CRITFC

TECHNICAL REPORT 03-2

Identification of Columbia Basin Sockeye Salmon Stocks Using Scale Pattern Analyses in 2002

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April 20, 2003

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ABSTRACT

In 2003, samples of adult Columbia Basin sockeye salmon, *Oncorhynchus nerka*, were collected at Bonneville Dam as well as at Tumwater Dam on the Wenatchee River and Wells Dam in the mid-Columbia River downstream of the Okanogan River. Tumwater and Wells dams were chosen to provide samples of sockeye salmon from the two principle stocks of Columbia Basin sockeye salmon, which originate from the Wenatchee and Okanogan basins. Age composition was estimated from the sampled sockeye salmon passing the three dams. Five-year-old fish were estimated to comprise 55% of the Bonneville Dam mixed-stock, 40% of the Okanogan stock, and 58% of the Wenatchee stock. Four-year-old fish were estimated to comprise 40% of the mixed-stock sockeye salmon migrating past Bonneville Dam, 44% of the Okanogan stock migrating past Wells Dam, and 42% of the Wenatchee stock migrating past Tumwater Dam. Three-year-old fish were estimated to comprise 1% of the Bonneville Dam mixed-stock, 2% of the Okanogan stock and none of the Wenatchee stock. Six-year-old fish were estimated to comprise 4% of the Bonneville Dam mixed-stock, 13% of the Okanogan stock and <1% of the Wenatchee stock. For the first time in 17 years of CRITFC Columbia River sockeye salmon studies, sockeye salmon were estimated to have spent more than two years in freshwater. Sockeye spending greater than two years in freshwater were estimated to comprise 11% of the Okanogan Lake, 4% of the Bonneville Dam mixed-stock, and none of the Wenatchee stock. Scale pattern analysis techniques were used to estimate that 72% of the sockeye salmon passing Bonneville Dam were of Okanogan origin, 27% were of Wenatchee stock, with the remaining 1% of unknown origin.

ACKNOWLEDGMENTS

We thank the following individuals for their assistance in this project: Bobby Begay, Jonas Greene, Doug Hatch, André Talbot, Rishi Sharma, Stuart Ellis, and Marianne McClure of the Columbia River Inter-Tribal Fish Commission; Brett Morgan of the Oregon Department of Fish and Wildlife; Rolf Larsen of Snow Creek Environmental Services; Carolyn Pearson; Chuck Peven of Public Utility District No. 1 of Chelan County; Shane Bickford and Rick Klinge of Public Utility District No. 1 of Douglas County; Jennifer Sturgill and Tammy Mackey of the US Army Corps of Engineers; Steve Lee, Mille Faulkender, and Dennis Quimps of the University of Idaho, and Andrew Murdoch, Charlie Cochron, Dan Rawding, Charlie Snow, and John Sneva of the Washington Department of Fish and Wildlife.

This report is the result of research funded by US Government (Bureau of Indian Affairs, Department of Interior) Contract No. GTP00X90107 for implementation of the US-Canada Pacific Salmon Treaty.

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INTRODUCTION

Sockeye salmon, *Oncorhynchus nerka,* is one of the species of Pacific salmon native to the Columbia River Basin. Before white settlers developed the region, it is estimated the Columbia Basin supported an annual sockeye salmon run averaging over three million fish (Northwest Power Planning Council 1986, Fryer 1995). Since the mid-1800's, however, this sockeye salmon population has severely declined. The estimated number of sockeye salmon entering the Columbia River over the six years from 1994-1999 averaged only 21,700 fish per year (DART 2002). Sockeye salmon runs have since increased to 93,391 fish in 2000, and 114,945 fish in 2001 before declining to 49,608 in 2002 (DART 2002).

The Columbia Basin sockeye salmon run was once composed of at least eight principal stocks (Fulton 1970, Fryer 1995). Today, only two major stocks remain[1] (Figure 1). From the 1960's through the early 1990's, both stocks were entirely naturally produced, originating in the Wenatchee River-Lake Wenatchee System (Wenatchee stock) and in the Okanogan River-Osoyoos Lake System (Okanogan stock). In recent years, enhancement programs in both systems have been initiated that capture returning adults, spawn the adults in hatcheries, and raise the offspring in net pens located in the rearing lakes before release (Hays 1992, Wells Project Coordinating Committee 1992). The Okanogan enhancement program was terminated following the 2000 release. These two Columbia Basin sockeye salmon rearing areas differ markedly (Allen and Meekin 1980, Mullan 1986). Lake Wenatchee is oligotrophic, with relatively deep, cold, and biologically unproductive waters. Conversely, Osoyoos Lake has the shallow, warm, and agriculturally enriched waters characteristic of eutrophic lake habitats.

