IDENTIFICATION OF COLUMBIA BASIN SOCKEYE SALMON STOCKS IN 2005

Technical Report 06-4

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ABSTRACT

In 2005, samples of adult Columbia Basin sockeye salmon *Oncorhynchus nerka* were collected at Bonneville Dam on the Columbia River 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. Four-year-old fish were estimated to comprise 89% of the mixed-stock sockeye salmon migrating past Bonneville Dam, 89% of the Okanogan stock migrating past Wells Dam, and 78% of the Wenatchee stock migrating past Tumwater Dam. Five-year-old fish were estimated to comprise 8% of the Bonneville Dam mixed-stock, 6% of the Okanogan stock, and 22% of the Wenatchee stock. Three-year-old fish were estimated to comprise 1% of the Bonneville Dam mixed-stock, 1% of the Okanogan stock and none of the Wenatchee stock. Scale pattern analysis techniques were used to estimate that 32% of the sockeye salmon passing Bonneville Dam were of Okanogan origin, 61% were of Wenatchee stock, with the remaining 7% of unknown origin. This estimate differed substantially from that derived from fish counts at mainstem dams of 78% Okanogan and 22% Wenatchee stock. Low known-stock classification accuracy (66%) due to the similarity of scale patterns on Okanogan and Wenatchee Age 1.2 sockeye salmon is likely responsible for this difference.

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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 most recent four year period (2002-2005) averaged 71,200 fish per year, though as recently as 1995-1998, the mean escapement was only 24,900 per year (DART 2005, Fish Passage Center 2005).

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 were initiated, each involving the capture of returning adults, spawning of the adults in hatcheries, and rearing of the offspring in net pens located in their respective rearing lakes before release (Hays 1992, Wells Project Coordinating Committee 1992). The Okanogan enhancement program was terminated following the 2000 release; however a similar program focusing on restoring sockeye salmon to Skaha Lake upstream of Osoyoos Lake began in 2003. The two remaining 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

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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 73,002 sockeye salmon passed Bonneville Dam in 2005, only 18 (0.02%) 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.

sockeye salmon stocks and the biological and migratory characteristics of each 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

Scale pattern analysis (SPA) has been the method of choice 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 among groups or stocks throughout a species' range and that these differences will be consistently exhibited in the scales of entire individuals within groups or stocks of fish. Scale patterns for fish from the Wenatchee and Okanogan sockeye salmon stocks in past years have differed in past years (Schwartzberg and Fryer 1988, 1989, 1990; Fryer and Schwartzberg 1991, 1993, 1994; Fryer et al. 1992; Fryer and Kelsey 2001, 2002, 2003; Fryer 2004, 2005), 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 at Bonneville Dam in 2005. 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 2005.

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 (Whiteaker et al. 2006). Sockeye salmon were sampled at Wells Dam in conjunction with a Washington Department of Fish and Wildlife (WDFW) summer Chinook brood stock collection program, while sampling at Tumwater Dam was done in conjunction with another WDFW research project. 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 (Fryer 1995), these minimum sample numbers have resulted in acceptable levels of precision (d=0.05) and accuracy (α=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. Daily counts of 2005 fish passage at fish ladders were obtained from DART (2005) and the Fish Passage Center (2005) for Bonneville and Wells dams and from WDFW for Tumwater Dam (Travis Maitland, WDFW, November 14, 2005 e-mail, personal communication).

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,

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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 2004 for example, Statistical Week 24 began on June 5 and ended on June 11.

located on the mainstem Columbia River. Each stock was also sampled in terminal areas to obtain representative scale samples specific to 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) just downstream from the mouth of the Okanogan River.

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 (Miranda et al. 2005). 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 this data was recorded, though are not included in this report.

Length Measurements

Fork lengths were measured to the nearest 0.5 cm at Bonneville, Wells, and Tumwater dams. Mean length and standard deviation were calculated for each age class, by weekly sampling period, and for the composite sample. Composite samples were weighted by weekly run size.

Age Determination

Scales were selected, 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, Borodin 1924, Van Oosten 1929). A sample of scales was brought 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.

