AGE AND LENGTH COMPOSITION OF COLUMBIA BASIN SPRING CHINOOK SALMON AT BONNEVILLE DAM IN 1991

Technical Report 92-1

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February 11, 1992

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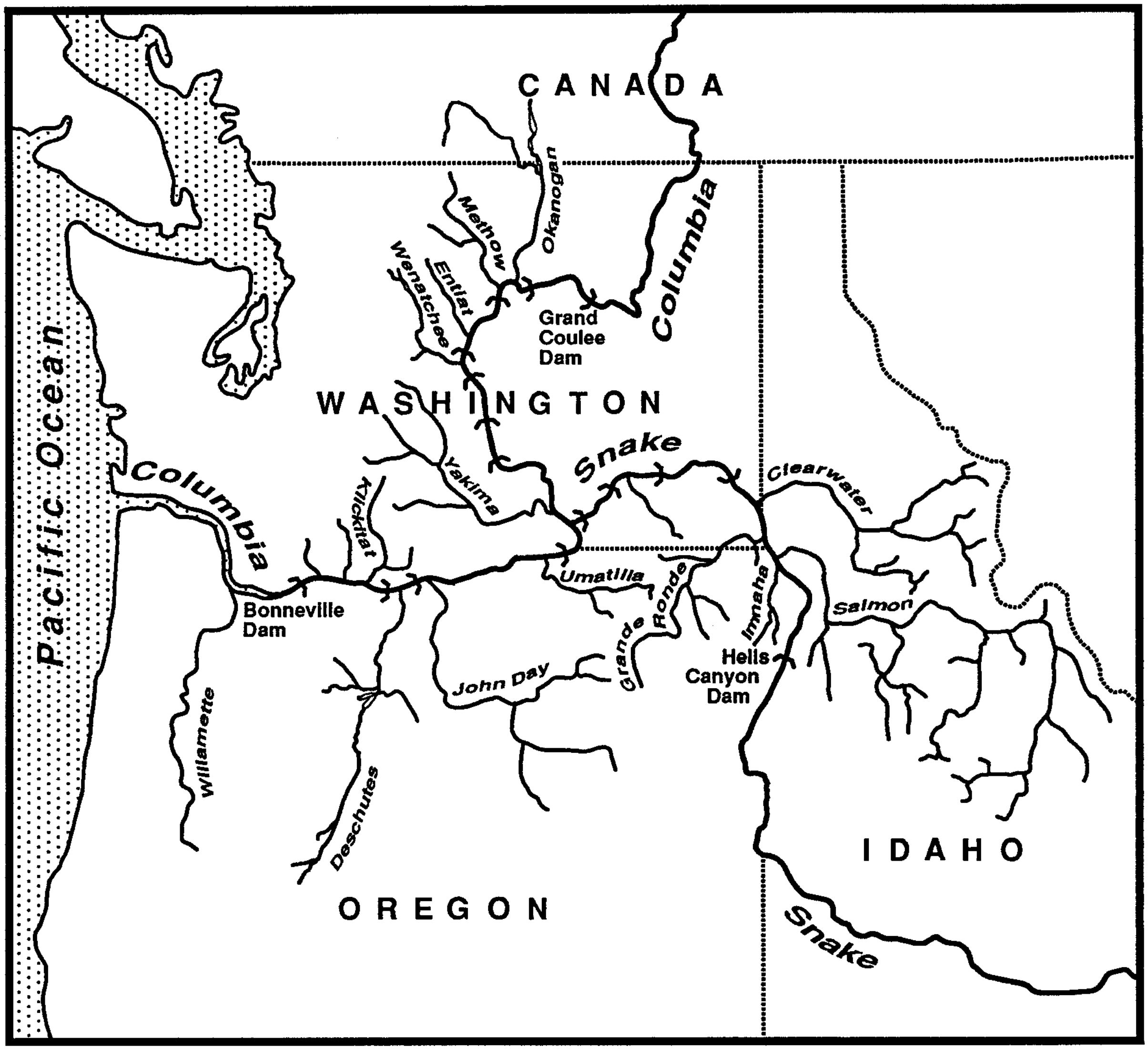
INTRODUCTION

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, located on the Columbia River at river kilometer 235 (Figure 1).