Reliable estimates of the overall run composition of Columbia Basin sockeye salmon stocks and the biological and migratory characteristics of each

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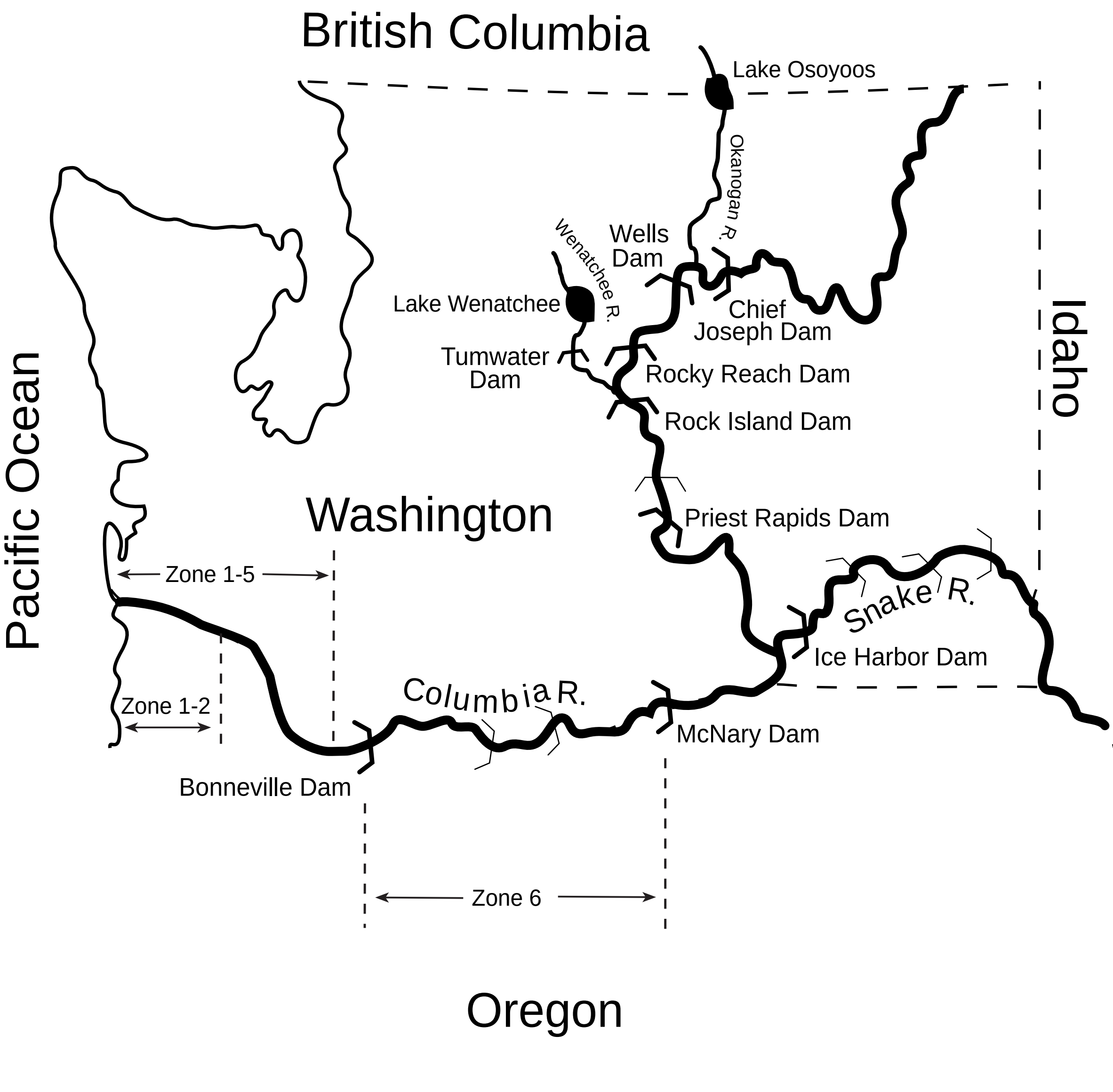
1 A small run of sockeye salmon return to the Snake River and are listed as endangered under the Endangered Species Act. These fish are almost entirely hatchery origin and adipose fin clipped. While an estimated 49,608 sockeye salmon passed Bonneville Dam in 2002, only 60 (0.1%) passed Ice Harbor Dam on the Snake River.

Figure 1. Map of the Columbia Basin showing the fishing Zones 1-2, 1-5 and 6, Bonneville, McNary, Ice Harbor, Priest Rapids, Rock Island, Rocky Reach, Tumwater, Wells, and Chief Joseph dams, and the two major sockeye salmon production areas.



stock are useful for run-reconstruction studies permitting accurate population size predictions, escapement monitoring, establishing spawner-recruit relationships, and developing discrete stock approaches to Columbia River mainstem harvest management. The Pacific Salmon Treaty (PST), ratified by the United States and Canada in 1985 (PST 1985), requires that certain Pacific salmon populations be monitored to determine the influence of Treaty-imposed ocean harvest regulations on *transboundary* stocks. Some Okanogan-stock sockeye salmon originating in Canadian waters but migrating through, and harvested in, the United States portion of the Columbia River constitutes such a stock. Stock identification research would aid in estimation of the proportion and abundance of Canadian-origin sockeye salmon caught within the United States. This study, begun in 1987 (Schwartzberg and Fryer 1988), was initiated to provide such information.

Scale pattern analysis (SPA) has been the method of study used for our stock identification research and is a well-established stock identification and classification technique (Clutter and Whitesel 1956, Henry 1961, Mosher 1963, Anas and Murai 1969). In many species of fish, including Pacific salmon, the use of SPA as a tool for stock identification depends on a high correlation between individual fish growth and scale growth (Koo 1955, Clutter and Whitesel 1956). Fish growth and scale growth are influenced by genetic factors and by such environmental conditions as water temperature, length of growing season, and food availability. Stock identification based on SPA assumes that growth patterns will differ throughout a species' range and that these differences will be exhibited in the scales of entire groups or stocks of fish. Scale patterns from the Wenatchee and Okanogan sockeye salmon stocks in past years have differed (Schwartzberg and Fryer 1988, 1989, 1990; Fryer and Schwartzberg 1991, 1993, 1994; Fryer et al. 1992; Fryer and Kelsey 2001, 2002), presumably reflecting differences in freshwater rearing conditions. In most years, Okanogan sockeye salmon scale samples have shown greater growth to both freshwater annulus and saltwater entry than have Wenatchee sockeye salmon scale samples.

