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TECHNICAL REPORT 02-2

Identification of Columbia Basin Sockeye Salmon Stocks Using Scale Pattern Analyses in 2001

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ABSTRACT

In 2001, 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. Additional samples were collected from the Zone 1-5 commercial fishery located in the Columbia River downstream of Bonneville Dam, the Zone 6 commercial fishery located between Bonneville and McNary dams, as well as the Wanapum tribal fishery just downstream of Priest Rapids Dam. Age composition was estimated from the sampled sockeye salmon passing the three dams, as well as for the sockeye salmon captured in the three fisheries. Four-year-old fish were estimated to comprise 81% of the mixed-stock sockeye salmon migrating past Bonneville Dam, 95% of the Okanogan stock migrating past Wells Dam, 54% of the Wenatchee stock migrating past Tumwater Dam, 88% of the Zone 1-5 fishery, 78% of the Zone 6 fishery and 90% of the Wanapum fishery. Five-year-old fish were estimated to comprise 18% of the Bonneville Dam mixed-stock, 2% of the Okanogan stock, 46% of the Wenatchee stock, 12% of the Zone 1-5 fishery mixed-stock, 17% of the Zone 6 fishery mixed-stock, and 10% of the Wanapum fishery mixed-stock. Three-year-old fish were estimated to comprise 1% of the Bonneville Dam mixed-stock, 3% of the Okanogan stock, none of the Wenatchee stock, none of the Zone 1-5 or Wanapum fisheries mixed-stock, and 3% of the Zone 6 fishery mixed-stock. Scale pattern analysis techniques were used to estimate that 68% of the Age 1.2 sockeye salmon, and 56% of the entire run, passing Bonneville Dam were of Okanogan stock, with the remaining percentage of Wenatchee stock. Sixty-six percent of the fish caught in the Zone 1-5 commercial fisheries 44% percent of the fish caught in the Zone 6 fishery, and 67% of the fish caught in the Wanapum tribal fishery were estimated to be of Okanogan stock, with the remainder of Wenatchee stock.

ACKNOWLEDGMENTS

We thank the following individuals for their assistance in this project: John Whiteaker, Bobby Begay, Doug Hatch, Randy Henry, Jason Ruszczyk, André Talbot, Rishi Sharma, Stuart Ellis, and Marianne McClure of the Columbia River Inter-Tribal Fish Commission; Brett Morgan, Kevleen Melcher, and Eric Ollerenshaw 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, Charles Boggs, and Dennis Quimps of the University of Idaho, and Andrew Murdoch, Charlie Cochron, Dan Rawding, Charlie Snow, Kelly Harlan, Rick Watson, 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

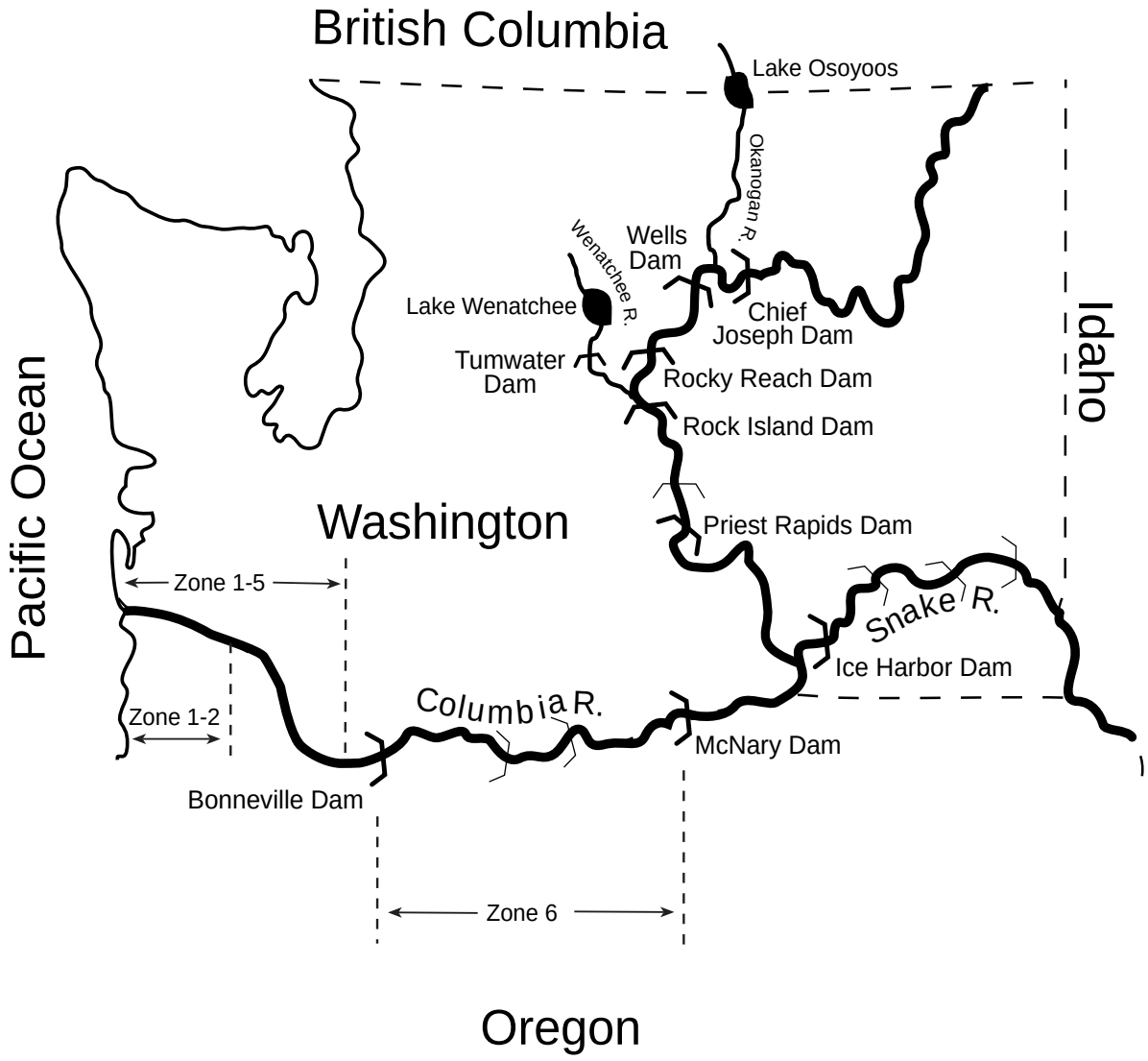
Sockeye salmon, *Oncorhynchus nerka,* is one of the species of Pacific salmon native to the Columbia River Basin. Before white settlers developed the region, it is estimated the Columbia Basin supported an annual sockeye salmon run averaging over three million fish (NPPC 1986, Fryer 1995). Since the 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 before increasing to 93,391 fish in 2000 and 114,945 fish in 2001 (DART 2001).