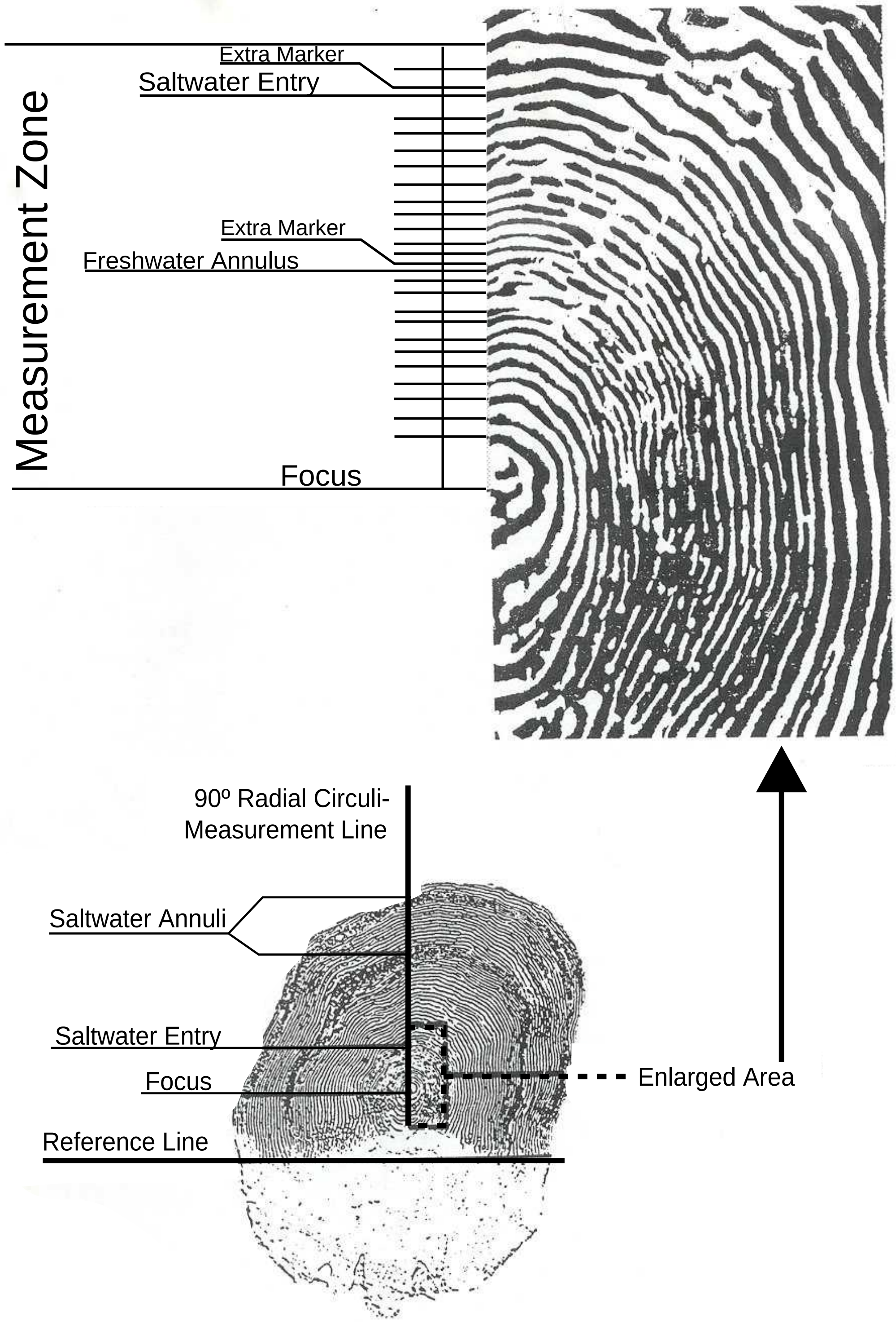
Weekly age composition estimates were compiled and weighted by weekly run size to estimate overall age composition at Bonneville, Wells, and Tumwater dams.

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

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



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 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 was approximately 200 from each known-stock group for each age class analyzed (Conrad 1985)[3]. As in most previous years, the only age class with a sufficiently large sample size to justify using SPA was Age 1.2. 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 Snake River or Wenatchee River hatchery programs.