This report presents estimates of the age and length-at-age composition of adult Columbia Basin sockeye salmon in 2002. Weekly and composite age composition estimates for fish sampled at Bonneville Dam (mixed-stocks of unknown origin) presented in this report are those found in a report detailing results from all CRITFC sampling activities at Bonneville Dam in 2002 (Kelsey and Fryer 2002). This report also presents age and length-at-age composition

estimates from the Wenatchee stock collected at Tumwater Dam on the Wenatchee River and the Okanogan stock collected at Wells Dam. Data collected from our mid-Columbia sampling program was used to estimate stock composition of the Bonneville Dam mixed-stock in 2002.

METHODS

Sample Design

Sockeye salmon were sampled at Bonneville Dam (river km 235) one to two days per statistical week[2] in conjunction with a summer chinook salmon sampling program (Kelsey and Fryer 2003). Sockeye salmon were sampled at Tumwater and Wells dams for one or two days per week during the period in which significant numbers of sockeye salmon were migrating past those sites. The desired total sample size for age composition estimates at each site was a minimum of 500 fish at Bonneville Dam, and 400 fish at Tumwater and Wells dams. In previous study years, these minimum sample numbers have resulted in acceptable levels of precision and accuracy (Fryer 1995) ($d=0.05$, $\alpha=0.10$). Smaller sample sizes are normally sufficient at Tumwater and Wells dams because the age composition tends to be more skewed towards one or two age classes than at Bonneville Dam. Year-to-date dam counts of fish passage were obtained from DART (2002) for Bonneville and Wells dams and from Washington Department of Fish and Wildlife (Andrew Murdoch, WDFW, January 16, 2003 e-mail) for Tumwater Dam.

A stratified sampling method that weighted weekly age and length-at-age estimates by actual migratory timing was used to obtain composite estimates for the Wenatchee and Okanogan known-stocks as well as the Bonneville mixed-stock (Cochran 1977).

Sampling Methods

Data and scales from mixed sockeye salmon stocks (or mixed-stocks) were obtained from fish sampled at the Bonneville Dam Adult Fish Facility, located on the mainstem Columbia River. Each stock was also sampled in

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2 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 2002 for example, Statistical Week 24 began on June 9 and ended on June 15.

terminal areas to obtain representative scale samples for each of the two Columbia Basin sockeye salmon groups (or known-stocks). Wenatchee stock data and scales were collected at Tumwater Dam on the Wenatchee River (river km 53), and Okanogan stock data and scales were obtained at Wells Dam on the mainstem Columbia River (river km 830).

Fish were trapped and anesthetized. Each fish was then sampled for scales, measured for fork length, inspected for markings and/or tag information and noted for other pertinent biological information (Kelsey and Fryer 2003). At Tumwater and Wells dams, inspection for biological information was not as extensive as at Bonneville Dam due to the need to handle fish quickly to allow our project to be run concurrently with broodstock collection and research projects being conducted by other parties. All fish were revived in freshwater and returned to the exit fishway. Four scales per fish were collected to minimize the sample rejection rate. The gender of specimens collected at Bonneville Dam could not be determined because all were in the earliest stages of sexual maturation. The gender of some specimens collected at Tumwater and Wells dams could be determined, and was recorded but this data is not included in this report.

Length Measurements

Fork lengths were measured to the nearest 0.5 cm at Bonneville, Wells, and Tumwater dams. Mean lengths and standard deviations were calculated for each age class, by weekly sampling period, and for the composite sample. Composite samples were weighted by weekly run size, if more than one fish represents the age class sample for each statistical week in which samples were caught.

Age Determination

Scales were selected, mounted, and pressed 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 (Gilbert 1913, Borodin 1924, Van Oosten 1929). A sample of scales was sent to John Sneva of

the Washington Department of Fish and Wildlife for corroboration of age estimates.