This report summarizes age and length-at-age composition estimates for upriver spring chinook salmon[1] *Oncorhynchus tshawytscha* (Walbaum) sampled at Bonneville Dam in 1991. 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 1990; Fryer and Schwartzberg 1991). Scale pattern analysis was and continues to be the primary study method used.

1. Columbia Basin upriver 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).

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

A representative sample of the Columbia River (upriver) spring chinook salmon population was collected at the Fisheries Engineering and Research Laboratory, located beside the Second Powerhouse of Bonneville Dam. 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. Data collected included length measurements, observed artificial mark and/or tag information, and the presence of wounds including those made by marine mammals. Six scales per fish were collected to minimize the sample rejection rate (Knudsen 1990). The gender of collected specimens, all in the earliest stages of maturation, could not be determined.

Sample Design

The desired composite sample size of 687 fish was estimated using a method (Fryer, in preparation) based on Bonneville Dam fish ladder counts (CRITFC 1991). This method was a variation (applicable to stratified populations) of that proposed by Thompson (1987) that computed sample sizes to measure the proportion of a multinomial population attributable to each of its component subgroups. The desired minimum overall level of precision and accuracy was $d=0.05$, $\alpha=0.10$. To determine desired estimated sample sizes for each statistical week[2] the composite sample size was factored by the weekly percentage of the total migratory population averaged over the previous ten years (Table 1). We also established and attempted to collect a minimum weekly sample size of 50 to achieve greater accuracy in weekly age and length-at-age composition estimates.

To further improve estimation accuracy, composite age and length-at-age estimates based on the above described sampling method, were adjusted post-season using a stratified sampling method that weighted weekly estimates to adjust for actual 1991 migration timing.

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2. Statistical weeks are sequentially numbered calender-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 1991, for example, Statistical Week 14 began on March 31 and Statistical Week 22 began on May 26.

Table 1. **Sample sizes for Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1991.**

Date	Statistical Week	Desired Number	Actual Number
4/03/91	14	50	5
4/10/91	15	75	4
4/17/91	16	123	22
4/24/91,4/26/91	17	111	94
5/01/91,5/03/91	18	104	73
5/08/91	19	74	67
5/15/91	20	50	33
5/21/91	21	50	52
5/29/91	22	50	35
Composite		**687**	**385**

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 projected using a microfiche reader, 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 rarely possible because few fish of known age were present in the sample.

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

Age composition estimates obtained during earlier years of this study, beginning in 1987, were compiled and compared with results from this year's work to explore inter-annual variation in age compositions estimates.

Intra-Annual Age Composition Estimates

Age composition estimates obtained in 1991 from Bonneville Dam scale samples were compared to estimates from two independent sources to explore differences in intra-annual age composition estimates. The first comparison was made to estimates, derived from length-age relationships, made in 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 identified as jacks, typically of age 1.1. An estimate of the percentage of these fish in the Bonneville Dam fish ladder counts was made by dividing the number of jacks by the total number of salmon counted.

The second comparison was made using 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, in preparation). The data are then used to predict both in-season and future population abundances. 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

Sample Design

A sample of 385 fish of 415 collected was used for age and length-at-age composition estimates made in this study (Table 1). Seven percent of the total sample was rejected and not classified by age because of unreadable scales. Small sample sizes in Statistical weeks 14 and 15 resulted in the pooling of data from statistical weeks 14 through 16 for analysis.

Age Composition Estimates

Throughout the spring chinook salmon migration, fish of less than 30 cm in length were occasionally observed. A few of these relatively small fish, known locally as *minijacks*, were sampled. Examination of minijack scale patterns indicated that all spent little time in saltwater. Therefore, fish of less than 30 cm in length were excluded in the preparation of the reported results.

Four-year-old fish were estimated to be the predominant age class, comprising 48% of the sample (Table 2). Five-year-old fish comprised 40% of the sample while three-year-old fish made up 10% of the sample. Two-year-old and six-year-old fish each made up less than 1% of the sample.

Six fish, or 1% of the composite sample was judged to be age 0-plus (including two each of age 0.1, 0.2, and 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.