Statistical Analyses

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

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 known stocks as well as between the two validation groups. 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, I 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 596 Bonneville mixed-stock, 388 Wenatchee known-stock, and 392 Okanogan known-stock. Of the original 613 sockeye salmon sampled at Bonneville Dam, 3% of the total sample was rejected and not classified by age because of unreadable scales. For the same reason, 3% of the 400 Wenatchee, and 2% of the 400 Okanogan samples were rejected.

Age Composition

The predominant age class for the Bonneville mixed-stock as well as for the Okanogan and Wenatchee known stocks was Age 1.2 (Table 1-3). Age 1.2 fish comprised 89% of the run for the Bonneville and Okanogan stocks, and 77% for the Wenatchee stock.

Four of the fish sampled at Bonneville Dam were adipose clipped, while another was judged to have a partial adipose clip. Adipose clipped fish comprised less than 1.0% of the entire run at Bonneville Dam. These fish are most likely from the Wenatchee Eastbank supplementation program, although the remote possibility does exist that fish from a Snake River program may also be included. Two of the adipose clipped fish were Age 1.2, while two were Age 1.3. and the partial adipose clipped fish was Age 1.2.

No fin clipped fish were sampled at Wells Dam. Fin-clipped fish were omitted from our sample at Tumwater Dam in 2005 as they were being sampled by WDFW for another program. A review of video of fish passage at Tumwater Dam estimated that 0.3% of sockeye salmon were adipose-clipped (Travis Maitland, WDFW, November 14, 2005 e-mail).

Table 1. Weekly and cumulative age composition Columbia Basin sockeye salmon sampled at Bonneville Dam in 2005.

Age Composition by Brood Year and Age Class

Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2002	2001		2000			1999	
					1.1	1.2	2.1	1.3	2.2	3.1	3.2	4.1
24[a]	6/1. 6/7, 6/9	27	27	2081	0.000	0.926	0.000	0.074	0.000	0.000	0.000	0.000
25	6/14,6/16	54	51	9872	0.020	0.902	0.020	0.059	0.000	0.000	0.000	0.000
26	6/20,6/22	160	157	18766	0.006	0.866	0.000	0.121	0.006	0.000	0.000	0.000
27	6/27,6/29	160	154	22559	0.013	0.883	0.013	0.071	0.006	0.000	0.006	0.006
28	7/5,7/8	140	135	12800	0.015	0.896	0.007	0.052	0.007	0.022	0.000	0.000
29	7/11,7/14	53	52	3978	0.000	0.962	0.019	0.019	0.000	0.000	0.000	0.000
30[b]	7/19	20	20	2946	0.000	0.850	0.050	0.000	0.050	0.000	0.050	0.000
Cumulative		**614**	**596**	**73002**	**0.011**	**0.888**	**0.011**	**0.073**	**0.007**	**0.004**	**0.004**	**0.002**

a Weekly run size includes sockeye passing Bonneville Dam between Weeks 20 and 23. Sampling began in Week 23 but only one fish was sampled, thus it was combined with Week 24.
b Weekly run size includes sockeye salmon passing Bonneville Dam between Weeks 31 and 43. Sampling ended in Week 30.

Table 2. Weekly and cumulative age composition of Okanogan sockeye salmon stocks sampled at Wells Dam in 2005.

Age Composition by Brood Year and Age Class

Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2002	2001		2000			1999
					1.1	1.2	2.1	1.3	2.2	3.1	4.1
28 [a]	7/5	59	56	12443	0.036	0.875	0.036	0.036	0.018	0.000	0.000
29	7/11	141	138	20443	0.007	0.928	0.007	0.029	0.029	0.000	0.000
30	7/18	115	113	11856	0.009	0.841	0.027	0.044	0.018	0.035	0.027
31 [b]	7/25	85	85	9351	0.012	0.871	0.035	0.059	0.024	0.000	0.000
Cumulative		**400**	**392**	**54093**	**0.015**	**0.887**	**0.023**	**0.039**	**0.023**	**0.008**	**0.006**

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 – 44. Sampling ended in Week 31.

Table 3. Weekly and cumulative age composition of Wenatchee sockeye salmon stocks sampled at Tumwater Dam in 2005.

