IDENTIFICATION OF COLUMBIA BASIN SOCKEYE SALMON STOCKS USING SCALE PATTERN ANALYSES IN 1992

Technical Report 93-2

Jeffrey K. Fryer
Matthew Schwartzberg

February 22, 1993

Columbia River Inter-Tribal Fish Commission
729 N.E. Oregon St., Portland, OR 97232
(503) 238-0667

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ABSTRACT

In 1992, the sixth year of the Columbia River Inter-Tribal Fish Commission's sockeye salmon stock identification study, a representative sample of the Columbia Basin sockeye salmon population was obtained at Bonneville Dam while known stock samples were collected from Wells (Columbia River km 829) and Tumwater (Wenatchee River km 31) dams. A small sample was also collected from the Methow River. The scales were examined to estimate the age of the fish and were measured for stock identification experiments. Four-year-old fish were estimated to comprise 66% of the Bonneville Dam mixed stock, 80% of the Okanogan known stock, and 48% of the Wenatchee known stock. Five-year-old fish were estimated to comprise 25% of the mixed stock, 2% of the Okanogan stock, and 51% of the Wenatchee stock. Three-year-old fish were estimated to comprise 6% of the mixed stock, 17% of the Okanogan stock, and less than 1% of the Wenatchee stock.

Using scale pattern analysis, 79% accuracy was achieved in classification of Age 1.2 fish of known origin. Eighty-two percent of the mixed-stock Age 1.2 population at Bonneville Dam were classified as Okanogan stock. Sixty-three percent of the entire mixed stock was estimated to be Okanogan stock. The small Methow sample appeared to be more similar to the Wenatchee stock than the Okanogan stock based on age composition and scale pattern analysis of the Age 1.2 samples.

At Bonneville Dam, 17% of the fish sampled were observed to be descaled, injured by marine mammals, or in some way cut or bruised. At Wells and Tumwater dams, 90% and 81%, respectively, of the sockeye salmon sample were similarly injured. Observation of sockeye salmon in poor physical condition has been relatively common at Wells Dam in recent years, but this is the first year in which large numbers of injured fish were seen at Tumwater Dam since sampling began at that location in 1988.

ACKNOWLEDGMENTS

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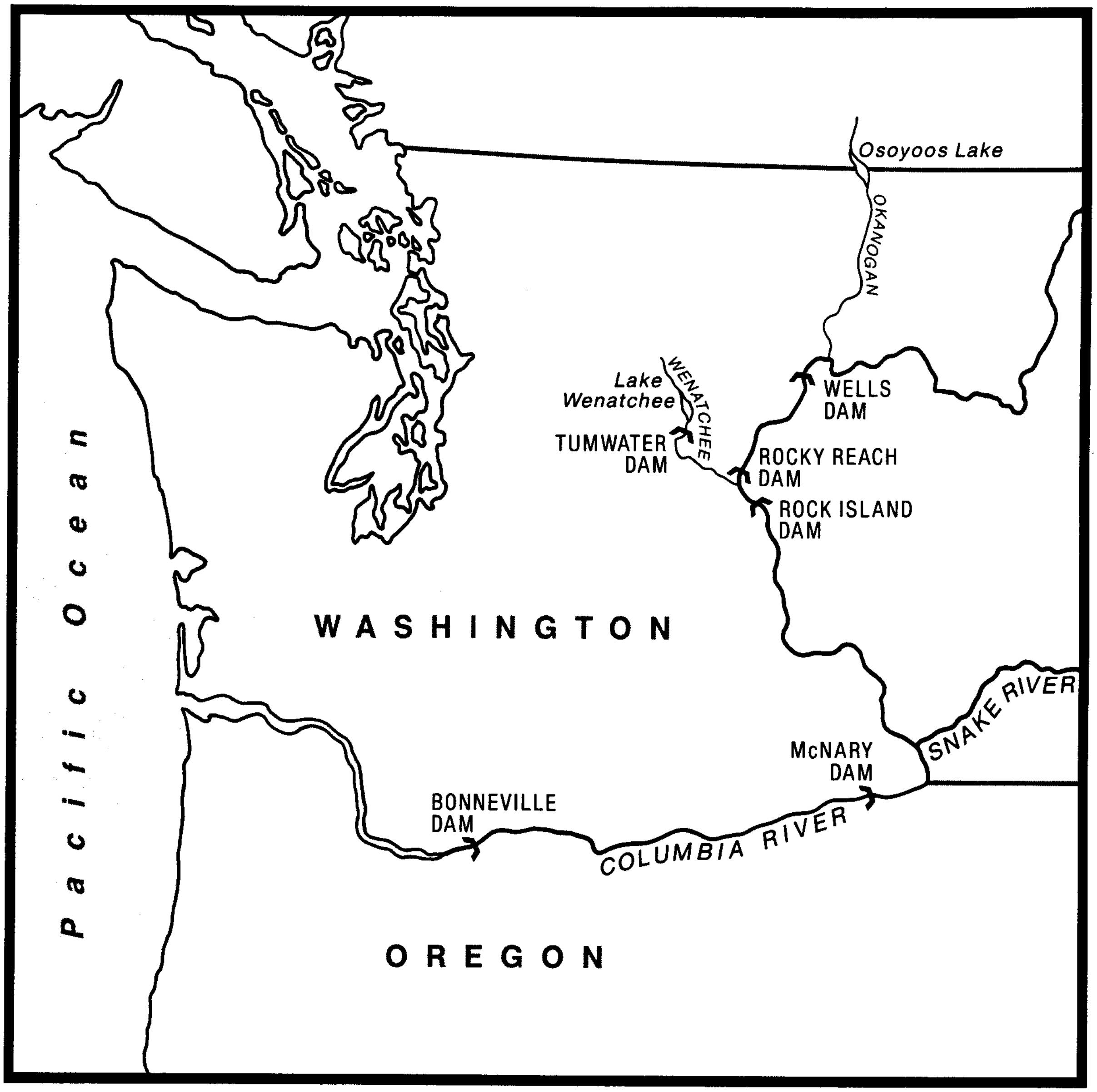
INTRODUCTION

Sockeye salmon *Oncorhynchus nerka* (Walbaum) is one of the five 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 four million fish (Northwest Power Planning Council 1986). 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 past four years (1989 through 1992) has averaged only 63,200 fish (CRITFC 1992).

The Columbia Basin sockeye salmon run was once composed of at least eight principal stocks (Fulton 1970). Today, only two major stocks remain (Figure 1). Both are naturally produced, originating in the Wenatchee River-Lake Wenatchee System (Wenatchee stock) and in the Okanogan River-Osoyoos Lake System (Okanogan stock). Markedly different conditions exist in these two remaining Columbia Basin sockeye salmon spawning and rearing areas (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.