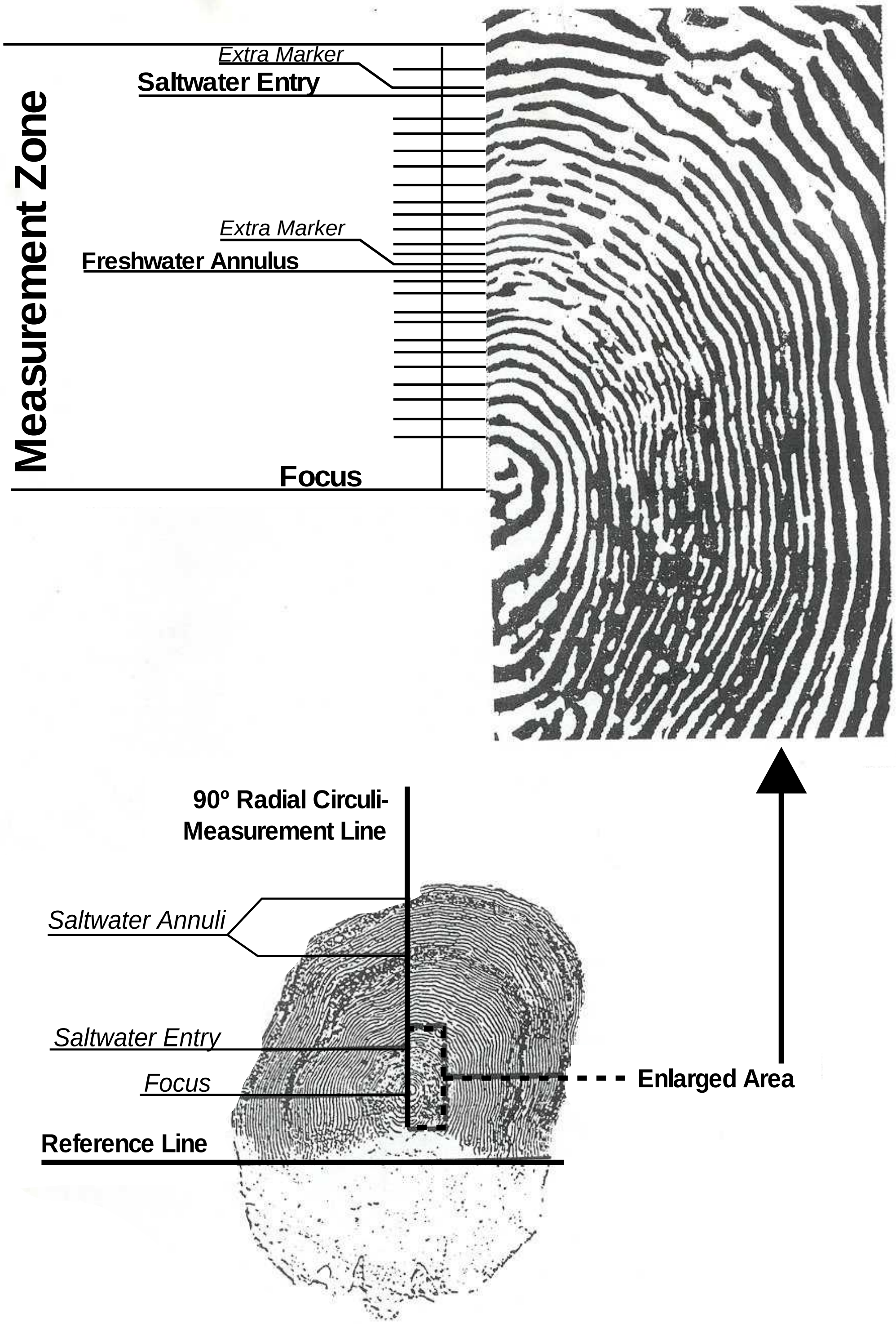
The European method for fish age description (Koo 1955) is used in this report. The number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The numeral following the period indicates the number of winters a fish spent in the ocean. Total age, therefore, is equal to one plus the sum of both numerals.

Scale Pattern Analyses

Scale pattern analysis of circuli in freshwater- and early saltwater-growth zones was used to identify each known-stock sample and to also classify mixed-stock samples. The methodology was applied to the predominant Age 1.2 class from all stocks. Scale features were first measured using a computer and video camera based system (BioSonics Optical Pattern and Recognition System [OPRS]) that included a microscope (2x, 4x, 6.3x, and 10x objectives; a 1.0x, 1.25x, and 1.5x magnification changer; and a 2.5x photocompensation adapter), a secondary monitor (53 cm), and a digitizing tablet connected to a personal computer with a video frame-grabber board (BioSonics 1987). Acetate impressions of scales were placed under the microscope and projected onto the monitor using a 4.0x objective, 1.0x magnification changer, and 2.5x photo-compensation adapter. This lens configuration created a scale image initially viewed at 130x actual size.

Working from the top of the scale card, the first scale impression with no focus regeneration and clearly defined circuli was selected and the projected image was oriented diagonally with the clear (posterior) portion of the scale in the lower left corner of the screen. A reference line was drawn along the base of the scale image (Figure 2). The reference line was placed in the posterior field of the scale image so that the line bridged the end points of circuli in the first saltwater annulus (Fryer and Schwartzberg 1994). The objective was then changed to 10x, resulting in a viewed scale image 325x actual size, and a radial line was then drawn perpendicular to the reference line. Circuli positions were marked at the marginal (outermost) edge of their intersection with the radial line. The OPRS software (version 1.0) measured the distance from the scale focus to

Figure 2. Age 1.2 Okanogan stock sockeye salmon scale showing growth and measurement zones.



each circuli marker. The portion of the scale where circuli measurements were made included the entire freshwater zone and part of the early saltwater growth zone.

Additional artificial circuli markers were placed to permit measurement of other key scale-features, specifically, freshwater annulus and saltwater-entry point. These features were respectively indicated by two sets of closely spaced circuli markers. The 'extra markers' were placed immediately after and adjacent to the original circuli position markers and were interpreted and removed by data analysis programs used in subsequent procedures (Fryer and Schwartzberg 1993). The freshwater annulus-position marker was placed beside the last circulus in the freshwater annulus and the saltwater-entry marker was placed immediately after the first circulus in the ocean zone.

For SPA studies, the desired sample size to reduce variance was approximately 200 from each known-stock group for each age class analyzed (Conrad 1985)[3]. In most years, the only age class with a sufficiently large sample size to justify using SPA has been Age 1.2. In 2002, sample sizes for Age 2.2 were as large as those of Age 1.2 so we used SPA. In addition, we also decided to use SPA on Age 1.3 fish since fish of this age class were estimated to consist of least 13% of the run at each location sampled. For all age classes, sample sizes were less than the target of 200 fish, which has the effect of increasing variance in the resulting mixed stock composition estimates. For SPA analysis of mixed-stocks, 100 was the desired sample size (Conrad 1985), although the actual sample size used for the Bonneville mixed-stock has normally been much larger to permit more precise weekly stock composition estimates. No adipose-fin or ventral fin-clipped sockeye salmon were included in any of the samples studied due to very small sample sizes as well as the fact that these were assumed to be from a hatchery program.