Age Composition by Brood Year and Age Class

Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly Run Size	2001	2000		1999
					1.2	1.3	2.2	2.3
29[a]	7/12	115	110	5862	0.764	0.209	0.027	0.000
30	7/19	188	181	4880	0.751	0.221	0.028	0.000
31[b]	7/26	97	97	3466	0.845	0.144	0.000	0.010
Cumulative		**400**	**388**	**14208**	**0.779**	**0.197**	**0.021**	**0.003**

a Weekly run size includes fish numbers from Weeks 27 – 29. Sampling started in Week 29.
b Weekly run size includes fish numbers from Weeks 31 – 41. Sampling ended in Week 31.

Length Composition

Mean fork lengths of Age 1.2 sampled at Bonneville, Tumwater, and Wells dams differed by less than 1.0 cm (Tables 4-6). As was the case in 2004, Wenatchee sockeye sampled at Tumwater dam had the greater lengths and this may be a result of the fact that many fish sampled 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. Among other age classes with much smaller sample sizes, mean fork lengths varied by up to 0.5 cm for Age 1.3 fish, 0.3 cm for Age 2.2 fish and 0.8 cm for Age 1.1 fish.

Classification of Known-Stock Samples

Known stock sample sizes for SPA were 221 Okanogan and 205 for the Wenatchee stock. The variable set chosen to classify known- and mixed-stock samples consisted of triplets between focus and circuli 24. The overall classification accuracy was 66.0% (Table 7).

Table 4. Length-at-age estimates for Columbia Basin sockeye salmon stocks sampled at Bonneville Dam in 2005.

Brood Year and	2002	2001		2000			1999
Age Class	1.1	1.2	1.3	2.2	3.1	3.2	4.1
Statistical Week 24							
Mean Fork Length (cm)		49.04	57.00				
Maximum		53.00	57.00				
Minimum		45.00	57.00				
Standard Deviation		2.34	-				
Sample Size		25	1				
Statistical Week 25							
Mean Fork Length (cm)	37.50	48.91	55.50				
Maximum	37.50	53.00	56.00				
Minimum	37.50	44.50	55.00				
Standard Deviation	-	2.05	0.50				
Sample Size	1	46	3				
Statistical Week 26							
Mean Fork Length (cm)	42.00	49.50	55.00	48.00			
Maximum	42.00	57.00	63.00	48.00			
Minimum	42.00	44.00	49.00	48.00			
Standard Deviation	-	2.40	3.12	-			
Sample Size	1	136	18	1			
Statistical Week 27							
Mean Fork Length (cm)	38.25	49.19	55.86	51.50		51.00	50.00
Maximum	39.50	55.00	60.50	51.50		51.00	50.00
Minimum	37.00	42.00	49.50	51.50		51.00	50.00
Standard Deviation	1.77	2.14	2.90	-		-	-
Sample Size	2	136	11	1		1	1
Statistical Week 28							
Mean Fork Length (cm)	39.00	49.13	54.71	50.50	49.00		
Maximum	39.50	55.00	57.00	50.50	53.00		
Minimum	38.50	44.50	51.00	50.50	46.00		
Standard Deviation	0.71	2.13	1.89	-	3.61		
Sample Size	2	121	7	1	3		
Statistical Week 29							
Mean Fork Length (cm)		49.44	54.50				
Maximum		55.00	54.50				
Minimum		45.00	54.50				
Standard Deviation		2.02	-				
Sample Size		50	1				
Statistical Week 30							
Mean Fork Length (cm)		49.44		49.00		47.00	
Maximum		54.00		49.00		47.00	
Minimum		41.00		49.00		47.00	
Standard Deviation		3.07		-		-	
Sample Size		17		1		1	
2005 Composite							
Mean Fork Length (cm)	39.00	49.26	55.25	49.75	49.00	49.00	50.00
Maximum	42.00	57.00	63.00	51.50	53.00	51.00	50.00
Minimum	37.00	41.00	49.00	48.00	46.00	47.00	50.00
Standard Deviation	1.79	2.23	2.63	1.55	3.61	2.83	-
Sample Size	6	531	42	4	3	2	1

Table 5. Length-at-age estimates for Wenatchee sockeye salmon stocks sampled at Tumwater Dam in 2005.