Before this study began (Schwartzberg and Fryer 1988), reliable methods for individual Columbia Basin sockeye salmon stock identification had not been developed to permit estimation of the overall run composition and the migratory characteristics of each component stock. Numerous potential research and management uses exist for such information. These include run-reconstruction studies to permit accurate population size forecasts, escapement monitoring, establishment of spawner-recruit relationships, and development of discrete stock approaches to Columbia River mainstem harvest management. The Pacific Salmon Treaty, 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

Figure 1. Map of the Columbia Basin showing Bonneville, McNary, Rock Island, Rocky Reach, Wells, and Tumwater dams and the two present sockeye salmon production areas.



Columbia River might constitute 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.

The Columbia River Inter-Tribal Fish Commission's Stock Identification Project is designed to develop and apply techniques for identification of individual or aggregate stocks of Columbia Basin salmon originating above Bonneville Dam. The collection and dissemination of basic stock-specific biological information is also an important project goal. Scale pattern analysis (SPA) is the method of study currently being used for stock identification. SPA 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 genetically or environmentally influenced 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 samples from the Wenatchee and Okanogan sockeye salmon stocks in past years have differed (Schwartzberg and Fryer 1988, 1989, 1990; Fryer and Schwartzberg 1991; Fryer et al. 1992), presumably reflecting differences in freshwater spawning and rearing conditions.

This report describes the age, length-at-age, and stock composition of Columbia Basin sockeye salmon in 1992. Weekly, as well as composite age and stock composition estimates are presented. The relationship between migratory timing and age or stock composition was examined. If such a relationship exists future mainstem sockeye salmon fisheries may be managed to target a specific stock or age class in the mixed stock population. The relationship between migratory timing and age composition is also examined for each known stock sampled. A system for evaluating the condition of the sampled fish, based on criteria developed in 1992, was used and the resulting data presented.

METHODS

Sampling

Sampling Methods

Scales from mixed sockeye salmon stocks (called *unknowns* or *unknown stocks*) were obtained from fish sampled at the Bonneville Dam Fisheries Engineering and Research Laboratory, located at river km 225 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 (*knowns* or *known stocks*). Wenatchee stock scales were collected at Tumwater Dam on the Wenatchee River (river km 31), while Okanogan stock scales were obtained at Wells Dam on the mainstem Columbia River (river km 829).

Fish were trapped, anesthetized, sampled for scales and length measurements, allowed to recover, and released (Schwartzberg 1987). Scales were collected and mounted according to methods described in Clutter and Whitesel (1956) and the International North Pacific Fisheries Commission (1963). Four scales per fish were collected to minimize the sample rejection rate. Fork length measurements were recorded to the nearest 0.5 cm. Observed mark and/or tag information was also recorded. 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 many specimens collected at Tumwater and Wells dams could be determined, and was recorded.

In recent years, a large percentage of Okanogan stock sockeye have been observed to be descaled or otherwise injured (Fryer et al. 1992, Fryer and Schwartzberg 1991). Therefore in 1992, we developed criteria to allow more accurate quantification of the condition of adult salmon at Columbia Basin sampling locations (Appendix A).

Scales were also obtained from eleven sockeye salmon carcasses sampled from the Methow River. Since there is no rearing lake on the Methow River, it is uncertain whether these fish are a separate stock that spawns in the Methow River but rears in mainstem reservoirs or are strays from the Wenatchee and/or Okanogan rivers.

Sample Design

Sockeye salmon were sampled at Bonneville Dam two days per week in conjunction with a summer chinook sampling program. Sampling at Tumwater and Wells dams was conducted one to two days per week during the period in which significant numbers of sockeye salmon were migrating past those sites. The desired total sample size at all sites for age composition estimates was a minimum of 500 fish which, in previous study years, has resulted in acceptable levels of precision and accuracy ($d=0.05$, $\alpha=0.10$). The actual mixed stock (Bonneville Dam) composite sample size used for age composition estimation was 751 fish. The actual known stock composite sample sizes used for age composition estimation were 383 fish from Tumwater Dam and 688 from Wells Dam.

For SPA studies, the desired sample size was approximately 200 from each known stock group (Conrad 1985). The Wenatchee stock subsample consisted of all 164 Age 1.2 specimens collected (see the following section entitled 'Age Determination and Scale Measurements' for a description of the fish age notation used herein). The Okanogan stock subsample consisted of 208 systematically selected (subsampled) Age 1.2 samples. Although a minimum desired sample size of 100 is recommended for classification of unknown groups in SPA studies (Conrad 1985) such as the Bonneville Dam mixed stock sample, 434 systematically selected (subsampled) Age 1.2 samples from the mixed stock were used in the analysis to permit more precise weekly stock composition estimates.

To further improve accuracy, composite age and length-at-age estimates based on the above described sampling methodology were adjusted post-season using a stratified sampling method that weighted weekly estimates to adjust for actual 1992 migration timing (Cochran 1977).