3 In many years, actual sample sizes have been considerably less due to low numbers of fish collected.

Statistical Analyses

A linear discriminant analysis technique developed by Fisher (1936) was used to differentiate stocks. Linear discriminant analysis permits the simultaneous use of many variables to form classification functions that typify and identify groups. This methodology has proven useful for determining the origins of individual fish stocks from mixed-stock samples (Bethe and Krasnowski 1977, Bethe et al. 1980, Major et al. 1978). Weekly stock composition estimates were weighted by the weekly run size to estimate the stock composition for the entire run.

Variables, composed of selected scale-measurements within the area from scale focus to Circulus 24, were tested to find those that most effectively characterized differences in growth between the two stocks. As in previous years' studies, distances between four adjacent circuli (or triplets) were the primary variable tested (Davis 1987). Distance measurements and number of circuli from scale focus to saltwater-entry and from scale focus to freshwater annulus margin (anterior) were also among the variables tested.

Accuracy of the discriminant analyses was determined by classifying the pooled known-stock samples from a particular analysis and then comparing results to actual (verifiable) known-stock identities. A jackknife procedure (Lachenbruch 1975, Dixon et al. 1983) was employed to correct for systematically biased results that are created in known-stock classification when the same samples are used for both calculating the discriminant function and estimating its accuracy. To correct for misclassification of mixed-stock samples, we used a method developed by Cook and Lord (1978) and Cook (1983). Variances on mixed-stock classification estimates were also computed (Pella and Robertson 1979).

RESULTS

Sample Sizes

Final sample sizes used for age and length-at-age composition estimates were 497 Bonneville mixed-stock, 393 Wenatchee known-stock, and 149 Okanogan known-stock. Of the original 517 sockeye salmon sampled at Bonneville Dam, 4% of the total sample was rejected and not classified by age because of unreadable scales. For the same reason, 2% of the 400 Wenatchee, and 3% of the 154 Okanogan samples were rejected.

Scale pattern analysis studies were conducted on the three age classes (1.2, 1.3, and 2.2) that comprised more than 13% of the run at each of the three locations sampled. For each age group for each stock, all fish with readable scales were used.

Age Composition

The predominant age class for both the Wenatchee known stock and the Bonneville mixed-stock was Age 2.2 (Table 1 and 2). The predominant age class for the Okanogan known-stock was Age 1.2 (Table 3). This age class was also within two percentage points of being the predominant age class for the two other stocks. Fish of Age 1.3 comprised over 13% of the run at each of the three sampling sites.

Table 1. Weekly and cumulative age composition Columbia Basin sockeye salmon sampled at Bonneville Dam in 2002.

Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1999 1.1	1998 1.2	1998 2.1	1997 1.3	1997 2.2	1997 3.1	1996 2.3	1996 3.2	1995 4.2
					Age Composition by Brood Year and Age Class								
24[a]	6/13	11	11	1767		0.273		0.455	0.273				
25	6/18, 20	103	100	7400		0.220		0.250	0.460		0.030	0.030	0.010
26	6/25, 27	150	144	20428	0.007	0.431		0.104	0.458				
27	7/1, 2	120	115	13299	0.009	0.461	0.009	0.122	0.330		0.009	0.052	0.009
28	7/11, 12	111	107	4860	0.009	0.449		0.065	0.393	0.009	0.019	0.056	
29[b]	7/16, 18, 25	22	20	1854	0.100	0.150		0.100	0.450		0.050	0.150	
Cumulative		517	497	49608	0.010	0.393	0.002	0.139	0.411	0.001	0.011	0.030	0.004

a Weekly run size includes fish numbers from Week 21 - 24. Sampling began in Week 24.
b Weekly run size includes fish numbers from Weeks 29 - 36. Sampling ended in Week 30. Due to small sample size (n=3) in Week 30, Weeks 29 and 30 were combined.

Table 2. Weekly and cumulative age composition of Wenatchee sockeye salmon stocks sampled at Tumwater Dam in 2002.

					Age Composition by Brood Year and Age Class			
					1998	1997		1996
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1.2	1.3	2.2	2.3
30[a]	7/24, 25	133	131	14887	0.420	0.168	0.412	
31	7/30, 31	170	167	8818	0.467	0.090	0.431	0.012
32[b]	8/6, 7, 8	97	95	4116	0.316	0.189	0.495	
Cumulative		400	393	27821	0.419	0.146	0.430	0.004

a Weekly run size includes fish numbers from Weeks 27 – 30. Sampling started in Week 30.
b Weekly run size includes fish numbers from Weeks 32 – 39. Sampling ended in Week 32.

Table 3. Weekly and cumulative age composition of Okanogan sockeye salmon stocks sampled at Wells Dam in 2002.