Brood Year and	2001	2000		1999
Age Class	1.2	1.3	2.2	2.3
Statistical Week 29				
Mean Fork Length (cm)	50.45	56.03	50.33	
Maximum	57.50	59.00	51.00	
Minimum	47.00	52.50	49.50	
Standard Deviation	2.14	1.48	0.76	
Sample Size	84	23	3	
Statistical Week 30				
Mean Fork Length (cm)	50.53	55.86	49.90	
Maximum	58.50	59.00	51.50	
Minimum	45.50	51.00	47.50	
Standard Deviation	2.31	1.87	1.98	
Sample Size	136	40	5	
Statistical Week 31				
Mean Fork Length (cm)	49.41	56.04		54.50
Maximum	53.00	59.50		54.50
Minimum	45.00	54.00		54.50
Standard Deviation	1.78	1.57		-
Sample Size	82	14		1
2005 Composite				
Mean Fork Length (cm)	50.21	55.94	50.06	54.50
Maximum	58.50	59.50	51.50	54.50
Minimum	45.00	51.00	47.50	54.50
Standard Deviation	2.18	1.69	1.57	-
Sample Size	302	77	8	1

Table 6. Length-at-age estimates for Okanogan sockeye salmon stocks sampled at Wells Dam in 2005.

Brood Year and	2002	2001		2000			1999
Age Class	1.1	1.2	2.1	1.3	2.2	3.1	4.1
Statistical Week 28							
Mean Fork Length (cm)	37.50	49.26	39.25	54.00	47.50		
Maximum	39.00	56.50	39.50	54.00	47.50		
Minimum	36.00	44.00	39.00	54.00	47.50		
Standard Deviation	2.12	2.42	0.35	0.00	-		
Sample Size	2	49	2	2	1		
Statistical Week 29							
Mean Fork Length (cm)	37.00	49.24	40.00	54.75	50.25		
Maximum	37.00	57.50	40.00	56.50	52.50		
Minimum	37.00	44.00	40.00	52.00	47.50		
Standard Deviation	-	2.21	-	1.94	2.40		
Sample Size	1	128	1	4	4		
Statistical Week 30							
Mean Fork Length (cm)	41.50	49.33	39.83	56.10	48.75	47.50	47.83
Maximum	41.50	56.50	41.50	57.50	53.00	49.00	48.00
Minimum	41.50	40.50	38.00	53.50	44.50	45.50	47.50
Standard Deviation	-	2.66	1.76	1.56	6.01	1.78	0.29
Sample Size	1	95	3	5	2	4	3
Statistical Week 31							
Mean Fork Length (cm)	37.5	49.23	39.33	57.00	51.25		
Maximum	37.5	57.50	40.50	58.50	52.50		
Minimum	37.5	42.50	38.00	55.00	50.00		
Standard Deviation	-	2.52	1.26	1.66	1.77		
Sample Size	1	74	3	5	2		
2005 Composite							
Mean Fork Length (cm)	38.20	49.26	39.56	55.78	49.83	47.50	47.83
Maximum	41.50	57.50	41.50	58.50	53.00	49.00	48.00
Minimum	36.00	40.50	38.00	52.00	44.50	45.50	47.50
Standard Deviation	2.14	2.43	1.13	1.83	2.94	1.78	0.29
Sample Size	5	346	9	16	9	4	3

Table 7. Known-stock classification resulting from using the linear discriminant analysis with Columbia Basin sockeye salmon stocks sampled in 2005.