Age Determination and Scale Measurement

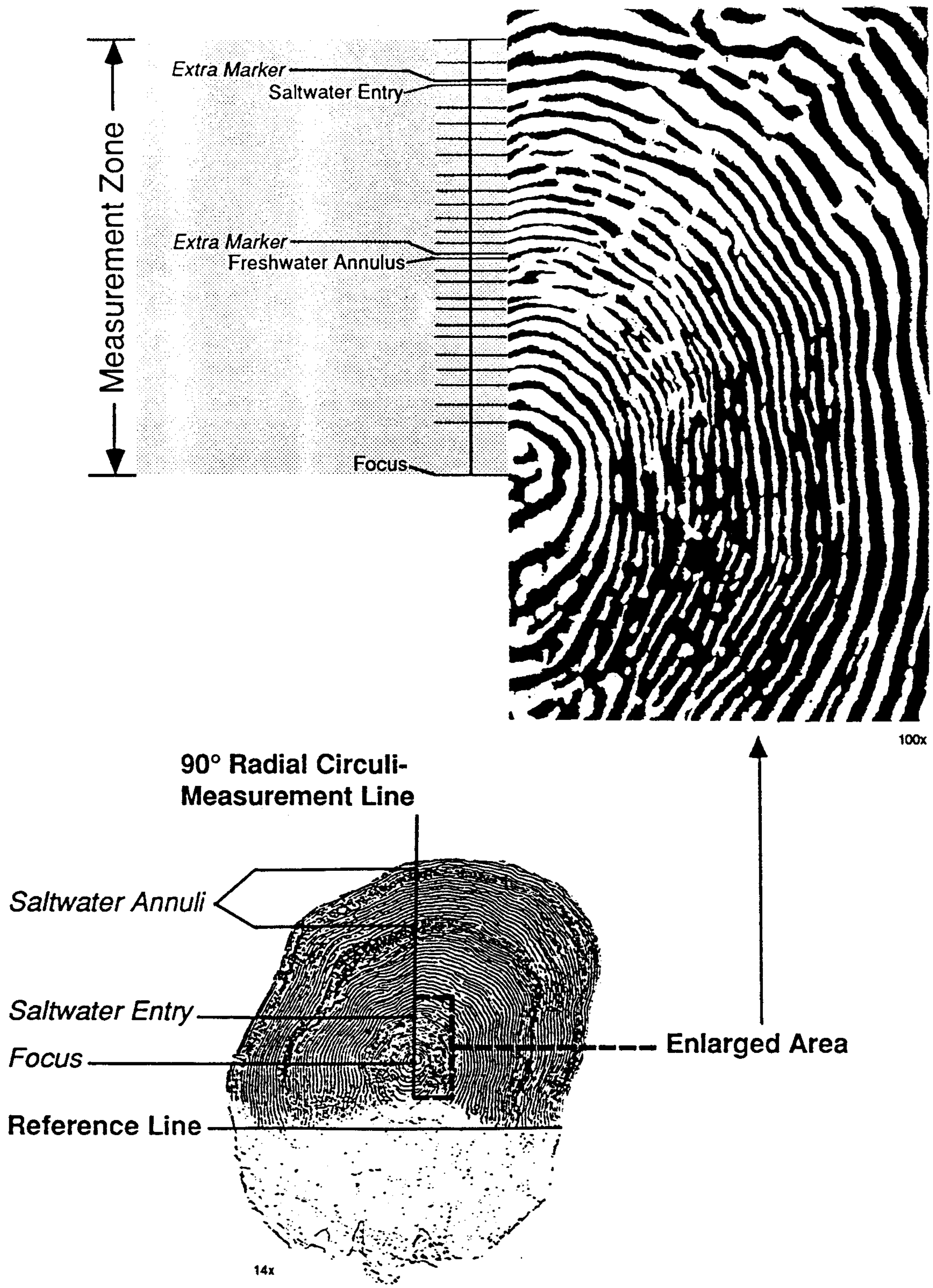
Under magnification, salmon scales display numerous concentric rings (*circuli*) radiating outward from a central focal area. A freshwater-growth zone of narrowly spaced circuli (Figure 2) is clearly distinguishable from a zone of more widely spaced saltwater-growth circuli in scales of Columbia Basin sockeye salmon. These fish typically spend one or two complete years in freshwater before migrating to the ocean. Fish age can be determined by counting *annuli*, the zones of closely spaced circuli formed yearly during winter and early spring periods of slow growth.

Using previously described techniques (Johnston 1905, Gilbert 1913, Borodin 1924, Van Oosten 1929), acetate scale impressions were magnified (56x) and examined visually. The method used for fish age notation is that recommended by Koo (1955), which is sometimes referred to as the *European* method. 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.

Scales were used to estimate the age composition of Bonneville Dam mixed stock as well as the Okanogan and Wenatchee known stock samples. Length-at-age relationships were also established for each stock. Scale ages were corroborated by Washington Department of Fisheries personnel. Validation of ages (Beamish and McFarlane 1983) was not possible as there were no fish of known age in any samples.

SPA 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 Age 1.2 samples from all stocks. SPA was not used to classify fish of age classes other than 1.2 in the mixed stock sample. Certain age classes were found to be overwhelmingly present in only one of the two known stock samples. These age classes were assumed to be attributable to a single stock and this relationship was used to categorize mixed stock samples of given age groups.

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



A computer and video camera were used to measure scale features (BioSonics 1985). The system employed consisted of 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 (33 cm), and a digitizing tablet connected to a 386 personal computer with a video frame-grabber board. Acetate impressions of scales were placed in the microscope and projected onto the monitor using a 2.0x objective, 1.0x magnification changer, and 2.5x photo-compensation adapter. This lens configuration created a scale image viewed at 65x actual size.

One scale impression from each fish was selected and the projected image was oriented diagonally with the clear (posterior) part of the scale in the lower left corner of the screen. A reference line was drawn along the scale-image base. 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 (Figure 2). The objective was 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 measured at their points of intersection with the radial line. All measurements were made to the marginal (outermost) edges of circuli. The zone measured included the entire freshwater zone and part of the early saltwater growth zone.

Additional 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 procedure (Appendix B). 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. The zone measured included the entire freshwater zone and part of the early saltwater growth zone.

Statistical Analyses

A linear discriminant analysis technique developed by Fisher (1936) was used to differentiate stocks and classify unknown mixed stock samples. 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).

Variables, composed of selected scale-measurements within the area from scale focus to approximately circulus 27, were tested to find those that most effectively characterized differences in growth between the two stocks. As in studies of previous years, distances between four adjacent circuli (or triplets), were the primary variable tested (Davis 1987). Other variables briefly tested included distances between adjacent circuli (singlets), three adjacent circuli (doublets), and five adjacent circuli (quadruplets). 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 improving its accuracy. To correct for misclassification of unknown mixed stock samples, we used a method described by Cook and Lord (1978). Variances on mixed stock classification estimates were also computed (Pella and Robertson 1979).

Classification of Unknown Mixed Stock Samples

Mixed stock Age 1.2 samples were classified using linear discriminant analysis techniques. Fish of age classes other than Age 1.2 were classified by age class. In past years of this study, Age 1.3 and 2.2 fish have been noted to be relatively common in the Wenatchee stock sample and rare in the Okanogan stock sample. (The only exception to this rule was in 1990 when 10% of the Okanogan sample was of Age 1.3. However, in 1990, since fewer than 8,000 fish were of Okanogan origin, the actual number of Okanogan Age 1.3 fish was very small relative to the number of Wenatchee Age 1.3 fish.) Therefore, all fish of these age classes in the Bonneville Dam mixed stock have been classified as Wenatchee stock. Similarly in previous years, no Age 1.1 and 2.1 fish were found in Wenatchee samples, although fish of those age classes are relatively common in Okanogan samples. Therefore, all Age 1.1 and 2.1 fish in the Bonneville Dam sample have been classified as Okanogan stock. These same classification rules were used in 1992.

Relationship of Migratory Timing to Stock and Age Composition

Tests were conducted to examine the relationship between migratory timing and stock and age composition in the mixed stock sample. This relationship was tested by regressing mean weekly stock and age composition estimates against the statistical week[1] weighted by the inverse of the variance for each estimate (Neter et al. 1985).