Comparison of Age Composition Estimates

Inter-Annual Age Composition Estimates

Age composition estimates from study years 1987 through 1991 are provided

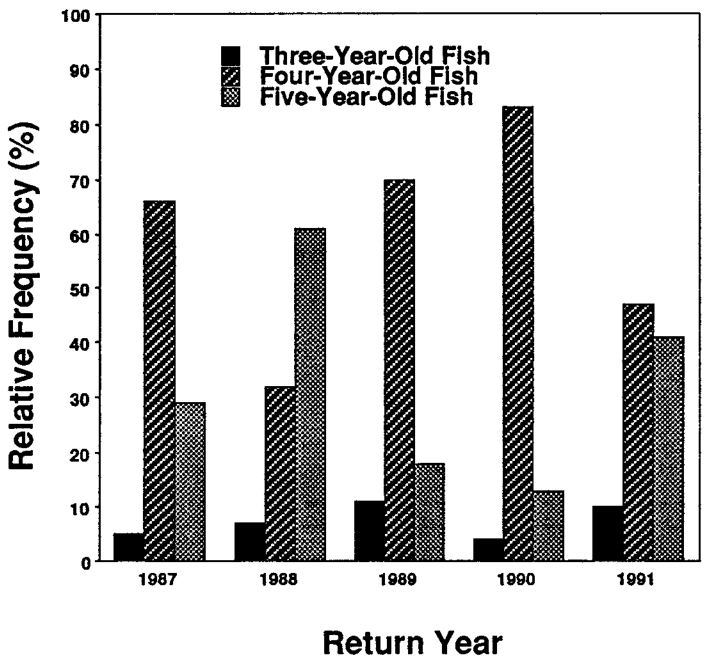
Table 2. Weekly age composition estimates (%) of Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1991.

Brood Year and Age Class

Statistical Week	1989	1988		1987		1986	1985
	0.1	0.2	1.1	0.3	1.2	1.3	1.4
14-16					52	48	
17		1	1		49	49	
18			20		56	22	1
19			37	3	28	31	
20	3		30		39	24	
21	2		42		25	31	
22			23		31	46	
Composite Sample	<1	<1	10	<1	48	40	<1

Figure 2. Age composition estimates (%) of Columbia Basin spring chinook salmon sampled at Bonneville Dam from 1987 through 1991.

Year	0.1	0.2	1.1	0.3	1.2	0.4	1.3	1.4
	Age Classes							
1987	0	1	4	<1	66	0	29	<1
1988	<1	1	6	1	31	<1	61	0
1989	0	<1	11	1	69	<1	18	<1
1990	0	1	3	<1	83	0	14	<1
1991	<1	<1	10	<1	47	0	41	<1



in Figure 2. 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

Three-year-old fish were estimated to comprise 10% of the composite 1991 sample compared to 6% based on visual fish ladder counts made at Bonneville Dam (CRITFC 1991). By comparison, 1987, 1988, 1989, and 1990 adjusted results from our studies estimated that three-year-old abundance was 4, 6, 11, and 3% respectively. Visual fish counts estimated abundances during these years of 3, 4, 7, and 2% during those years, respectively.

In the 1991 Corbett test fishery (Dammers, in preparation), four-year-old fish were estimated to comprise 37% of the catch, five-year-old fish 62%, and six-year-old fish 1% of the total catch (n=291).