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 2000. 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 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

1 A small run of sockeye salmon return to the Snake River and are listed as endangered under the Endangered Species Act. While an estimated 114,945 sockeye salmon passed Bonneville Dam in 2001, only 28 (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.



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), 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 of adult Columbia Basin sockeye salmon in 2001. 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 2001 (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 2001. The size and stock selectivity of 2001 Zone 1-5 and Zone 6 commercial and Wanapum tribal fisheries is also examined.

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 2002). Sampling at Tumwater and Wells dams was planned for one or two days per week during the period in which significant numbers of sockeye salmon were migrating past those sites. However, due to the desire to work with other sampling and broodstock collection programs to minimize the impact of trapping on salmon runs at Tumwater and Wells dams, sampling at both locations did not begin until over half of the run had passed both locations. 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 (2001) for Bonneville and Wells dams and from Washington Department of Fish and Wildlife (Andrew Murdoch, personal communication) 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).

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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 2001 for example, Statistical Week 24 began on June 10 and ended on June 16.

Scale samples were also obtained from sockeye salmon sampled from a commercial fishery conducted below Bonneville Dam (referred to as Zone 1-5[3]), a tribal fishery conducted between Bonneville and McNary (river km 463) dams (referred to as Zone 6) and in a Wanapum Tribal fishery conducted immediately below Priest Rapids Dam (river km 630). This provided additional mixed-stock sockeye salmon population samples. We used these additional samples to estimate the age, size, and stock selectivity of these fisheries. A multinomial test for proportions was used to test for age selectivity (Zar 1984).

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 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 2002). 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

3 For fishery management purposes, the lower Columbia River is divided into zones separated by Washington county lines. In 2001 the Zone 1-5 commercial fishery was conducted exclusively in Zones 1 and 2, which are located between the river mouth and river km 84. River km 84 marks the boundary between Wahkiakum and Cowlitz counties in Washington state.

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.

The Zone 1-5 and Zone 6 commercial fisheries were sampled systematically (at rates of 1 in 1, 1 in 2, 1 in 10, and 1 in 20 depending on the date and sampling location) by Oregon Department of Fish and Wildlife personnel. Length, sex, weight, and mark information were collected with three scales per fish. Scale samples were collected by tribal fisherman from all fish caught in the Wanapum tribal fishery. Length, sex, and mark information were also collected. Five other fisheries occurred in 2001 but were not sampled: a Zone 6 ceremonial and subsistence fishery, a sport fishery in Lake Wenatchee, and three tribal fisheries: one in the pool behind Priest Rapids Dam, one just downstream of Chief Joseph Dam (river km 865) and one in the Canadian portion of the Okanogan basin (Table A1).

Length Measurements

Fork lengths were measured to the nearest 0.5 cm at Bonneville, Wells, and Tumwater dams. Lengths of fish sampled in the Zone 1-5 and Zone 6 fishery were measured to the nearest 0.1 cm while lengths of fish sampled in the Wanapum tribal fishery were measured to the nearest inch (2.54 cm). 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. All Wanapum fishery scale samples were aged by John Sneva.