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1. 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 1992 for example, Statistical Week 24 began on June 7 and ended on June 13.

RESULTS

Sample Sizes

Final sample sizes used for age and length-at-age composition estimates were 751 mixed stock, 383 Wenatchee known stock, 688 Okanogan known stock, and 10 Methow stock. Of the original 784 sockeye salmon sampled at Bonneville Dam, four percent of the total sample was rejected and not classified by age because of unreadable scales. For the same reason, four percent of the 399 Wenatchee known stock sockeye salmon sampled at Tumwater Dam, and two percent of the 714 Okanogan known stock sockeye salmon sampled at Wells Dam were rejected. Because we later discovered a temporary trap malfunction had biased the sample collected in Statistical Week 28 at Wells Dam, an additional 12 fish were excluded from the Okanogan stock sample. We rejected one of the eleven Methow River fish from the sample because of unreadable scales.

Age and Length-at-Age Composition

The predominant age class for known and unknown stocks was Age 1.2. This age class was estimated to represent 73% of the Okanogan known stock, 66% of the Bonneville mixed stock, and 48% of the Wenatchee known stock (Tables 1 and 2).

In the Methow River sample (n=10), 30% were estimated to be of Age 1.2, 20% were estimated to be of Age 2.2, and 50% were estimated to be of Age 1.3.

Mean fork-lengths by age class displayed little difference among fish collected at the three sampling locations (Figure 3). Methow River length data is not presented because of the small number of fish and inherent inaccuracies in measurements of spawning-ground collected specimens.

Table 1. Age composition estimates (%) of Columbia Basin sockeye salmon stocks sampled at Bonneville Dam in 1992.

Statistical Week	Sampling Dates	Sample Size	Brood Year and Age Class 1989 1.1	1988 1.2	1988 2.1	1987 1.3	1987 2.2	1986 2.3
23-24	6/03,10	20	0	70	0	0	30	0
25	6/17,19	147	3	65	3	10	20	0
26	6/24,26	213	3	67	<1	8	22	0
27	7/01,02	171	7	65	4	9	16	0
28	7/08,10	126	11	70	7	3	9	0
29	7/15,17	49	10	63	10	2	14	0
30-31	7/22,24,29	25	20	48	8	4	20	0
Population Estimate		**751**	**6**	**66**	**3**	**7**	**18**	**0**

Table 2. Age composition estimates (%) of Wenatchee and Okanogan sockeye salmon stocks sampled in 1992.

Wenatchee Stock

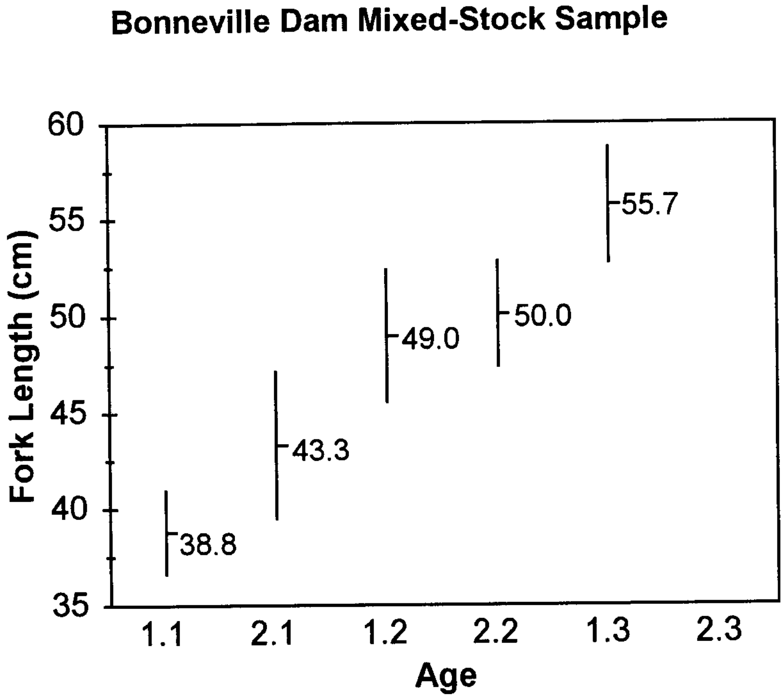
Statistical Week	Sampling Dates	Sample Size	Brood Year and Age Class 1989 1.1	1988 1.2	1988 2.1	1987 1.3	1987 2.2	1986 2.3
29	7/14,15	239	0	48	0	12	40	0
30	7/23,24	0[a]	0	0	0	0	0	0
31	7/27	128	1	48	0	11	40	1
32	8/4	16	0	44	0	6	50	0
Population Estimate		**383**	**<1**	**48**	**0**	**11**	**40**	**<1**

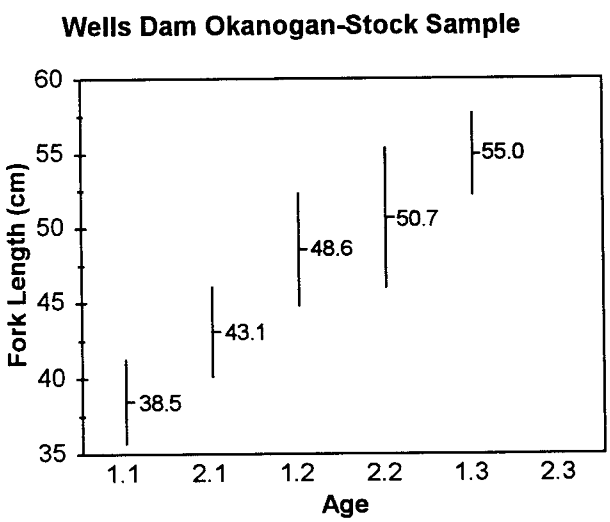
Okanogan Stock

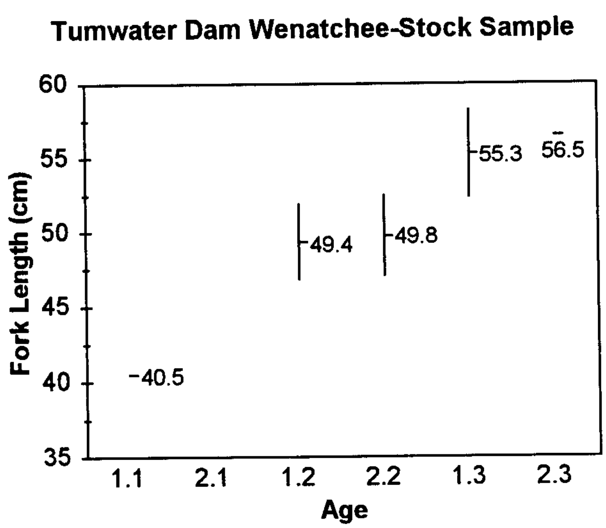
Statistical Week	Sampling Dates	Sample Size	Brood Year and Age Class 1989 1.1	1988 1.2	1988 2.1	1987 1.3	1987 2.2	1986 2.3
28	7/10	177	13	76	7	2	2	0
29	7/13	197	11	82	6	0	2	0
30	7/20	121	27	65	7	1	0	0
31	7/27	97	25	63	9	3	0	0
32	8/03	96	28	62	6	3	0	0
Population Estimate		**688**	**17**	**73**	**7**	**1**	**1**	**0**