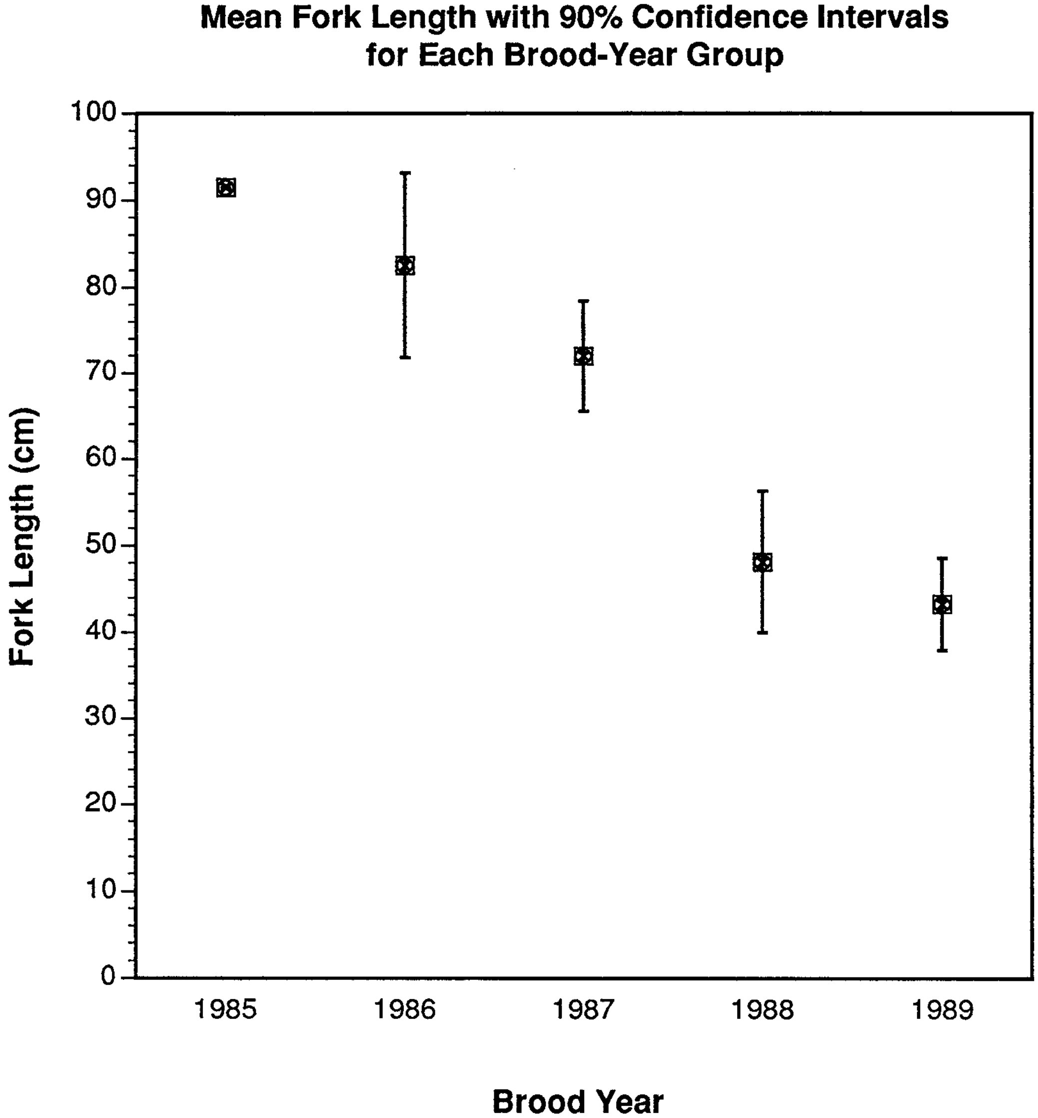
Length-at-Age Composition

The mean fork length of three-year-old fish (1988 brood) in the total sample was 48.1 cm (Table 3, Figure 3). The 90% confidence interval was 40.0 to 56.3 cm (n = 83). The mean fork length of four-year-old fish (1987 brood) was 70.6 cm, with a 90% confidence interval of 62.6 to 78.6 cm (n = 161). The mean fork length of five-year-old fish (1985 brood) was 82.9 cm with a 90% confidence interval of 72.0 to 93.8 cm (n = 138).

Table 3. Weekly and total length-at-age composition estimates of Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1991.