Stock	Percent Correct	Sample Classification: *Wenatchee*	*Okanogan*
Wenatchee	66.3	136	69
Okanogan	65.6	76	145
Composite Accuracy	66.0		

Classification of Mixed-Stock Samples

The percentage of Age 1.2 sockeye salmon of Wenatchee origin was 68% (σ=10%), with the remaining 32% (σ=10%) of Okanogan origin. 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 were found in the Wenatchee known-stock sample but were found in the Okanogan known-stock sample, Age 1.1 fish at Bonneville Dam were allocated to the Okanogan stock. Since no fish in the Wenatchee sample returned after spending only one year in saltwater, or spent more than two years in freshwater, the handful of Age 3.1, 3.2, and 4.1 fish were also allocated to the Okanogan stock. The Age 1.3 and 2.2 fish were considered to be of unknown origin. Among all sockeye passing over Bonneville Dam in 2005, an estimated 61% (σ=10%) were of Wenatchee stock, 32% (σ=10%) were of Okanogan stock, and 7% (σ=1%) were of unknown origin. As will be noted in the Discussion section, this differs substantially from what was observed based on upstream dam counts.

DISCUSSION

The 2005 Columbia Basin sockeye salmon run of over 73,000 fish at Bonneville Dam was almost 40% below the 123,000 returning in 2004 and less than the most recent four-year (2001-2004) average of 81,800 fish. The 2005 run was typical in that Age 1.2 group made up the majority of the run at Bonneville, Wells, and Tumwater dams.

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 55,570 sockeye salmon (which presumably are Okanogan stock), and the difference in Rocky Reach and Rock Island counts of 15,656 fish[4], the proportion of the run in the mid-Columbia of Okanogan origin was 78%, compared to 28% estimated by this report. Even if all unknowns are attributed to the Okanogan stock, the upper 95% confidence interval for the Okanogan estimate is only 54%. This year's scale pattern analysis work greatly underestimated the Okanogan portion of the run. The reason our stock composition estimates deviating so far from what was observed is likely related to our low known-stock classification accuracy of 66%. This is the lowest accuracy rate since our sockeye stock identification studies commenced in 1985 and is likely attributable to uncharacteristically similar growth patterns exhibited by Wenatchee and Okanogan Age 1.2 sockeye (Figure 3).

The linear discriminant model we have traditionally used for differentiating sockeye salmon stocks has always included triplets and has sometimes included distance and number of circuli to freshwater annulus. Also measured is distance and number of circuli to ocean entry. I have not used this scale feature in the discriminant model because I felt that ocean entry could not be consistently located. Including the two ocean entry variables into the discriminant analysis in 2005 increased the classification accuracy from 66% to 84% and changed the classification of sockeye salmon at Bonneville Dam to 84% Okanogan, 8.7%

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4 These are the fish that presumably comprise the Wenatchee stock, however the estimated number of sockeye salmon passing Tumwater Dam on the Wenatchee River in 2005 based on video counts was 14,211 fish (Travis Maitland, WDFW, November 14, 2005 e-mail).

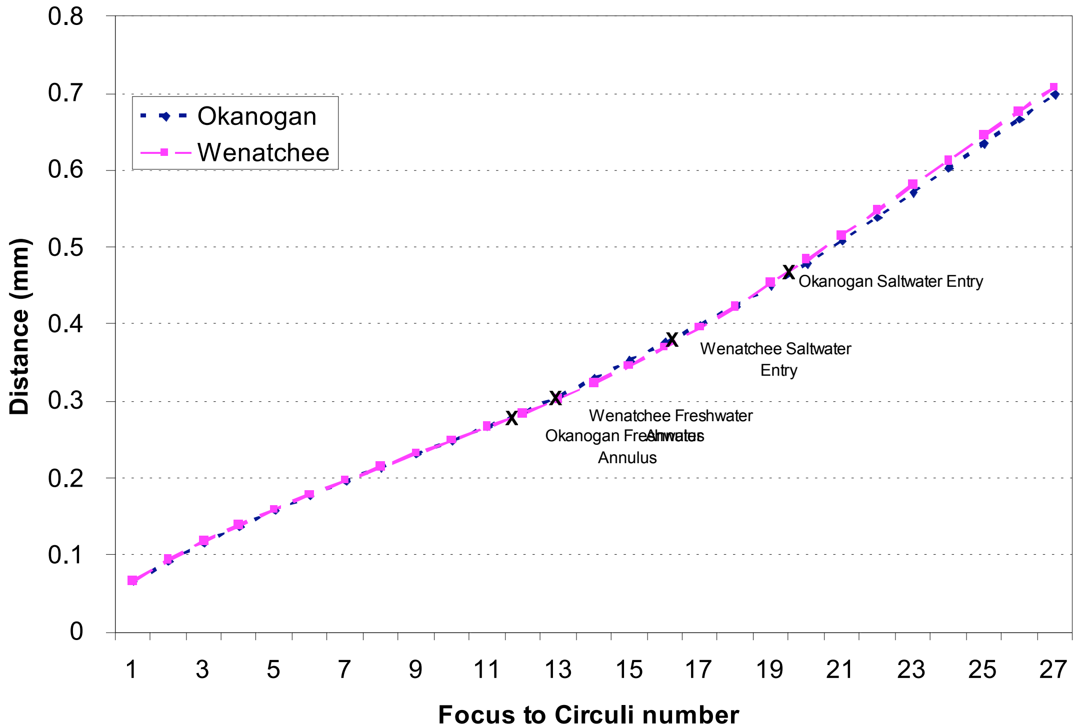
Wenatchee, and 7.3% unknown origin. However, I measured 10 scales for each stock (Okanogan, Wenatchee, Bonneville) twice and found that the mean measurement of ocean entry varied by 12-14%, compared to an average of 3.8% for the other variables used. This tends to confirm my view that ocean entry cannot be determined with sufficient precision to use this variable in the discriminant analysis model.