a. No fish were trapped in two days of sampling at Tumwater Dam in Statistical Week 30. We theorize that heavy rain earlier in the week likely caused the fish to stop moving upstream during these days.

Figure 3. Length-at-age estimates (with 90% confidence intervals) for sockeye salmon stocks sampled at Bonneville, Tumwater, and Wells dams in 1992.







Sockeye Salmon Physical Condition

While only 17% of the specimens in the mixed stock sample exhibited some form of physical injury, 81% of the Wenatchee stock sample and 90% of the Okanogan stock sample exhibited such injuries (Table 3).

Classification of Known Stock Samples

Among the variables tested, triplets resulted in among the highest classification accuracies and were used to provide consistency with results of previous years. As has been the case in previous years, those variables highly dependent on individual operator judgment were excluded to limit subjectivity. Therefore, variables directly related to freshwater annulus and saltwater entry positions were rejected from the final variable subset. The variables used by the stepwise procedure were the distances between the focus and third circuli, third and sixth circuli, ninth and twelfth circuli, fifteenth and eighteenth circuli, eighteenth and twenty-first circuli, and twenty-first and twenty-fourth circuli. For classification of Age 1.2 fish, after application of the jackknife procedure, 79% of the known stock samples were accurately classified by this variable set (Table 4). A total of 28 of 164 Wenatchee samples were misclassified as Okanogan stock, while 51 of 208 Okanogan samples were misclassified as Wenatchee stock.

Table 3. Percentage of the Columbia Basin mixed and known stock sockeye salmon sample injured by marine mammals, gill nets, descaling, and other causes in 1992.

Injury Category	Bonneville Stock	Okanogan Stock	Wenatchee Stock
Marine Mammal			
Bite	1	0	0
Claw Rake	2	3	2
Twin Arches	1	<1	<1
Total Marine Mammal[a]	4	3	2
Descaling			
5-20% Descaling			
Right Side	3	26	22
Left Side	4	19	15
Either Side	4	31	26
>20% Descaling			
Right Side	1	8	2
Left Side	1	5	2
Either Side	3	10	3
General			
Bruise[b]	0	50	32
Cut	1	3	2
Eye Wound/Scar	0	1	1
Fin	<1	2	7
Fungus	1	<1	2
Gash[b]	1	18	32
Gill Net Wounds/Scar	1	5	2
Lamprey Wound/Scar	0	1	1
Nose	1	38	19
Parasite	0	<1	1
Tail	1	6	7
Total General Injuries[a]	7	82	72
Total Injured[a]	17	90	81

a. Totals for these categories may not equal the sum of the subcategories due to either 1) fish displaying more than one type of injury or 2) injuries being noted but not accurately described.

b. These categories were added after Wells and Bonneville dam sampling had commenced. Therefore, Okanogan and Bonneville estimates for these injury categories are likely to be low. (However, few injuries of these types were observed at Bonneville Dam.)

Table 4. Known stock classification tests using linear discriminant analyses with Age 1.2 Columbia Basin sockeye salmon stocks sampled in 1992.

Stock	Percent Correct	Sample Classification	
		Wenatchee	*Okanogan*
Wenatchee	83	136	28
Okanogan	76	51	157
Composite Accuracy	79		

Classification of Unknown Mixed Stock Samples

After correcting for classification bias, 82% of the Age 1.2 sockeye salmon migrating past Bonneville Dam were estimated to be Okanogan stock (Table 5). The remaining 18% of the Age 1.2 sockeye salmon population at Bonneville Dam was estimated to be Wenatchee stock. Confidence intervals (90%) ranged from 74% to 90% for the Okanogan stock and from 10% to 26% for the Wenatchee stock estimate.

Of the three Age 1.2 Methow River sockeye salmon, two were classified as being of Wenatchee stock while the third was classified as being of Okanogan stock. There were insufficient Methow River samples to use statistical techniques to consider the possibility of these fish comprising a third stock.

Combining the results of SPA classification of Age 1.2 unknowns (based on linear discriminant analyses), with the classification of Age 1.2 unknowns (based on age alone), 63% of the mixed stock was estimated to be Okanogan stock and the remaining 37% of Wenatchee stock (Table 5). Confidence intervals (90%) ranged from 58% to 68% for the Okanogan stock and from 32% to 42% for the Wenatchee stock estimate. Using the above stock composition estimates, individual stock escapement estimates were made at Bonneville Dam. Of the 84,991 sockeye salmon recorded at Bonneville Dam visual fish counts, 31,447 were estimated to be Wenatchee origin and the remaining 53,544 of Okanogan origin.

A comparison of Bonneville Dam stock composition estimates since 1987 shows that only in 1988 was there a higher percentage of Okanogan stock sockeye than in 1992 (Figure 4). In the last three years, the percentage of fish of Okanogan stock has steadily increased.

Relationship of Migratory Timing to Stock Composition

Weekly unknown mixed stock composition estimates (Table 5) show a significant relationship at $\alpha=0.10$ ($p=0.08$) between migratory timing and stock composition using linear regression techniques. These tests indicate that,

Table 5. Stock composition estimates of Columbia Basin sockeye salmon at Bonneville Dam in 1992.