	Brood Year and Age Class						
	1989	1988		1987		1986	1985
	0.1	0.2	1.1	0.3	1.2	1.3	1.4
Statistical Weeks 14-16							
Mean Fork Length (cm)					71.8	81.8	
Minimum					64.0	61.5	
Maximum					79.5	94.0	
Standard Deviation					3.8	7.3	
n in Group					16	15	
Statistical Week 17							
Mean Fork Length (cm)		68.5	48.5		69.1	83.7	
Minimum		68.5	48.5		56.0	71.0	
Maximum		68.5	48.5		79.0	97.5	
Standard Deviation		—	—		5.4	6.1	
n in Group		1	1		46	46	
Statistical Week 18							
Mean Fork Length (cm)			47.4		70.1	85.8	91.5
Minimum			40.0		60.0	79.5	91.5
Maximum			53.5		85.0	94.5	91.5
Standard Deviation			3.8		5.8	4.4	—
n in Group			15		41	16	1
Statistical Week 19							
Mean Fork Length (cm)			46.3	71.8	70.0	83.1	
Minimum			39.5	70.5	57.5	73.5	
Maximum			53.0	73.0	79.5	99.0	
Standard Deviation			3.9	1.2	6.2	6.8	
n in Group			25	2	19	21	
Statistical Week 20							
Mean Fork Length (cm)	46.5	44.5	50.4		68.7	86.1	
Minimum	46.5	44.5	42.5		54.0	80.0	
Maximum	46.5	44.5	59.5		79.5	91.0	
Standard Deviation	—	—	5.1		7.3	3.2	
n in Group	1	1	10		13	8	
Statistical Week 21							
Mean Fork Length (cm)	40.0		48.8		66.8	84.2	
Minimum	40.0		32.5		54.0	72.0	
Maximum	40.0		58.5		73.5	90.0	
Standard Deviation	—		6.5		5.4	5.0	
n in Group	1		22		13	16	
Statistical Week 22							
Mean Fork Length (cm)			49.8		73.0	85.7	
Minimum			46.0		64.5	70.0	
Maximum			60.0		82.0	95.5	
Standard Deviation			4.4		6.5	5.8	
n in Group			8		11	16	
1991 COMPOSITE							
Mean Fork Length (cm)	44.2	60.8	47.6	71.8	70.6	82.9	91.5
Minimum	40.0	44.5	32.5	70.5	54.0	61.5	91.5
Maximum	46.5	68.5	60.0	73.0	85.0	99.0	91.5
Standard Deviation	3.2	12.0	4.5	1.2	4.9	6.6	—
N in Group	2	2	81	2	159	138	1

Figure 3. Length-at-age composition estimates of Columbia Basin spring chinook salmon sampled at Bonneville Dam in 1991.



DISCUSSION

Actual sample sizes fell below the desired sample size for all but one week of sampling. This difference was especially apparent in the first three weeks of sampling and was a result of a later, smaller than average, upstream migration of spring chinook salmon.

Comparison of 1991 study results to those obtained in study years 1987 through 1990 shows variability with no trends yet discernible in composite-sample age composition estimates (Figure 2). In the five study years, 1991 was notable for having a relatively large percentage of three- and five-year-old fish as well as a relatively low percentage of four-year-old fish.

The progeny of a salmon population in a given year will 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, in preparation). By combining age composition estimates from previous studies (Schwartzberg 1988; Schwartzberg and Fryer 1989, 1990; Fryer and Schwartzberg 1991) with visual count data (CRITFC 1991), estimates of age distribution of progeny for each brood year can be obtained (Figure 4). Because these studies began 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 five years, this 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. Using linear regression techniques, and based on the estimated 6,300 three-year-old fish returning in 1991, the number of four-year-old fish returning in 1992 is predicted to be 53,500 with a 90% confidence interval of 27,000 to 79,000 (Figure 5). Using slightly different techniques (Fryer and Schwartzberg 1991), the number of four year fish returning in 1991 was predicted to be between 17,300 to 26,500 compared to the actual number of 29,200.

Figure 4. Comparison of Columbia Basin spring chinook salmon cohort sizes in 1983 through1988.

