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CRITFC

TECHNICAL REPORT 04-2

AGE AND LENGTH COMPOSITION OF COLUMBIA BASIN CHINOOK, SOCKEYE, AND COHO SALMON AT BONNEVILLE DAM IN 2003

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ABSTRACT

In continuation of the Stock Assessment Project, the Columbia River Inter-Tribal Fish Commission (CRITFC) conducted a field study at Bonneville Dam in 2003 to assess the age, length-at-age and stock composition of Pacific salmon migrating up the Columbia River, and to predict the 2004 Chinook salmon run. Adult spring, summer and fall Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*) and coho salmon (*O. kisutch*) were randomly collected, sampled for scales and additional biological data, revived and released. Caudal fin clips were also taken from Chinook salmon for later genetic analysis. Scales were examined to estimate age composition; the results contributed to an ongoing database for age class structure of Columbia Basin salmon populations. Based on scale analysis of Chinook salmon, five-year-old fish (from brood year [BY] 1998) comprised 53.9% of the spring Chinook, 50.5% of the summer Chinook, and 26.9% of the bright fall Chinook salmon migration. Four-year-old fish (BY 1999) comprised 38.5% of the spring Chinook, 32.5% of the summer Chinook, and 60.4% of the bright fall Chinook salmon migration. The largest proportion of the sockeye salmon migration through Bonneville Dam was four-year-old fish (38.4%). The coho salmon migration consisted of 93.1% three-year-old fish. A year-class regression over the past 14 years of data was used to predict spring, summer, and bright fall Chinook salmon population sizes for 2004. Based on three-year-old returns, the relationship predicts four-year-old returns of 191,300 ($\pm$ 67,400, 90% predictive interval [PI]) spring Chinook, 60,400 ($\pm$ 23,400, 90% PI) summer, and 98,200 ($\pm$ 149,400, 90% PI) bright fall Chinook salmon for the 2004 runs. Based on four-year-old returns, the relationship predicts five-year-old returns of 25,600 ($\pm$ 44,100, 90% PI) spring, 38,400 ($\pm$ 7,000, 90% PI) summer, and 182,900 ($\pm$ 89,600, 90% PI) bright fall Chinook salmon for the 2004 runs. The 2004 run size predictions should be used with caution; some of these predictions are well beyond the range of previously observed data.

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INTRODUCTION

In 1985, the US-Canada Pacific Salmon Treaty was formed between the governments of the United States and Canada in an effort to manage, research and enhance Pacific salmon (PSC 2000). The treaty established the Spawning Escapement-Monitoring program to assess indicator stocks within the Columbia River Basin and improve methods for providing population estimates, escapement monitoring, establishing spawner-recruit relationships and developing harvest management approaches (PST 1985). As part of this program, the Columbia River Inter-Tribal Fish Commission has developed a comprehensive research strategy to monitor the age and stock composition of adult Pacific salmon returning to the Columbia River. This project has monitored the above Bonneville Dam adult migration of sockeye salmon since 1985, spring Chinook salmon since 1987, summer Chinook salmon since 1990, and up-river bright fall Chinook salmon and coho salmon since 1998.

Scale pattern analysis, the analysis of concentric rings or circuli to provide records of previous life history, is a common method for age determination in Pacific salmon. Fast summer growth widens the distances between circuli on the scale and slow winter growth shortens the distance between circuli. Typically, age can be determined by counting the number of winters observed on the scale (Gilbert 1913, Rich and Holmes 1929). This method is valuable in Pacific salmon management because scales can be collected without sacrificing the fish and scale samples can be collected, processed and aged promptly. Problems with this method may include variability in scale growth, scale reabsorption and difficulties in age validation (Knudsen 1990, Beamish and McFarlane 1983).

Scale pattern analysis can also be used to determine stock composition if specific scale pattern can be linked to specific stocks. This method has been successful in discriminating Columbia River sockeye partly because there are only two major runs of sockeye in the system, which experience drastically different early rearing environments (Fryer 2004). However, this method was found to be less successful with Chinook salmon where numerous populations can exhibit similar early life histories. Currently a coast wide genetic database is being developed to create baseline genetic data for individual Chinook populations throughout the region. This baseline genetic stock information can be utilized in mixed stock sampling to distinguish individual stocks and will be useful for the Chinook sampling program at Bonneville Dam.

The primary objectives of the 2003 sampling year were to estimate the age composition and length-at-age composition of Chinook, sockeye and coho salmon using scale pattern analysis, to

forecast the 2004 run size for Chinook salmon using the age composition data and to collect tissue samples that will be used in the development of a genetic stock identification program for Chinook salmon.

METHODS

Study Area

Research was conducted at the Adult Fish Facility (AFF) located adjacent to the Second Powerhouse at Bonneville Dam (river km 235) on the north side of the Columbia River (Figure 1). This facility uses a picket weir to divert migrating fish, ascending the Washington shore fish ladder, into the adult sampling facility collection pool. An attraction flow is used to draw fish through a false weir where they can be selected for sampling. Fish not selected and fish that have recovered from sampling then migrate back to the Washington Shore Fish ladder above the picket weir.

Chinook salmon generally migrate between March and November and are typically categorized into three races based on migration timing past Bonneville Dam. Chinook salmon passing Bonneville from March 15 through May 31 are classified as spring Chinook, from June 1 through July 31 are classified as summer Chinook and August 1 through November 15 are classified as fall Chinook. The fall Chinook run consists of both the lower river Tules and the Upriver Bright fall Chinook. Based on the needs of the Pacific Salmon Commission, this study only collects information on Upriver Bright fall Chinook. Sockeye salmon migrate between May 15 and August 1 and coho between August 1 and November 1.

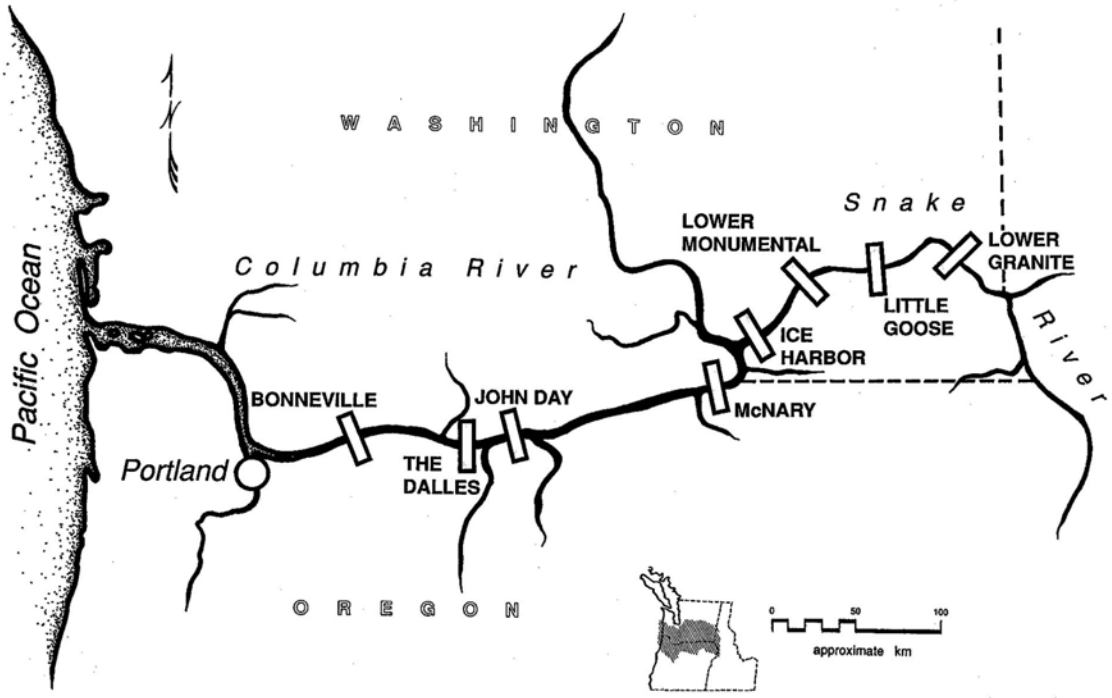

Figure 1: Map of the Columbia River displaying federal dams. Bonneville Dam (rkm 235) is the first dam upstream from the mouth.

Sample Design

Adult fish were sampled one or two days per statistical week[1] from March through October. A desired minimum sample size of 610 fish each was set for spring, summer, and fall Chinook and sockeye salmon. This sample size was derived from simulations we conducted based on the work of Thompson (1987) and assumes that the sample is distributed approximately proportional to the weekly run size. Also assumed is that our weekly sample represents a random sample of the run passing over Bonneville Dam that week. Given these assumptions, desired levels of precision and accuracy (d=0.05, a=0.10) for age composition estimates are achieved. No minimum sample size was set for coho which are not a species of interest to the Pacific Salmon Commission and have been sampled incidentally with fall Chinook salmon. The composite age and length-at-age estimates are calculated from weekly estimates weighted by the number of each species migrating past Bonneville Dam during the sample week (Fryer 1995). Weekly and annual dam counts of fish passage[2] were obtained from DART (2003) and the Fish Passage Center (2003).

1. Statistical weeks are sequentially numbered calendar-year weeks starting with the week that includes January 1 (Week 1). Excepting the first and last weeks of most years, weeks are seven days long, beginning on Sunday and ending on Saturday. In 2003, for example, Statistical Week 13 began on March 23 and ended on March 29.
2. Tule fall Chinook counts are subtracted from the total fall Chinook counts to estimate the upriver bright fall Chinook.

Fish Collection

Fish of each species were randomly trapped at the AFF and anesthetized. Chinook salmon under 35 cm were not sampled to exclude precocious juveniles. All sockeye and coho were sampled. Each fish was measured for fork length to the nearest 0.5 cm, checked for identifying marks, tags, coloration and condition. Scale samples were collected from all fish for aging and caudal fin tissue was collected from all Chinook salmon for genetic stock composition analysis. These genetic samples will be used in the development of a genetic stock identification program for Columbia River Chinook salmon. All fish were revived in a freshwater tank or pool and returned to a fishway leading to the Washington shore fish ladder.

Fish Coloration and Condition

Fish coloration and condition were recorded for all species at the time of sampling. Coloration was based on qualitative observations with the categories of Bright, Intermediate and Dark. Overall fish condition was also qualitative and was classified on a scale of 1 to 5. Fish classified as a 5 had no major injuries that break the skin, 4 had injuries that broke the skin, 3 had injuries that penetrate the muscle tissue, 2 had injuries that penetrate a body cavity and 1 are fish missing large sections of the body. In addition to the fish condition classification, specific recognizable injuries or afflictions were recorded. These included percentage of descaling, marine mammal injuries, net damage, parasites, fungus, headburn[1], gas bubble trauma, deformities and various other injuries.