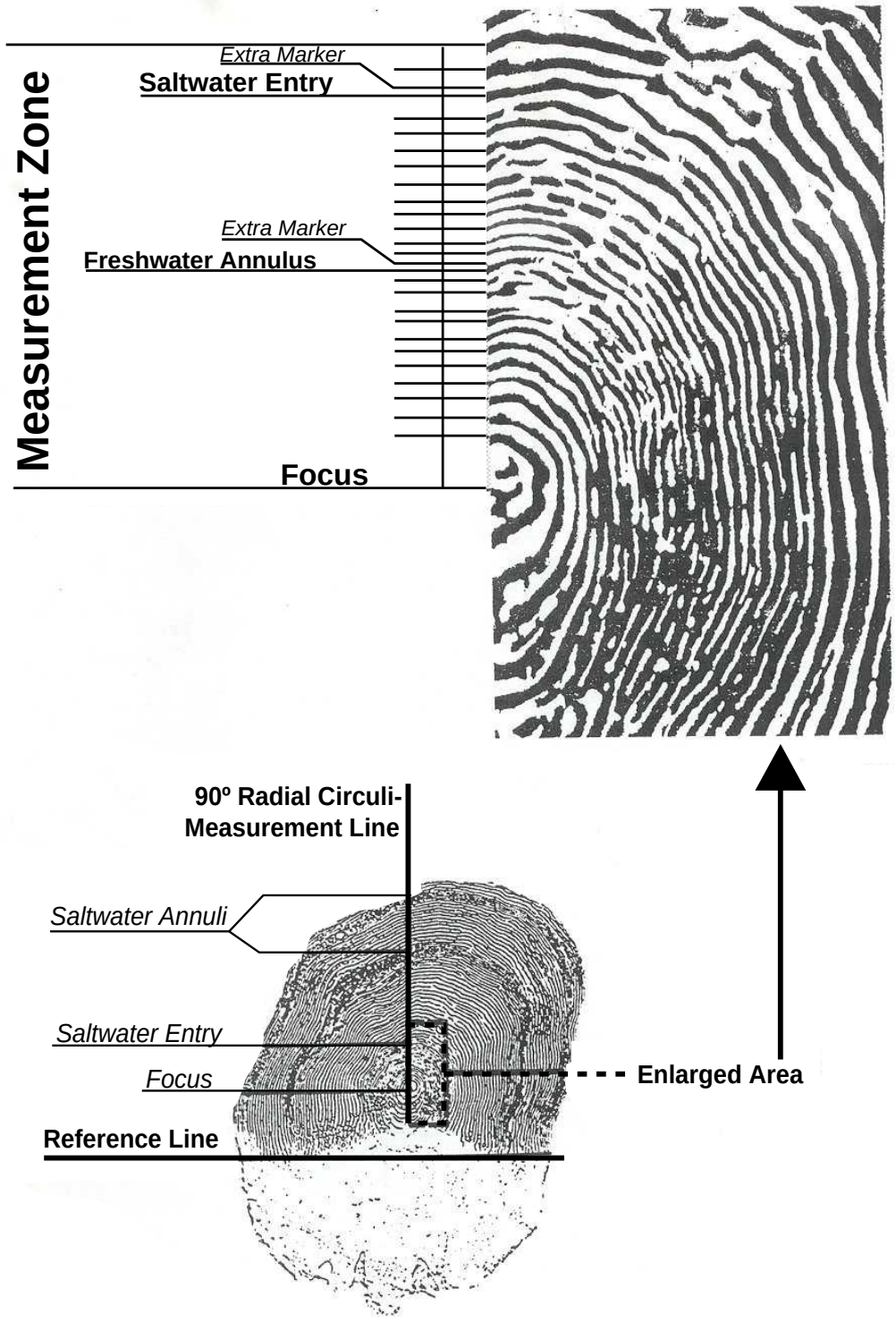
The European method for fish age description (Koo 1955) is used in this report. The number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The numeral following the period indicates the number of winters a fish 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 in 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 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.

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



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 the predominant Age 1.2 age class (Conrad 1985). This age class has been found to be the only age class that is present in sufficient abundance in both known-stocks to permit SPA studies. 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 was much larger to permit more precise weekly stock composition estimates. No adipose-clipped sockeye salmon were included in any of the samples studied due to very small sample sizes and the fact that adipose-clipped fish were known to be from the Wenatchee sockeye salmon supplementation program[4].

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

4 There is a very small probability that adipose-clipped sockeye salmon could originate in a Redfish Lake program seeking to restore Snake River sockeye salmon. However, the magnitude of this program is much smaller than the Wenatchee program.

stock composition for the entire run. In the Zone 6 and 1-5 fisheries, where sampling rates differed, each sample was weighted by the sampling rate to compute an overall stock composition estimate.

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 542 Bonneville mixed-stock, 378 Wenatchee known-stock, and 396 Okanogan known-stock. Of the original 557 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, 1% of the 382 Wenatchee, and 1% of the 400 Okanogan samples were rejected. Of the 356 samples that were collected from the Zone 1-5 fishery, 7% were rejected because of missing or unreadable scales. Ninety-six samples were collected from the Zone 6 fishery. However, 18 samples were rejected as they were not randomly sampled. Of the remaining 78 samples, an additional 10% were rejected because of missing or unreadable scales. Of the 183 samples that were collected from the Wanapum fishery, 10% were rejected because of missing or unreadable scales.

The only age class with sufficiently large sample sizes to permit scale pattern analysis studies was Age 1.2. For mixed-stock groups the total sample size used was 443 systematically selected from the 542 Age 1.2 fish sampled at Bonneville Dam, 120 systematically selected from the Zone 1-5 fishery, 48 sampled from the Zone 6 fishery, and 137 collected in the Wanapum tribal fishery. The Okanogan known-stock group consisted of 185 fish systematically selected from the Wells Dam sample, while the Wenatchee known-stock group consisted of all 197 Age 1.2 fish with readable scales sampled at Tumwater Dam.