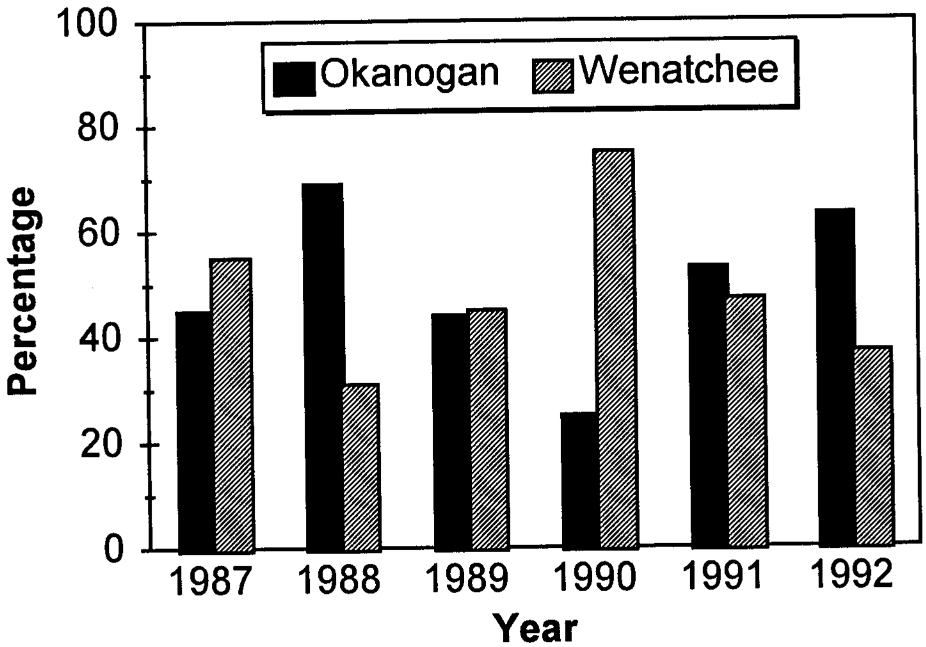
Classification of only Age 1.2 Sockeye Salmon

Statistical Week	Sample Size	Sample Classification *Wenatchee*	*Okanogan*	Standard Error
24	14	7	93	21
25	85	20	80	10
26	98	17	83	9
27	98	23	77	9
28	86	18	82	10
29	31	8	92	15
30	12	29	71	25
Population Estimate	**434**	**18**	**82**	**5**

Classification of Sockeye Salmon of All Ages

Statistical Week	Sample Size	Sample Classification *Wenatchee*	*Okanogan*	Standard Error
24	20	35	65	18
25	147	43	57	8
26	213	41	59	7
27	171	39	61	7
28	126	24	76	8
29	49	21	79	12
30	25	38	62	16
Population Estimate	**751**	**37**	**63**	**4**

Figure 4. Stock composition estimates of Columbia Basin sockeye salmon stocks at Bonneville Dam from 1987 through 1992.



in 1992, the relative proportion of Okanogan stock sockeye salmon increased with time as the mixed stock migration progressed. Conversely, the relative proportion of Wenatchee stock sockeye salmon decreased over the migratory period. Overall, however, Okanogan stock fish predominated throughout the migratory period.

Age composition analyses using a similar linear regression technique indicated that the relative abundance of Age 1.1, 2.2, and 1.3 sockeye salmon in the 1992 unknown mixed stock sample (Table 1 and 2) was related to migratory timing at α=0.10 (p=0.02, 0.06, and 0.02 respectively). Age 1.3 and 2.2 sockeye salmon were proportionally more numerous early in the migratory period. Percentages of Age 1.1 fish increased as the migration progressed. No linear relationship was found (p=0.52) between Age 1.2 sockeye salmon abundance and mixed stock migratory timing at Bonneville Dam. Among the known stock, the only age class showing a significant relationship at α=0.10 between relative abundance and migratory timing was Okanogan Age 1.1 fish which increased as the migration progressed (p=0.10).

DISCUSSION

This paper reports results from the sixth year of a Columbia Basin sockeye salmon stock identification research project (Schwartzberg and Fryer 1988, 1989, 1990; Fryer and Schwartzberg 1991; Fryer et al. 1992). Throughout this study, Wenatchee and Okanogan stock sockeye salmon were identified using a linear discriminant analysis procedure. Classification accuracy in 1991 was 79%, which was the second lowest figure achieved in the past six years. By comparison, classification accuracy was 91% in 1987, 86% in 1988, 81% in 1989, 65% in 1990, and 86% in 1991.

In 1992 as in most previous years, Age 1.2 was the predominant estimated age class in both known stocks, as well as in the mixed stock. Also similar to previous study years, Age 1.3 and 2.2 sockeye salmon were present in significant numbers only in the Wenatchee stock, and Age 1.1 and 2.1 fish were present, with the exception of a single fish, only in the Okanogan stock.

Adult migrating salmon are visually counted, predominately during daylight hours, in fish ladders at the mainstem Columbia and Snake river dams. Except for a remnant Snake River stock, all Columbia Basin sockeye salmon stocks returning to spawning grounds pass Rock Island Dam (river km 729). Only Okanogan stock fish pass Rocky Reach Dam (river km 761). Using the difference between Rock Island and Rocky Reach dam counts as an estimate of the Wenatchee stock escapement, and using the Rocky Reach Dam counts as an estimate of Okanogan stock escapement, 58% (39,902) of the 1992 escapement estimate at Rock Island Dam may be attributed to the Okanogan stock and 42% (29,293) to the Wenatchee stock. Our stock composition estimate does not differ significantly ($p=0.23$) from that based on visual counts at mid-Columbia dams. Although results were similar, our study offers a stock composition estimate for the Columbia River sockeye salmon population at a point in their adult migration where they have has been, and probably will continue to be commercial and tribal ceremonial fisheries. Combining the results of our studies with mid-Columbia dam counts, it is possible to obtain an estimate of stock-specific mortality on the upstream migration. If Columbia basin sockeye salmon are to be managed on a stock specific basis, it will be important to have stock specific estimates of mortality on the upstream migration.

In 1992, a significant linear relationship was found between stock composition and migratory timing in the mixed stock unknown-origin sample. The percentage of Wenatchee stock sockeye decreased as the migration progressed while the percentage of Okanogan stock sockeye increased. A similar significant relationship was found in 1989 and 1990, but not in 1991. If a consistent and predictable relationship is found between stock composition and migratory timing, adjustment of potential future mainstem Columbia River sockeye salmon fisheries may be possible to permit harvest of a greater proportion of a particular stock.

In both 1990 and 1991, Okanogan stock fish sampled at Wells Dam were observed to be in poor condition (Fryer and Schwartzberg 1991, Fryer et al. 1992). The majority of the sockeye salmon sampled were descaled and/or exhibited cuts and bruises. Many fewer injuries were observed in fish sampled at Tumwater Dam (Wenatchee stock) and Bonneville Dam (mixed stocks) in 1990 and 1991. This year, we developed a method to quantify the relative condition of fish sampled. Using this method, we observed physical injuries to 90% of the fish sampled at Wells Dam in 1992. Unlike previous years, in 1992 large numbers of Wenatchee stock fish were also observed to be injured (although their condition was not judged to be as poor as that of Okanogan stock specimens sampled at Wells Dam). It is not known why the level of injuries differed between the two stocks. In 1992, however, fish captured in a small tribal fishery above Priest Rapids Dam (river km 630) were already observed to be in poor condition (L. LaVoy, Washington Department of Fisheries, personal communication). We hope that future commercial fishery monitoring will include an evaluation of fish condition similar to the one we are employing.