Age Determination

To minimize the scale sample rejection rate, six scales (three per side) were collected for each Chinook and coho salmon sampled (Knudsen 1990) and four scales (two per side) were collected from each sockeye salmon sampled. Scales were mounted and pressed according to methods described by 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 (Gilbert 1913, Rich and Holmes 1929). A sub-sample of scales was sent to John Sneva of the Washington Department of Fish and Wildlife for

2. Headburn, the exfoliation of skin and tissues of the jaw and cranial region, has been identified as a possible stress indicator of high river flow conditions or spillway discharge from dams (Elston 1996, Groberg 1996).

corroboration of age estimates. Direct age validation (Beamish and McFarlane 1983) was not performed, as ages estimated from scale patterns could not be compared to known ages during this sampling season.

The European method for fish age description (Koo 1962) is used in this report. 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.

Age and Length-at-Age Composition

Age composition was determined by weighing the proportion of each age class sampled by the total counts of each species passing Bonneville dam during each statistical week. The length-at-age composition for each species sampled is determined by calculating the mean length for each age class present during each statistical week.

Chinook Salmon Run-Size Prediction

Salmon mature and return to spawn between two and seven years of age. Age composition, life history and total age vary among species. For this analysis a brood year (BY) is defined as the year in which the eggs are fertilized and a brood is defined as all the returning progeny of a given BY. This run-size prediction model is based on the relationship between the survivors within a single brood returning at different ages in successive years.

Fryer and Schwartzberg (1994) determined that the number of three-year-old fish for a given BY was a relatively good predictor of the number of subsequent returning four-year-old fish of the same BY. This relationship and a regression analysis (Neter et al. 1985, Weisberg 1985) are used herein to predict the abundance (four-year-old fish in 2004) and the predictive interval ([PI] range), from a known value (the three-year-old fish that returned in 2003). A similar relationship is used to predict returning five-year-old fish in 2004 from four-year-old fish that returned in 2003.

RESULTS/ DISCUSSION

Sampling

Chinook salmon (spring, summer and fall) were sampled for 24 weeks (March through October) during their migration representing 76.6% of the entire Chinook salmon run. A total of 795 spring Chinook were sampled, 551 summer Chinook and 614 fall Chinook (Table 2, 3 and 4 respectively). A total of 389 sockeye salmon were sampled (Table 5) over 6 weeks (June through July) representing 97.6% of their run, and 670 coho salmon were sampled (Table 6) over 7 weeks (September through October) representing 74.9% of the coho run. There was no sampling during statistical weeks 30 through 36 due to river water temperatures exceeding 20°C, which is approaching the lethal temperature for migrating adult Chinook salmon (McCullough 1999). Because of the near-lethal water temperatures, we were unable to sample during statistical weeks 30 and 31 of the summer Chinook run and weeks 32 through 36 of the fall Chinook and coho run.

Fish Coloration and Condition

Bright coloration was observed in the majority of each species, 96.3% of spring Chinook, 95.5% of summer Chinook, 77.4% of fall Chinook, 99.7% of sockeye and 81.6% of coho. The highest condition rating of 5 was given to 89.4% of spring Chinook, 96.2% of summer Chinook, 91.7% of fall Chinook, 96.9% of sockeye and 86.1% of coho (Table 1). Additional fish condition data can be found in Appendix A.

Table 1: Composition (%) of observed coloration and condition of Columbia Basin salmon sampled at Bonneville Dam in 2003.

Species	Spring	Summer	Fall	Sockeye	Coho
Coloration					
Bright	96.3	95.5	77.4	99.7	81.6
Intermediate	3.4	4.4	19.1	0.3	14.8
Dark	0.3	0.2	3.6	0.0	3.6
Condition					
5	89.4	96.2	91.7	96.9	86.1
4	6.4	2.4	6.0	2.3	11.6
3	3.5	1.3	2.1	0.8	2.2
2	0.6	0.2	0.2	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0

Age Composition

Based on scale pattern analysis spring Chinook salmon returns were estimated to be 53.9% five-year-olds (Table 2, Figure 2), 38.5% four-year-old fish and a small proportion of three- and six-year-old fish at 7.2% and 0.3% respectively. An estimated 0.4% of the run had scale patterns indicating an ocean-type life history and 99.6% of the run had a stream-type life history (Table 2, Figure 3).

The summer Chinook salmon run consisted of 50.5% five-year-old fish (Table 3, Figure 2), 32.5% four-year-old fish and smaller proportions of three-, six- and two-year-old fish at 12.8%, 3.5% and 0.7% respectively. Scale patterns indicated that 22.8% of the summer run had an ocean-type life history and 77.2% of the run had a stream-type life history (Table 3, Figure 3).

Upriver Bright fall Chinook salmon were mostly four- (60.4%) and five-year-olds (26.9%), with smaller proportions of three- (9.6%), two- (3.0%) and six-year-old (0.12%) age classes (Table 4, Figure 2). Scale patterns indicated that 83.5% of the fall run had scale patterns indicating an ocean-type life history and 16.5% had a stream-type life history (Table 4, Figure 3).

Table 2: Weekly and cumulative age composition of Columbia Basin spring Chinook salmon sampled at Bonneville Dam in 2003.

					Age Composition by Brood Year and Age Class						
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2000	1999		1998		1997	
					1.1	0.3	1.2	0.4	1.3	1.4	2.3
13[a]	3/26	23	21	11196	0.048		0.048		0.905		
14	4/01, 4/03	85	80	15380			0.175		0.825		
15	4/08, 4/11	42	40	33413			0.325		0.675		
16	4/15, 4/17	110	88	29004			0.375		0.614		0.011
17	4/22, 4/24	140	113	32720	0.009		0.549		0.442		
18	4/29, 5/01	140	118	26054	0.127	0.008	0.551		0.314		
19	5/06, 5/08	71	60	15785	0.233		0.433		0.333		
20	5/13, 5/16	68	59	15323	0.136		0.288		0.576		
21	5/20, 5/22	90	83	15835	0.253		0.373		0.349	0.024	
22	5/29	26	22	11558	0.091		0.409	0.045	0.455		
Cumulative		795	684	206268	0.072	0.001	0.384	0.003	0.537	0.002	0.002
Ten Year Average		739	687	112037	0.063	0.002	0.783	0.000	0.149	0.002	0.000

Official spring chinook run at Bonneville Dam begins March 15 and ends May 31.

a Weekly run size includes fish numbers from Weeks 11-12. Sampling began in Week 13.

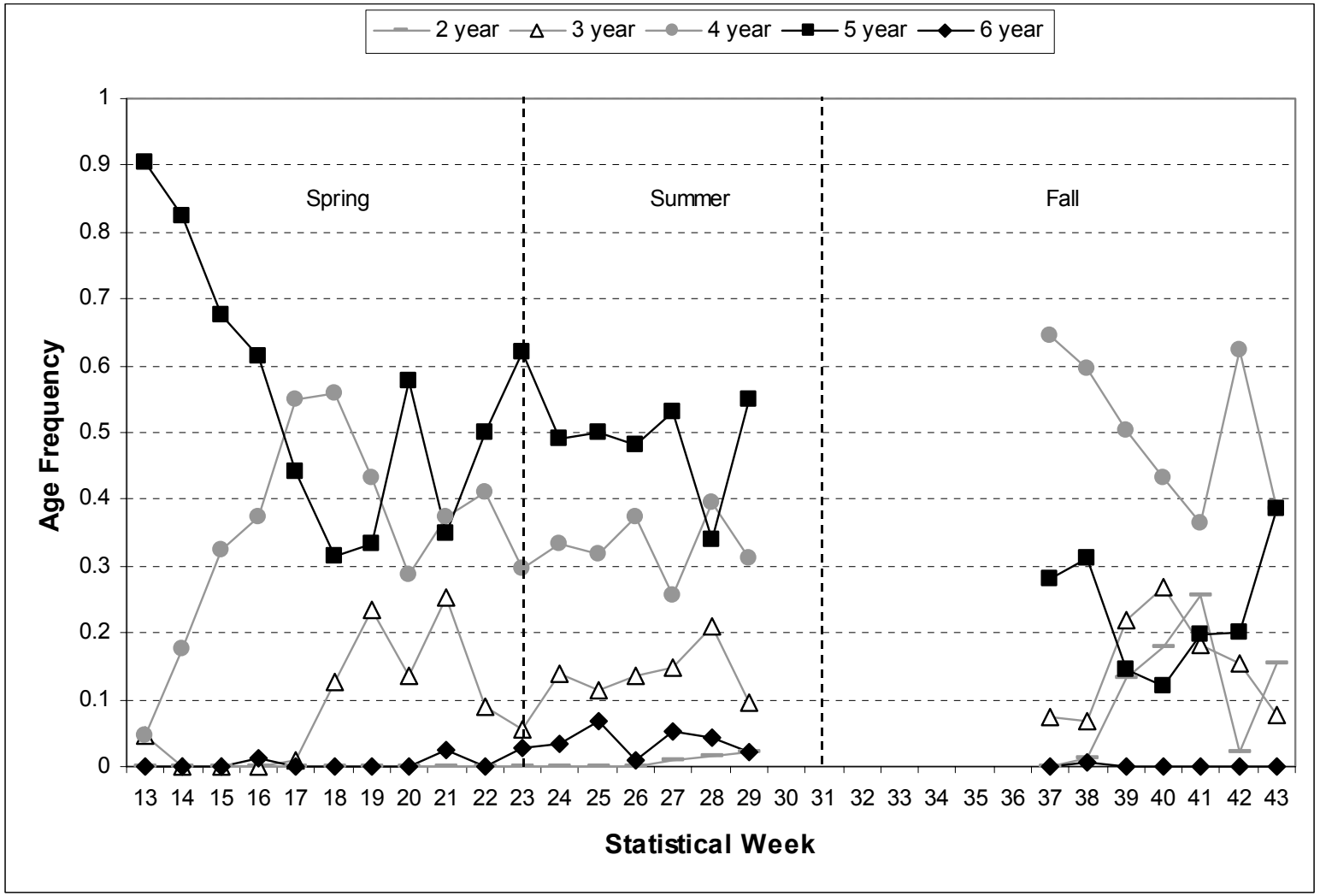

Figure 2: Weekly age composition estimates for age groups of Columbia Basin Chinook salmon sampled at Bonneville Dam in 2003. Sampling did not occur during Weeks 30-36.

Table 3: Weekly and cumulative age composition of Columbia Basin summer Chinook salmon sampled at Bonneville Dam in 2003.