Age Composition

The predominant age class for both known- and mixed-stocks was Age 1.2. This age class was estimated to represent 80% of the Bonneville mixed-stock, 54% of the Wenatchee known-stock, and 94% of the Okanogan known-stock sample (for age details Tables 1-3).

Table 1. Weekly and cumulative age composition Columbia Basin sockeye salmon sampled at Bonneville Dam in 2001.

					Age Composition by Brood Year and Age Class				
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1998 1.1	1997 1.2	1997 2.1	1996 1.3	1996 2.2
24[a]	5/29, 6/5, 6/12	57	56	16986		0.786		0.161	0.054
25	6/19, 21	180	177	55204		0.814		0.124	0.062
26	6/26, 29	180	175	25686	0.006	0.800	0.006	0.074	0.114
27	7/3	80	78	11684	0.013	0.808	0.013	0.064	0.102
28	7/10, 13	50	47	3377	0.064	0.745	0.064	0.042	0.085
29[b]	7/17, 25	10	9	1996	0.222	0.778			
Cumulative		557	542	114933	0.008	0.803	0.005	0.108	0.076

a Weekly run size includes fish numbers from Week 21 - 24. Sampling began in Week 22. Due to small sample sizes in Weeks 22 and 23, Weeks 22 - 24 were combined.

b Weekly run size includes fish numbers from Weeks 30 - 37. Sampling ended in Week 30. Due to small sample size (n=2) 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 2001.

					Age Composition by Brood Year and Age Class		
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1997	1996	
					1.2	1.3	2.2
29[a]	7/18, 19	81	81	23183	0.519	0.173	0.309
30	7/25, 26	204	201	4471	0.592	0.184	0.224
31[b]	8/1	97	96	4828	0.573	0.115	0.313
Cumulative		382	378	32482	0.537	0.166	0.298

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 – 39. Sampling ended in Week 31.

Table 3. Weekly and cumulative age composition of Okanogan sockeye salmon stocks sampled at Wells Dam in 2001.

					Age Composition by Brood Year and Age Class				
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1998	1997		1996	
					1.1	1.2	2.1	1.3	2.2
28[a]	7/9	160	159	56358	0.006	0.969		0.025	
29	7/16	120	119	10704	0.109	0.866	0.017		0.008
30	7/23	80	79	4174	0.063	0.873	0.025	0.025	0.013
31[b]	7/30	40	39	3254	0.154	0.769	0.051		0.026
Cumulative		400	396	74490	0.031	0.940	0.006	0.020	0.003

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 – 39. Sampling ended in Week 31

Adipose-clipped fish comprised 2.3% of the fish sampled at Bonneville Dam (Table A1). 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. One fish in Week 28 was identified as an Age 1.3 fish that had both an adipose and a left ventral fin clip. While sockeye salmon produced by the Okanogan River Cassimer Bar supplementation program have a ventral fin clipped, no known program or research would clip two fins on one sockeye salmon so the origin of this fish remains unknown.

No fin-clipped fish were found in the sample collected at Wells Dam. No fin-clipped fish were sampled at Tumwater Dam as those fish were being used for other research, though a Wenatchee River spawning ground survey of over 6,000 fish found that 2.7% of the fish were adipose-clipped (Andrew Murdoch, WDFW, personal communication). Adipose-clipped fish were estimated to comprise 2.0% of those fish captured in the Zone 1-5 fishery (Stuart Ellis, CRITFC, personal communication). All fin-clipped fish captured in the Zone 1-5 fishery were released without any records of length or collection of scales. Adipose-clipped fish were estimated by this study to represent 5.3% of the harvest in the Zone 6 fishery and 3.8% in the Wanapum fishery. However, only three adipose-clipped fish were included in the random sample upon which the Zone 6 estimate is based, while the Wanapum estimate is based on seven fish. No fin clips other than adipose were observed in samples from any fishery.

The predominant age class in all fisheries was Age 1.2 (Table 4). A multinomial test for proportions found that the age distribution of fish caught in the Wanapum fishery differed significantly from that estimated at Bonneville Dam for ages 1.2 and 1.3 (P=0.001 for both tests), but not for Age 2.2 (P=0.490). The age distribution of fish caught in the Zone 6 commercial fishery did not differ from that estimated at Bonneville Dam for Age 1.2 (P=0.684), Age 1.3 (P=0.875), and Age 2.2 (P=0.844) fish. The age distribution of fish caught in the Zone 5 commercial fishery differed from that estimated at Bonneville Dam for Age 1.2 (P=0.021) and Age 1.3 (P=0.007) but not for Age 2.2 (P=0.252) fish.

Table 4. Age composition of sockeye salmon sampled in the Wanapum tribal fishery, and Zone 1-5 and Zone 6 commercial fisheries in 2001.