					Age Composition by Brood Year and Age Class							
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1999	1998		1997		1996	
					1.1	1.2	2.1	1.3	2.2	2.3	3.2
28[a]	7/8	8	8	1844		0.375		0.125	0.250	0.125	0.125
29	7/15	45	45	3813	0.022	0.356	0.022	0.200	0.267	0.133	
30	7/22	75	70	2966		0.500		0.186	0.243	0.071	
31[b]	7/29	26	26	2036	0.038	0.577	0.038	0.077	0.154	0.115	
Cumulative		154	149	10659	0.015	0.441	0.015	0.160	0.236	0.022	0.111

a Weekly run size includes fish numbers from Weeks 25 – 28. Sampling started in Week 28.
b Weekly run size includes fish numbers from Weeks 31 – 41. Sampling ended in Week 31.

Adipose-clipped fish comprised 1.5% of the fish sampled at Bonneville Dam. These fish are most likely from the Wenatchee Eastbank supplementation program, although the remote possibility does exist that fish from the Snake River program may also be included. Two fish had only right ventral clips. One fish, in Week 25, was identified as Age 1.3 while the other fish, in Week 28, was identified as Age 1.2. The Age 1.3 fish was likely a release from the 1997 Brood Year Cassimer Bar supplementation program in the Okanogan basin. However, there was no program that applied a right ventral clip for 1998 brood fish.

No fin-clipped fish were found in the sample collected at Wells Dam. Video counts of fish at Tumwater Dam found that 2.1% of the fish were adipose-clipped (Andrew Murdoch, WDFW, January 16, 2003 e-mail). However, no fin-clipped fish were sampled at Tumwater Dam as those fish were being used for other research.

Length Composition

Mean fork lengths by age classes by site differ by up to 2.3 cm (for Age 1.3 fish), with fish sampled at Tumwater and Wells dams typically having greater lengths than those sampled at Bonneville Dam (Tables 4-6). However, many fish sampled at Wells Dam, and especially at Tumwater Dam, had well-developed secondary sexual characteristics, including the development of an elongated snout in the males, which would result in an increase in fork length.

Classification of Known-Stock Samples

The variable set chosen to classify known- and mixed-stock samples consisted of triplets between focus and circuli 24. As in previous years, distance and number of circuli to saltwater entry variables were felt to be highly dependent on operator judgment as the location of saltwater entry was often difficult to determine. The freshwater annulus, on the other hand, was relatively easy to locate, particularly for Age 1.2 and 1.3 fish, and not nearly as subject to operator judgement. Distance and number of circuli to freshwater annulus was included in the variable set for Age 1.3 fish as it greatly increased classification

Table 4. **Length-at-age estimates for Columbia Basin sockeye salmon stocks sampled at Bonneville Dam in 2002. Composite estimates are weighted by weekly run size.**

	Brood Year and Age Class								
	1999	1998		1997			1996		1995
	1.1	1.2	2.1	1.3	2.2	3.1	2.3	3.2	4.2
Statistical Week 24									
Mean Fork Length (cm)		50.50		58.00	51.33				
Maximum		51.5		61.0	54.0				
Minimum		49.0		53.5	48.0				
Standard Deviation		1.32		2.89	3.06				
Sample Size		3		5	3				
Statistical Week 25									
Mean Fork Length (cm)		51.45		57.64	51.79		58.00	51.17	59.50
Maximum		57.5		61.5	57.0		60.0	55.0	59.5
Minimum		46.0		54.0	46.5		54.5	48.0	59.5
Standard Deviation		2.75		2.17	2.35		3.04	3.55	--
Sample Size		22		25	46		3	3	1
Statistical Week 26									
Mean Fork Length (cm)	37.00	51.38		56.67	52.09				
Maximum	37.0	54.5		59.0	57.5				
Minimum	37.0	46.5		50.5	48.5				
Standard Deviation	--	1.98		2.37	1.80				
Sample Size	1	62		15	66				
Statistical Week 27									
Mean Fork Length (cm)	39.50	50.95	39.00	55.96	52.21		58.50	53.17	42.00
Maximum	39.5	55.0	39.0	59.5	58.5		58.5	56.0	42.0
Minimum	39.5	46.5	39.0	52.0	46.0		58.5	49.5	42.0
Standard Deviation	--	2.17	--	2.19	2.49		--	2.58	--
Sample Size	1	53	1	14	38		1	6	1
Statistical Week 28									
Mean Fork Length (cm)	39.00	50.64		57.64	51.75	36.50	54.50	54.33	
Maximum	39.0	56.0		61.5	56.0	36.5	56.5	58.0	
Minimum	39.0	44.0		54.5	45.0	36.5	52.5	51.5	
Standard Deviation	--	2.44		2.32	2.12	--	2.83	2.40	
Sample Size	1	48		7	42	1	2	6	
Statistical Week 29									
Mean Fork Length (cm)	37.75	52.00		52.50	52.83		55.00	52.83	
Maximum	39.0	52.5		54.50	56.00		55.0	55.0	
Minimum	36.5	51.5		50.50	49.50		55.0	51.0	
Standard Deviation	1.77	0.50		2.83	2.28		--	2.02	
Sample Size	2	3		2	9		1	3	
2002 Composite									
Mean Fork Length (cm)	38.20	51.15	39.00	56.85	52.05	36.50	56.64	53.02	50.75
Maximum	39.5	57.5	39.0	61.5	58.5	36.5	60.0	58.0	59.5
Minimum	36.5	44.0	39.0	50.5	45.0	36.5	52.5	48.0	42.0
Standard Deviation	1.35	2.15	--	2.31	2.06	--	2.81	2.79	12.37
Sample Size	5	191	1	68	204	1	7	18	2