					Age Composition by Brood Year and Age Class								
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2001	2000			1999		1998		1997
					0.1	0.2	1.1	2.0	0.3	1.2	0.4	1.3	1.4
23	6/3	40	37	14516			0.054			0.297	0.054	0.568	0.027
24	6/12	60	57	20961			0.140		0.053	0.281	0.140	0.351	0.035
25	6/17	50	44	17153			0.114		0.068	0.250	0.114	0.386	0.068
26	6/24, 6/26	120	110	21995		0.009	0.127		0.136	0.236	0.109	0.373	0.009
27	7/1, 7/2	103	94	19150	0.011		0.128	0.021	0.106	0.149	0.064	0.468	0.053
28	7/8, 7/10	78	71	13121	0.014	0.028	0.183		0.211	0.183	0.028	0.310	0.042
29[a]	7/15, 7/17	100	93	21270	0.022	0.022	0.075		0.204	0.108	0.151	0.398	0.022
Cumulative		551	506	128166	0.007	0.008	0.116	0.003	0.113	0.212	0.100	0.405	0.035
Ten Year Average		498	457	43290	0.005	0.024	0.112	0.000	0.091	0.408	0.041	0.297	0.019

Official summer chinook run at Bonneville dam begins June 1 and ends July 31.

Age composition of ten year average does not add to 100% as not all age classes of previous years are displayed.

a Weekly run size includes fish numbers from Weeks 30-31. Sampling ended in Week 29.

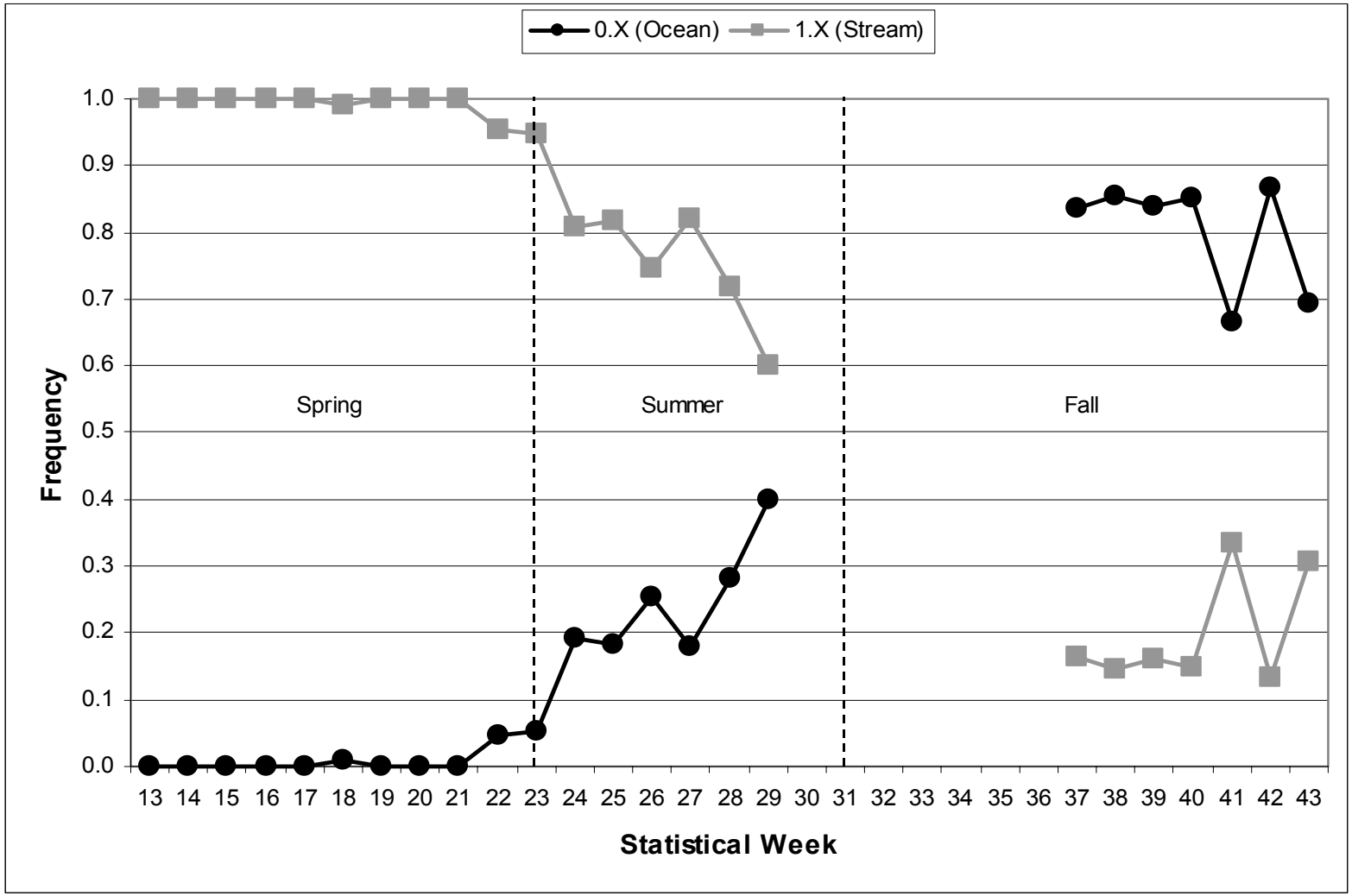

Figure 3: Weekly freshwater age composition estimates of Columbia Basin Chinook salmon sampled at Bonneville Dam in 2003. Freshwater 2.X age classes were not graphed. Sampling did not occur during Weeks 30 through 36.

Table 4: Weekly and cumulative age composition of Columbia Basin bright fall Chinook salmon sampled at Bonneville Dam in 2003.

					Age Composition by Brood Year and Age Class								
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2001		2000		1999		1998		1997
					0.1	1.0	0.2	1.1	0.3	1.2	0.4	1.3	0.5
37[a]	9/9, 9/12	116	110	295177			0.045	0.027	0.545	0.100	0.245	0.036	
38	9/15, 9/16	150	144	100461	0.014		0.028	0.042	0.535	0.063	0.271	0.042	0.007
39	9/23, 9/24	149	137	44939	0.117	0.015	0.131	0.088	0.453	0.051	0.139	0.007	
40	9/30, 10/1	70	67	16705	0.179		0.179	0.090	0.403	0.030	0.090	0.030	
41	10/7, 10/8	70	66	11009	0.182	0.076	0.015	0.167	0.318	0.045	0.152	0.045	
42	10/14, 10/16	46	45	5980	0.022		0.133	0.022	0.556	0.067	0.156	0.044	
43[b]	10/23	13	13	7711	0.077	0.077	0.077		0.231	0.154	0.308	0.077	
Cumulative		614	582	481982	0.026	0.004	0.055	0.041	0.520	0.084	0.233	0.035	0.001
Six Year Average		593	554	258862	0.046	0.000	0.252	0.040	0.371	0.094	0.140	0.046	0.003

Official fall chinook run at Bonneville Dam begins August 1 and ends November 15.

Age composition of six year average does not add to 100% as not all age classes of previous years are displayed.

a Weekly run size includes fish numbers from Weeks 30-36. Sampling began in Week 37.

b Weekly run size includes fish numbers from Weeks 44-46. Sampling ended in Week 43.

The Sockeye salmon run was estimated to be composed of 38.4% four-year-olds, 27.8% five-year-olds and 25.4% three-year-old fish. There were smaller proportions of six- (8.4%) and seven-year-old fish (0.1%). Age class 1.2 was the most abundant (32.4%) followed by the 1.1 (25.4%) age class (Table 5).

The 2003 coho salmon run passing Bonneville Dam was estimated as 99.1% three-year-old fish (age class 1.1) from the 2000 BY (Table 6), while 0.9% of the run were aged as two-year-old fish (age class 1.0).

Length-at-Age Composition

Length-at-age composition estimates are presented in Appendix A and in Figure 4.

Table 5: Weekly and cumulative age composition of Columbia Basin sockeye salmon sampled at Bonneville Dam in 2003.

					Age Composition by Brood Year and Age Class									
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2000	1999		1998			1997			1996
					1.1	1.2	2.1	1.3	2.2	3.1	2.3	3.2	4.1	3.3
24[a]	6/12	11	11	1843	0.091	0.818		0.091						
25	6/17	30	30	5832	0.100	0.467	0.067	0.167		0.133		0.033	0.033	
26	6/24, 6/26	70	68	15165	0.132	0.338	0.044	0.235		0.103	0.015	0.044	0.088	
27	7/1, 7/2, 7/3	134	127	9795	0.315	0.276	0.094	0.094		0.173	0.008	0.016	0.024	
28	7/8, 7/9, 7/10	131	124	4266	0.621	0.113	0.048	0.032	0.008	0.121	0.008	0.016	0.024	0.008
29[b]	7/15, 7/17	13	13	2390	0.615	0.077	0.077	0.077		0.154				
Cumulative		389	373	39291	0.254	0.324	0.060	0.152	0.001	0.125	0.009	0.028	0.048	0.001
Five Year Average		495	479	57800	0.032	0.746	0.006	0.097	0.109	0.000	0.003	0.005	0.000	0.000

Age composition of five year average does not add to 100% as not all age classes of previous years are displayed.

a Weekly run size includes fish numbers from Week 22-23. Sampling began in Week 24.

b Weekly run size includes fish numbers from Weeks 30-37. Sampling ended in Week 29.

Table 6: Weekly and cumulative age composition of Columbia Basin coho salmon sampled at Bonneville Dam in 2003.

					Age Composition by Brood Year and Age Class	
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2001 1.0	2000 1.1
37[a]	9/9	5	4	51304		1.000
38	9/15, 9/16	60	54	32924		1.000
39	9/23, 9/24	80	72	10614		1.000
40	9/30, 10/1	150	147	7155		1.000
41	10/7, 10/8	130	120	10520	0.075	0.925
42	10/12, 10/14, 10/16	205	189	12764	0.011	0.989
43[b]	10/23	40	38	8615	0.026	0.974
Cumulative		670	624	133896	0.009	0.991
Three Year Average		377	358	152341	0.027	0.970

Age composition of three year average does not add to 100% as not all age classes of previous years are displayed.

a Weekly run size includes fish numbers from Weeks 28-36. Sampling began in Week 37.

b Weekly run size includes fish numbers from Weeks 44-46. Sampling ended in Week 43.