Wanapum Fishery

Statistical Week	Sampling Date	Number Sampled	Number Ageable	Age Composition by Brood Year and Age Class				
				1998	1997		1996		1995
				1.1	1.2	2.1	1.3	2.2	2.3
26	6/29	50	44		0.909		0.045	0.045	
27	7/3, 7/6	113	101		0.891		0.030	0.079	
28	7/10	20	19		0.947		0.053	0.000	
Cumulative		183	164		0.902		0.037	0.061	

Zone 1-5 Fishery[a]

Statistical Week	Sampling Date	Number Sampled	Number Ageable	1998	1997		1996		1995
				1.1	1.2	2.1	1.3	2.2	2.3
26	6/26, 28	356	332		0.875		0.043	0.082	
Cumulative		356	332		0.875		0.043	0.082	

Zone 6 Fishery

Statistical Week	Sampling Date	Number Sampled	Number Ageable	1998	1997		1996		1995
				1.1	1.2	2.1	1.3	2.2	2.3
26	6/25, 26, 30	78	70	0.028	0.777		0.100	0.068	0.027
Cumulative		78	70	0.028	0.777		0.100	0.068	0.027

a Note that the estimated 2% of the catch which was adipose-clipped was released without scales being collected. Therefore, these fish are not included in the age composition estimates.

Length Composition

Mean fork lengths, calculated by age class, appear greater among fish sampled at Tumwater Dam than those sampled at either Wells or Bonneville dams or in the Wanapum tribal, Zone 1-5, and Zone 6 commercial fisheries (Tables 5-8). However, this difference is relatively small (<1.1 cm for all age classes) and 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.

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, and not nearly as subject to operator judgement. However, including this variable in the variable set did not improve the classification accuracy so it was omitted.

The variables used by the stepwise procedure for the classification of Age 1.2 fish were the distances between the sixth and ninth circuli, ninth and twelfth circuli, twelfth and fifteenth circuli, fifteenth and eighteenth circuli, and twenty-first and twenty-fourth circuli. After application of the jackknife procedure, 89% of the known-stock samples were accurately classified by this variable set (Table 9), which is among the highest rates since this study began in 1987. Nineteen of 197 Wenatchee and 23 of 185 Okanogan samples were misclassified.

Table 5. Length-at-age estimates for Columbia Basin sockeye salmon stocks sampled at Bonneville Dam in 2001. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class				
	1998	1997		1996	
	1.1	1.2	2.1	1.3	2.2
Statistical Week 24					
Mean Fork Length (cm)		51.26		57.72	53.67
Maximum		55.0		60.5	54.0
Minimum		40.0		54.5	53.0
Standard Deviation		2.69		2.15	0.58
Sample Size		44		9	3
Statistical Week 25					
Mean Fork Length (cm)		51.44		57.73	53.14
Maximum		59.5		61.0	56.5
Minimum		46.0		52.5	50.5
Standard Deviation		2.33		2.26	1.78
Sample Size		144		22	11
Statistical Week 26					
Mean Fork Length (cm)	37.00	51.75	43.00	58.35	52.48
Maximum	37.0	59.0	43.0	66.5	56.0
Minimum	37.0	46.0	43.0	54.0	45.0
Standard Deviation	0.00	2.36	0.00	3.26	2.51
Sample Size	1	139[a]	1	13	20
Statistical Week 27					
Mean Fork Length (cm)	42.00	51.49	45.00	56.60	53.56
Maximum	42.0	56.5	45.0	58.5	56.0
Minimum	42.0	47.5	45.0	54.5	51.5
Standard Deviation	0.00	2.04	0.00	1.60	1.74
Sample Size	1	63	1	5	8
Statistical Week 28					
Mean Fork Length (cm)	41.17	50.30	45.00	58.00	51.75
Maximum	42.0	55.5	47.5	58.0	55.0
Minimum	39.5	42.5	42.0	58.0	49.0
Standard Deviation	1.44	2.87	2.78	0.00	2.50
Sample Size	3	35	3	2	4
Statistical Week 29					
Mean Fork Length (cm)	43.50	52.43			
Maximum	47.0	56.0			
Minimum	40.0	49.0			
Standard Deviation	4.95	2.52			
Sample Size	2	7			
2001 Composite					
Mean Fork Length (cm)	41.36	51.47	44.60	57.76	52.99
Maximum	47.0	59.5	47.5	66.5	56.5
Minimum	37.0	40.0	42.0	52.5	45.0
Standard Deviation	3.09	2.35	2.16	2.42	1.86
Sample Size	7	432	5	51	46

a Length data was not recorded for one Age 1.2 fish and therefore it is not included in this table.

Table 6. Length-at-age estimates for Wenatchee sockeye salmon stocks sampled at Tumwater Dam in 2001. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class		
	1997	1996	
	1.2	1.3	2.2
Statistical Week 29			
Mean Fork Length (cm)	53.08	59.36	53.54
Maximum	57.5	61.5	58.0
Minimum	49.0	56.0	50.0
Standard Deviation	2.45	1.68	1.75
Sample Size	42	14	25
Statistical Week 30			
Mean Fork Length (cm)	52.60	57.41	52.67
Maximum	59.5	63.0	59.0
Minimum	41.5	47.5	47.5
Standard Deviation	2.59	3.50	2.64
Sample Size	119	37	45
Statistical Week 31			
Mean Fork Length (cm)	52.11	57.68	52.83
Maximum	58.0	61.0	58.0
Minimum	47.5	54.0	46.0
Standard Deviation	2.13	2.12	2.69
Sample Size	55	11	30
2001 Composite			
Mean Fork Length (cm)	52.85	58.89	53.34
Maximum	59.5	63.0	59.0
Minimum	41.5	47.5	46.0
Standard Deviation	2.44	1.79	1.83
Sample Size	216	62	100