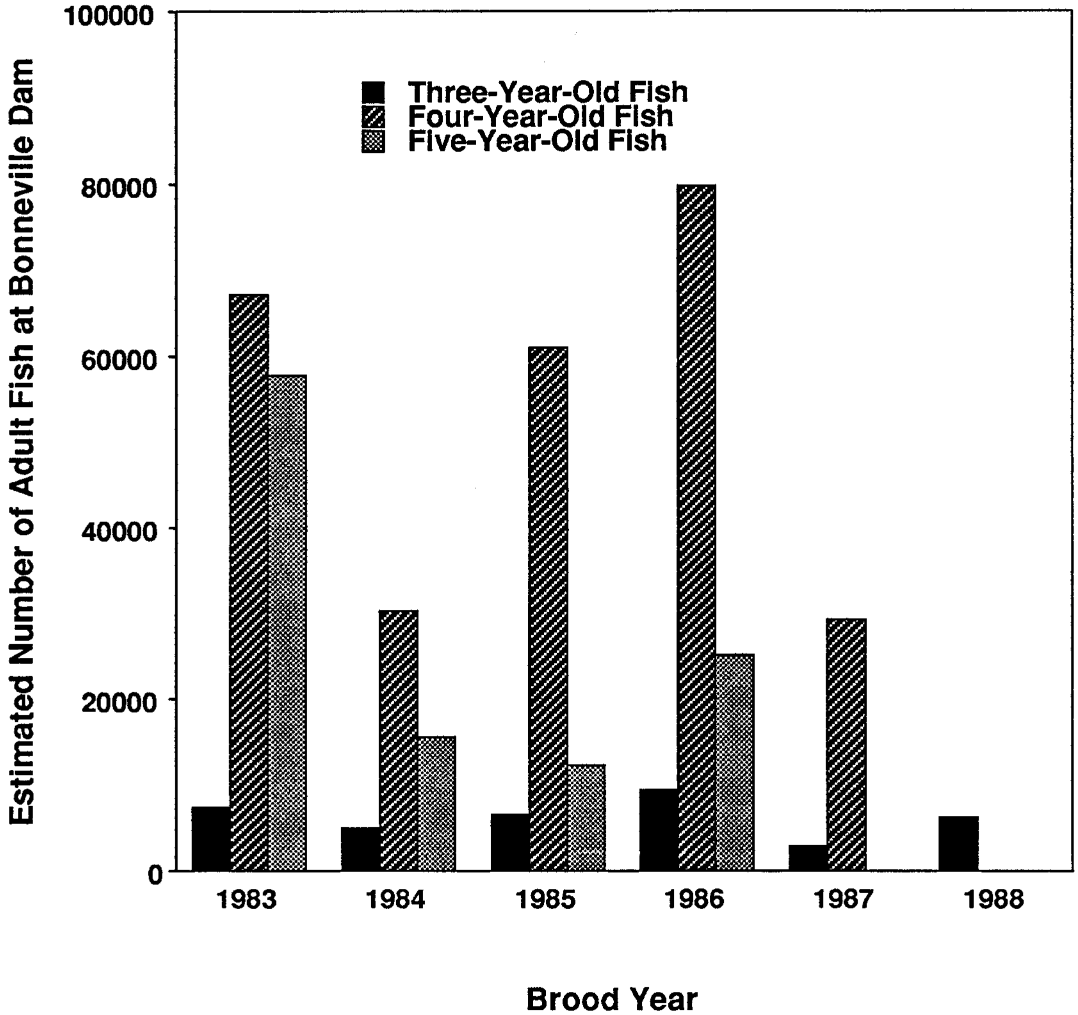
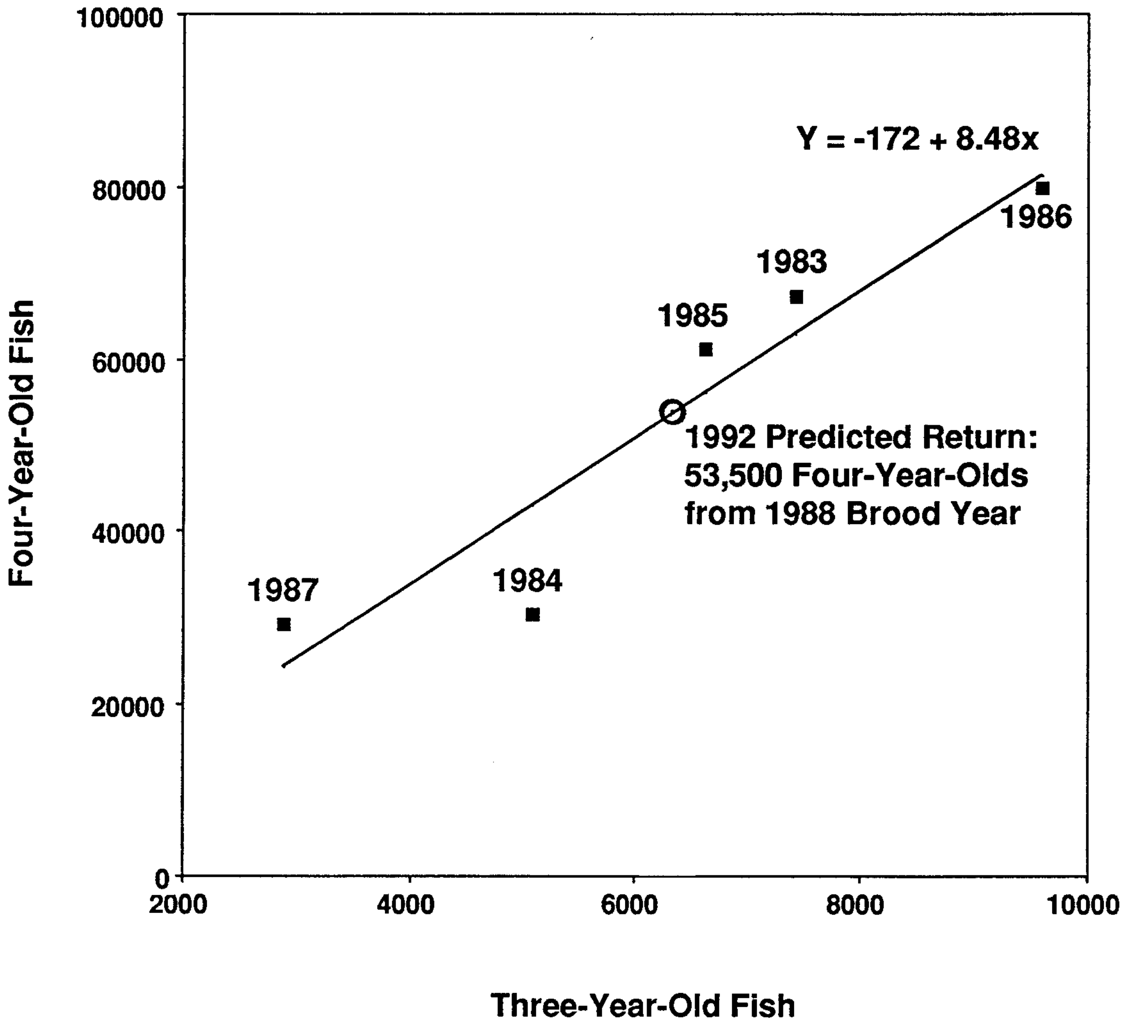