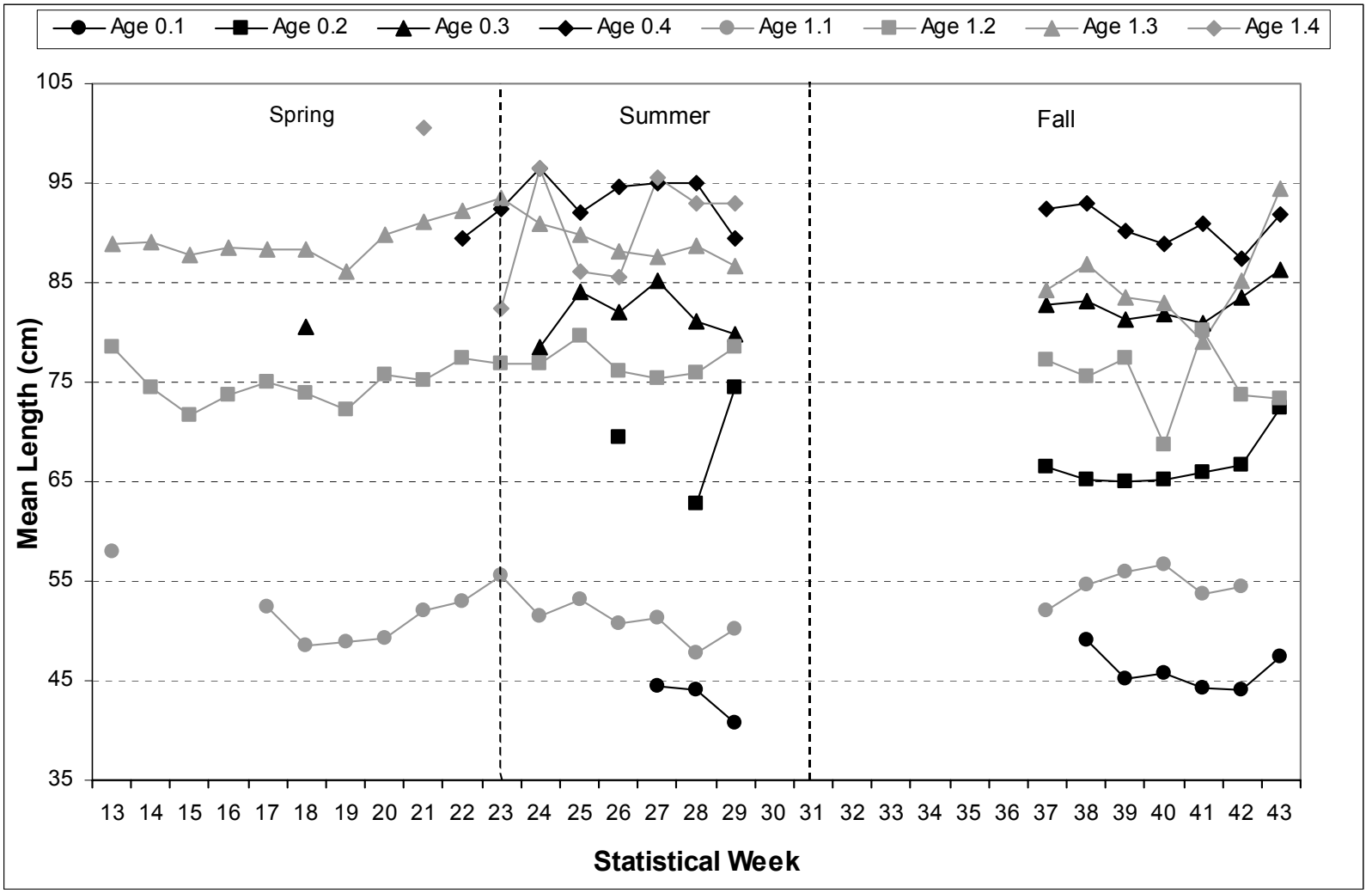

Figure 4: Weekly mean length estimates of Columbia Basin Chinook salmon by age class (showing ocean- and stream-type) sampled at Bonneville Dam in 2003. Not all life history types were present each week of sampling. Age classes (1.0, 2.0, 0.5 and 2.3) with few fish were not graphed. Sampling did not occur during Weeks 30 through 36.

Chinook Salmon Run-Size Prediction for 2004

Using a linear relationship between the 2003 three- and four-year-old returns of spring Chinook (Figure 5) to predict the abundance of four-year-old adult spring Chinook salmon returning to Bonneville Dam in 2004, the estimated number of adult returns is 191,300 (± 67,400, 90% PI). Using the relationship between four- and five-year-olds to construct the model (Figure 6), albeit poorer than that existing between three-year-olds and four-year-olds, predicts that the 2004 five-year-old adult abundance at Bonneville Dam will be 25,600 (± 44,100, 90% PI).

For the 2004 summer Chinook salmon run at Bonneville Dam, the relationship between three- and four-year-olds (Figure 7) results in a prediction of 60,400 (± 23,400, 90% PI) four-year-olds. The relationship between four- and five-year-olds (Figure 8), the model predicts a return of 38,400 (± 7,000, 90% PI) five-year-olds.

Based on the relationship between three- and four-year-olds (Figure 9), the model results in a prediction of 98,200 (± 149,400, 90% PI) four-year-old Upriver Bright fall Chinook salmon returns for 2004. Using the relationship between four- and five-year-olds (Figure 10), the model results in a prediction of 182,900 (± 89,600, 90% PI) returning five-year-olds.

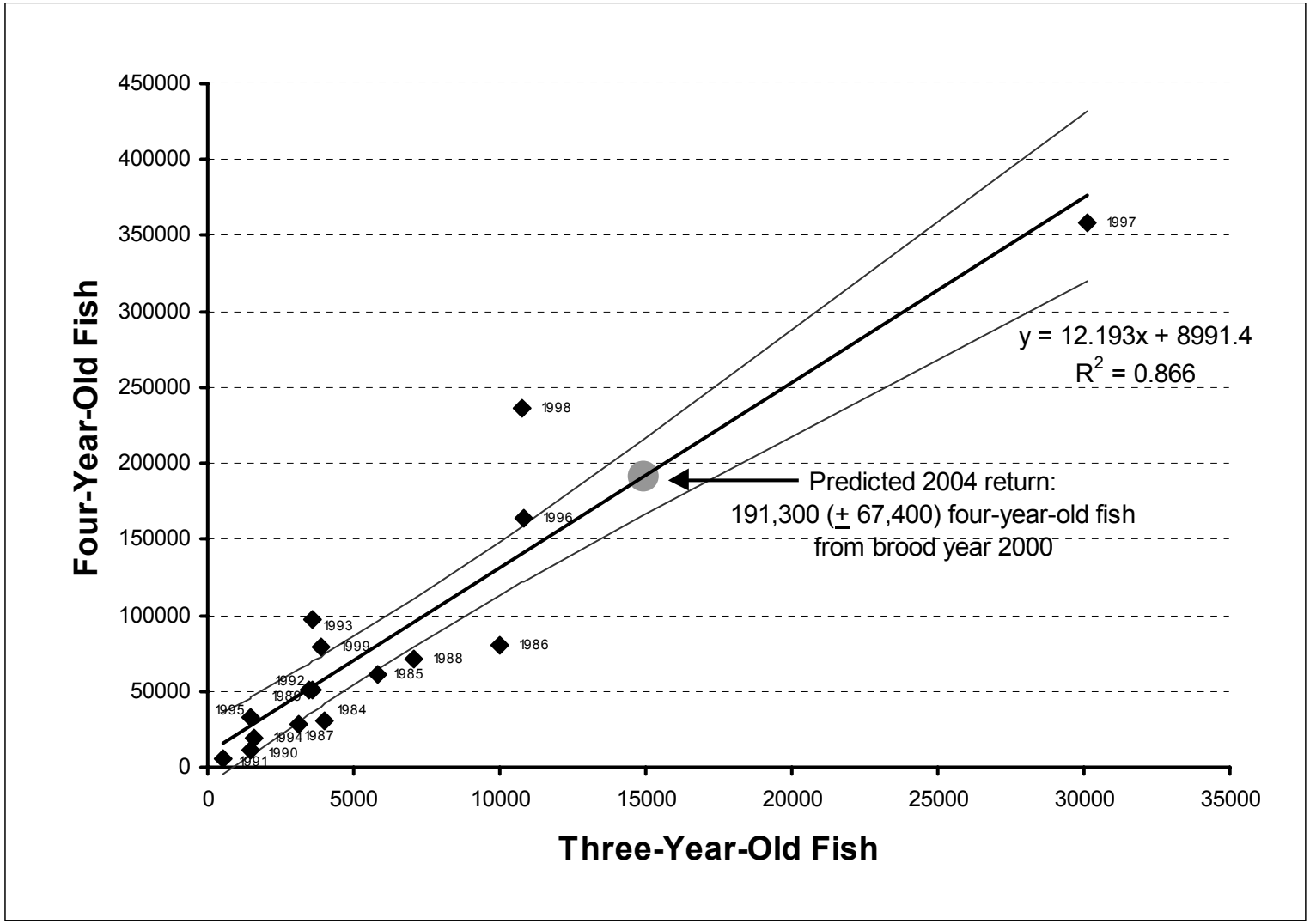

Figure 5: Predicted 2004 four-year-old Columbia Basin spring Chinook salmon abundance (at Bonneville Dam) based on a linear relationship between four-year-old and three-year-old fish abundance during brood years 1984 through 1999. Confidence intervals (90%) are also graphed.