Table 7. Length-at-age estimates for Okanogan sockeye salmon stocks sampled at Wells Dam in 2001. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class				
	1998	1997		1996	
	1.1	1.2	2.1	1.3	2.2
Statistical Week 28					
Mean Fork Length (cm)		51.63		56.50	
Maximum		59.0		60.5	
Minimum	a	41.5		50.0	
Standard Deviation		2.66		4.56	
Sample Size		154		4	
Statistical Week 29					
Mean Fork Length (cm)	40.12	50.83	43.00		55.50
Maximum	41.5	55.5	45.0		55.5
Minimum	39.0	40.5	41.0		55.5
Standard Deviation	0.89	2.42	2.83		0.00
Sample Size	13	103	2		1
Statistical Week 30					
Mean Fork Length (cm)	41.10	51.31	42.75	53.50	50.50
Maximum	43.0	56.0	44.5	55.0	50.5
Minimum	39.5	46.5	41.0	52.0	50.5
Standard Deviation	1.56	2.22	2.47	2.12	0.00
Sample Size	5	69	2	2	1
Statistical Week 31					
Mean Fork Length (cm)	40.33	51.38	44.50		54.50
Maximum	43.5	59.0	45.5		54.5
Minimum	33.0	44.0	43.5		54.5
Standard Deviation	3.79	3.21	1.41		0.00
Sample Size	6	30	2		1
2001 Composite					
Mean Fork Length (cm)	40.31	51.50	43.42	55.50	53.50
Maximum	43.5	59.0	45.5	60.5	55.5
Minimum	33.0	40.5	41.0	50.0	50.5
Standard Deviation	1.41	2.65	1.99	3.97	2.65
Sample Size	24	356	6	6	3

a Length data was not recorded for one Age 1.1 fish and therefore it is not included in this table.

Table 8. Length-at-age estimates for sockeye salmon stocks captured in the Wanapum tribal fishery, and Zone 1-5 and Zone 6 commercial fisheries in 2001.

	Brood Year and Age Class					
	1998	1997		1996		1995
	1.1	1.2	2.1	1.3	2.2	2.3
Wanapum Fishery						
Mean Fork Length (cm)		53.3		58.4	54.4	
Maximum		61.0		61.0	58.4	
Minimum		45.7		55.9	48.3	
Standard Deviation		2.8		2.3	3.2	
Sample Size		148		6	10	
Zone 1-5 Fishery						
Mean Fork Length (cm)		51.4		57.5	53.0	
Maximum		57.9		60	57	
Minimum		42.2		54.2	48.5	
Standard Deviation		2.4		2.2	2.4	
Sample Size		299		10	23	
Zone 6 Fishery						
Mean Fork Length (cm)	39.8	51.9		57.0	52.8	55.2
Maximum	41.9	55.7		60.2	55.8	55.2
Minimum	37.7	45.8		54.4	51.2	55.2
Standard Deviation	3.0	2.0		2.0	2.1	0.0
Sample Size	2	54		9	4	1

Table 9. Known-stock classification resulting from using the linear discriminant analysis with Age 1.2 Columbia Basin sockeye salmon stocks sampled in 2001.

		Sample Classification	
Stock	**Percent Correct**	***Wenatchee***	***Okanogan***
Wenatchee	90.4	178	19
Okanogan	87.6	23	162
Composite Accuracy	89.0		

Classification of Mixed-Stock Samples

After weighting weekly stock composition estimates by weekly run size, 68% (σ=4%) of the non-adipose-clipped Age 1.2 sockeye salmon were estimated to be Okanogan stock (Table 10). 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 and 2.1 were found in the Wenatchee known-stock sample but were found in the Okanogan known-stock sample, Age 1.1 and 2.1 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]. Although Age 2.2 and 1.3 fish were found in both Wenatchee and Okanogan known-stocks, these fish were found in much higher proportions in the Wenatchee known-stock. Age 2.2 and 1.3 fish at Bonneville Dam were therefore allocated to the Wenatchee stock[6]. Among all sockeye passing over Bonneville Dam in 2001, we estimate that 56% (σ=4%) were of Okanogan stock. The proportion of fish of Okanogan origin estimated at Bonneville dam steadily increased over the migration period until Week 28 when small sample sizes resulted in very wide bounds on the estimate.

Classification of Fishery Samples

After weighting stock composition estimates by sampling rate, 76% (σ=6%) of the non-adipose-clipped Age 1.2 sockeye salmon in the Zone 1-5 fishery were estimated to be Okanogan stock (Table 11). The previously described classification techniques were used to classify fish of other ages by age class. The single Age 2.3 fish captured in the Zone 6 fishery was allocated to the Wenatchee stock as, in past years, this age class has been much more common in the Wenatchee stock than the Okanogan stock. After classification of all ages, 66% (σ=5%) of the Zone 1-5 fishery was estimated to be Okanogan

5 Sockeye salmon raised as part of a Snake River supplementation 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.

6 In most previous years Age 2.2 and 1.3 fish have also been found to be overwhelmingly of Wenatchee origin and allocated to the Wenatchee stock.