Table 5. Length-at-age estimates for Wenatchee sockeye salmon stocks sampled at Tumwater Dam in 2002. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class			
	1998	**1997**		**1996**
	1.2	**1.3**	**2.2**	**2.3**
Statistical Week 30				
Mean Fork Length (cm)	52.08	58.95	52.61	
Maximum	56.0	62.0	59.0	
Minimum	49.0	55.0	47.5	
Standard Deviation	1.54	1.69	2.26	
Sample Size	55	22	54	
Statistical Week 31				
Mean Fork Length (cm)	51.72	58.10	52.23	56.00
Maximum	59.5	61.5	58.5	57.0
Minimum	45.0	51.0	45.0	55.0
Standard Deviation	2.49	2.65	2.55	1.41
Sample Size	78	15	72	2
Statistical Week 32				
Mean Fork Length (cm)	51.87	58.17	52.81	
Maximum	57.5	64.5	58.5	
Minimum	47.0	55.0	47.0	
Standard Deviation	2.45	2.26	2.39	
Sample Size	30	18	47	
2002 Composite				
Mean Fork Length (cm)	51.93	58.64	52.52	56.00
Maximum	59.5	64.5	59.0	57.0
Minimum	45.0	51.0	45.0	55.0
Standard Deviation	1.87	2.00	2.34	1.41
Sample Size	163	55	173	2

Table 6. Length-at-age estimates for Okanogan sockeye salmon stocks sampled at Wells Dam in 2002. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class						
	1999	1998		1997		1996	
	1.1	1.2	2.1	1.3	2.2	2.3	3.2
Statistical Week 28							
Mean Fork Length (cm)		52.17		53.00	51.00	52.00	51.00
Maximum		54.5		53.0	52.5	52.0	51.0
Minimum		48.0		53.0	49.5	52.0	51.0
Standard Deviation		3.62		--	2.12	--	--
Sample Size		3		1	2	1	1
Statistical Week 29							
Mean Fork Length (cm)	37.00	52.31	38.00	55.56	53.17		53.50
Maximum	37.0	55.0	38.0	58.0	56.0		56.0
Minimum	37.0	50.0	38.0	50.0	50.0		51.5
Standard Deviation	--	1.35	--	2.60	2.22		2.21
Sample Size	1	16	1	9	12		6
Statistical Week 30							
Mean Fork Length (cm)		52.04		57.08	52.59		53.80
Maximum		57.0		60.5	56.5		59.0
Minimum		48.5		52.5	47.0		51.0
Standard Deviation		1.99		2.36	2.31		3.27
Sample Size		35		13	17		5
Statistical Week 31							
Mean Fork Length (cm)	38.00	52.77	40.00	56.25	51.25		53.83
Maximum	38.0	59.0	40.0	58.5	55.0		55.0
Minimum	38.0	50.0	40.0	54.0	45.5		52.5
Standard Deviation	--	2.60	--	3.18	4.09		1.26
Sample Size	1	15	1	2	4		3
2002 Composite							
Mean Fork Length (cm)	37.50	52.32	39.00	56.30	52.37	52.00	53.50
Maximum	38.0	59.0	40.0	60.5	56.5	52.0	59.0
Minimum	37.0	48.0	38.0	50.0	45.5	52.0	51.0
Standard Deviation	0.71	2.08	1.41	2.54	2.57	--	2.35
Sample Size	2	69	2	25	35	1	15

accuracy and decreased variance of resulting stock composition estimates (and had no impact on the overall classification of unknown samples)

The variables used by the stepwise procedure for classification differed by age group (Table 7). After application of a jackknife procedure, classification accuracies ranged from 83% for Age 2.2 fish to 95% for Age 1.3 fish (Table 8).

Table 7. Variables used by stepwise discriminant analyses of Age 1.2, 1.3, and 2.2 sockeye salmon.

	Age		
Variable	**1.2**	**1.3**	**2.2**
Between focus and circuli 3	X		
Between circuli 3 and 6	X		
Between circuli 6 and 9			X
Between circuli 9 and 12		X	
Between circuli 12 and 15			
Between circuli 15 and 18	X	X	X
Between circuli 18 and 21	X		X
Between circuli 21 and 24	X		
Distance to freshwater annulus	NA[4]		NA[4]
Number of circuli to freshwater annulus	NA[4]	X	NA[4]

4 Variable not included among the potential variables for the stepwise discriminant analysis.

Table 8. Known-stock classification resulting from using the linear discriminant analysis with Columbia Basin sockeye salmon stocks sampled in 2002.

Age 1.2

Stock	Percent Correct	Sample Classification	
		Wenatchee	***Okanogan***
Wenatchee	92.6	137	11
Okanogan	89.7	7	61
Composite Accuracy	91.1		

Age 1.3

Stock	Percent Correct	Sample Classification	
		Wenatchee	***Okanogan***
Wenatchee	100.0	28	0
Okanogan	90.5	2	19
Composite Accuracy	95.2		

Age 2.2

Stock	Percent Correct	Sample Classification	
		Wenatchee	***Okanogan***
Wenatchee	95.4	103	5
Okanogan	71.0	9	22
Composite Accuracy	83.2		