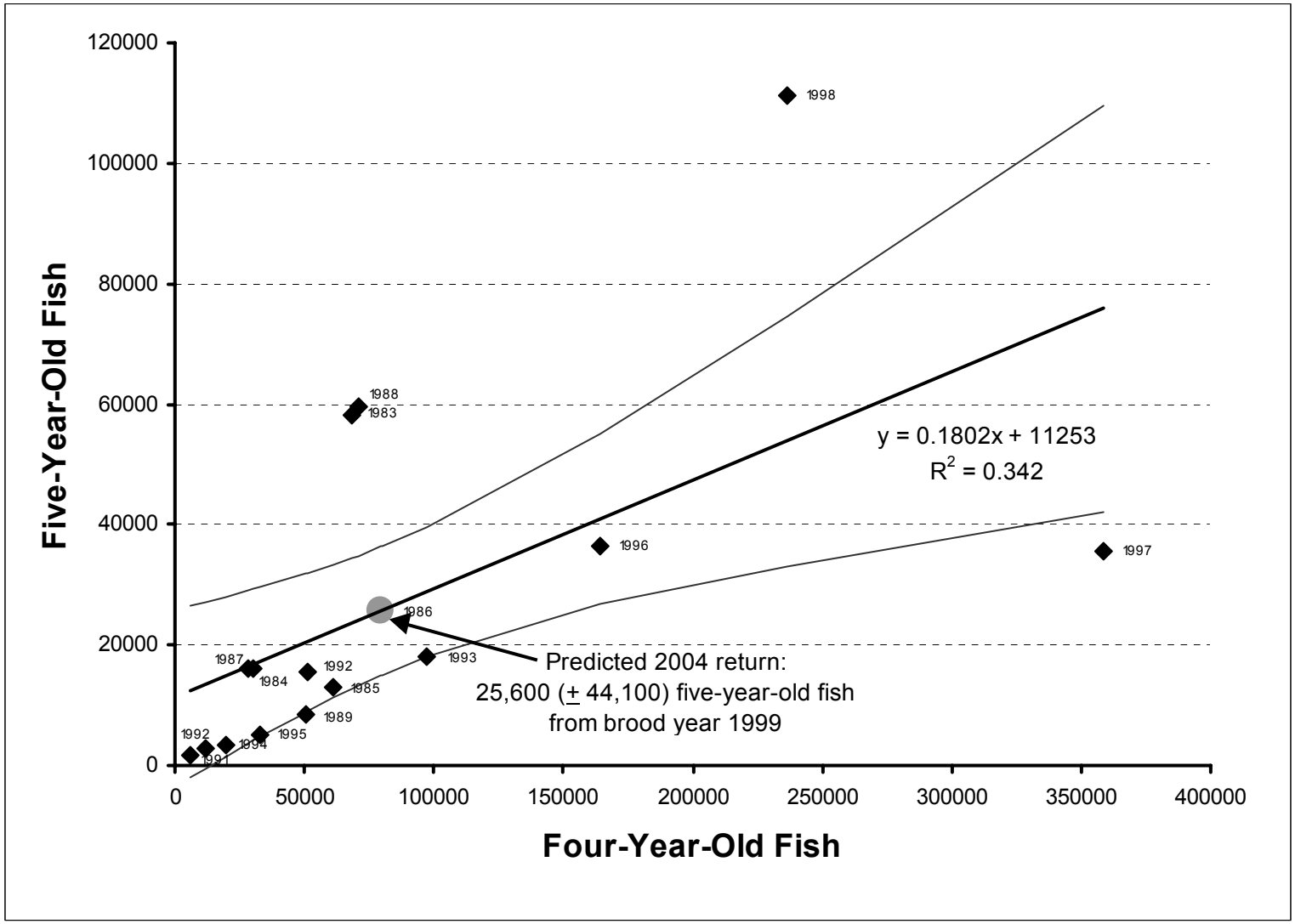

Figure 6: Predicted 2004 five-year-old Columbia Basin spring Chinook salmon abundance (at Bonneville Dam) based on a linear relationship between five-year-old and four-year-old fish abundance during brood years 1983 through 1998. Confidence intervals (90%) are also graphed.

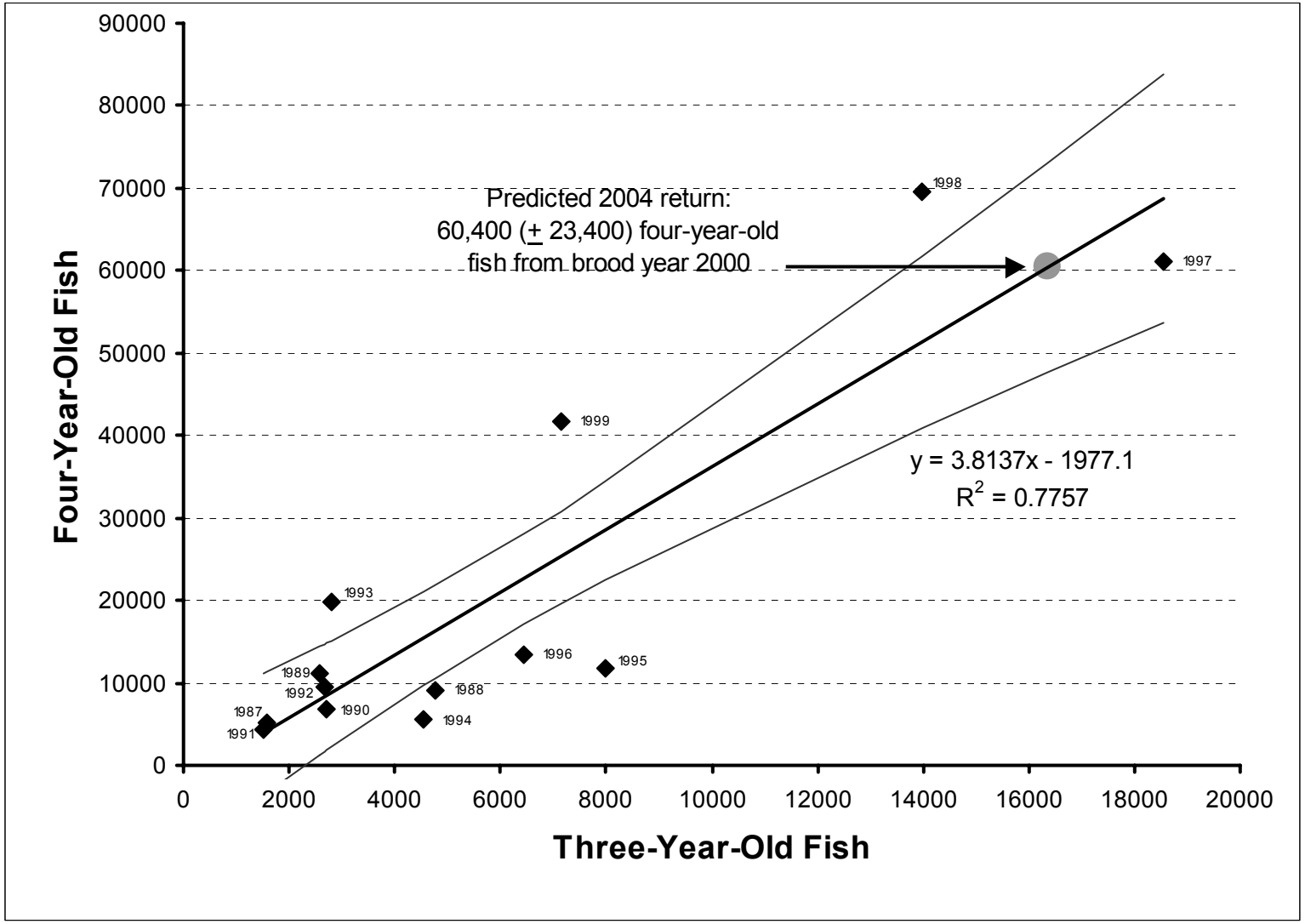

Figure 7: Predicted 2004 four-year-old Columbia Basin summer Chinook salmon abundance (at Bonneville Dam) based on a linear relationship between four-year-old and three-year-old fish abundance during brood years 1987 through 1999. Confidence intervals (90%) are also graphed.

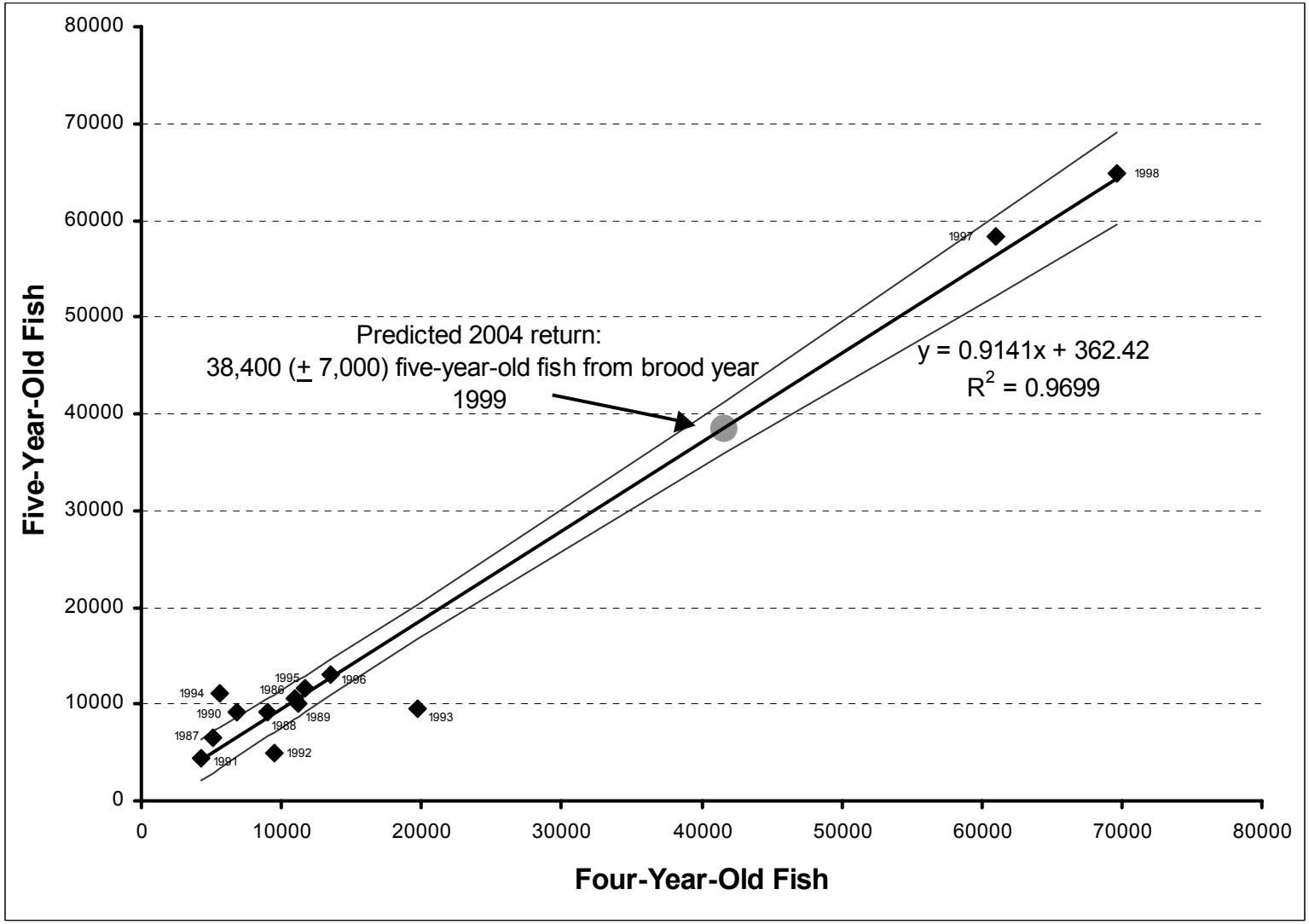

Figure 8: Predicted 2004 five-year-old Columbia Basin summer Chinook salmon abundance (at Bonneville Dam) based on a linear relationship between five-year-old and four-year-old fish abundance during brood years 1986 through 1998. Confidence intervals (90%) are also graphed.