Table 10. Stock composition estimates (%) of Columbia Basin sockeye salmon at Bonneville Dam in 2001.

Classification of only Age 1.2 Sockeye Salmon						
		Sample Classification				
Statistical Week	Sample Size	Wenatchee $\bar{x}$	Wenatchee s	Okanogan $\bar{x}$	Okanogan s	
22-23	42	30	10	70	10	
24	104	38	7	62	7	
25	101	23	6	77	7	
26	160	25	8	75	8	
27	29	28	11	72	12	
28	7	57	24	43	24	
Population Estimate	**443**	**32**	**4**	**68**	**4**	
Classification of Sockeye Salmon of all ages						
22-23	56	45	10	55	10	
24	177	50	6	50	6	
25	175	38	6	62	6	
26	78	37	8	63	9	
27	47	34	11	66	12	
28	9	45	24	55	24	
Population Estimate	**542**	**44**	**4**	**56**	**4**	

Table 11. Stock composition estimates (%) of Columbia Basin sockeye salmon in the Wanapum tribal, and Zone 1-5[7] and Zone 6 commercial fisheries in 2001.

Classification of only Age 1.2 Sockeye Salmon					
		Sample Classification			
Statistical Week	Sample Size	Wenatchee $\bar{x}$	s	Okanogan $\bar{x}$	s
26	37	36	10	64	11
27	82	23	7	77	7
28	18	29	14	80	14
Wanapum	**137**	**26**	**6**	**74**	**6**
Zone 1-5	**120**	**24**	**6**	**76**	**6**
Zone 6	**48**	**47**	**10**	**53**	**11**
Classification of Sockeye Salmon of all ages					
26	44	42	11	58	10
27	101	32	7	68	7
28	19	24	14	76	14
Wanapum	**164**	**33**	**6**	**67**	**5**
Zone 1-5	**332**	**34**	**6**	**66**	**5**
Zone 6	**70**	**56**	**11**	**44**	**9**

7 The Zone 1-5 stock composition estimates do not include those fish caught and released without sampling because they were adipose-clipped. These fish are likely of Wenatchee origin.

stock. In the Zone 6 commercial fishery, 53% (σ=11%) of the non-adipose-clipped Age 1.2 sockeye salmon were considered to be Okanogan stock. Among all age classes 44% (σ=9%) of the Zone 6 commercial fishery were estimated to be Okanogan stock. In the Wanapum fishery, 74% (σ=6%) of the non-adipose-clipped Age 1.2 sockeye salmon were estimated to be Okanogan stock. Among all age classes, 67% (σ=5%) of the Wanapum fishery were estimated to be Okanogan stock. The percentage of the harvest estimated to be of Okanogan origin steadily increased as the run progressed.

DISCUSSION

The 2001 sockeye run of 114,933 fish at Bonneville Dam was the largest since 1987 (DART 2001). Using the count at Wells Dam of 74,490 sockeye salmon (which presumably are Okanogan stock), and the difference in Rocky Reach and Rock Island counts of 38,620 fish[8], the proportion of the run in the mid-Columbia of Okanogan origin was 66%. This differs from the estimate of 56% (±6%, 90% C.I., Table 10) presented in this report. In most past years, our estimate of stock composition using scale patterns has been closer to that estimated by inter-dam counts. This is the second straight year that our study has estimated a lower proportion of Okanogan sockeye salmon at Bonneville Dam than that estimated from dam counts. There are a number of possible explanations. One possibility is the inaccuracy of dam counts. For example, if the 2001 Rocky Reach sockeye salmon count of 66,220 is used as an estimate of Okanogan stock abundance instead of the Wells Dam count, the percentage of the run in the mid-Columbia estimated to be of Okanogan origin drops to 63%.

We are also slightly underestimating the proportion of fish at Bonneville Dam of Okanogan origin by allocating all Age 1.3 and 2.2 fish to the Wenatchee stock since some fish of these age classes are of Okanogan stock. Sample sizes for these age classes are insufficient to permit SPA studies.

Another possibility for the difference between our stock composition estimate and that produced by dam counts may be that our known-stock samples did not adequately represent the Okanogan and Wenatchee stocks. The representativeness of these samples may have been adversely affected by the fact that over 52% of the Okanogan run had passed Wells Dam prior to our

8 These are the fish that presumably comprise the Wenatchee stock, however the estimated 2001 Tumwater Dam sockeye count was only 32,482 (Andrew Murdoch, WDFW, personal communication). Using 32,482 as an estimate of Wenatchee stock abundance, and the Wells count as an estimate of the Okanogan stock abundance, results in the proportion of the run in the mid-Columbia of Okanogan stock origin being estimated as 70%.

beginning sampling and 60% of the Wenatchee run had passed Tumwater Dam prior to sampling.

A final possibility is differential stock mortality on the upstream migration. In 2001, the large run size resulted in the opening of several sockeye salmon fisheries (Table A1). Scale samples that were collected from the Zone 1-5 commercial, Zone 6 commercial, and Wanapum tribal fisheries, upon analysis, indicated that the fisheries impacted the two stocks differently. The Zone 6 commercial fishery tended to catch a higher number of the Wenatchee stock, while the Wanapum fishery and Zone 1-5 fishery (located downstream of Bonneville Dam) fishery tended to catch a higher number of the Okanogan stock compared to the estimated proportions of these stocks at Bonneville Dam. The small sample of 79 fish from the Zone 6 fishery we analyzed were almost entirely from June 25 and 26, thus our sample may not have adequately represented the harvest of this fishery.