Classification of Mixed-Stock Samples

After weighting weekly stock composition estimates by weekly run size, the percentage of non-fin-clipped sockeye of Wenatchee origin was 61% (σ=5%) for Age 1.2, 81% (σ=5%) for Age 1.3 and 89% (σ=6%) for Age 2.2 (Table 9). In an effort to derive a weekly and total stock composition estimate for all age classes, other age classes sampled at Bonneville Dam were allocated to the two stocks (Fryer 1995). Given the fact that no fish of Age 1.1, 2.1, and 3.2 were found in the Wenatchee known-stock sample but were found in the Okanogan known-stock sample, Age 1.1, 2.1, and 3.2 fish at Bonneville Dam were allocated to the Okanogan stock. All adipose-clipped fish were allocated to the Wenatchee stock as these are most likely fish from a Wenatchee supplementation program[5]. Since no fish in the Wenatchee sample returned after one year in saltwater, or spent more than two years in freshwater, all Age 3.1 and 4.2 fish were also allocated to the Okanogan stock. The Age 1.3 RV clipped fish was allocated to the Okanogan stock. The Age 1.2 RV clipped fish and the Age 2.3 fish were considered to be of unknown origin. Among all sockeye passing over Bonneville Dam in 2002, we estimate that 72% (σ=9%) were of Wenatchee stock, 27% (σ=10%) were of Okanogan stock, and 1% (σ<0.5%) were of unknown origin (Table 10). The proportion of fish of Wenatchee origin estimated at Bonneville dam steadily declined after the Week 25.

5 Sockeye salmon raised as part of a Snake River captive brood program are also adipose clipped. However, the number of sockeye salmon returning to the Snake River is very small relative to those returning to the Wenatchee River.

Table 9. **Stock composition estimates (%) by age class of Columbia Basin sockeye salmon at Bonneville Dam in 2002.**

Classification of only Age 1.2 Sockeye Salmon					
		Sample Classification			
		Wenatchee		Okanogan	
Statistical Week	Sample Size	$\bar{x}$	s	$\bar{x}$	s
24	3	68	33	32	34
25	23	67	12	33	12
26	59	70	8	30	8
27	45	63	9	37	9
28	42	22	9	78	9
29	3	28	33	72	34
Population Estimate	**175**	**61**	**5**	**39**	**5**
Classification of only Age 1.3 Sockeye Salmon					
24	4	72	23	28	25
25	24	82	8	18	9
26	15	92	8	8	9
27	12	73	13	28	15
28	6	100	0	0	0
29	1	0	7	100	8
Population Estimate	**62**	**81**	**5**	**19**	**6**
Classification of only Age 2.2 Sockeye Salmon					
24	1	100	7	0	9
25	45	92	10	8	13
26	57	82	10	18	13
27	35	100	10	0	12
28	36	88	12	12	14
29	8	78	26	11	31
Population Estimate	**183**	**89**	**6**	**11**	**7**

Table 10. Stock composition estimates (%) of all Columbia Basin sockeye salmon at Bonneville Dam in 2002.

Classification of Sockeye Salmon of all ages		Sample Classification					
		Wenatchee		Okanogan		Unclassified	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
22-23	11	79	10	21	10	0	0
24	100	78	6	20	6	2	2
25	144	78	6	22	6	0	0
26	115	71	8	28	9	1	1
27	107	52	11	45	12	3	2
28	20	39	24	56	24	5	5
Population Estimate	**497**	**72**	**9**	**27**	**10**	**1**	**0**

DISCUSSION

The 2002 sockeye salmon run of 49,608 fish at Bonneville Dam was less than half the 2001 sockeye run of 114,933 fish but more than twice the 1994-1999 mean run size of 21,700 fish. The 2002 run was notable for it's unusual age composition. This is the first year, since sampling began in 1985, that Age 2.2 formed the largest portion of the run at Bonneville Dam. It was also the first year that any sockeye salmon of age 3.1, 3.2 or 4.2 were sampled any site. Fish of these age classes likely originated upstream of Wells Dam for no fish were collected at Tumwater Dam that spent more than two years in freshwater or fewer than two years in saltwater. Whether these fish originated from Lake Osoyoos, or are kokanee originating elsewhere is unknown. It is possible that the 3.2 and 4.2 age fish are kokanee that migrated downstream from above Chief Joseph Dam or from Okanagan Lake during high flows in the spring of 2000.

A commonly used method to determine the percentage of Columbia Basin sockeye salmon by stock is to use the split in upstream dam counts. Using the count at Rocky Reach Dam of 12,383 sockeye salmon (which presumably are Okanogan stock), and the difference in Rocky Reach and Rock Island counts of 31,946 fish[6], the proportion of the run in the mid-Columbia of Wenatchee origin was 72%, which is the same as that estimated by this report. In most years, our stock composition estimate has been very similar to that offered by dam count splits.

Unlike 2000 and 2001, sockeye salmon fisheries were minimal in 2002 due to the much lower run size. Estimated release mortalities were 18 in zones 1-5 (Columbia River downstream of Bonneville Dam) sport fishery, one in the shad fishery, and a harvest of 2564 in the zone 6 (between Bonneville and McNary dams) tribal fisheries. Sockeye salmon are also harvested in tribal

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6 These are the fish that presumably comprise the Wenatchee stock, however the estimated 2002 Tumwater Dam sockeye count was only 27,821 (Andrew Murdoch, WDFW, personal communication).

fisheries at the base of Chief Joseph Dam and in the Okanogan River in both the United States and Canada.

Research on Columbia Basin sockeye salmon will continue in 2003 and we will continue to develop an age, length-at-age, and stock composition database for this population. Data obtained from this program may be useful to monitor the impact of future main-stem Columbia fisheries, supplementation programs in the Wenatchee basin, as well as sockeye salmon stock recovery efforts in other Columbia River subbasins.

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