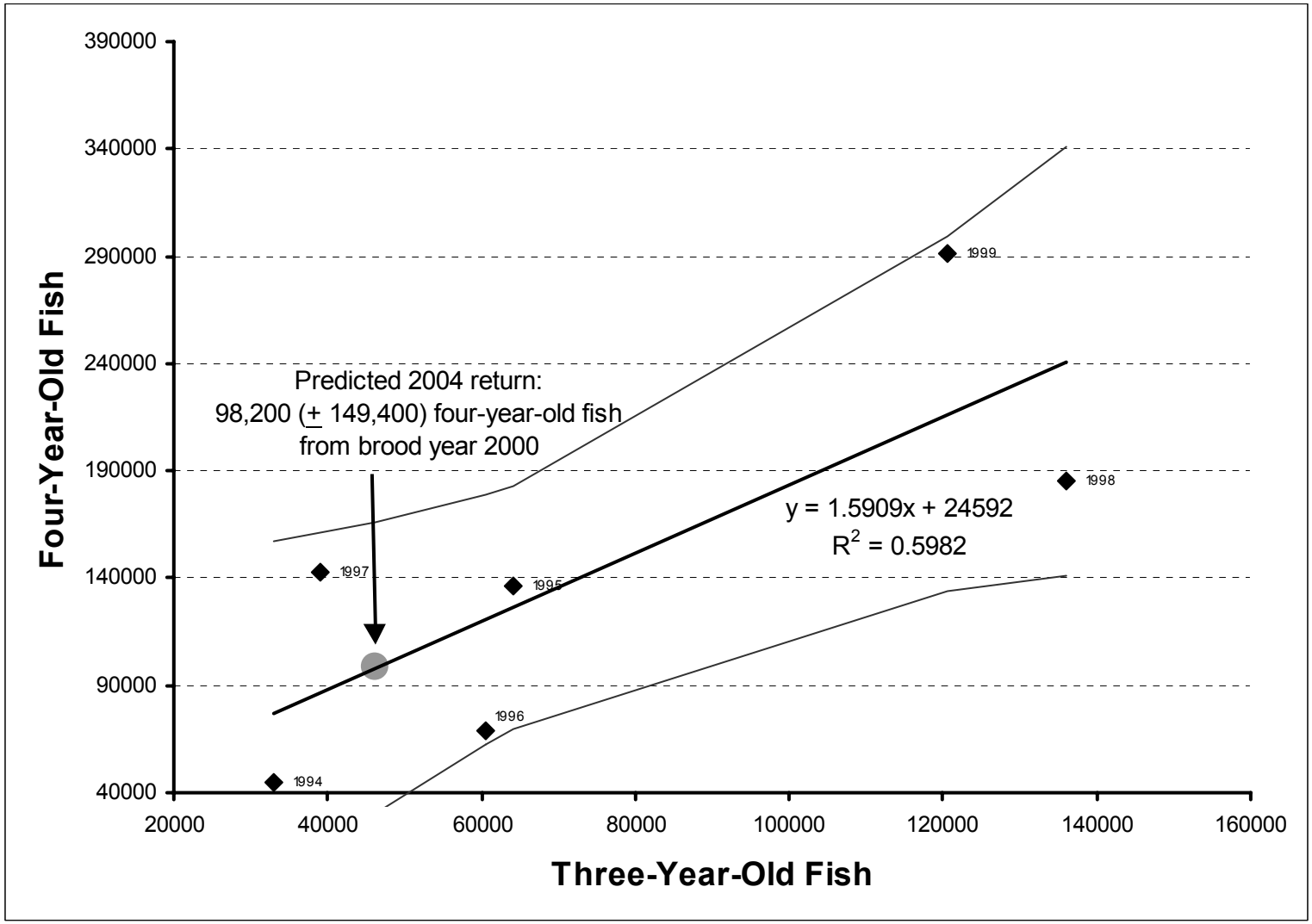

Figure 9: Predicted 2004 four-year-old Columbia Basin bright fall Chinook salmon abundance (at Bonneville Dam) based on a linear relationship between four-year-old and three-year-old fish abundance during brood years 1994 through 1999. Confidence intervals (90%) are also graphed.

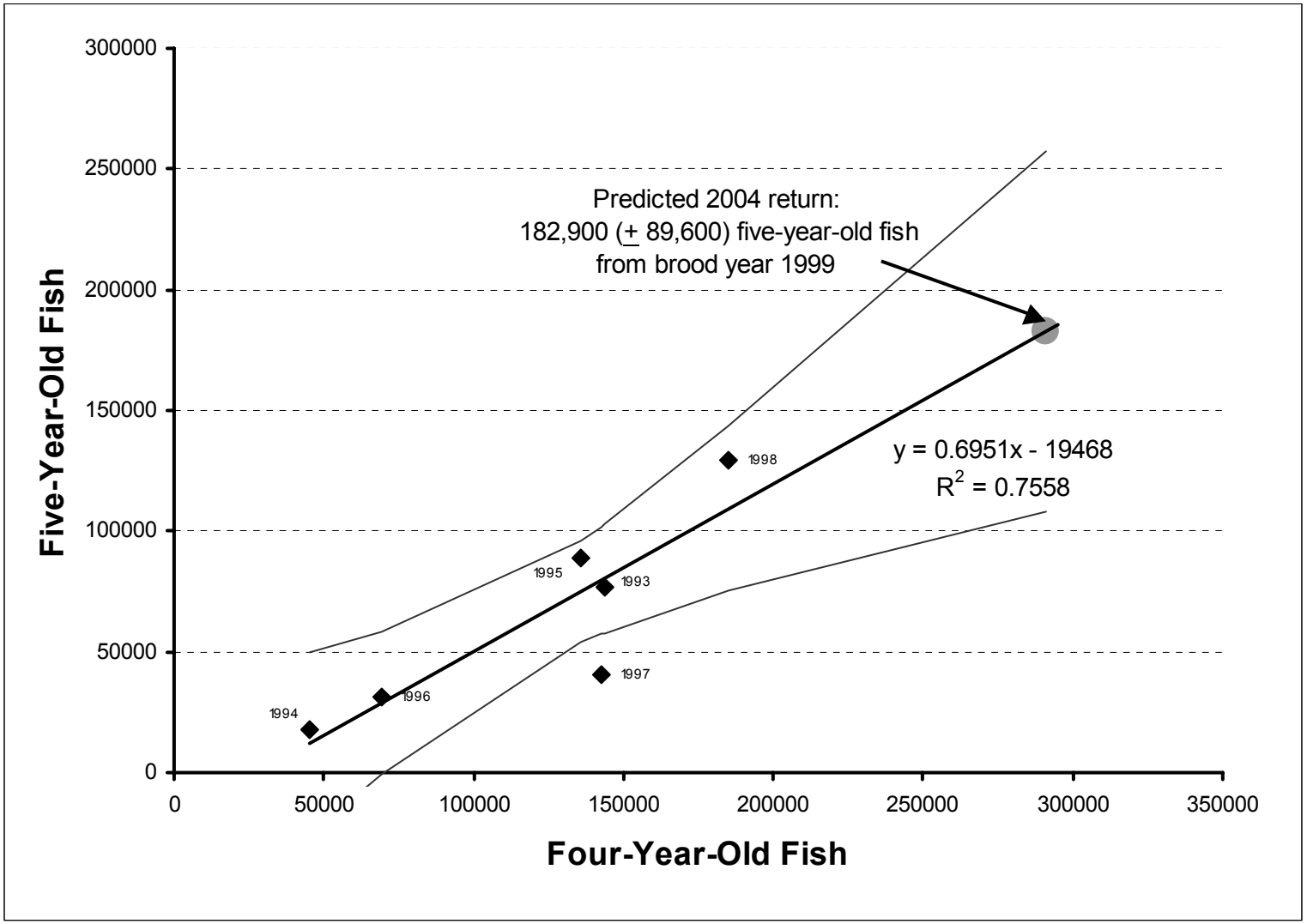

Figure 10: Predicted 2004 five-year-old Columbia Basin bright fall Chinook salmon abundance (at Bonneville Dam) based on a linear relationship between five-year-old and four-year-old fish abundance during brood years 1993 through 1998. Confidence intervals (90%) are also graphed.

Based on 2002 results, we made run size predictions for four- and five-year-old spring, summer, and bright fall Chinook salmon returning to Bonneville Dam in 2003 (Kelsey and Fryer 2003) using the methods discussed in this report. For the two principle age groups (four-year-old and five-year-old), we predicted 90,500 spring, 87,600 summer and 260,200 bright fall Chinook versus DART (2003) and the Fish Passage Center (2003) estimated returns of 190,600 spring, 106,500 summer and 420,600 bright fall Chinook salmon. Five of the six age groups predicted for 2003 were within the 90% prediction interval (Table 6). We significantly underestimated the 2003 return of five-year-old spring Chinook.

Table 7: Predicted and estimated abundance of Chinook salmon returning to Bonneville Dam.

Species	2002 Report's Predicted (± 90%) for Year 2003	Year 2003 Estimate	Predicted (± 90%) for Year 2004
Spring Chinook 4-year-old	54,200 (± 66,600)	79,400	191,300 (± 67,400)
Spring Chinook 5-year-old	36,300 (± 35,400)	111,200	25,600 (± 44,100)
Summer Chinook 4-year-old	23,800 (± 19,100)	41,700	60,400 (± 23,400)
Summer Chinook 5-year-old	63,800 (± 10,300)	64,800	38,400 (± 7,000)
Bright Fall Chinook 4-year-old	169,100 (± 139,500)	291,100	98,200 (± 149,400)
Bright Fall Chinook 5-year-old	91,100 (± 69,400)	129,500	182,900 (± 89,600)

2003 estimate is calculated using the proportion of X-year-old returning in 2003 multiplied by the count of spring, summer and fall chinook at Bonneville Dam.

Overall, we predict that the 2004 spring and summer Chinook return of four-year-old and five-year-old fish will be similar to the 2003 return of 190,600 and 106,500 fish respectively (Table 6). We predict that the 2004 Upriver Bright fall Chinook salmon run of four- and five-year-old fish will be less than 2003 return of 420,600 fish.

All of our predictions for Chinook returning in 2004 are based on a relatively low number of data points and are beyond the majority of historical data points. Particularly, our prediction for five-year-old Upriver Bright fall Chinook salmon returning in 2004 is based on a low number of data points and is beyond the range of all previous data for five-year-old Upriver Bright fall Chinook salmon. A regression to predict beyond the range of past data should be used with extreme caution, as it cannot be assumed that the regression function that fits the past data is appropriate over a wider range (Neter et al. 1985).

It is expected that this study will continue to develop an accurate age composition and length-at-age database for Columbia Basin upriver salmon populations, and work towards improving the forecasting of terminal runs, which is important for the calibration of the Chinook Technical Committee's Chinook model. The data will also aid fisheries managers in formulating spawner-return relationships and analyzing productivity. Continued data collection on age composition and length-at-age will allow managers to more accurately monitor the effects of ocean harvest restrictions agreed upon by the Pacific Salmon Treaty.