The estimated harvest in Zone 1-5 (downstream of Bonneville Dam) was four fish, with an additional 1,727 fish harvested in the Zone 6 (between Bonneville and McNary dams) tribal commercial and 2,766 in the Zone 6 tribal ceremonial and subsistence fishery (January 17, 2005 e-mail from Stuart Ellis, CRITFC, personal communication). No scales were collected in 2005 from any sockeye captured in these fisheries so SPA could not be used to estimate the stock composition of these harvests.

Sockeye salmon are also harvested in tribal fisheries upstream of Wells Dam. In 2004, the estimated number of sockeye salmon harvested in the Chief Joseph Dam snag fishery was six, while a minimum[5] of 201 sockeye salmon were harvested in an Okanogan River sockeye net fishery (Colville Confederated Tribes Fish and Wildlife Department memorandum from Christopher J. Fisher to Enrique Patino dated December 12, 2005). An estimated 50 sockeye salmon were harvested in Okanagan Band tribal Lake Osoyoos gill net and Okanagan River snag fisheries (Howie Wright, Okanagan Nation Alliance, March 29, 2006, personal comunication). Given the low return past Tumwater Dam, there was no Lake Wenatchee sport fishery in 2005.

5 One tribal fisherman reported catching 60-80 fish in July but did not specify how many fish were sockeye salmon.

Figure 3. **Comparison of mean scale measurements from focus to circuli numbers 1 to 27 for Age 1.2 Wenatchee and Okanogan sockeye salmon. Freshwater annulus and saltwater entry positions are also denoted.**



For both 2006 and 2007 we have been funded by the Pacific Salmon Commission Southern Fund to enhance our sockeye stock identification program by inserting PIT tags in all sockeye salmon sampled at Bonneville Dam. These fish will then be detected at PIT tag detectors located in adult fish ladders at McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams as well as at dams in the Snake Basin (though we do not expect to tag any sockeye salmon returning to the Snake Basin). This will allow us to assign sockeye salmon passing upstream of Rock Island Dam to a particular stock. Those detected at Rocky Reach Dam comprise the Okanogan stock, and those detected at Rock Island Dam, but not Rocky Reach Dam, comprise the Wenatchee stock. (Installation of detection facilities at Tumwater Dam, planned for 2007, will allow more precise stock composition estimate.) Stock composition during the upstream migration will be estimated by stock and by week at Bonneville, McNary, Priest Rapids, and Rock Island dams. The Bonneville Dam stock composition estimates will be compared with that estimated from our annual scale pattern analysis study.. In addition, we will be able to correlate survival between dams with adult PIT tag detection with age (as determined by scales) migratory timing, water temperature, flow, and spill.

Research on Columbia Basin sockeye salmon will continue in 2006 and we will continue to develop an age, length-at-age, and stock composition data-base 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 and Okanogan basins, as well as sockeye salmon stock recovery efforts in other Columbia River subbasins.

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