For the first time since this project began in 1987, we estimated a sockeye salmon in the Wenatchee stock sample to be Age 1.1. We believe this fish was likely a product of a hatchery supplementation program begun by the

Washington Department of Fisheries in 1989[2]. Broodstock for that program are collected at Tumwater Dam, spawned, and their progeny raised in net pens in Lake Wenatchee. The first downstream migrants from the program emigrated from Lake Wenatchee in 1991, a year in which 25% of all smolts sampled at Rock Island Dam were estimated to be Wenatchee net-pen reared fish (Peven 1992). Net-pen reared fish were not marked in the first year of the program; and therefore, confirmation of the origin of the specimen we collected is not possible. However, the scale pattern of this fish appeared to be similar to that of juvenile net-pen reared fish sampled from 1991 downstream migrants. Four-year-old fish from the 1989 brood year will be returning in 1993 and are expected to include larger numbers of net-pen reared fish. Since these fish will not have been marked, the only way to identify these fish in 1993, and to estimate the number of fish returning from the net-pen program, will be by using SPA techniques.

This is the first year in which scale samples were available from sockeye salmon from the Methow River. Whether these fish comprise a separate stock or are strays from the Okanogan and/or Wenatchee sockeye salmon stocks has long been debated. Mullan (1986) concluded that sockeye runs were established in the Methow and Entiat rivers in the 1940's, despite the lack of a natural rearing lake, as a result of sockeye rearing programs at Winthrop and Entiat hatcheries. Winthrop Hatchery continued to release sockeye salmon in the Methow River through 1957 (Mullan 1986). After sockeye releases were curtailed, a naturally spawning population persisted. An electronic counting weir on the Methow River counted 357 sockeye in 1965 and 1,013 sockeye in 1966 (Meekin 1967). Mullan (1986) reported a small number of sockeye were observed in the Methow River from 1969-1981. In recent years, sockeye have commonly been observed spawning between river km 57 and 64, just downstream of the town of Twisp and approximately 40 sockeye salmon redds were observed in this area in 1992 (T. Hillman, Don Chapman Consultants, Boise; personal communication).

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2. This program is coordinated with a sockeye salmon reintroduction project in the Yakima River, Washington (Flagg et al. 1988).

The lack of a natural rearing lake for Methow and Entiat spawner offspring has led some to theorize that these fish are actually strays from elsewhere in the Columbia Basin (Pratt et al. 1991). Sockeye stocks with juveniles rearing in rivers or estuaries are rare (Burgner 1991) and Columbia River mainstem reservoirs with their relatively small volumes and high flushing rates appear to offer poor sockeye rearing habitat (Mullan 1986).

The results presented in this report indicate that the Methow River spawning fish spend one to two years in freshwater. Furthermore, the age distribution and visual inspection of scale patterns both suggest that Methow River sockeye are similar to the Wenatchee stock. However, this does not necessarily mean that Methow River spawning sockeye salmon are strays from the Wenatchee River. Growth rates as well as scale patterns from a stock rearing in the Methow River or the mainstem reservoirs could be relatively similar to those fish rearing in Lake Wenatchee. The Methow River sample was too small to use SPA to explore the possibility that other mid-Columbia sockeye salmon stocks may exist. Sockeye salmon were also observed in the Similkameen and Entiat rivers in 1992 (L. LaVoy, Washington Department of Fisheries, Wenatchee, WA; G. Swann, National Marine Fisheries Service, Pasco, WA, personal communication). It is hoped that a larger sample size can be obtained from Methow River spawning sockeye salmon in 1993.

Research on sockeye salmon will continue in 1993 and we will continue to develop an accurate age, length-at-age, and stock composition database for the Columbia Basin sockeye salmon population. This information will aid fisheries managers in predicting changes in population sizes and in the stock composition of the sockeye salmon population.

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APPENDIX A. Description of fish condition assessment notation.

Prior to 1992, sampling personnel had the option of noting the condition of fish in the comments section of the sampling form. This resulted in an assessment of fish condition which varied with sampling personnel, sampling site, and sampling date. In an effort to standardize this information so as to allow meaningful comparisons of relative fish condition by date or site, new criteria (Figure A1) and sample forms (Figure A2) were developed. Similar criteria will be used as part of 1993 sampling procedures.

Figure A1. Fish condition assessment notation.

Injuries to be noted:

1. Gill Net
2. Descaling, left side; estimate actual percentage descaled
3. Descaling, right side; estimate actual percentage descaled
4. Marine mammal injuries as follows:
   - **C:** Claw Rake (2-3 or more parallel scratches on flanks of fish)
   - **G**: Twin Arches (2-3 or more curved scratches on flanks of fish)
   - **B**: Bite (Ragged wounds, often in caudal area)
5. General injuries as follows:
   - **E:** Eye
   - **N**: Nose
   - **H:** Fish Hook
   - **P**: Parasite
   - **L**: Lamprey, circular wound
   - **RP, LP, LV, RV, D, A, T** (Tail or Caudal Fin): Fin
   - **C:** Cut
   - **F:** Fungus

For all injuries, a plus (+) indicates the injury is judged severe (extensive scarring or blood/flesh visible). A check (√) indicates that the injury is judged to have recently occurred (i.e. on the upstream migration).

Figure A2. Sampling form used in sockeye salmon sampling.

LOCATION:__________ SPECIES: Sockeye Salmon PAGE:_____ OF _____

DATE:__________ WEEK: __________ SAMPLERS: __________

Scale Card #	Position	Fork Length	Mid-Eye Length	Gender	Gill Net Injuries	Descaling Right	Descaling Left	Marine Mammal	General Injuries	Fin Clip	Comments	Scale Card #	Position	Fork Length	Mid-Eye Length	Gender	Gill Net Injuries	Descaling Right	Descaling Left	Marine Mammal	General Injuries	Fin Clip	Comments
	1												1										
	2												2										
	3												3										
	4												4										
	5												5										
	6												6										
	7												7										
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	20												20										

APPENDIX B. Data handling and manipulation for scale pattern analysis.