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APPENDIX A

LIST OF TABLES

Table A1: Percent of sampled Chinook, sockeye and coho salmon at Bonneville Dam having identifying clips by statistical week and total sampled in 2003.

Statistical Week	Spring Chinook	Summer Chinook	Fall Chinook	Sockeye	Coho
11	X				
12	X				
13	47.8				
14	52.9				
15	47.6				
16	48.2				
17	42.1				
18	44.3				
19	56.3				
20	54.4				
21	50.0				
22	34.6				
23		47.5			
24		43.3		0.0	
25		48.0		0.0	
26		48.3		4.3	
27		59.2		0.0	
28		53.8		0.0	X
29		50.0		0.0	X
30		X			X
31		X	X		X
32			X		X
33			X		X
34			X		X
35			X		X
36			X		X
37			5.2		0.0
38			8.0		26.7
39			6.0		18.8
40			8.6		28.0
41			7.1		28.5
42			4.3		33.7
43			15.4		40.0
44			X		X
45			X		X
46			X		X
% of Total Sampled	47.9	50.8	6.8	0.8	29.1

X Represents a week that a species was present, but sampling did not occur. Therefore, the percent in a statistical week before or after an X is assumed to represent the weeks during which sampling did not occur. For example, spring Chinook were first sampled in Week 13 and this week is assumed to represent Weeks 11 and 12 as well.

Table A2: Composition (%) of observed injuries of Columbia Basin Chinook salmon sampled at Bonneville Dam in 2003.

Injury Category	Spring	Summer	Fall
Marine Mammal			
Bite	2.9	0.5	0.0
Claw Rake	14.3	4.4	9.3
Golden Arches	10.7	4.9	2.9
Total[a]	27.4	9.8	12.2
Descaling			
< 3%			
Right side	1.1	1.6	4.9
Left side	1.4	0.7	4.4
Total[b]	0.6	1.3	3.1
3-19%			
Right side	13.2	15.6	23.5
Left side	12.5	11.4	23.1
Total[c]	13.6	15.6	23.9
≥20%			
Right side	0.9	1.1	2.4
Left side	0.8	1.3	2.8
Total[d]	1.0	1.5	3.7
Other Injuries			
Bruise	0.1	0.0	1.1
Cut	0.5	0.2	0.0
Head Injury	3.9	5.1	17.4
Head Burn	0.8	0.2	0.2
Fin	19.2	15.8	37.1
Fungus	2.0	0.9	2.1
Gash	2.3	0.0	0.7
Gas Bubble Trauma	0.4	0.0	0.0
Gill Net	2.6	0.0	9.4
Fish Hook	1.8	0.7	3.3
Lamprey	0.6	0.4	0.7
Parasite	4.4	0.4	0.7
Total[a]	28.8	19.4	49.7

a Totals do not represent the sum of subcategories, they are the number of fish with at least one injury. Fish can display more than one type of marine mammal or general injury. Marine mammal injuries described as follows: Bite (ragged wounds, often in caudal area), Claw Rake (2-3 or more parallel scratches on flanks of fish) and Golden Arches (2-3 or more curved scratches on flanks of fish).

b This total represents the number of fish with descaling on either side, which is less than 3% descaled. If either side is ≥ 3%, the fish moves into another category.

c This total represents, as a percentage, the number of fish with descaling on either side, which is 3 – 19% descaled. If either side is > 19% the fish moves into another category.

d This total represents the number of fish with descaling on at least one side that is ≥ 20% descaled.

Table A3: Composition (%) of observed injuries of Columbia Basin sockeye and coho salmon sampled at Bonneville Dam in 2003.

Injury Category	Sockeye	Coho
Marine Mammal		
Bite	1.0	0.0
Claw Rake	2.6	10.7
Golden Arches	2.3	5.1
Total[a]	5.9	15.5
Descaling		
< 3%		
Right side	1.0	5.2
Left side	2.3	5.8
Total[b]	1.0	3.6
3-19%		
Right side	20.3	32.4
Left side	23.1	33.1
Total[c]	19.3	31.8
≥20%		
Right side	2.3	6.3
Left side	1.3	7.0
Total[d]	3.3	8.5
Other Injuries		
Bruises	0.3	0.9
Cuts	0.3	0.3
Head Injury	0.8	21.3
Head Burn	0.0	0.0
Fin	2.1	33.7
Fungus	0.5	2.8
Gash	0.0	0.9
Gas Bubble Trauma	0.0	0.0
Gill Net	0.3	29.9
Fish Hook	0.0	2.1
Lamprey	0.0	0.7
Parasite	0.0	1.6
Total[a]	3.9	59.4

a Totals do not represent the sum of subcategories, they are the number of fish with at least one injury. Fish can display more than one type of marine mammal or general injury. Marine mammal injuries described as follows: Bite (ragged wounds, often in caudal area), Claw Rake (2-3 or more parallel scratches on flanks of fish) and Golden Arches (2-3 or more curved scratches on flanks of fish).

b This total represents the number of fish with descaling on either side, which is less than 3% descaled. If either side is ≥ 3%, the fish moves into another category.

c This total represents, as a percentage, the number of fish with descaling on either side, which is 3 – 19% descaled. If either side is > 19% the fish moves into another category.

d This total represents the number of fish with descaling on at least one side that is ≥ 20% descaled.

Table A4: Length-at-age estimates for Columbia Basin spring Chinook salmon sampled at Bonneville Dam in 2003. Composite estimates of age classes are weighted by weekly run size.

Brood Year and Age Class	2000 1.1	1999 0.3	1999 1.2	1998 0.4	1998 1.3	1997 1.4	1997 2.3
Statistical Week 13							
Mean Fork Length (cm)	58.00		78.50		88.84		
Maximum	58.0		78.5		100.5		
Minimum	58.0		78.5		79.0		
Standard Deviation	-		-		5.80		
Sample Size	1		1		19		
Statistical Week 14							
Mean Fork Length (cm)			74.46		89.14		
Maximum			80.5		110.5		
Minimum			69.0		76.5		
Standard Deviation			3.71		5.28		
Sample Size			14		66		
Statistical Week 15							
Mean Fork Length (cm)			71.65		87.74		
Maximum			79.0		97.5		
Minimum			57.5		71.5		
Standard Deviation			6.47		5.42		
Sample Size			13		27		
Statistical Week 16							
Mean Fork Length (cm)			73.70		88.58		87.00
Maximum			80.5		101.0		87.0
Minimum			67.0		80.0		87.0
Standard Deviation			3.39		4.93		-
Sample Size			33		54		1
Statistical Week 17							
Mean Fork Length (cm)	52.50		75.06		88.24		
Maximum	52.5		88.0		98.0		
Minimum	52.5		67.0		75.5		
Standard Deviation	-		4.02		5.38		
Sample Size	1		62		49		
Statistical Week 18							
Mean Fork Length (cm)	48.43	80.50	73.89		88.24		
Maximum	55.5	80.5	81.0		98.0		
Minimum	43.0	80.5	59.0		75.0		
Standard Deviation	3.79	-	4.36		5.54		
Sample Size	15	1	65		37		
Statistical Week 19							
Mean Fork Length (cm)	48.89		72.27		86.13		
Maximum	57.0		96.0		97.0		
Minimum	41.0		58.5		69.5		
Standard Deviation	4.41		7.64		7.16		
Sample Size	14		26		20		
Statistical Week 20							
Mean Fork Length (cm)	49.25		75.79		89.81		
Maximum	57.0		82.0		101.0		
Minimum	42.0		69.0		77.0		
Standard Deviation	4.58		3.64		5.75		
Sample Size	8		17		34		
Statistical Week 21							
Mean Fork Length (cm)	52.00		75.21		91.13	100.50	
Maximum	56.0		89.0		104.0	104.0	
Minimum	44.5		58.5		83.0	97.0	
Standard Deviation	3.31		7.31		4.68	4.95	
Sample Size	21		31		28	2	
Statistical Week 22							
Mean Fork Length (cm)	53.00		77.33	89.50	92.20		
Maximum	53.5		85.5	89.5	99.5		
Minimum	52.5		72.0	89.5	87.0		
Standard Deviation	0.71		4.33	-	3.59		
Sample Size	2		9	1	10		
2003 Composite							
Mean Fork Length (cm)	50.22	80.50	74.30	89.50	88.84	100.50	87.00
Maximum	58.0	80.5	96.0	89.5	110.5	104.0	87.0
Minimum	41.0	80.5	57.5	89.5	69.5	97.0	87.0
Standard Deviation	4.14	-	5.13	-	5.47	4.95	-
Sample Size	62	1	271	1	344	2	1

Table A5: Length-at-age estimates for Columbia Basin summer Chinook salmon sampled at Bonneville Dam in 2003. Composite estimates of age classes are weighted by weekly run size.

Brood Year and	2001	2000			1999		1998		1997
Age Class	0.1	0.2	1.1	2.0	0.3	1.2	0.4	1.3	1.4
Statistical Week 23									
Mean Fork Length (cm)			55.50			76.77	92.50	93.57	82.50
Maximum			55.5			82.0	93.5	104.0	82.5
Minimum			55.5			69.0	91.5	83.0	82.5
Standard Deviation			-			4.32	1.41	5.61	-
Sample Size			1			11	2	21	1
Statistical Week 24									
Mean Fork Length (cm)			51.50		78.50	76.88	96.44	90.88	96.50
Maximum			55.0		82.5	89.0	107.0	104.0	101.0
Minimum			46.0		72.5	69.5	72.5	66.5	92.0
Standard Deviation			3.65		5.29	5.15	11.53	8.47	6.36
Sample Size			8		3	16	8	20	2
Statistical Week 25									
Mean Fork Length (cm)			53.10		84.00	79.55	92.10	89.82	86.17
Maximum			58.5		87.5	87.5	95.0	105.5	95.0
Minimum			44.0		80.0	68.5	88.0	75.5	72.5
Standard Deviation			5.49		3.77	7.07	3.09	6.73	12.00
Sample Size			5		3	11	5	17	3
Statistical Week 26									
Mean Fork Length (cm)		69.50	50.75		82.07	76.08	94.71	88.11	85.50
Maximum		69.5	65.5		94.5	91.0	107.0	103.0	85.5
Minimum		69.5	41.0		69.0	62.0	86.0	70.5	85.5
Standard Deviation		-	5.91		7.13	7.35	5.55	7.09	-
Sample Size		1	14		15	26	12	41	1
Statistical Week 27									
Mean Fork Length (cm)	44.50		51.33	39.25	85.22	75.39	94.92	87.52	95.60
Maximum	44.5		60.5	40.0	103.0	85.0	103.0	98.0	102.0
Minimum	44.5		40.0	38.5	78.5	69.0	88.5	75.0	86.5
Standard Deviation	-		7.19	1.06	7.85	4.68	5.37	5.06	5.85
Sample Size	1		12	2	9	14	6	43	5
Statistical Week 28									
Mean Fork Length (cm)	44.00	62.75	47.85		81.13	75.85	95.00	88.64	93.00
Maximum	44.0	64.0	57.0		89.0	86.0	100.0	100.0	101.0
Minimum	44.0	61.5	42.0		56.5	63.0	90.0	72.0	87.0
Standard Deviation	-	1.77	5.01		7.57	8.04	7.07	6.96	7.21
Sample Size	1	2	13		15	13	2	22	3
Statistical Week 29									
Mean Fork Length (cm)	40.75	74.50	50.21		79.87	78.45	89.54	86.65	93.00
Maximum	44.0	78.0	60.0		88.0	88.0	96.0	103.0	102.0
Minimum	37.5	71.0	41.0		59.5	65.5	80.0	69.0	84.0
Standard Deviation	4.60	4.95	6.93		6.81	6.71	5.11	7.63	12.73
Sample Size	2	2	7		19	10	14	37	2
2003 Composite									
Mean Fork Length (cm)	42.50	68.80	50.55	39.25	81.56	76.77	93.19	88.76	91.91
Maximum	44.5	78.0	65.5	40.0	103.0	91.0	107.0	105.5	102.0
Minimum	37.5	61.5	40.0	38.5	56.5	62.0	72.5	66.5	72.5
Standard Deviation	3.34	6.45	5.81	1.06	7.08	6.38	6.73	6.98	8.20
Sample Size	4	5	60	2	64	101	49	201	17

