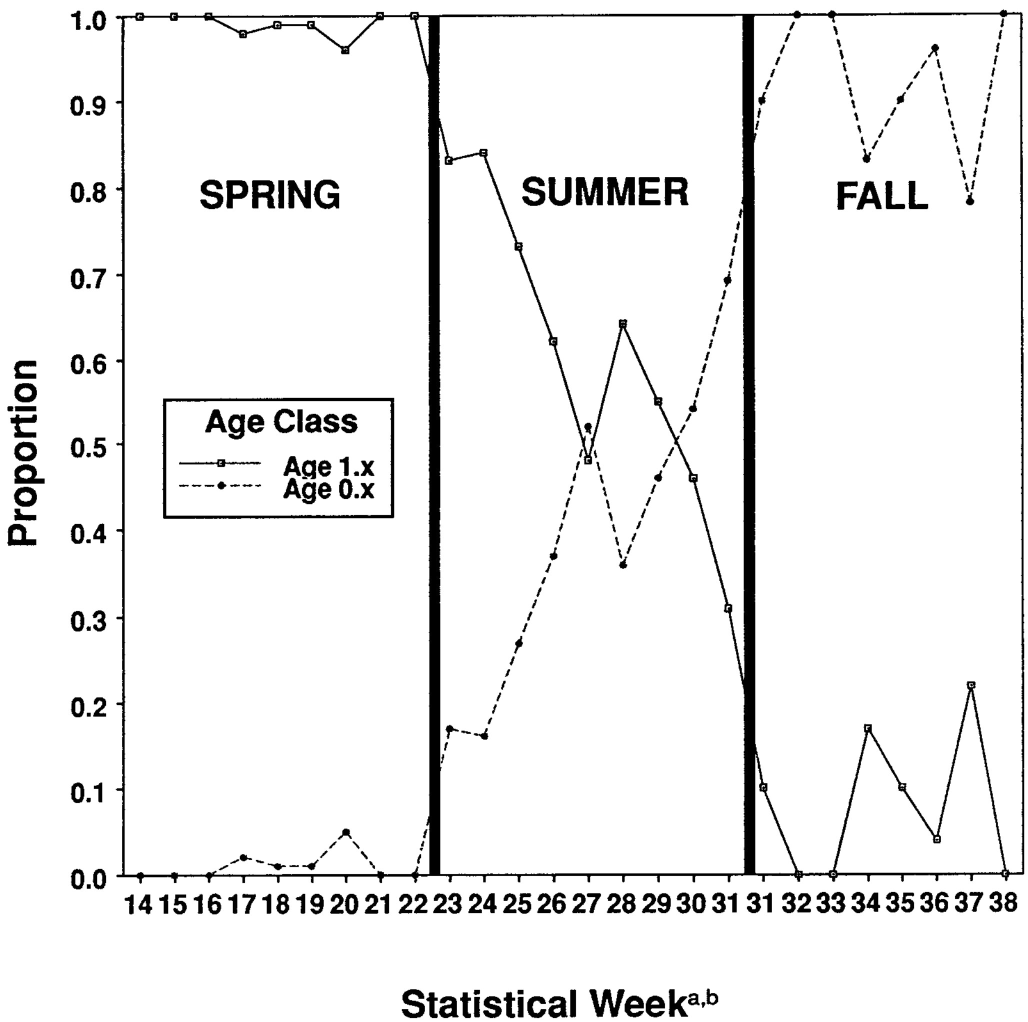
We had no way to test whether the two observed freshwater life history component groups of Columbia Basin chinook salmon migrating past Bonneville Dam in June and July were, in fact, representatives of early and late migrating spring and fall chinook salmon stocks. However, a graphical depiction of Columbia Basin chinook salmon freshwater age composition estimates (for adult chinook salmon sampled at Bonneville Dam throughout the entire 1990 chinook salmon migratory period) was created to use as a basis for inference of stock classification (Figure 6). Using this graph,

Table 4. **Age composition estimates of Columbia Basin spring, summer, and fall chinook salmon sampled at Bonneville Dam in 1990.**

Brood Year and Age Class

Chinook Stock	1988	1987		1986		1984		1985	
	0.1	0.2	1.1	0.3	1.2	0.4	1.3	0.5	1.4
Spring	0.00	0.01	0.04	0.00	0.82	0.00	0.13	0.00	0.00
Summer	0.01	0.01	0.04	0.12	0.24	0.23	0.26	0.01	0.07
Fall	0.03	0.19	0.01	0.40	0.03	0.24	0.05	0.05	0.00
Composite Sample	0.02	0.12	0.02	0.26	0.27	0.17	0.09	0.03	<0.01

Figure 6. Freshwater age composition of Columbia Basin spring, summer, and fall chinook salmon sampled at Bonneville Dam in 1990.



a. Statistical weeks are sequentially numbered calendar-year weeks. Excepting 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 Weeks 23 began on June 3 and Statistical Week 31 began on July 29.

b. Sampling was conducted for both the summer and fall chinook salmon migratory period in Statistical Week 31.

one could speculate that only two groups may exist. The earlier migrating stock would be primarily composed of yearling outmigrants (denoted as age 1.x) with the other later migrating stock being primarily composed of subyearling outmigrants (denoted as age 0.x). The months of June and July (presently recognized as the Columbia Basin summer chinook migratory period at Bonneville Dam) might be considered the time of overlapping migration for the two groups. Other studies, particularly those based on genetic stock identification techniques, have supported a case for reevaluation of the method by which Columbia Basin chinook salmon are categorized. Referring to Snake River Basin spring and summer chinook salmon, Matthews and Waples (1991) reported that it was "inappropriate at this time ... to assume that the two forms represent independent evolutionary lineages." A study of meristic and genetic characteristics of 56 stocks of Columbia Basin chinook salmon resulted in the similar categorization of mid-Columbia summer and fall chinook salmon using cluster analysis techniques (Schreck et al. 1986). In the same study, Snake River spring and summer chinook salmon were categorized as being closely related. Another study encompassing the genetic composition of all Pacific Northwest chinook salmon stocks found strong similarities between Snake River Basin spring and summer chinook salmon (Utter et al. 1989).

In contrast to the above-mentioned research, studies based on field observations of the spawning location and spawn timing characteristics of Columbia Basin summer chinook salmon stocks have generally reaffirmed the existence of three distinct stock groups. Although some among-stock overlap was typically observed in spawning location and timing, these studies generally concluded that notable differences do exist among spring, summer, and fall groups (Fulton 1968, Fast 1988, Hays and Peven 1991; Ted Bjornn, University of Idaho, personal communication).

We believe this analysis, albeit a limited and highly speculative one at this time, is certainly worth future consideration. The identification of Columbia Basin summer chinook salmon stocks is important in the management of Pacific salmon stocks. This sampling program will continue in future years to identify these stocks as well as to develop an accurate age- and length-at-age composition database. Such information will aid fisheries managers in detecting and possibly explaining changes in the composition of stocks. Detectable patterns in age and length-at-age composition of successive brood groups may allow managers to more accurately monitor the effects of ocean harvest restrictions, such as those imposed by the Pacific Salmon Treaty (PST 1985). As this study progresses, the database being created may also provide a foundation for future population size prediction models.

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