Weekly age and stock composition estimates from the Wanapum fishery indicate that the percentage estimated to be Okanogan stock steadily increased. In Statistical Week 26 (June 24-June 30) 58% of the catch was estimated to be Okanogan stock, in Week 27, 68%, and in Week 28, 76%.

No samples were collected from the tribal fishery in the reservoir above Priest Rapids Dam. This fishery used the same gear, and was conducted at roughly the same time as the Wanapum fishery located just downstream of Priest Rapids Dam. Based on the results of the Wanapum fishery sampling just downstream, it is likely that this fishery also targeted primarily the Okanogan stock.

The Zone 6 platform fishery used different gear than other fisheries and was conducted over a much longer time period, so it is impossible to use data from the other fisheries to measure the stock or age selectivity of this fishery. The other fisheries that were not sampled occur in areas where only a single stock is present. Targeting the Okanogan stock are the Chief Joseph fishery and Okanagan tribal fisheries, while the Lake Wenatchee sport fishery targets the Wenatchee stock.

Research on Columbia Basin sockeye salmon will continue in 2002 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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APPENDIX

A

Table A1. Summary of the Columbia Basin sockeye salmon harvest in 2001.

Location	Type	Dates	Equipment	Harvest	% Ad Clipped[a]	% Okanogan[b]	Data Source
Zones 1-5[c] (Astoria-rkm 84)	Commercial	June 26, 28	114 mm (4½") gill net	1558[d]	2.0%	66%	Stuart Ellis, CRITFC
Zone 1-5 (Astoria-Bonneville Dam)	Steelhead sport fishery	May 16-July 31	Hook and line	116[e]	unknown	unknown	Stuart Ellis, CRITFC
Area 2S (rkm 190 to rkm 224 [Sandy River to Beacon Rock])	Shad Commercial	Periodic openings between May 21-June 29	137-159 mm gill net	15[f]	unknown	unknown	Stuart Ellis, CRITFC
Zone 6 (Bonneville-McNary)	Tribal Ceremonial & Subsistence	June 1-30	Hoop nets, dip nets, and hook and line	1386	unknown	unknown	Stuart Ellis, CRITFC
Zone 6 (Bonneville-McNary)	Tribal Commercial	June 25, 26, 30, July 1	114 mm gill net	5580	3.8%	53%	Stuart Ellis, CRITFC
Downstream of Priest Rapids Dam	Wanapum Tribal	June 29-July 10	114 mm gill net	184	5.3%	74%	Rick Watson, WDFW
Priest Rapids Pool	Yakama Tribal	July 4-14	114 mm gill net	1850	unknown[g]	unknown[g]	Steve Parker, YIN
Lake Wenatchee	Sport	August 10-19	Hook and line	3265[h]	5.7%	0%[i]	Andrew Murdoch, WDFW
Chief Joseph Dam tailrace	Colville Tribal	July 1-September 9	Snagging hooks	<50	0%[j]	100%[i]	Chris Fisher, CTCIR
Okanogan River, Canada	Okanagan Tribal	unavailable	unavailable	unavailable	0%[j]	100%[i]	Deana Machin, Okanagan Nation

a. % Ad Clipped for Zone 6 commercial and the Wanapum tribal fisheries was estimated in this report. All other estimates are from the sources listed in the "Source" column. All adipose-clipped fish captured in the Lake Wenatchee sport and Zone 1-5 commercial fisheries were released and so are not included in the total listed in the harvest column. The actual number of adipose fin-clipped fish captured and released in the Lake Wenatchee sport fishery was 197.

b. The difference between 100% and the Okanogan stock harvest is that estimated to be Wenatchee stock harvest. Estimates for the Zone 1-5 and Zone 6 commercial and Wanapum Tribal fisheries are those estimated by this report. Harvests in Okanogan terminal area are assumed to be 100% Okanogan stock; similarly harvest in the Wenatchee terminal area is assumed to be 100% Wenatchee stock.

c. Zone 1-5 actually extends upstream to Bonneville Dam, but only the 2001 fishery was only conducted over part of this zone.

d. This does not include the 2.0% of the harvest that was comprised of adipose-clipped fish that were released.

e. Incidental catch. The estimated mortality includes immediate and non-retention mortalities.

f. Incidental catch. All sockeye captured in this fishery were released alive. The harvest is an estimate of delayed mortality.

g. Given the similarity in timing and equipment between this fishery and the Wanapum tribal fishery conducted immediately downstream, it is likely that the fish harvested by this fishery share similar characteristics to those harvested by the Wanapum tribal fishery.

h. An additional 197 adipose-clipped fish were captured and released.

i. This fishery is located in a terminal area and is assumed only to harvest fish bound for that terminal area.

j. No records are available regarding fin clips on fish captured in this fishery. However, since this fishery is located far from the two basins where fish are adipose-clipped (Wenatchee and Snake), it is assumed that no adipose-clipped fish were captured in this fishery.