Table A6: Length-at-age estimates for Columbia Basin bright fall Chinook salmon sampled at Bonneville Dam in 2003. Composite estimates of age classes are weighted by weekly run size.

Brood Year and	2001		2000		1999		1998		1997
Age Class	0.1	1.0	0.2	1.1	0.3	1.2	0.4	1.3	0.5
Statistical Week 37									
Mean Fork Length (cm)			66.50	52.00	82.70	77.18	92.46	84.25	
Maximum			77.5	61.0	100.0	85.0	107.5	91.0	
Minimum			55.0	47.0	71.5	68.0	81.0	79.0	
Standard Deviation			9.01	7.81	5.99	5.08	7.42	5.38	
Sample Size			5	3	60	11	27	4	
Statistical Week 38									
Mean Fork Length (cm)	49.00		65.13	54.58	83.23	75.61	92.90	86.92	97.00
Maximum	50.0		70.0	58.5	103.0	89.0	105.0	103.0	97.0
Minimum	48.0		59.5	49.0	65.5	61.5	76.5	74.5	97.0
Standard Deviation	1.41		4.48	4.38	5.40	8.46	6.25	9.71	-
Sample Size	2		4	6	77	9	39	6	1
Statistical Week 39									
Mean Fork Length (cm)	45.22	38.75	65.06	55.96	81.35	77.43	90.13	83.50	
Maximum	60.0	39.0	74.5	64.5	92.5	86.0	99.5	83.5	
Minimum	38.0	38.5	55.5	46.0	68.0	70.5	85.0	83.5	
Standard Deviation	4.90	0.35	6.13	5.97	4.66	5.62	4.46	-	
Sample Size	16	2	18	12	62	7	19	1	
Statistical Week 40									
Mean Fork Length (cm)	45.75		65.17	56.67	81.80	68.75	88.83	83.00	
Maximum	51.0		79.5	63.0	94.0	70.0	99.0	90.5	
Minimum	41.0		49.5	51.0	68.0	67.5	82.5	75.5	
Standard Deviation	3.12		8.05	4.50	6.91	1.77	5.97	10.61	
Sample Size	12		12	6	27	2	6	2	
Statistical Week 41									
Mean Fork Length (cm)	44.25	38.60	66.00	53.77	80.93	80.17	91.00	79.00	
Maximum	49.5	39.5	66.0	64.0	92.0	81.0	101.0	81.0	
Minimum	41.0	38.0	66.0	46.0	72.0	79.5	87.0	77.0	
Standard Deviation	2.49	0.65	-	6.23	5.36	0.76	4.21	2.00	
Sample Size	12	5	1	11	21	3	10	3	
Statistical Week 42									
Mean Fork Length (cm)	44.00		66.75	54.50	83.50	73.67	87.36	85.25	
Maximum	44.0		78.5	54.5	94.0	79.0	97.0	87.5	
Minimum	44.0		56.0	54.5	73.0	69.5	75.5	83.0	
Standard Deviation	-		9.97	-	5.34	4.86	8.06	3.18	
Sample Size	1		6	1	25	3	7	2	
Statistical Week 43									
Mean Fork Length (cm)	47.50	49.50	72.50		86.33	73.25	91.88	94.50	
Maximum	47.5	49.5	72.5		87.5	73.5	102.0	94.5	
Minimum	47.5	49.5	72.5		85.5	73.0	86.0	94.5	
Standard Deviation	-	-	-		1.04	0.35	7.12	-	
Sample Size	1	1	1		3	2	4	1	
2003 Composite									
Mean Fork Length (cm)	45.30	40.00	65.64	54.90	82.43	76.14	91.55	84.74	97.00
Maximum	60.0	49.5	79.5	64.5	103.0	89.0	107.5	103.0	97.0
Minimum	38.0	38.0	49.5	46.0	65.5	61.5	75.5	74.5	97.0
Standard Deviation	3.69	3.87	7.07	5.55	5.54	5.99	6.34	7.15	-
Sample Size	44	8	47	39	275	37	112	19	1

Table A7: Length-at-age estimates for Columbia Basin sockeye salmon sampled at Bonneville Dam in 2003. Composite estimates of age classes are weighted by weekly run size.

Brood Year and	2000	1999		1998			1997			1996
Age Class	1.1	1.2	2.1	1.3	2.2	3.1	2.3	3.2	4.1	3.3
Statistical Week 24										
Mean Fork Length (cm)	37.50	49.83		60.00						
Maximum	37.5	52.0		60.0						
Minimum	37.5	48.5		60.0						
Standard Deviation	-	1.15		-						
Sample Size	1	9		1						
Statistical Week 25										
Mean Fork Length (cm)	39.17	50.11	43.75	56.80		48.50		52.00	49.00	
Maximum	40.0	56.0	44.5	58.5		51.0		52.0	49.0	
Minimum	38.5	44.0	43.0	54.0		45.5		52.0	49.0	
Standard Deviation	0.76	2.90	1.06	1.75		2.92		-	-	
Sample Size	3	14	2	5		4		1	1	
Statistical Week 26										
Mean Fork Length (cm)	40.00	51.39	43.67	57.28		50.36	59.50	53.33	50.42	
Maximum	41.5	54.0	45.0	61.0		54.0	59.5	54.0	56.0	
Minimum	37.0	48.0	43.0	50.5		45.0	59.5	52.5	46.0	
Standard Deviation	1.46	1.64	1.15	3.13		3.25	-	0.76	3.50	
Sample Size	9	22	3	16		7	1	3	6	
Statistical Week 27										
Mean Fork Length (cm)	40.50	50.63	41.82	58.25		51.07	59.00	51.75	53.83	
Maximum	51.0	57.0	46.5	62.0		54.0	59.0	54.5	63.0	
Minimum	36.0	43.0	38.0	55.0		47.0	59.0	49.0	48.0	
Standard Deviation	3.58	2.52	2.64	2.05		2.08	-	3.89	8.04	
Sample Size	39	35	11	12		22	1	2	3	
Statistical Week 28										
Mean Fork Length (cm)	39.56	50.64	44.83	60.25	50.50	50.27	57.00	54.75	51.67	59.00
Maximum	46.0	55.0	47.0	63.0	50.5	55.0	57.0	55.5	53.0	59.0
Minimum	34.0	45.0	43.0	58.5	50.5	43.0	57.0	54.0	51.0	59.0
Standard Deviation	2.17	2.74	1.37	2.02	-	3.45	-	1.06	1.15	-
Sample Size	75	14	6	4	1	15	1	2	3	1
Statistical Week 29										
Mean Fork Length (cm)	38.00	49.50	41.00	53.00		50.00				
Maximum	41.0	49.5	41.0	53.0		50.0				
Minimum	36.0	49.5	41.0	53.0		50.0				
Standard Deviation	2.00	-	-	-		0.00				
Sample Size	7	1	1	1		2				
2003 Composite										
Mean Fork Length (cm)	39.76	50.64	42.98	57.78	50.50	50.48	58.50	53.13	51.38	59.00
Maximum	51.0	57.0	47.0	63.0	50.5	55.0	59.5	55.5	63.0	59.0
Minimum	34.0	43.0	38.0	50.5	50.5	43.0	57.0	49.0	46.0	59.0
Standard Deviation	2.64	2.34	2.38	2.72	-	2.75	1.32	2.00	4.31	-
Sample Size	134	95	23	39	1	50	3	8	13	1

Table A8: Length-at-age estimates for Columbia Basin coho salmon sampled at Bonneville Dam in 2003. Composite estimates of age classes are weighted by weekly run size.

Brood Year and Age Class	2001 1.0	2000 1.1
Statistical Week 37		
Mean Fork Length (cm)		68.38
Maximum		85.0
Minimum		59.0
Standard Deviation		11.81
Sample Size		4
Statistical Week 38		
Mean Fork Length (cm)		65.69
Maximum		83.0
Minimum		51.5
Standard Deviation		6.76
Sample Size		53
Statistical Week 39		
Mean Fork Length (cm)		62.33
Maximum		79.5
Minimum		49.0
Standard Deviation		6.34
Sample Size		71
Statistical Week 40		
Mean Fork Length (cm)		62.21
Maximum		80.0
Minimum		47.5
Standard Deviation		7.21
Sample Size		147
Statistical Week 41		
Mean Fork Length (cm)	39.17	62.05
Maximum	45.0	76.5
Minimum	35.0	40.5
Standard Deviation	3.17	7.46
Sample Size	9	110
Statistical Week 42		
Mean Fork Length (cm)	39.50	64.53
Maximum	40.0	81.0
Minimum	39.0	38.5
Standard Deviation	0.71	7.71
Sample Size	2	187
Statistical Week 43		
Mean Fork Length (cm)	42.50	67.57
Maximum	42.5	79.5
Minimum	42.5	52.0
Standard Deviation	-	6.38
Sample Size	1	37
2003 Composite		
Mean Fork Length (cm)	39.50	63.58
Maximum	45.0	85.0
Minimum	35.0	38.5
Standard Deviation	2.88	7.42
Sample Size	12	609