Figure 5. Prediction of 1992 four-year-old Columbia Basin spring chinook salmon abundance (at Bonneville Dam) based on a linear relationship between four-year-old and three-year-old spring chinook salmon abundance during brood years 1983 through 1987.



After standardizing results to account for the fact that Corbett gear does not effectively catch smaller fish (Dammers, in preparation), both studies reported similar age composition results in both 1989 and 1990. In 1991 however, a significant difference between the results of the two studies was noted. The difference between the two estimates could be, at least in part, a result of small sample sizes collected at Bonneville Dam in Statistical weeks 14 through 17, which was the period during which the Corbett test fishery was in operation.

Spring chinook salmon of all ages were shorter in 1991 than in any of the other five years studied. The mean fork length for three-year-old fish in 1991 was 48.1 cm, compared with a range of 48.6 to 52.4 cm in 1987 through 1990. The mean fork length for four-year-old fish in 1991 was 70.6, compared with a range of 71.6 to 72.7 cm in 1987 through 1990. The mean fork length for five-year-old fish in 1991 was 82.9 cm, compared with a range of 86 to 87.9 cm in 1987 through 1990. No explanation is apparent for the comparatively small size of spring chinook salmon returning in 1991.

For each of the past five study years, a comparison of this study's estimated percentage of age 1.1 fish in the composite sample was higher than estimates based upon age-length relationships from Bonneville Dam visual fish ladder counts. During these years, Bonneville Dam visual fish ladder age estimates were in relative agreement with those made at other mainstem Columbia River dams. This suggests the possibility that either this study overestimates abundance of age 1.1 fish or that the abundance of this group is systematically underestimated in mainstem Columbia River dam fish ladder counting programs. In 1992, a project will be initiated using video technology to estimate the accuracy of mainstem dam fish counting programs. Also, a closer examination of the sampling methods used in this study will be conducted in 1992 to determine if the number of three-year-old fish sampled is representative of the entire population.

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 population size prediction models.

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