During the scale data acquisition process, information associated with each scale data record is stored along with actual scale measurements in four separate fields of the data record *header* (Optical Pattern Recognition System, OPRS; BioSonics Inc. 1985). The sample number, denoted by the appropriate scale card and the sample position number (separated by a period) is recorded in the *sample id* field. Thus, sample number 3 on card number 1 would be recorded as 1.03. The estimated age of the fish from which the scale sample was taken is recorded in the *specimen id* field while the length, sex (M, F, or U), and stock (if known) are recorded in the field labeled *other.* In addition to this user supplied information, the header includes system supplied data including a sequential record number, the microscope magnification conversion factor, a microscope lens calibration factor, a record validity indicator, the total number of circuli in the record, and the angle of the radial line used.

Once circuli measurements are made and a scale data record is saved to the computer's hard disk, scale measurement data cannot be further edited. The operator may, however, edit user supplied header information. The desired record can be located and displayed (by using the OPRS *EDT* page and the *display data* command). Each record is displayed and contains header information and distance measurements from the scale focus to each circulus measured in *sampling units* (Figure B1). Measurements in sampling units can range from 1 to 700 and must be multiplied by the microscope magnification conversion factor to determine metric distances from the scale focus to each marked circulus. Each circulus measurement is stored on a separate line.

To more effectively edit and prepare data for further statistical analysis, the *convert to ASCII* feature of the EDT page is used. This command creates an ASCII file that can be manipulated by a program we have written that detects the extra markers in each record (marking freshwater annulus margin (anterior) and saltwater entry point), converts scale data measurements to actual metric distances, and stores this information in a more compact format (Figure B2). Using still another program, the information necessary to perform statistical analyses is extracted from this file and transferred to statistical software.

Figure B1. **A sample OPRS data record for a single sockeye salmon scale freshwater-growth-zone measurement.**

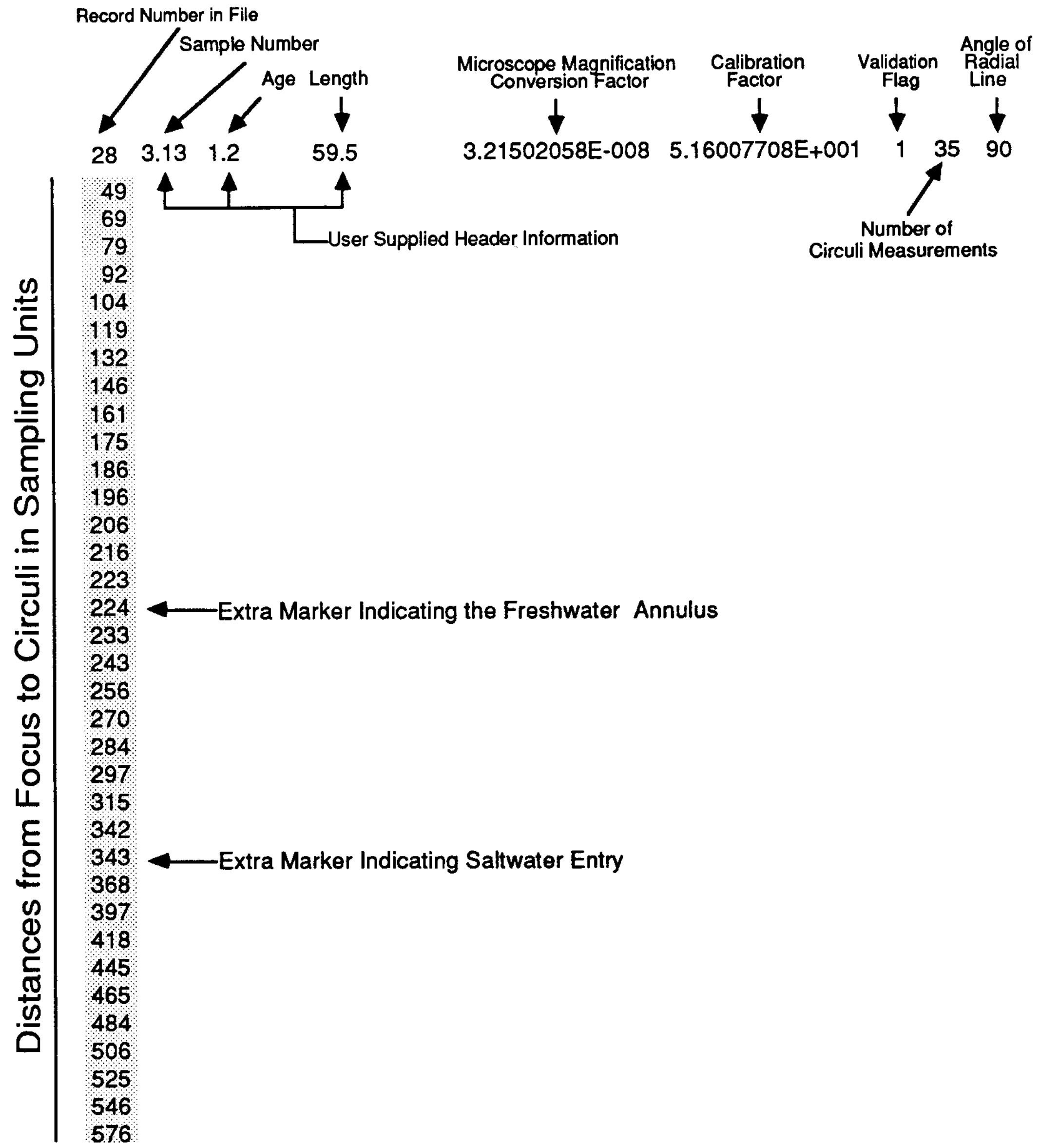

Figure B2. A sample compact-format data record for a single sockeye salmon scale freshwater-growth-zone measurement.

Sample Number; Sample Age; Sample Length (cm); Number of Circuli; Distances from Focus to Circuli in Micrometers

3.13	1.2	47.5	33	*1.57536*	*2.21836*	*2.53987*	*2.95782*	*2.95782*
3.34362	*3.82587*	*4.24383*	*4.69393*	*5.17618*	*5.62629*	*5.97994*	*6.30144*	
6.62294	*6.94444*	*7.16950*	*7.49100*	*7.81250*	*8.23045*	*8.68056*	*9.13066*	
9.54861	*10.12731*	*10.99537*	*11.83128*	*12.76363*	*13.43879*	*14.30684*	*14.94985*	
15.56070	*16.26800*	*17.55401*	*18.51852*	15	23			

15: Number of Circuli from Focus to Freshwater Annulus

23: Number of Circuli from Focus to end of Freshwater Growth Zone